Exhibit 1027

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Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Date
09.03.20

Reference	Application No./Patent No.
P-EP93434Y	13745198.5 - 1009 / 2867550
Applicant/Proprietor	
Outotec (Finland) Oy	

Communication regarding the expiry of the time limit within which notice of opposition may be filed

You are hereby informed that on expiry of the nine-month time limit from the publication of the mention of the grant of European patent No. 2867550 no notice of opposition had reached the files.

The entry in the Register of European Patents will be automatically generated by the electronic data processing system.

For the Examining Division

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Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Date
13.05.19

Reference	Application No./Patent No.
P-EP93434Y	13745198.5 - 1013 / 2867550
Applicant/Proprietor	
Outotec (Finland) Oy	

Transmission of the certificate for a European patent pursuant to Rule 74 EPC

The certificate for a European patent is herewith transmitted.

The European patent specification can be downloaded from the EPO publication server **https://data.epo.org/publication-server/** (see OJ EPO 2005, 126).

Note:
A corrected title page of the European patent specification will be published, if the bibliographic data have been changed after completion of the technical preparations.

For the Examining Division

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Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Date
04.04.19

Reference	Application No./Patent No.
P-EP93434Y	13745198.5 - 1013 / 2867550
Applicant/Proprietor	
Outotec (Finland) Oy	

Decision to grant a European patent pursuant to Article 97(1) EPC

Following examination of European patent application No. 13745198.5 a European patent with the title and the supporting documents indicated in the communication pursuant to Rule 71(3) EPC (EPO Form 2004C) or in the information (EPO Form 2004W, cf. Notice from the EPO dated 8 June 2015, OJ EPO 2015, A52) dated 28.11.18 is hereby granted in respect of the designated Contracting States.

Patent No. : 2867550
Date of filing : 28.06.13
Priority claimed : 28.06.12/AUA 2012902770

Designated Contracting States and Proprietor(s) : AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Outotec (Finland) Oy
Rauhalanpuisto 9
02230 Espoo/FI

This decision will take effect on the date on which the European Patent Bulletin mentions the grant (Art. 97(3) EPC).

The mention of the grant will be published in European Patent Bulletin 19/18 of 01.05.19.

Examining Division

Martin, Christophe Hutter, Manfred Cerva-Pédrin, Sonia

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Registered letter
EPO Form 2006A 07.15 (28/03/19)

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to EPO postal service: 29.03.19

ANMERKUNG ZUR ENTSCHEIDUNG ÜBER DIE ERTEILUNG
EINES EUROPÄISCHEN PATENTS (EPA Form 2006)

1. **EPA Informationsbroschüre "Nationales Recht zum EPÜ"**
Diese Broschüre enthält nützliche Informationen zu den formalen Erfordernissen und den Handlungen, die vor den Patentbehörden der Vertragsstaaten vorzunehmen sind, um Rechte in diesen Staaten zu erlangen. Da diese Handlungen einem ständigen Wandel unterworfen sind, sollte immer nur die neueste Ausgabe der Broschüre benutzt werden. Nachträgliche Informationen werden im Amtsblatt veröffentlicht.

2. **Übersetzung der europäischen Patentschrift nach Artikel 65 (1) des Europäischen Patentübereinkommens**
Sie werden erneut darauf hingewiesen, dass bestimmte Vertragsstaaten nach Artikel 65 (1) EPÜ eine Übersetzung der europäischen Patentschrift verlangen; hierauf wird in der Mitteilung gemäß Regel 71 (5) EPÜ verwiesen. Die Nichteinreichung dieser Übersetzung kann zur Folge haben, dass das Patent in dem betreffenden Staat/in den betreffenden Staaten als von Anfang an nicht eingetreten gilt. Weitere Einzelheiten entnehmen Sie bitte der oben genannten Broschüre.

3. **Zahlung von Jahresgebühren für europäische Patente**
Nach Artikel 141 EPÜ können "nationale" Jahresgebühren für das europäische Patent für die Jahre erhoben werden, die an das Jahr anschließen, in dem der Hinweis auf die Erteilung des europäischen Patents im "Europäischen Patentblatt" bekanntgemacht wird. Weitere Einzelheiten entnehmen Sie bitte der oben genannten Broschüre.

NOTE RELATING TO THE DECISION TO GRANT A
EUROPEAN PATENT (EPO Form 2006)

1. **EPO Information Brochure "National law relating to the EPC"**
This brochure provides useful information regarding formal requirements and the steps to be taken before the patent authorities of the Contracting States in order to acquire rights in those states. Since the necessary steps are subject to change the latest edition of the brochure should always be used. Subsequent information is published in the Official Journal.

2. **Translation of the European patent application under Article 65(1) of the European Patent Convention**
Your attention is again drawn to the requirements regarding translation of the European patent specification laid down by a number of Contracting States under Article 65(1) EPC, to which reference is made in the communication under Rule 71(5) EPC. Failure to supply such translation(s) may result in the patent being deemed to be void "ab initio" in the State(s) in question. For further details you are recommended to consult the above-mentioned brochure.

3. **Payment of renewal fees for European patents**
Under Article 141 EPC "national" renewal fees in respect of a European patent may be imposed for the years which follow that in which the mention of the grant of the European patent is published in the "European Patent Bulletin". For further details you are recommended to consult the above-mentioned brochure.

REMARQUE RELATIVE A LA DECISION DE DELIVRANCE
D'UN BREVET EUROPEEN (OEB Form 2006)

1. **Brochure d'information de l'OEB "Droit national relatif à la CBE"**
Cette brochure fournit d'utiles renseignements sur les conditions de forme requises et sur les actes à accomplir auprès des offices de brevet des Etats contractants aux fins d'obtenir des droits dans les Etats contractants. Etant donné que les actes indispensables sont susceptibles de modifications, il serait bon de toujours consulter la dernière édition de la brochure. Toute information ultérieure est publiée au Journal Officiel.

2. **Traduction du fascicule du brevet européen en vertu de l'article 65(1) de la Convention sur le brevet européen**
Votre attention est de nouveau attirée sur l'obligation faite par certains États contractants, en vertu de l'article 65(1) CBE, de fournir une traduction du fascicule du brevet européen, à laquelle il est fait référence dans la notification établie conformément à la règle 71(5) CBE. Si la(les) traduction(s) n'est(ne sont) pas fournie(s), le brevet européen peut, dès l'origine, être réputé sans effet dans cet(ces) Etat(s). Pour plus de détails, nous vous renvoyons à la brochure susmentionnée.

3. **Paiement des taxes annuelles pour le brevet européen**
Conformément à l'article 141 CBE des taxes annuelles "nationales" dues au titre du brevet européen peuvent être perçues pour les années suivant celle au cours de laquelle la mention de la délivrance du brevet européen est publiée au "Bulletin européen des brevets. Pour plus de détails, nous vous renvoyons à la brochure susmentionnée.

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FLS v. Metso - IPR2025-00985

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Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	7304089
Application number	EP13745198.5
Date of receipt	21 March 2019
Receiving Office	European Patent Office, The Hague
Your reference	P-EP93434MN
Applicant	All applicants as on file
Documents submitted	package-data.xml epf1038.pdf (2 p.) CLMSTRAN-FR-1.pdf\Claims_FR.pdf (4 p.) ep-sfd-request.xml IGRA-1.pdf\Acceptance decision response to EPO.pdf (1 p.) CLMSTRAN-DE-1.pdf\Claims_DE.pdf (3 p.)
Submitted by	CN=Jarmo Tanskanen 23717
Method of submission	Online
Date and time receipt generated	21 March 2019, 09:02 (CET)
Message Digest	BC:C1:A8:75:AD:49:1C:9A:0A:BD:80:0A:07:AD:88:80:46:21:5B:14

Correction by the EPO of errors in debit instructions filed by eOLF
Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

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PAPULA NEVINPAT
YOUR EXCLUSIVE RIGHT

Papula-Nevinpat
Business ID 0236098-2
VAT number FI02360982

Head office
Mechelininkatu 1 a
FI-00180 Helsinki, Finland

Mail address
POB 981
FI-00101 Helsinki, Finland

Phone
+358 (0)9 348 0060

Fax
+358 (0)9 3480 0630, 3480 0631

E-mail
papula@papula-nevinpat.com
firstname.lastname@papula-nevinpat.com

western-patents@papula-nevinpat.com
eurasian-patents@papula-nevinpat.com
trademarks@papula-nevinpat.com
designs@papula-nevinpat.com
validation@papula-nevinpat.com
annuities@papula-nevinpat.com

Internet
www.papula-nevinpat.com

European Patent Office
D-80298 München
Germany

Our ref: P-EP93434MN
Date: 19 March 2019

European patent application No. 13745198.5
- Outotec (Finland) Oy

Sirs,

Referring to the Communication under Rule 71(3) EPC dated 28 November 2018, we enclose claims in French and in German. We also pay the fee for grant including the fee for publication (EUR 925,00).

Respectfully

PAPULA OY

ENCS Claims in French and in German

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REVENDICATIONS

1.- Palier fluide multidirectionnel pour une portée d'arbre, comprenant :

une base (14) ayant une première surface orthogonale à une seconde surface, un ou plusieurs orifices d'alimentation en fluide lubrifiant et une pluralité de passages en communication fluidique avec lesdits orifices d'alimentation en fluide lubrifiant, ladite première surface et ladite seconde surface,

un premier patin d'appui en polymère (17A) pouvant être monté sur ladite première surface, ledit patin d'appui en polymère (17A) ayant une première surface externe (13A) et au moins un renfoncement (18) pour recevoir un fluide lubrifiant à partir d'au moins l'un de ladite pluralité de passages et distribuer ledit fluide lubrifiant sur ladite première surface externe (13A), et

un second patin d'appui en polymère (17B) pouvant être monté sur ladite seconde surface, ledit second patin d'appui en polymère (17B) ayant une seconde surface externe (13B) et au moins un renfoncement pour recevoir un fluide lubrifiant à partir d'au moins l'un de ladite pluralité de passages et distribuer ledit fluide lubrifiant sur ladite seconde surface externe (13B),

dans lequel au moins un renfoncement (18) dudit au moins un desdits premier et second patins d'appui en polymère (17A, 17B) comprend au moins une ouverture (18A) pour recevoir au moins un matériel de fixation (23) pour monter ledit au moins un patin

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d’appui en polymère sur ladite base, dans lequel ledit au moins un renfoncement comprend une languette de verrouillage (28) pour retenir une partie tête (26) dudit matériel de fixation à l’intérieur dudit au moins un renfoncement, ladite partie tête étant conique pour faciliter la rétention dudit au moins un matériel de fixation à l’intérieur dudit au moins un renfoncement par ladite languette de verrouillage.

2.- Palier fluide multidirectionnel selon la revendication 1, dans lequel ledit premier patin d’appui en polymère (17A) est monté amovible sur ladite première surface.

3.- Palier fluide multidirectionnel selon la revendication 1 ou 2, dans lequel ledit second patin d’appui en polymère (17B) est monté amovible sur ladite seconde surface.

4.- Palier fluide multidirectionnel selon l’une quelconque des revendications 1 à 3, dans lequel ledit premier patin d’appui en polymère (17A) recouvre sensiblement ladite première surface et ledit second patin d’appui en polymère (17B) recouvre sensiblement ladite seconde surface pour créer respectivement des joints liquides entre lesdits premier et second patins d’appui en polymère et ladite base.

5.- Palier fluide multidirectionnel selon l’une quelconque des revendications 1 à 4, dans lequel ladite première surface externe (13A) est partiellement incurvée de sorte que ledit premier patin d’appui en polymère (17A) joue le rôle d’un palier hydrostatique radial.

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6.- Palier fluide multidirectionnel selon l'une quelconque des revendications 1 à 5, dans lequel ladite seconde surface externe (13B) est sensiblement plane de sorte que ledit second patin d'appui en polymère (17B) joue le rôle d'un palier axial.

7.- Palier fluide multidirectionnel selon l'une quelconque des revendications 1 à 6, dans lequel au moins l'un desdits premier et second patins d'appui en polymère (17A, 17B) comprend un chanfrein (37) au niveau d'un bord externe pour retenir un fluide lubrifiant au niveau dudit bord externe et transférer ledit fluide lubrifiant vers une portée d'arbre (4).

8.- Palier fluide multidirectionnel selon la revendication 7, dans lequel ledit chanfrein présente un bord externe qui est déplacé par rapport à une portée d'arbre quand ladite portée d'arbre vient au contact dudit au moins un patin d'appui en polymère.

9.- Palier fluide multidirectionnel selon l'une quelconque des revendications 1 à 8, dans lequel il y a une pluralité de l'au moins un desdits premier et second patins d'appui en polymère, dans lequel lesdites surfaces externes respectives de ladite pluralité d'au moins un desdits premier et second patins en polymère forment une surface d'appui sensiblement uniforme pour ladite portée d'arbre.

10.- Palier fluide multidirectionnel selon la revendication 9, dans lequel chacun de ladite pluralité d'au moins un desdits premier et second patins d'appui en polymère (17A, 17B) comprend au moins une partie de connexion latérale pour un engagement réciproque avec

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une partie de connexion latérale correspondante d'un patin d'appui en polymère adjacent.

11.- Palier fluide multidirectionnel selon l'une quelconque des revendications 1 à 10, dans lequel ledit au moins un matériel de fixation comprend un alésage pour acheminer un fluide lubrifiant depuis ledit au moins un passage vers ledit au moins un renfoncement (18), ledit au moins un matériel de fixation étant partiellement reçu dans ledit au moins un passage.

12.- Palier fluide multidirectionnel selon l'une quelconque des revendications 1 à 11, dans lequel ladite base comprend (14) au moins une bride (9) à des fins d'engagement avec une partie de montage (8) d'au moins un desdits premier et second patins d'appui en polymère (17A, 17B) pour fixer solidement ledit au moins un patin d'appui en polymère à ladite base (14).

13.- Palier fluide multidirectionnel selon la revendication 12, dans lequel ladite bride (9) est située au niveau d'un bord externe de ladite base.

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ANSPRÜCHE

1. Mehrdirektionales Fluidlager für einen Wellenzapfen, Folgendes umfassend:

ein Basisteil (14), das Folgendes umfasst: eine erste Fläche, die orthogonal zu einer zweiten Fläche steht, eine oder mehrere Zuführungsöffnungen für Schmierfluid und mehrere Durchgänge, die in Fluidkommunikation mit den Zuführungsöffnungen für Schmierfluid, der ersten Fläche und der zweiten Fläche stehen,

ein erstes Polymer-Lagerkissen (17A), das an der ersten Fläche angebracht werden kann, wobei das Polymer-Lagerkissen (17A) Folgendes hat: eine erste Außenfläche (13A) und wenigstens eine Vertiefung (18), um Schmierfluid von wenigstens einem von den mehreren Durchgängen zu erhalten und um dieses Schmierfluid an die erste Außenfläche (13A) zu verteilen, und

ein zweites Polymer-Lagerkissen (17B), das an der zweiten Fläche angebracht werden kann, wobei das zweite Polymer-Lagerkissen (17B) Folgendes hat: eine zweite Außenfläche (13B) und wenigstens eine Vertiefung, um Schmierfluid von wenigstens einem von den mehreren Durchgängen zu erhalten und um dieses Schmierfluid an die zweite Außenfläche (13B) zu verteilen,

wobei wenigstens eine Vertiefung (18) von wenigstens einem von dem ersten und zweiten Polymer-Lagerkissen (17A, 17B) wenigstens eine Öffnung (18A) umfasst, um wenigstens ein Befestigungsmittel (23) aufzunehmen, um das wenigstens eine Polymer-Lagerkissen an dem Basisteil zu befestigen, wobei die wenigstens eine Vertiefung einen Verriegelungslappen (28) umfasst, um einen Kopfabschnitt (26) des Befestigungsmittels innerhalb der wenigstens einen Vertiefung zu halten, wobei der Kopfabschnitt konisch zulaufend ist, um das Zurückhalten des wenigstens einen Befestigungsmittels innerhalb der wenigstens einen Vertiefung durch den Verriegelungslappen zu unterstützen.

2. Mehrdirektionales Fluidlager nach Anspruch 1, wobei das erste Polymer-Lagerkissen (17A) abnehmbar an der ersten Fläche befestigt ist.

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3. Mehrdirektionales Fluidlager nach Anspruch 1 oder 2, wobei das zweite Polymer-Lagerkissen (17B) abnehmbar an der zweiten Fläche befestigt ist.

4. Mehrdirektionales Fluidlager nach einem der Ansprüche 1 bis 3, wobei das erste Polymer-Lagerkissen (17A) im Wesentlichen die erste Fläche abdeckt und das zweite Polymer-Lagerkissen (17B) im Wesentlichen die zweite Fläche abdeckt, um jeweils Fluiddichtungen zwischen dem ersten und zweiten Polymer-Lagerkissen und dem Basisteil herzustellen.

5. Mehrdirektionales Fluidlager nach einem der Ansprüche 1 bis 4, wobei die erste Außenfläche (13A) derart teilweise gekrümmt ist, dass das erste Polymer-Lagerkissen (17A) als ein radiales hydrostatisches Lager arbeitet.

6. Mehrdirektionales Fluidlager nach einem der Ansprüche 1 bis 5, wobei die zweite Außenfläche (13B) im Wesentlichen eben ist, derart, dass das zweite Polymer-Lagerkissen (17B) als ein axiales Lager arbeitet.

7. Mehrdirektionales Fluidlager nach einem der Ansprüche 1 bis 6, wobei wenigstens eines von dem ersten und zweiten Polymer-Lagerkissen (17A, 17B) eine Abschrägung (37) an einer Außenkante umfasst, um Schmierfluid an der Außenkante zu halten und um das Schmierfluid zu einem Wellenzapfen (4) zu übertragen.

8. Mehrdirektionales Fluidlager nach Anspruch 7, wobei die Abschrägung eine Außenkante hat, die von einem Wellenzapfen abgesetzt ist, wenn der Wellenzapfen auf dem wenigstens einen Polymer-Lagerkissen liegt.

9. Mehrdirektionales Fluidlager nach einem der Ansprüche 1 bis 8, wobei mehrere von wenigstens einem von dem ersten und zweiten Polymer-Lagerkissen vorhanden sind und wobei die jeweiligen Außenflächen der mehreren von dem wenigstens einen von dem ersten und zweiten Polymer-Lagerkissen für den Wellenzapfen eine im Wesentlichen gleichmäßige Lagerfläche bilden.

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10. Mehrdirektionales Fluidlager nach Anspruch 9, wobei jedes von den mehreren von dem wenigstens einen von dem ersten und zweiten Polymer-Lagerkissen (17A, 17B) wenigstens einen seitlichen Verbindungsabschnitt zum gegenseitigen Ineinandergreifen mit einem entsprechenden seitlichen Verbindungsabschnitt an einem benachbarten Polymer-Lagerkissen umfasst.

11. Mehrdirektionales Fluidlager nach einem der Ansprüche 1 bis 10, wobei das wenigstens eine Befestigungsmittel eine Bohrung umfasst, um Schmierfluid von dem wenigstens einen Durchgang zu der wenigstens einen Vertiefung (18) zu transportieren, wobei das wenigstens eine Befestigungsmittel in dem wenigstens einen Durchgang teilweise aufgenommen ist.

12. Mehrdirektionales Fluidlager nach einem der Ansprüche 1 bis 11, wobei das Basisteil (14) wenigstens einen Kragen (9) umfasst, um mit einem Befestigungsabschnitt (8) von wenigstens einem von dem ersten und zweiten Polymer-Lagerkissen (17A, 17B) ineinanderzugreifen, um das wenigstens eine Polymer-Lagerkissen sicher am Basisteil (14) zu befestigen.

13. Mehrdirektionales Fluidlager nach Anspruch 12, wobei der Kragen (9) sich an einer Außenkante des Basisteils befindet.

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FLS v. Metso - IPR2025-00985

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Office européen des brevets

Letter accompanying subsequently filed items

Representative:

Papula Oy
397
P.O. Box 981
00101 Helsinki
Finland

Phone: +358-9-3480060
Fax: +358-9-34800630
E-mail: western-patents@papula-nevinpat.com

80298 Munich
Germany
Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818
2280 HV Rijswijk
Netherlands
Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin
Germany
Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	13745198.5
Applicant's or representative's reference	P-EP93434MN

	Description of document	Original file name	Assigned file name
1	Reply to the communication under rule 71(3) EPC	Acceptance decision response to EPO.pdf	IGRA-1.pdf
2	French translations of the claims	Claims_FR.pdf	CLMSTRAN-FR-1.pdf
3	German translations of the claims	Claims_DE.pdf	CLMSTRAN-DE-1.pdf

	Fees	Factor applied	Fee schedule	Amount to be paid
15-1	007 Fee for grant, including fee for publication of the European patent specification (R71(3))	1	925.00	925.00
	Total:		**EUR**	**925.00**

	Payment	
1	Method of payment	Debit from deposit account
	Currency:	EUR
	The European Patent Office is hereby authorised, to debit from the deposit account with the EPO any fees and costs indicated on the fees page.	
	Deposit account number:	28150011
	Account holder:	Papula Oy
2	Refund/Reimburserment	
	Reimbursement (if any) to be made to EPO deposit account:	28150011
	Account holder:	Papula Oy

Signatures

Place:

Date: **21 March 2019**

Signed by: **Jarmo Tanskanen 23717**

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FLS v. Metso - IPR2025-00985

Association:	**Papula Oy**
Representative name:	**Jarmo Tanskanen**
Capacity:	**(Representative)**

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Europäisches Patentamt
European Patent Office
Office européen des brevets

European Patent Office
Postbus 5818
2280 HV Rijswijk
NETHERLANDS
Tel: +31 70 340 2040
Fax: +31 70 340 3016

Annex to EPO Form 2004, Communication pursuant to Rule 71(3) EPC

Bibliographical data of European patent application No. 13 745 198.5

For the intended grant of the European patent, the bibliographical data are set out below, for information:

Title of invention:	- VERBESSERUNGEN VON FLUIDLAGERN - IMPROVEMENTS IN FLUID BEARINGS - AMÉLIORATIONS DE PALIERS FLUIDES
Classification:	INV. F16C32/06
Date of filing:	28.06.2013
Priority claimed:	AU / 28.06.2012 / AUA2012902770
Contracting States* for which fees have been paid:	AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Extension States* for which fees have been paid:	
Validation States* for which fees have been paid:	
Applicant(s):**	Outotec (Finland) Oy Rauhalanpuisto 9 02230 Espoo FI
Inventor(s):	BRAITHWAITE, Daniel 5/17 Hertha Road, Innaloo, Western Australia 6018 AU BELKE, Jeffrey, Victor 11 Cowrie Cresent, Mt Pleasant, Western Australia 6153 AU GREEN, Nicholas, John 98a Toorak Road, Rivervale, Western Australia 6103 AU

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European Patent Office
Postbus 5818
2280 HV Rijswijk
NETHERLANDS
Tel: +31 70 340 2040
Fax: +31 70 340 3016

TATE, Chris
187 Delgado Parade,
Iluka, Western Australia 6028
AU

HARRISON, Oscar
35 Campsbourne Street,
Balcatta, Western Australia 6021
AU

VAAGE, Knut
Middlethunsgate 23,
0368 Oslo
NO

*)	If the time limit for the payment of designation fees according to Rule 39(1) EPC has not yet expired and the applicant has not withdrawn any designation, **all Contracting States/Extension States/Validation States** are currently still deemed to be designated. See also Rule 71a(3) EPC and, if applicable, the above Note to users of the automatic debiting procedure.
**)	If two or more applicants have designated different Contracting States, this is indicated here.

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Postbus 5818
2280 HV Rijswijk
NETHERLANDS
Tel: +31 70 340 2040
Fax: +31 70 340 3016

Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Formalities Officer
Name: Rincón Ruiz, C
Tel: +31 70 340 - 4346
or call
+31 (0)70 340 45 00

Application No.	Ref.	Date
13 745 198.5 - 1013	P-EP93434Y	28.11.2018
Applicant: Outotec (Finland) Oy		

Communication under Rule 71(3) EPC

1. Intention to grant

You are informed that the examining division intends to grant a European patent on the basis of the above application, with the text and drawings and the related bibliographic data as indicated below.

A copy of the relevant documents is enclosed.

1.1 In the text for the Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

Description, Pages

1-28	filed in electronic form on	25-01-2018

Claims, Numbers

1-13	filed in electronic form on	25-01-2018

Drawings, Sheets

1/13-5/13, 8/13-13/13	as published	
7/13	filed in electronic form on	24-03-2017
6/13	filed in electronic form on	25-01-2018

With the following amendments to the above-mentioned documents proposed by the division

Description, Pages	1, 3-11, 13, 14, 17, 25, 27, 28
Claims, Numbers	1, 13

Comments

DESCRIPTION
Page 1: Mention of relevant prior art in the description (Rule 42(1) EPC)
Pages 3-11, 13, 14, 17, 25, 27: Description adapted to amended claims (Art. 84 EPC)
Pages 11, 28: Error(s) in spelling, grammar, typography corrected
Page 28: Guidelines F-IV, 4.4
CLAIMS
Page 29, Claim 1: Error(s) in spelling, grammar, typography corrected
Page 29, Claim 1: Insertion of reference signs in claims (Rule 43(7) EPC)
Page 29, Claim 1: Scope of claim unclear - clarified (Art. 84 EPC): otherwise the features that come after the introduction of the "at least one opening", as well as the features of claim 11, do not make sense
Page 30, Claim 13: "Preferably" empties the claim of any substance, rendering its scope unclear (Article 84 EPC).

1.2 Bibliographic data

The title of the invention in the three official languages of the European Patent Office, the international patent classification, the designated contracting states, the registered name(s) of the applicant(s) and the other bibliographic data are shown on **EPO Form 2056** (enclosed).

2. Invitation

You are invited, **within a non-extendable period of four months** of notification of this communication,

2.1 to EITHER approve the text communicated above and verify the bibliographic data (Rule 71(5) EPC)

(1) by filing a translation of the claim(s) in the other two official languages of the EPO

	Fee code	EUR
(2a) by paying the fee for grant including the fee for publication:	**007**	925.00
minus any amount already paid (Rule 71a(5) EPC):		0.00
Total amount:		925.00
(3) by paying additional claims fees under Rule 71(4) EPC; number of claims fees payable: 0	**016**	0.00
minus any amount already paid (Rule 71a(5) EPC):		0.00
Total amount:		0.00

Important: If the translations of the claims and fees have already been filed and paid respectively in reply to a previous communication under Rule 71(3) EPC, e.g. in the case of resumption of examination after approval (see Guidelines C-V, 6), **agreement as to the text to be granted** (Rule 71a(1) EPC) must be expressed within the same time limit (e.g. by approving the text and verifying the bibliographic data, by confirming that grant proceedings can go ahead with the documents on file and/or by stating which translations of the claims already on file are to be used).

Note 1: See "Notes concerning fee payments" below.

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Note 2: Any overpaid "minus" amounts will be refunded when the decision to grant (EPO Form 2006A) has been issued.
Note 3: For the calculation of the grant fee under Article 2(2), No. 7, RFees (old fee structure), the number of pages is determined on the basis of a clean copy of the application documents, in which text deleted as a result of any amendments by the examining division is not shown. Such clean copy is made available via on-line file inspection only.

2.2 OR, in the case of disapproval, to request reasoned amendments or corrections to the text communicated above or keep to the latest text submitted by you (Rule 71(6) EPC).

In this case the translations of the claims and fee payments mentioned under point 2.1 above are NOT due.

The terms "amendment(s)" and "correction(s)" refer only to amendments or corrections of the application documents and not of other documents (e.g. bibliographic data, the designation of the inventor, etc.).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the examining division requesting that you correct this deficiency (Rule 137(4) EPC).

2.3 Bibliographic data

Where you request a change or correction of bibliographic data in response to the Rule 71(3) communication, this will **not** cause the sending of a further communication under Rule 71(3) EPC. You will still have to pay the fees and file translations in reply to the Rule 71(3) communication in the case of 2.1 above, unless you also file a reasoned request for amendments or corrections in response to the Rule 71(3) communication (see case 2.2 above).

3. Loss of rights

If neither of the two possible actions above (see points 2.1 or 2.2) is performed in due time, the European patent application will be deemed to be withdrawn (Rule 71(7) EPC).

4. Further procedure

4.1 In the case of point 2.1 above

4.1.1 The decision to grant the European patent will be issued, and the **mention of the grant** of the patent will be published in the European Patent Bulletin, if the requirements concerning the translation of the claims and the payment of all fees are fulfilled and there is agreement as to the text to be granted (Rule 71a(1) EPC).

Note on payment of the renewal fee:
If a renewal fee becomes due before the next possible date for publication of the mention of the grant of the European patent, publication will be effected only after the renewal fee and any additional fee have been paid (Rule 71a(4) EPC).

Under Article 86(2) EPC, the obligation to pay renewal fees to the European Patent Office terminates with the payment of the renewal fee due in respect of the year in which the mention of the grant of the European patent is published.

Note on payment of the designation fee(s):
If the designation fee(s) become(s) due after the communication under Rule 71(3) EPC, the mention of the grant of the European patent will not be published until these fees have been paid (Rule 71a(3) EPC).

4.1.2 After publication, the **European patent specification** can be downloaded free of charge from the EPO publication server https://data.epo.org/publication-server.

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4.1.3 Filing of translations in the contracting states

As regards translation requirements prescribed by the contracting states under Article 65(1) EPC, please consult the website of the European Patent Office
www.epo.org ➞Law & practice ➞Legal texts, National law relating to the EPC
www.epo.org ➞Law & practice ➞All Legal texts ➞London Agreement

In the case of a valid extension or validation

As regards translation requirements prescribed by the extension or validation states, please consult the website of the European Patent Office
www.epo.org ➞Law & practice ➞Legal texts, National law relating to the EPC

Failure to supply a prescribed translation in a contracting state, or in an extension or validation state may result in the patent being deemed to be void *ab initio* in the state concerned (Art. 65(3) EPC).

4.2 In the case of 2.2 above

If the present communication under Rule 71(3) EPC is based on an auxiliary request and, within the time limit, you maintain the main request or a higher ranking request which is not allowable, the application will be refused (Art. 97(2) EPC).

If the examining division gives its consent to the requested amendments or corrections, it will issue a new communication under Rule 71(3) EPC; otherwise, it shall resume the examination proceedings (Rule 71(6) EPC).

5. Filing of a divisional application

Any divisional application relating to this European patent application must be filed directly with the European Patent Office in Munich, The Hague or Berlin and will be in the language of the proceedings for the present application, or if the latter was not in an official language of the EPO, the divisional application may be filed in the language of the present application as filed (see Article 76(1) and Rule 36(2) EPC). Any such divisional application must be filed while the present application is still pending (Rule 36(1) EPC; Guidelines A-IV, 1.1.1).

6. Notes concerning fee payments

6.1 Making payments

For payments made via deposit account, please note that as from 1 December 2017 debit orders will only be carried out if filed in an electronically processable format (xml), using an accepted means of filing as laid down in the Arrangements for deposit accounts (ADA), published in the Supplementary publication in the Official Journal.

All relevant information related to the modes of payment of fees to the EPO can be retrieved from the EPO website at "**Making Payments**".

6.2 Information concerning fee amounts

Procedural fees are usually adjusted every two years, on even years, with effect from 1 April. Therefore, before making a payment, parties should verify the amounts actually due on the date of payment using the applicable version of the Schedule of fees and expenses, published as a Supplement to the Official Journal of the EPO, available on the EPO website (**www.epo.org**) at **www.epo.org/schedule-of-fees**. The "Schedule of fees" table allows the viewing, downloading and searching of individual fee amounts, both current and previous.

6.3 Note to users of the automatic debiting procedure

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The fee for grant, including the fee for publication, and any additional claims fees due under Rule 71(4) EPC will be debited automatically on the date of filing of the translations of the claims, or on the last day of the period of this communication. However, if the designation fee(s) become(s) due as set out in Rule 71a(3) EPC and/or a renewal fee becomes due as set out in Rule 71a(4) EPC, these should be paid separately by another permitted way of payment in order not to delay the publication of the mention of the grant. The same applies in these circumstances to the payment of extension and validation fees. The same applies in these circumstances to the payment of extension and validation fees.

Note: If a waiver is expressed in response to a Rule 71(3) communication (see OJ EPO 2015, A52), the fee for grant, including the fee for publication/printing, and any additional claims fees will not be debited automatically. These fees must be paid separately by another means of payment allowed under the Rules relating to Fees.

Examining Division:

Chairman:	Cerva-Pédrin, Sonia
2nd Examiner:	Hutter, Manfred
1st Examiner:	Martin, Christophe

Rincón Ruiz, C
For the Examining Division
Tel. No.: +31 70 340 - 4346 **Branch at The Hague**

Enclosures: Text intended for grant

EPO Form 2056

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Europäisches Patentamt
European Patent Office
Office européen des brevets

European Patent Office
Postbus 5818
2280 HV Rijswijk
NETHERLANDS
Tel: +31 70 340 2040
Fax: +31 70 340 3016

Application No.: 13 745 198.5

IV.2. Patent classification

The classification indicated on the published patent application remains unchanged. It is as follows:

INV. F16C32/06

IV.3. Title of the invention

The title has been changed. It now is as follows:

VERBESSERUNGEN VON FLUIDLAGERN

IMPROVEMENTS IN FLUID BEARINGS

AMÉLIORATIONS DE PALIERS FLUIDES

IV.4. Documentation

CDOC The following documents not mentioned in the Search Report were cited during the Examination Procedure:

DE 27 31 074 A1 (ZUEBLIN AG) 25 January 1979 (1979-01-25)

30.10.2018
Date

Cerva-Pédrin, Sonia
Chairman

Martin, Christophe
1st examiner

Hutter, Manfred
2nd examiner

Enclosure(s):

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Field of the Invention

[0001] The present invention relates to a fluid bearing of the type disclosed e.g. in GB 1 508 384 and in a particular a hydrostatic polymeric bearing for use in a mill. The invention has been developed primarily for use as a hydrostatic polymeric bearing in grinding mills and will be described hereinafter by reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use, but also extends to other types of fluid bearings such as hydrodynamic bearings and hybrid bearings (i.e. bearings that use a combination of hydrodynamic and continuous hydrostatic flow for lubrication).

Background of the Invention

[0002] The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its advantages to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an express or implied admission that such art is widely known or forms part of common general knowledge in the field.

[0003] A grinding mill has a mill chamber and two journal shafts, the journals being mounted upon supports for rotation. Typical bearings have two main components; a steel base for mounting to the support and a bearing pad or surface for contact with the mill journal. These mill bearings are installed between the mill journals and the supports so that the mill journals rotate on the bearing pads during operation of the grinding mill.

[0004] The applicant developed a hydrostatic pad bearing system for grinding mills that is currently in use. In this hydrostatic pad bearing system, an external oil supply system pumps high-pressure oil to recesses machined into the bearing so that the oil forms a thin film on the bearing pad surface. The resultant hydraulic pressure is sufficient to completely lift the mill journal off the hydrostatic pads and separate the sliding surfaces. Thus, mill actually “floats” on a film of oil between journal and bearing. As such the bearing will operate under both static and dynamic conditions. Since the surfaces are completely separated and the bearing is self aligning there is no metal-to-metal contact between the bearing surface and the mill journal due to the oil film, thus

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resulting in only low friction. Consequently, maintaining the oil film between the surfaces means that there is virtually no wear in the bearing.

[0005] Despite the advantages conferred by this hydrostatic bearing system, a loss of oil pressure (and thus a reduction in the oil film thickness) can cause failure of the bearings, leading to damage to the bearing pad and/or the mill journal. For example, it can take a few seconds for a grinding mill to stop turning in the event of a power failure, and when this happens there is a high risk of damage to the mill bearing pads or journal surfaces due to a loss of oil reducing the oil film thickness, thereby bringing the journal and bearings into direct metal to metal contact. The consequential downtime for replacement of any damaged bearings and/or journals severely impairs operation of the mill, reducing its efficiency.

[0006] To prevent this type of damage, grinding mill lubrication systems usually have pressure accumulator systems that are typically used to store and deliver high pressure oil to the bearing in the event of a power failure and the oil supply system fails. These pressure accumulators are expensive, require frequent maintenance to ensure that they are at the appropriate pressure level and can interfere with control systems in the mill. Thus, there are increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and then the oil supply ports for delivering high pressure oil to the recesses are then drilled into the base. Bronze is spray welded or cast onto the relevant parts of the steel base to form the bearing pad or lining. Spray welding enables the bronze metal to form a seal with the base. White metal may be used instead of bronze, but is cast onto the base. Due to this manufacturing process, the repair and/or refurbishment of these bearings involves initially cleaning the damaged bearing surface, machining any parts of the steel base and either spray welding the bronze or re-casting the bronze/white metal. This repair process cannot be performed on-site but requires the bearing to be returned to the manufacturer. Consequently, mills must keep a sufficient stock of spare bearings to account for the absence of damaged bearings being repaired. This adds to the maintenance costs of the mill.

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[0008] It is an object of the present invention to overcome or substantially ameliorate one or more of the disadvantages of prior art, or at least to provide a useful alternative.

[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] As part of the invention, there is provided a polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means for securely mounting said polymer bearing pad to said base.

[0011] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0012] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0013] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

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[0014] According to the invention, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. Said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0015] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0016] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0017] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0018] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0019] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0020] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0021] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

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[0022] As part of the invention, there is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

the polymer bearing pad of the first aspect of the present invention mountable to said base.

[0023] Preferably, said polymer bearing pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect, preferably said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] According to the invention, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

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[0028] Said at least one fastener is partially received in said at least one passage. Said at least one fastener comprises a head portion for engagement with said at least one recess. According to the invention, said at least one recess has a locking tab for retaining said head portion within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing could have comprised a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener would be countersunk into said at least one recess.

[0030] Preferably, said at least one fastener would be substantially retained within said at least one recess by a locking element. More preferably, said locking element could have comprised a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] According to the invention, the base comprises a first surface, a second surface orthogonal thereto, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

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wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] According to the invention,

said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] An unclaimed method of making a polymer bearing pad for a fluid bearing, could be such that it comprises

forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] An unclaimed method of making a fluid bearing for a journal, could be such that it comprises

the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for

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connecting said polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] A fluid bearing for a journal, could comprise:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer could be inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer could be inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

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[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface orthogonal thereto, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first outer surface and said polymer bearing pad substantially covers said second outer surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] According to the invention, at least one recess of said at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. Said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

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[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] According to the invention, at least one recess of said at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Said at least one polymer bearing pad comprises a locking tab for retaining said at least one fastener within said at least one recess.

[0058] Preferably, at least one of said first and second polymer bearing pads comprises a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

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Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

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[0076] Figures 11 and 11A are schematic partial views of a fastener according to the invention for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative unclaimed fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

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[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the

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journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to

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act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

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[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An unclaimed fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent

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any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23 also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the

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event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a “hovercraft” type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20,

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21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems

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damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the “lead-in” chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the “lead-in” chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the “lead-out” chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of

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the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased “off the shelf” in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural

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integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same

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reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

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[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the

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polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the “axial float”. Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

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[0119] While the preferred embodiments of the invention have been described using one possible fastener arrangement as illustrated in Figures 11, 11A, it will be appreciated that other fastener type arrangements may be used to implement the invention.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

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[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permit the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms, within the scope as defined in the claims.

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Claims

1. A multidirectional fluid bearing for a journal, comprising:

a base (14) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad (17A) mountable to said first surface, said polymer bearing pad (17A) having a first outer surface (13A) and at least one recess (18) for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface (13A), and

a second polymer bearing pad (17B) mountable to said second surface, said second polymer bearing pad (17B) having a second outer surface (13B) and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (13B)

wherein at least one recess (18) of said at least one of said first and second polymer bearing pads (17A, 17B) comprises at least one opening (18A) for receiving at least one fastener (23) for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab (28) for retaining a head portion (26) of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

2. The multidirectional fluid bearing of claim 1, wherein said first polymer bearing pad (17A) is removably mounted to said first surface.

3. The multidirectional fluid bearing of claim 1 or 2, wherein said second polymer bearing pad (17B) is removably mounted to said second surface.

4. The multidirectional fluid bearing of any one of claims 1 to 3, wherein said first polymer bearing pad (17A) substantially covers said first surface and said second polymer bearing pad (17B) substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

5. The multidirectional fluid bearing of any one of claims 1 to 4, wherein said first outer surface (13A) is partially curved such that said first polymer bearing pad (17A) acts as a radial hydrostatic bearing.

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6. The multidirectional fluid bearing of any one of claims 1 to 5, wherein said second outer surface (13B) is substantially planar such that said second polymer bearing pad (17B) acts as an axial bearing.

7. The multidirectional fluid bearing of any one of claims 1 to 6, wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises a chamfer (37) at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal (4).

8. The multidirectional fluid bearing of claim 7, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

9. The multidirectional fluid bearing of any one of claims 1 to 8, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

10. The multidirectional fluid bearing of claim 9, wherein each of said plurality of at least one of said first and second polymer bearing pads (17A, 17B) comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

11. The multidirectional fluid bearing of any one of claims 1 to 10, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess (18), said at least one fastener being partially received in said at least one passage.

12. The multidirectional fluid bearing of any one of claims 1 to 11, wherein said base comprises (14) at least one flange (9) for engagement with a mounting portion (8) of at least one of said first and second polymer bearing pads (17A, 17B) to securely mount said at least one polymer bearing pad to said base (14).

13. The multidirectional fluid bearing of claim 12, wherein said flange (9) is located at an outer edge of said base.

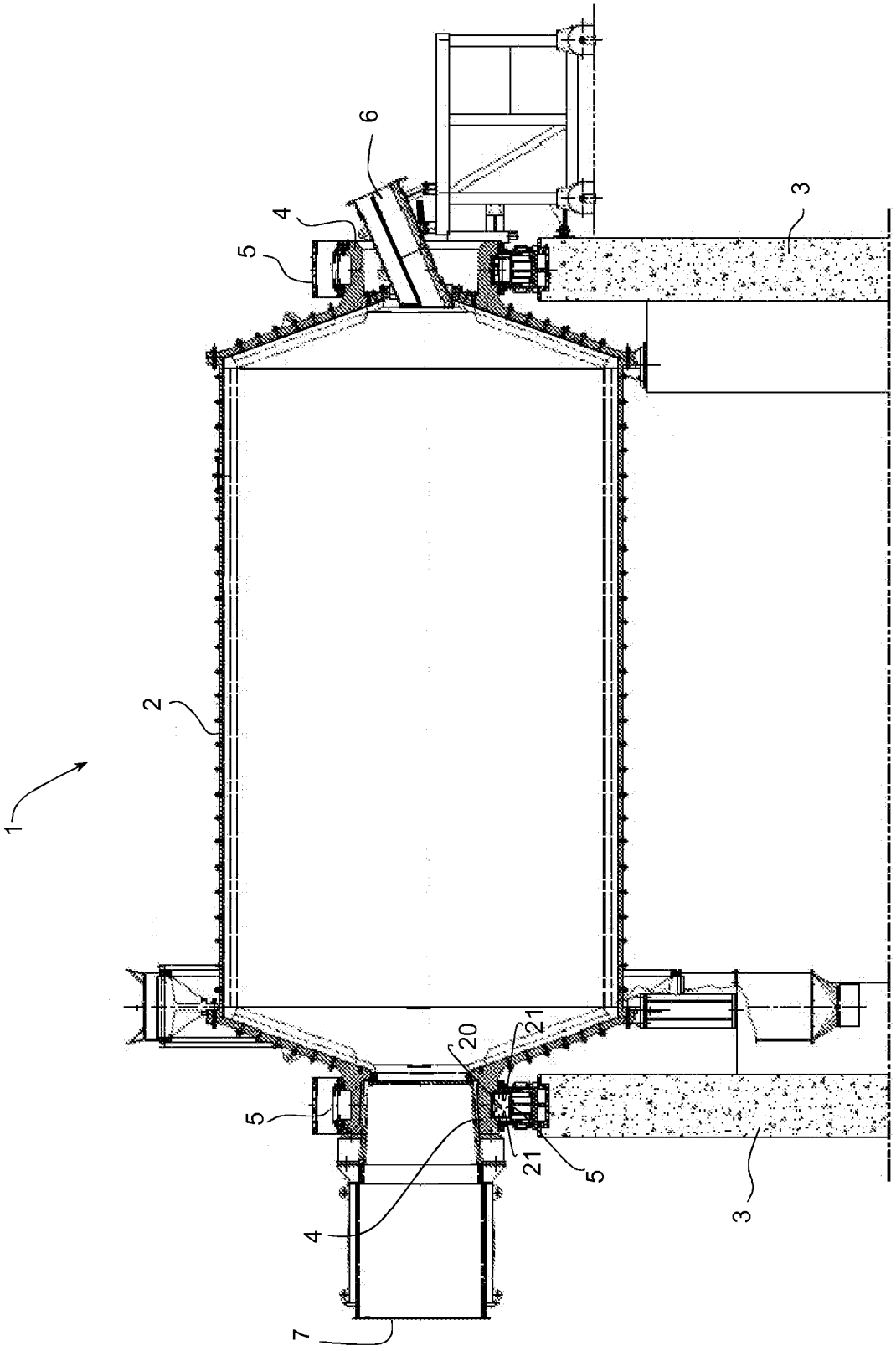


Fig. 1

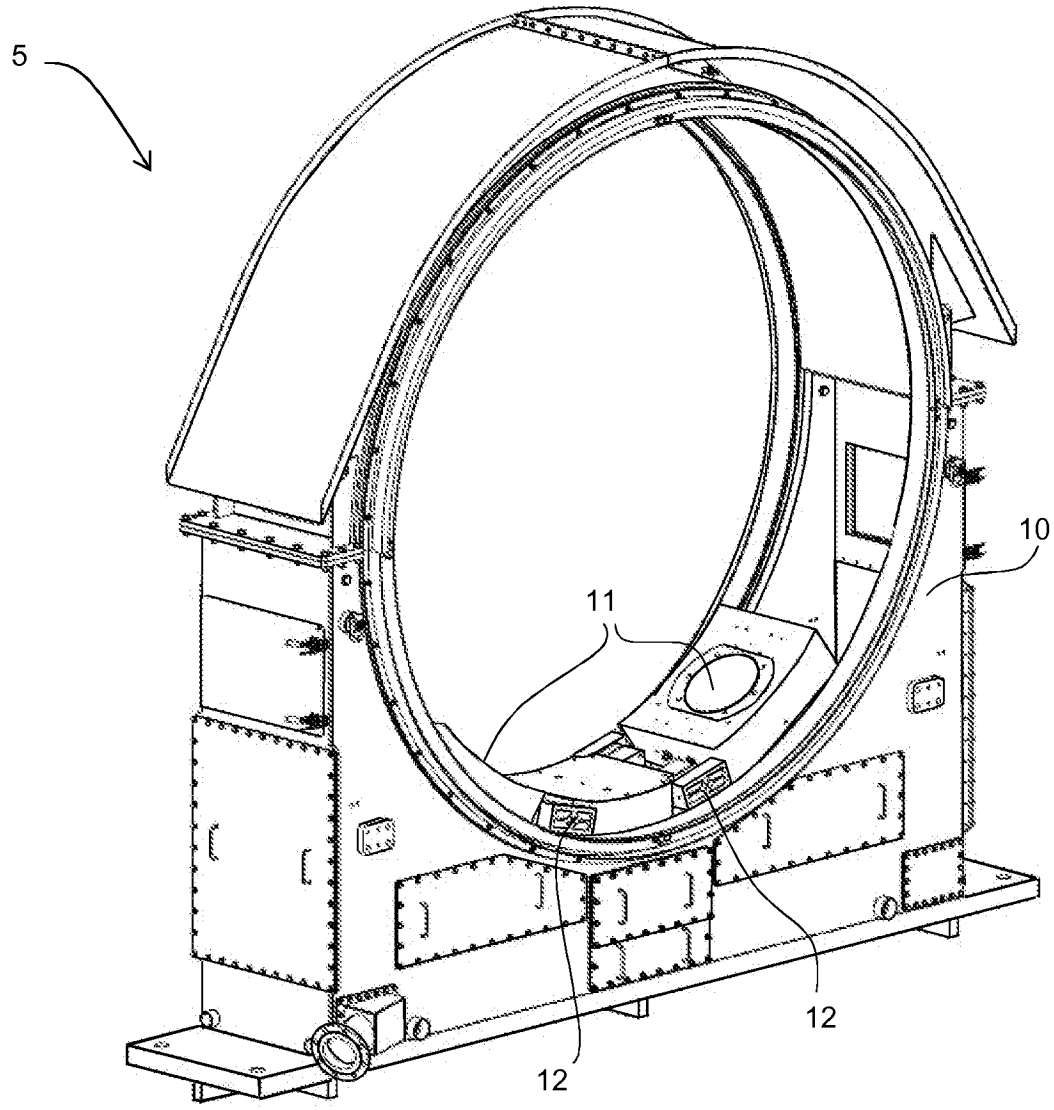


Fig. 2

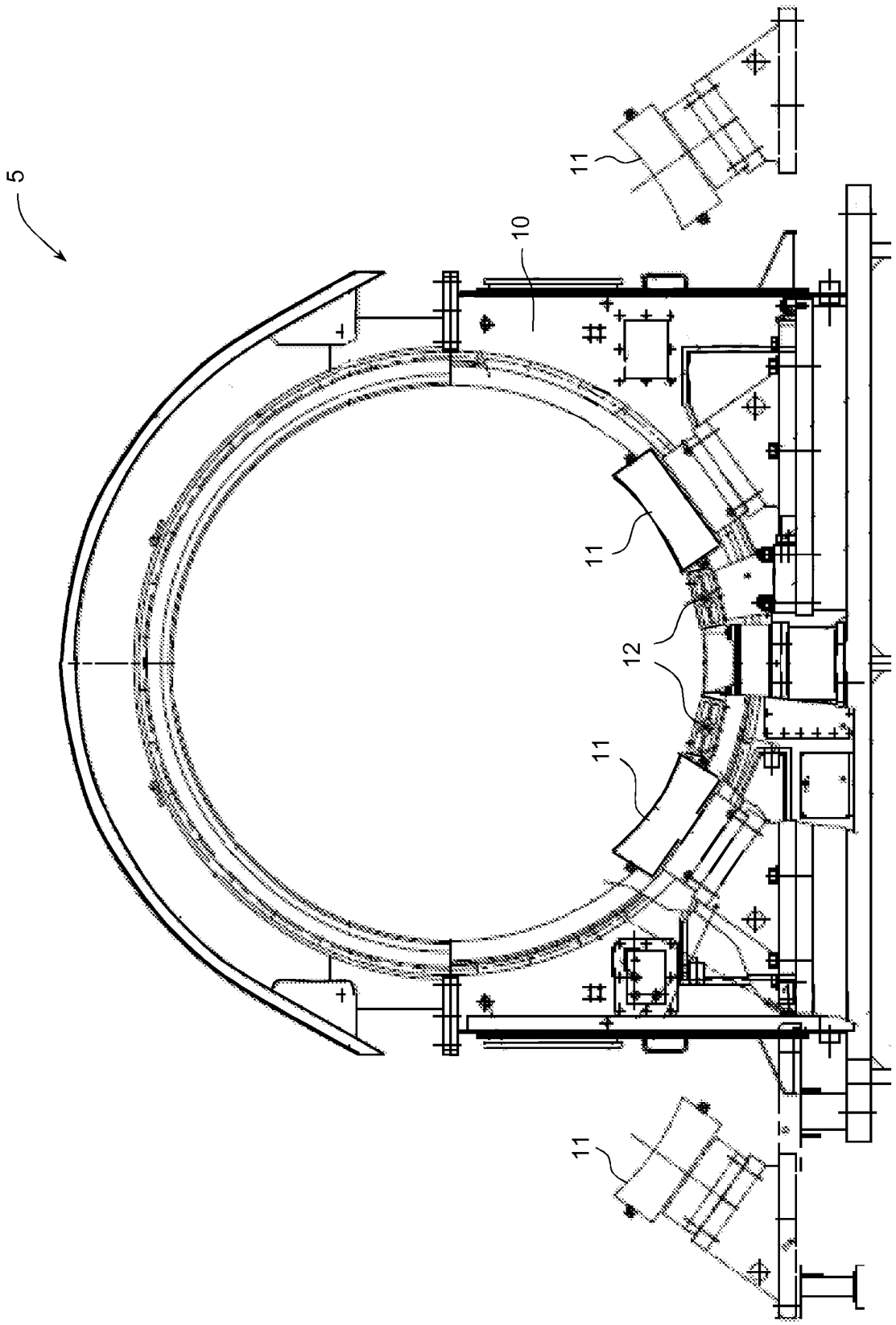


Fig. 3

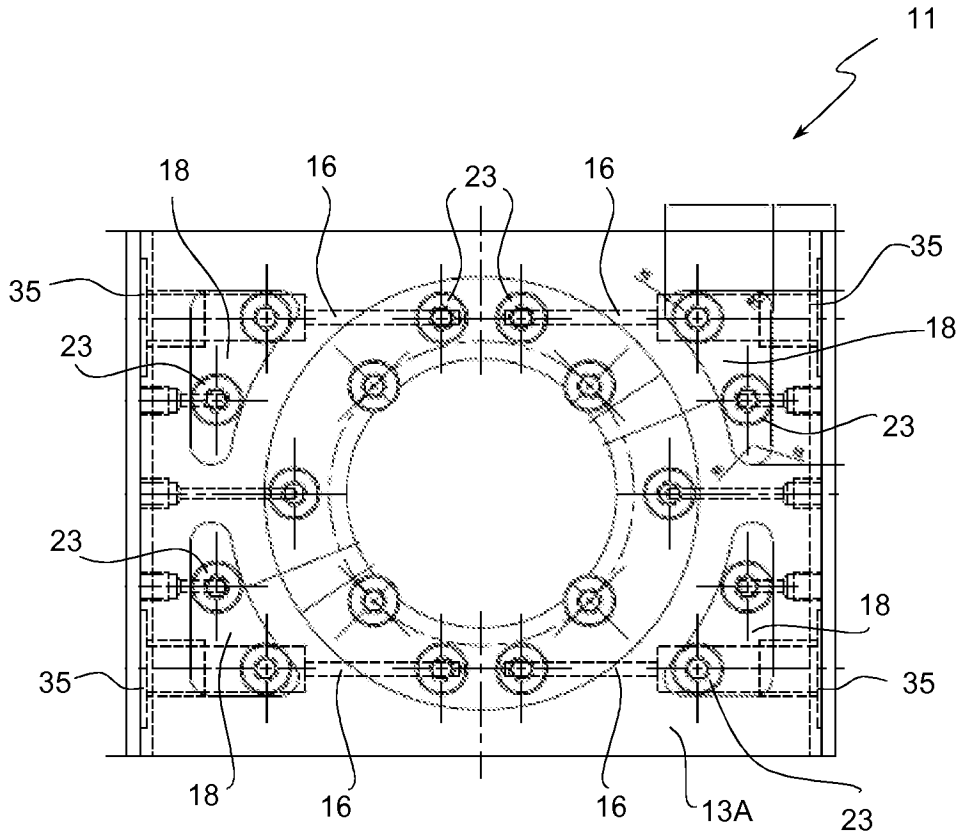


Fig. 4

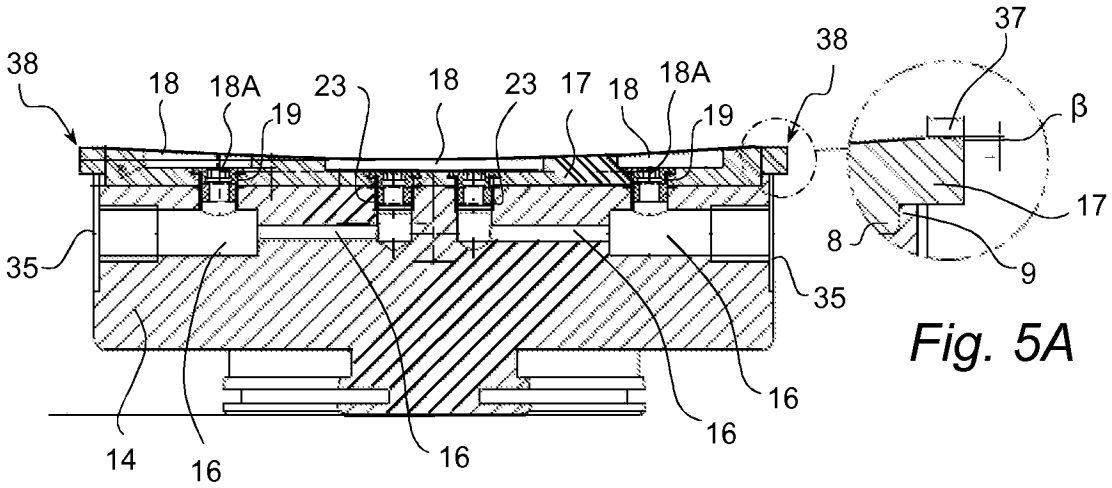


Fig. 5A

Fig. 5

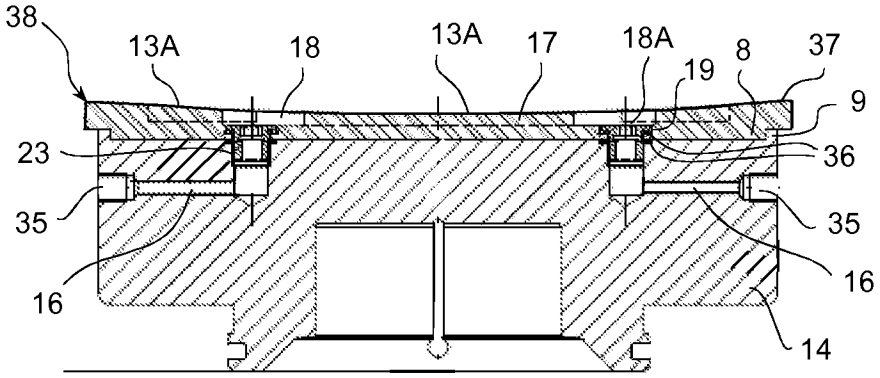


Fig. 6

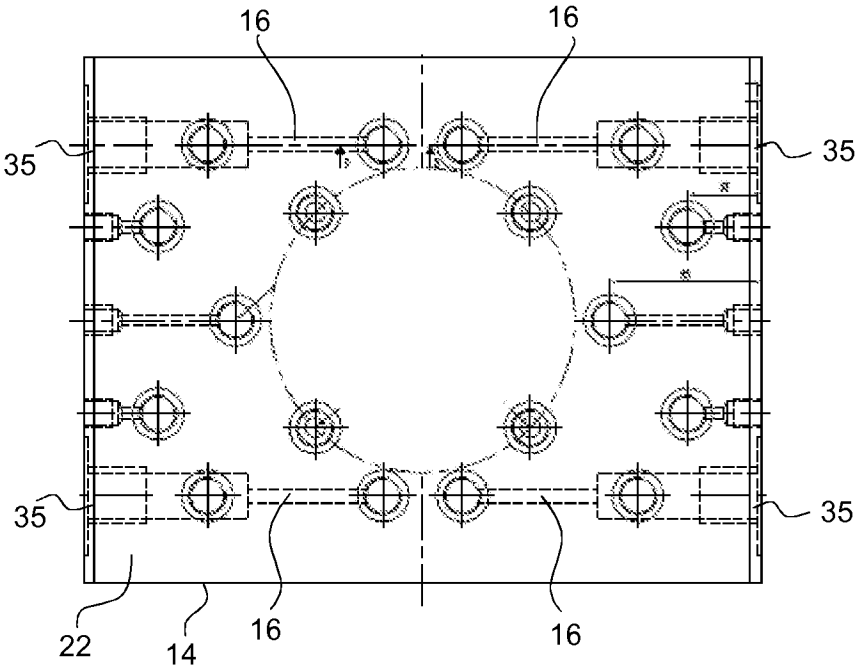


Fig. 7

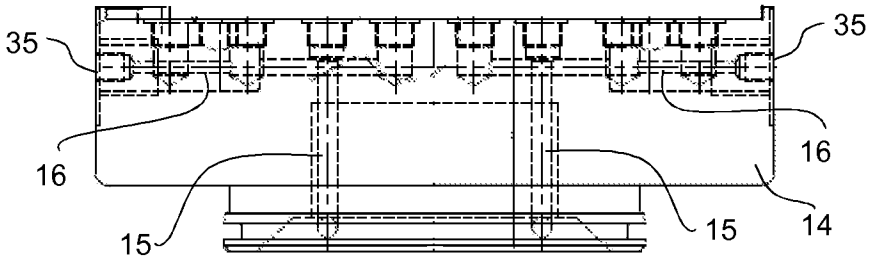


Fig. 8

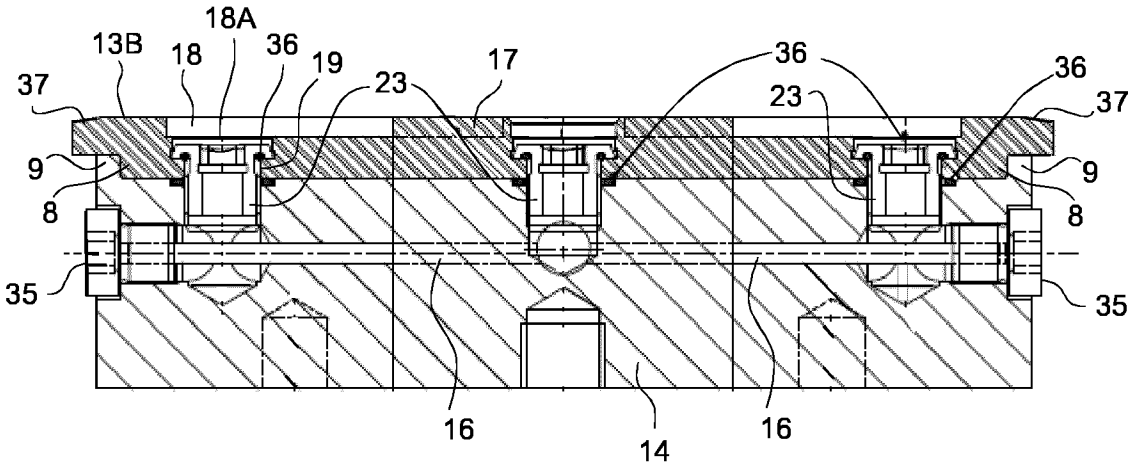

18A
13B
18
36
19
23
17
36
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37
37
9
8
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8
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35
16
14
16

Fig. 9

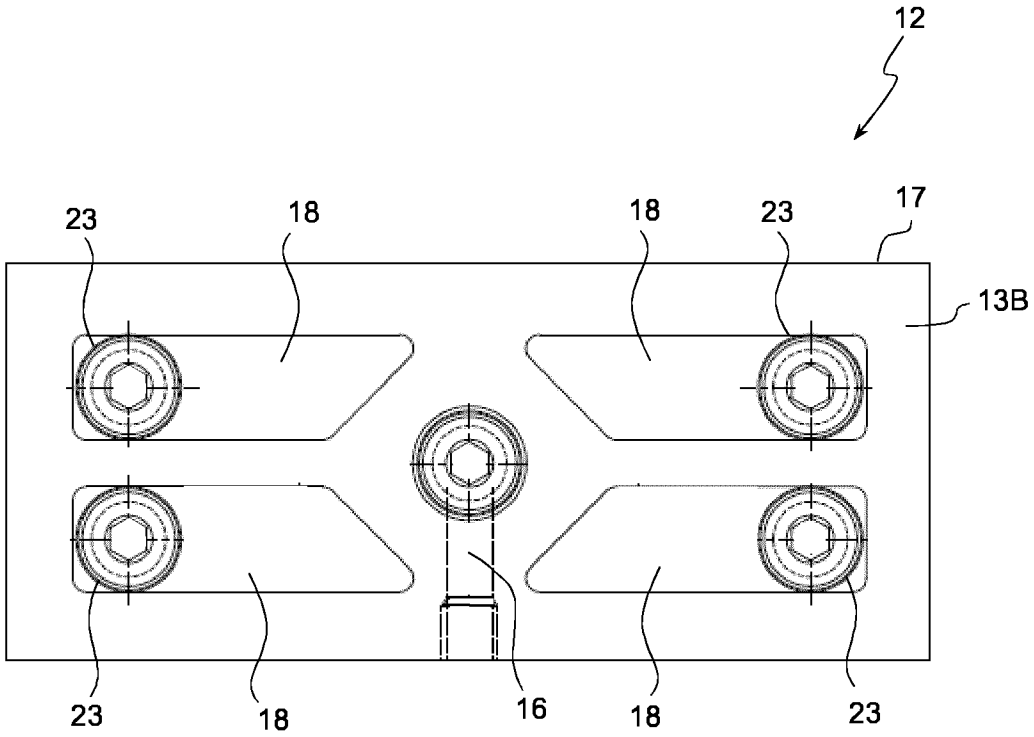

12
23
18
18
23
17
13B
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18
16
18
23

Fig. 10

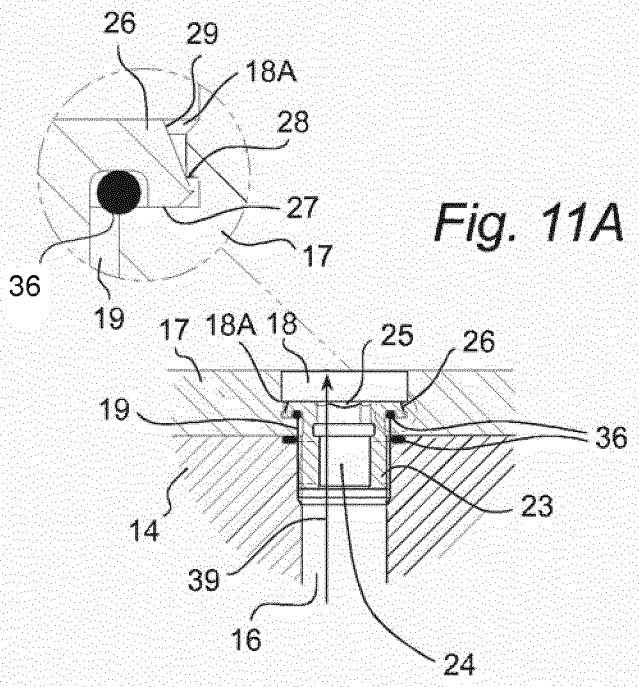


Fig. 11A

Fig. 11

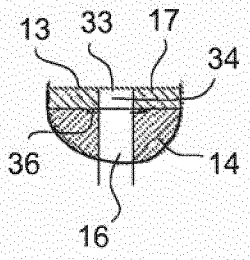


Fig. 12A

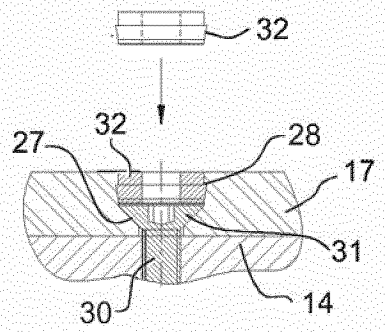


Fig. 12

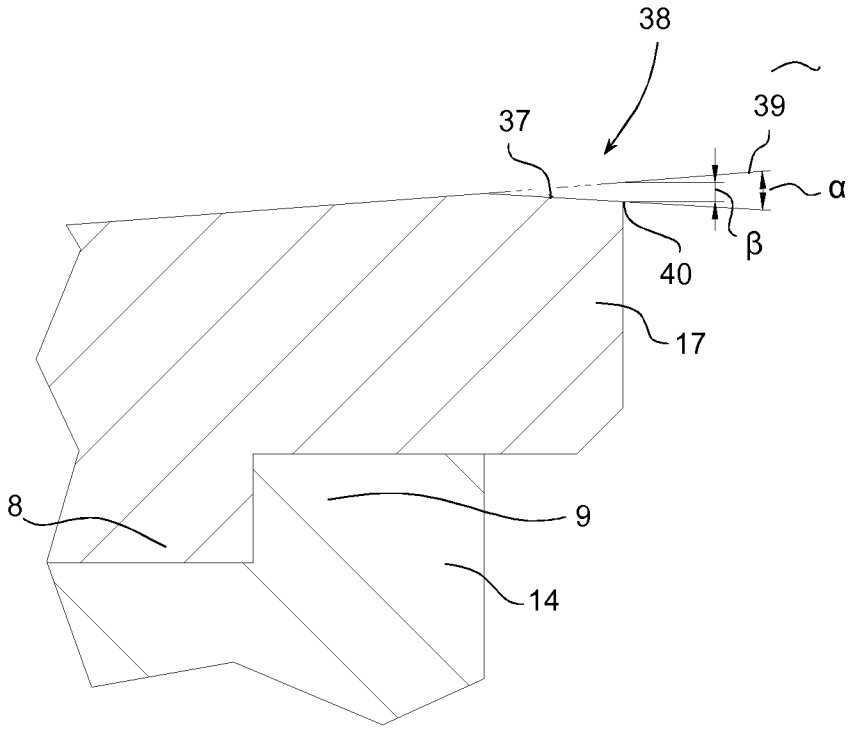


Fig. 13

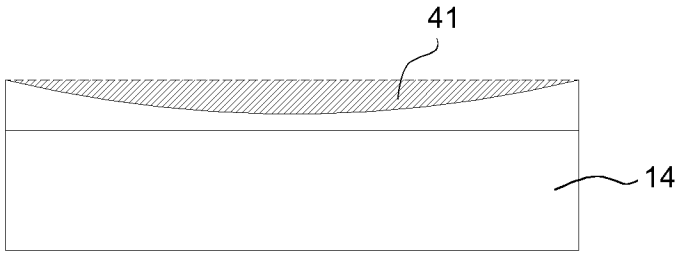


Fig. 14

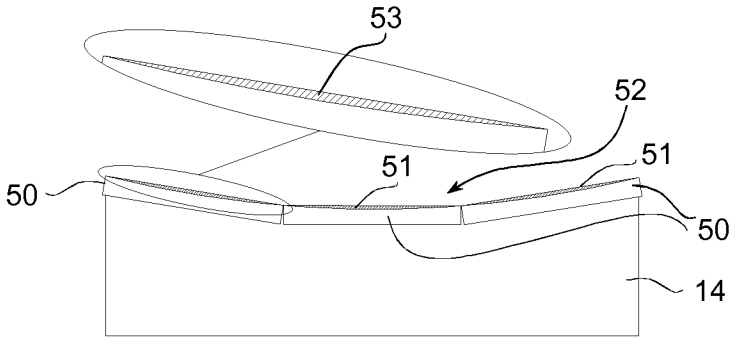


Fig. 15

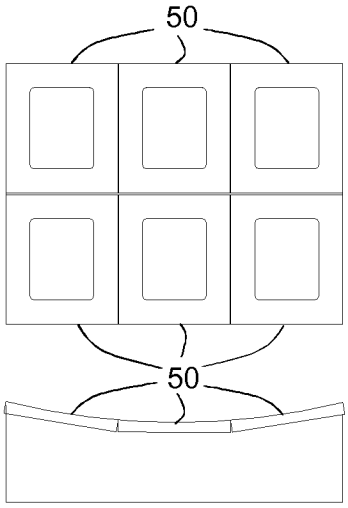


Fig.16

Fig.16A

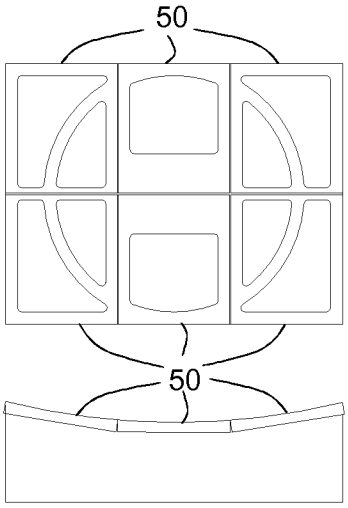


Fig.17

Fig.17A

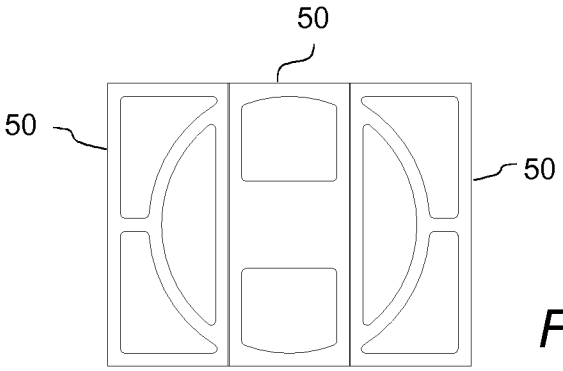


Fig. 18

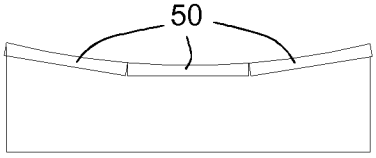


Fig. 18A

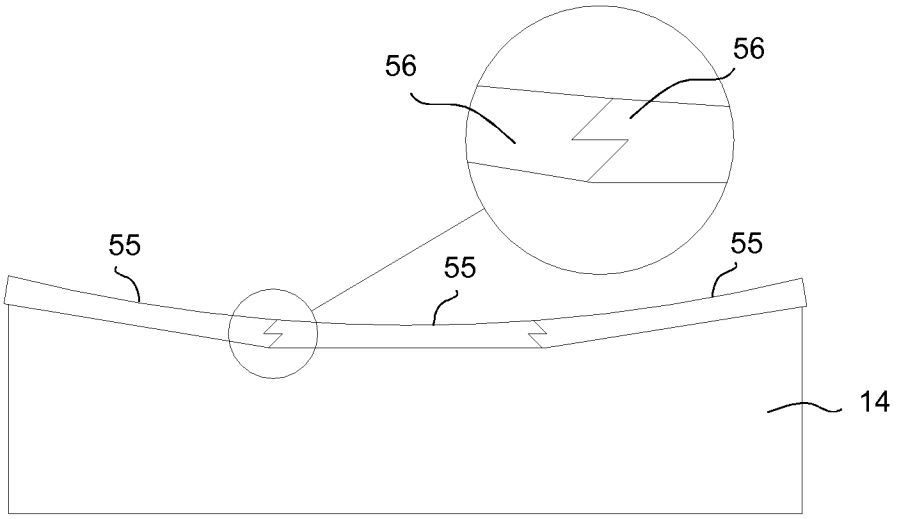


Fig. 19

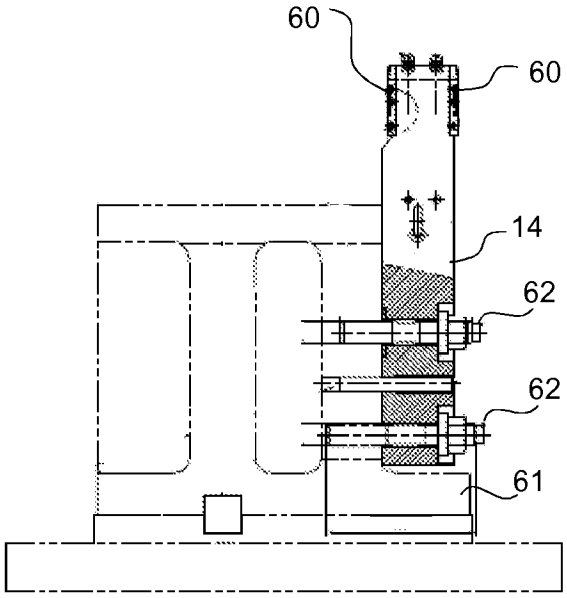
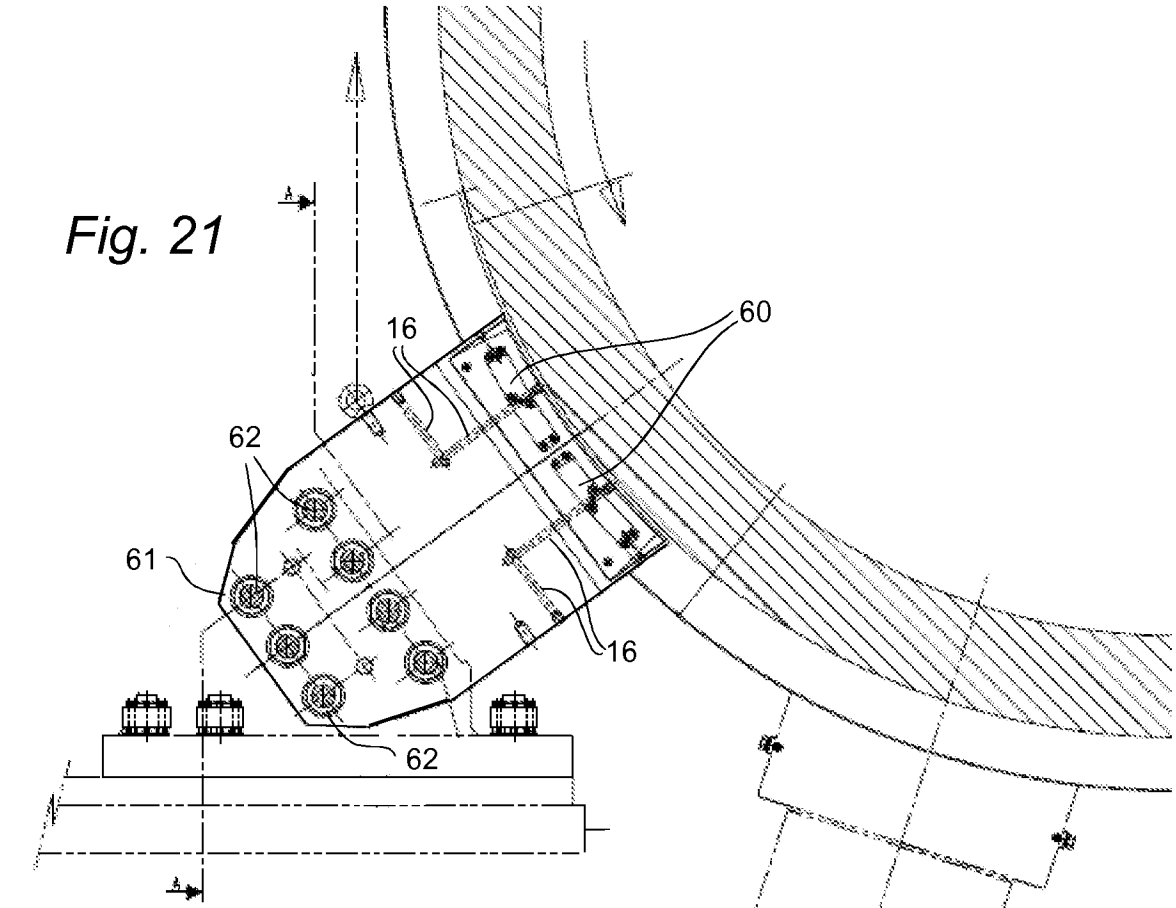


Fig. 22

Fig. 21



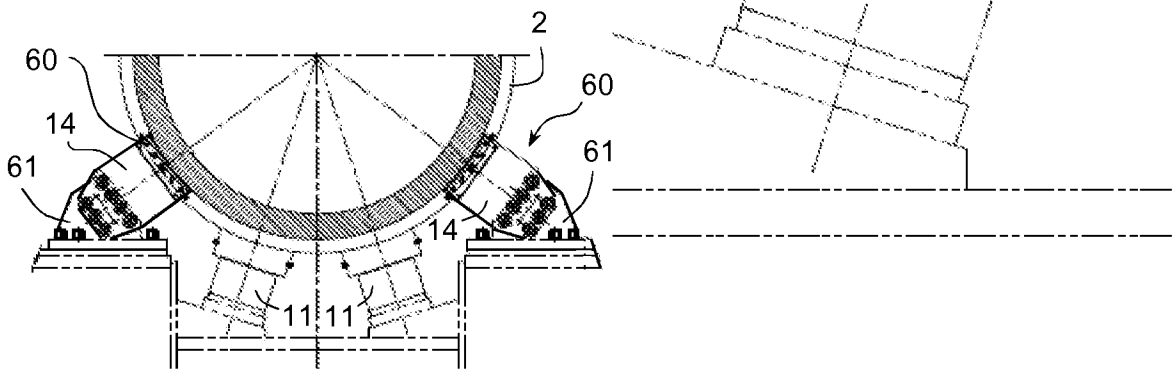


Fig. 20

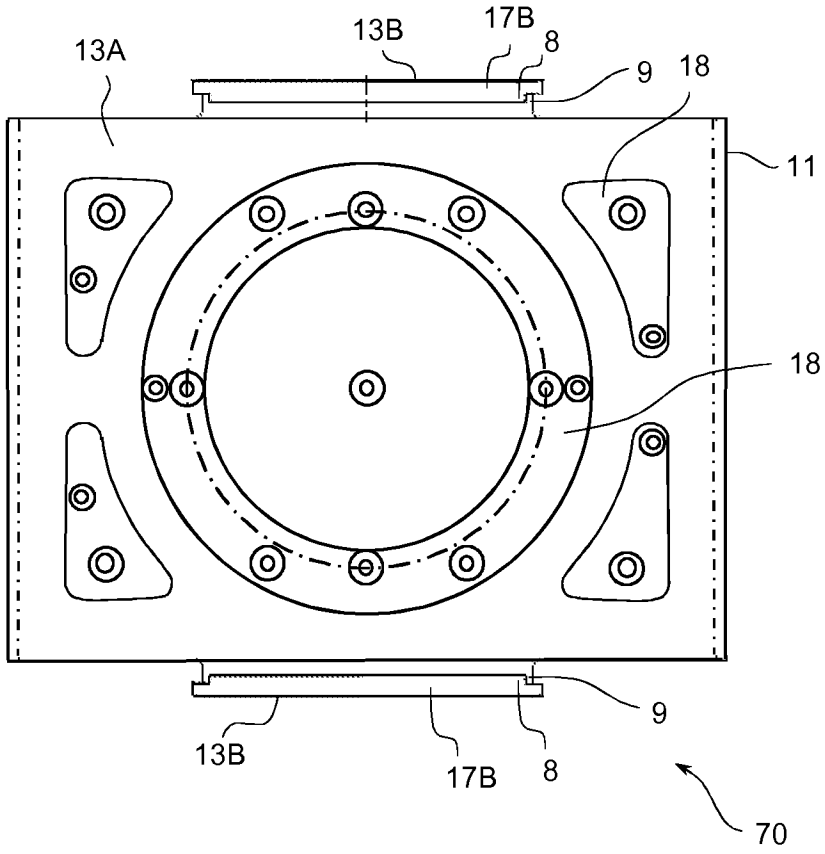


Fig. 23

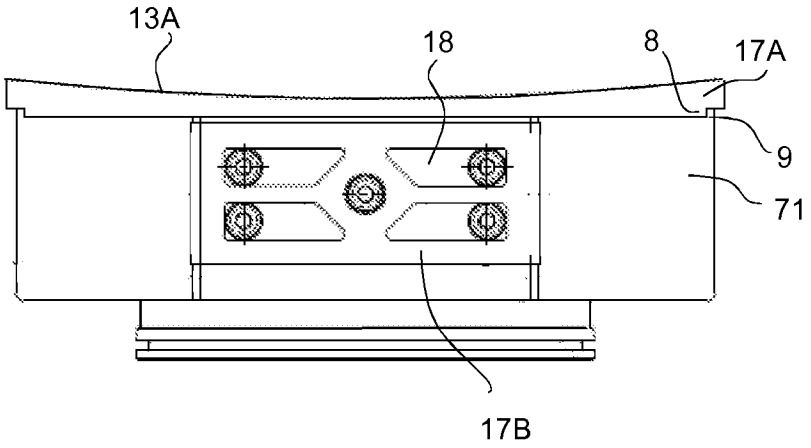


Fig. 24

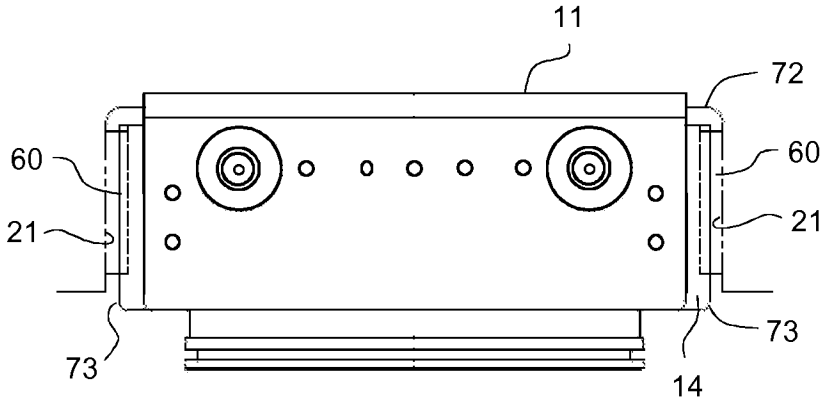


Fig. 25

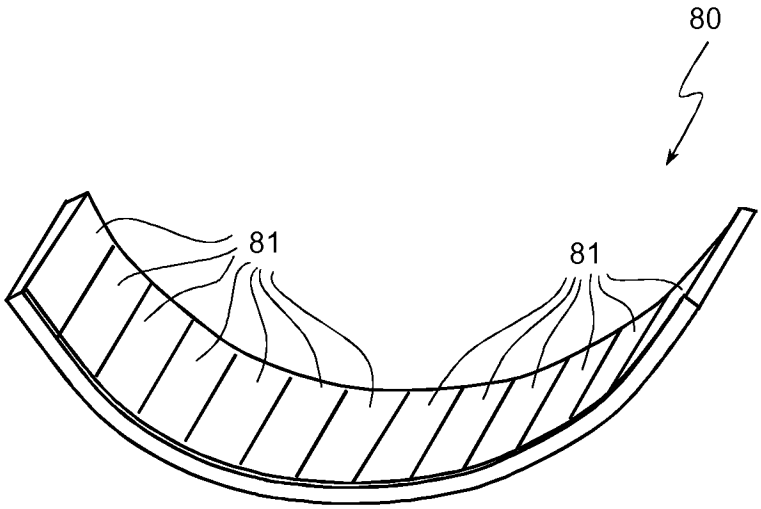


Fig. 26

Field of the Invention

[0001] The present invention relates to a fluid bearing of the type disclosed e.g. in GB 1 508 384 and in a particular a hydrostatic polymeric bearing for use in a mill. The invention has been developed primarily for use as a hydrostatic polymeric bearing in grinding mills and will be described hereinafter by reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use, but also extends to other types of fluid bearings such as hydrodynamic bearings and hybrid bearings (i.e. bearings that use a combination of hydrodynamic and continuous hydrostatic flow for lubrication).

Background of the Invention

[0002] The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its advantages to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an express or implied admission that such art is widely known or forms part of common general knowledge in the field.

[0003] A grinding mill has a mill chamber and two journal shafts, the journals being mounted upon supports for rotation. Typical bearings have two main components; a steel base for mounting to the support and a bearing pad or surface for contact with the mill journal. These mill bearings are installed between the mill journals and the supports so that the mill journals rotate on the bearing pads during operation of the grinding mill.

[0004] The applicant developed a hydrostatic pad bearing system for grinding mills that is currently in use. In this hydrostatic pad bearing system, an external oil supply system pumps high-pressure oil to recesses machined into the bearing so that the oil forms a thin film on the bearing pad surface. The resultant hydraulic pressure is sufficient to completely lift the mill journal off the hydrostatic pads and separate the sliding surfaces. Thus, mill actually “floats” on a film of oil between journal and bearing. As such the bearing will operate under both static and dynamic conditions. Since the surfaces are completely separated and the bearing is self aligning there is no metal-to-metal contact between the bearing surface and the mill journal due to the oil film, thus

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resulting in only low friction. Consequently, maintaining the oil film between the surfaces means that there is virtually no wear in the bearing.

[0005] Despite the advantages conferred by this hydrostatic bearing system, a loss of oil pressure (and thus a reduction in the oil film thickness) can cause failure of the bearings, leading to damage to the bearing pad and/or the mill journal. For example, it can take a few seconds for a grinding mill to stop turning in the event of a power failure, and when this happens there is a high risk of damage to the mill bearing pads or journal surfaces due to a loss of oil reducing the oil film thickness, thereby bringing the journal and bearings into direct metal to metal contact. The consequential downtime for replacement of any damaged bearings and/or journals severely impairs operation of the mill, reducing its efficiency.

[0006] To prevent this type of damage, grinding mill lubrication systems usually have pressure accumulator systems that are typically used to store and deliver high pressure oil to the bearing in the event of a power failure and the oil supply system fails. These pressure accumulators are expensive, require frequent maintenance to ensure that they are at the appropriate pressure level and can interfere with control systems in the mill. Thus, there are increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and then the oil supply ports for delivering high pressure oil to the recesses are then drilled into the base. Bronze is spray welded or cast onto the relevant parts of the steel base to form the bearing pad or lining. Spray welding enables the bronze metal to form a seal with the base. White metal may be used instead of bronze, but is cast onto the base. Due to this manufacturing process, the repair and/or refurbishment of these bearings involves initially cleaning the damaged bearing surface, machining any parts of the steel base and either spray welding the bronze or re-casting the bronze/white metal. This repair process cannot be performed on-site but requires the bearing to be returned to the manufacturer. Consequently, mills must keep a sufficient stock of spare bearings to account for the absence of damaged bearings being repaired. This adds to the maintenance costs of the mill.

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[0008] It is an object of the present invention to overcome or substantially ameliorate one or more of the disadvantages of prior art, or at least to provide a useful alternative.

[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] As part of the invention, there ~~There~~ is provided a polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means for securely mounting said polymer bearing pad to said base.

[0011] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0012] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0013] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

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[0014] According to the invention, ~~Alternatively or additionally,~~ said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. Said ~~More preferably, said~~ at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0015] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0016] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0017] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0018] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0019] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0020] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0021] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

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[0022] As part of the invention, there ~~There~~ is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

the polymer bearing pad of the first aspect of the present invention mountable to said base.

[0023] Preferably, said polymer bearing pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect, preferably said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] According to the invention, ~~Preferably,~~ said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

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[0028] Said ~~Preferably, said~~ at least one fastener is partially received in said at least one passage. Said ~~Preferably, said~~ at least one fastener comprises a head portion for engagement with said at least one recess. According to the invention, ~~More preferably,~~ said at least one recess has a locking tab for retaining said head portion within said at least one recess, ~~recess. In one preferred form,~~ said head portion being ~~is~~ tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing could have comprised ~~comprises~~ a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener would be ~~is~~ countersunk into said at least one recess.

[0030] Preferably, said at least one fastener would be ~~is~~ substantially retained within said at least one recess by a locking element. More preferably, said locking element could have comprised ~~comprises, but is not limited to,~~ a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] According to the invention, the base ~~Preferably, said base further~~ comprises a first surface, a second surface orthogonal thereto, ~~surface,~~ a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

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wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] According to the invention, ~~Preferably,~~ said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] An unclaimed ~~There is provided a~~ method of making a polymer bearing pad for a fluid bearing, could be such that it comprises ~~comprising~~ forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] An unclaimed ~~There is provided a~~ method of making a fluid bearing for a journal, could be such that it comprises ~~comprising~~ the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for

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connecting said polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] A fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface orthogonal thereto, ~~surface,~~ at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first outer surface and said polymer bearing pad substantially covers said second outer surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] According to the invention, ~~Preferably,~~ at least one recess of said at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Said ~~More preferably, said~~ at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. Said ~~In one preferred form, said~~ head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

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[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] According to the invention, ~~Preferably,~~ at least one recess of said at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Said ~~Preferably, said~~ at least one polymer bearing pad comprises a locking tab ~~element~~ for retaining said at least one fastener within said at least one recess.

[0058] Preferably, at least one of said first and second polymer bearing pads comprises a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

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Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

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[0076] Figures 11 and 11A are schematic partial views of a fastener 2 according to the invention 2 for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative 2 unclaimed 2 fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

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[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with ~~a further embodiment of~~ the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the

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journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to

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act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

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[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An 2 unclaimed 2 ~~alternative~~ fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent

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any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23 also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the

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event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a “hovercraft” type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20,

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21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems

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damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the “lead-in” chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the “lead-in” chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the “lead-out” chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of

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the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased “off the shelf” in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural

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integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same

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reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to ~~another aspect of~~ the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the

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polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the “axial float”. Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one ~~of two~~ possible fastener arrangement ~~arrangements~~ as illustrated in Figures 11, 11A, ~~12 and 12A,~~ it will be appreciated that other fastener type arrangements may be used to implement the invention. ~~For example, in one preferred form the fasteners are substantially retained within the recesses 10 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.~~

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

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[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages Z permit Z ~~permits~~ the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other Z forms, within the scope as defined in the claims. Z ~~forms.~~

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Claims

1. A multidirectional fluid bearing for a journal, comprising:

a base (14) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad (17A) mountable to said first surface, said polymer bearing pad (17A) having a first outer surface (13A) and at least one recess (18)

for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface (13A), and

a second polymer bearing pad (17B) mountable to said second surface, said second polymer bearing pad (17B) having a second outer surface (13B) and at least one recess for receiving lubricating fluid from at least one of said plurality of

passages and distributing said lubricating fluid to said second outer surface (13B)

wherein at least one recess (18) of said ~~at~~ least one of said first and second polymer bearing pads (17A,

17B) comprises at least one opening (18A) for receiving at least one fastener (23) for mounting

said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab (28) for retaining a head portion (26) of said fastener within said at

least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

2. The multidirectional fluid bearing of claim 1, wherein said first polymer bearing pad (17A) is removably mounted to said first surface.

3. The multidirectional fluid bearing of claim 1 or 2, wherein said second polymer bearing pad (17B) is removably mounted to said second surface.

4. The multidirectional fluid bearing of any one of claims 1 to 3, wherein said first polymer bearing pad (17A) substantially covers said first surface and said second polymer bearing pad (17B) substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

5. The multidirectional fluid bearing of any one of claims 1 to 4, wherein said first outer surface (13A) is partially curved such that said first polymer bearing pad (17A) acts as a radial hydrostatic bearing.

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6. The multidirectional fluid bearing of any one of claims 1 to 5, wherein said second outer surface (13B) is substantially planar such that said second polymer bearing pad (17B) acts as an axial bearing.

7. The multidirectional fluid bearing of any one of claims 1 to 6, wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises a chamfer (37) at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal (4).

8. The multidirectional fluid bearing of claim 7, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

9. The multidirectional fluid bearing of any one of claims 1 to 8, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

10. The multidirectional fluid bearing of claim 9, wherein each of said plurality of at least one of said first and second polymer bearing pads (17A, 17B) comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

11. The multidirectional fluid bearing of any one of claims 1 to 10, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess (18), said at least one fastener being partially received in said at least one passage.

12. The multidirectional fluid bearing of any one of claims 1 to 11, wherein said base comprises (14) at least one flange (9) for engagement with a mounting portion (8) of at least one of said first and second polymer bearing pads (17A, 17B) to securely mount said at least one polymer bearing pad to said base (14).

13. The multidirectional fluid bearing of claim 12, wherein said flange (9) is ~~preferably~~ located at an outer edge of said base.

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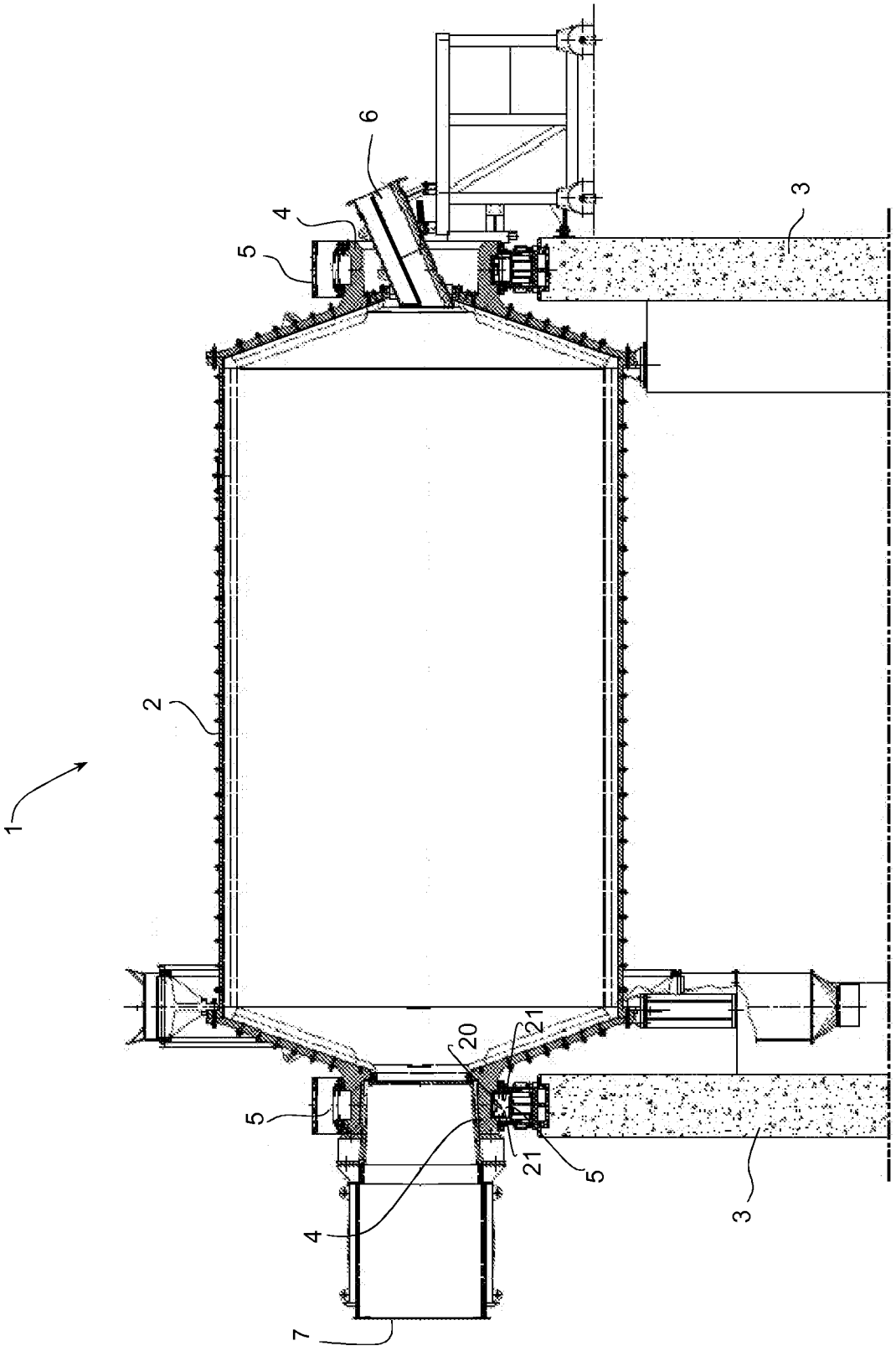


Fig. 1

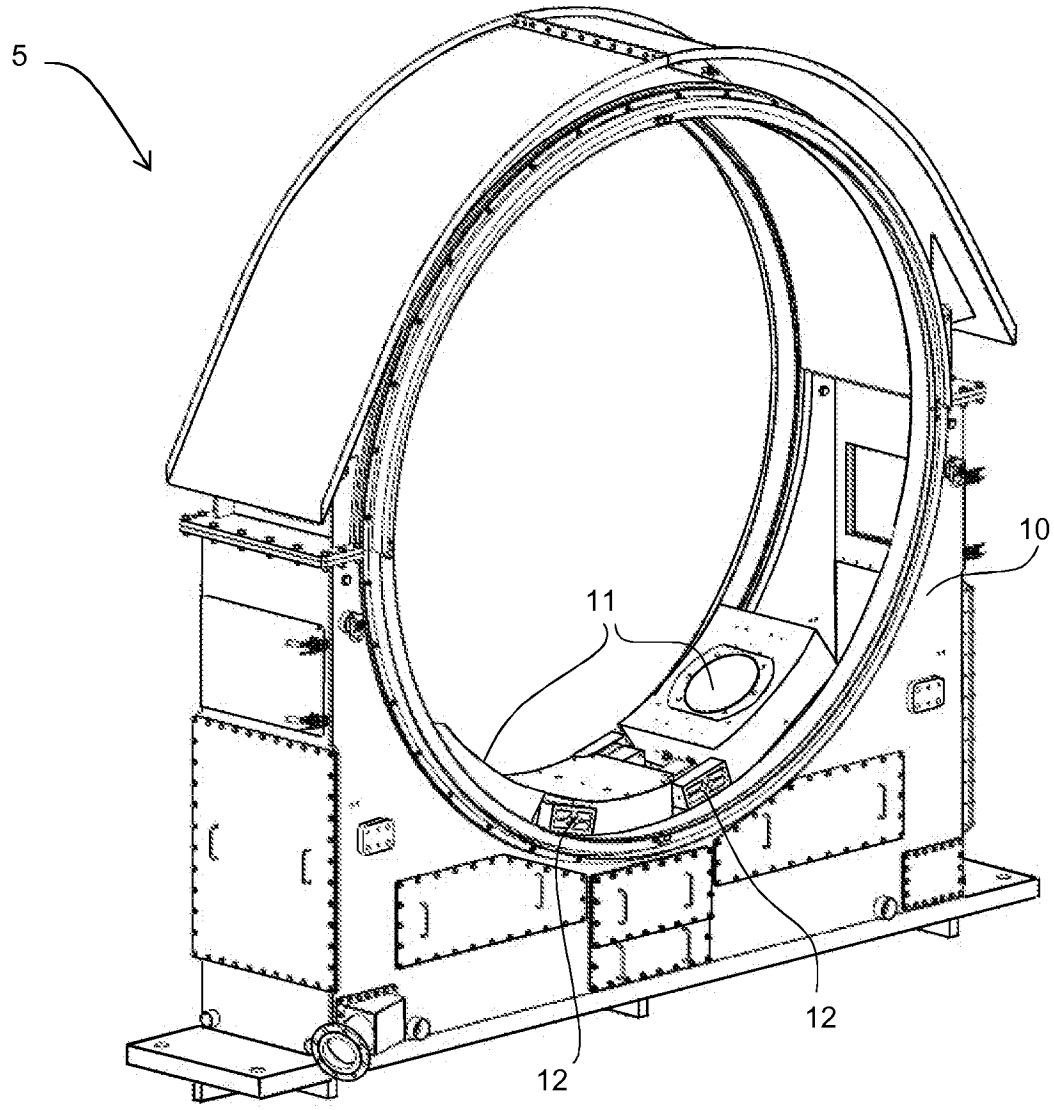


Fig. 2

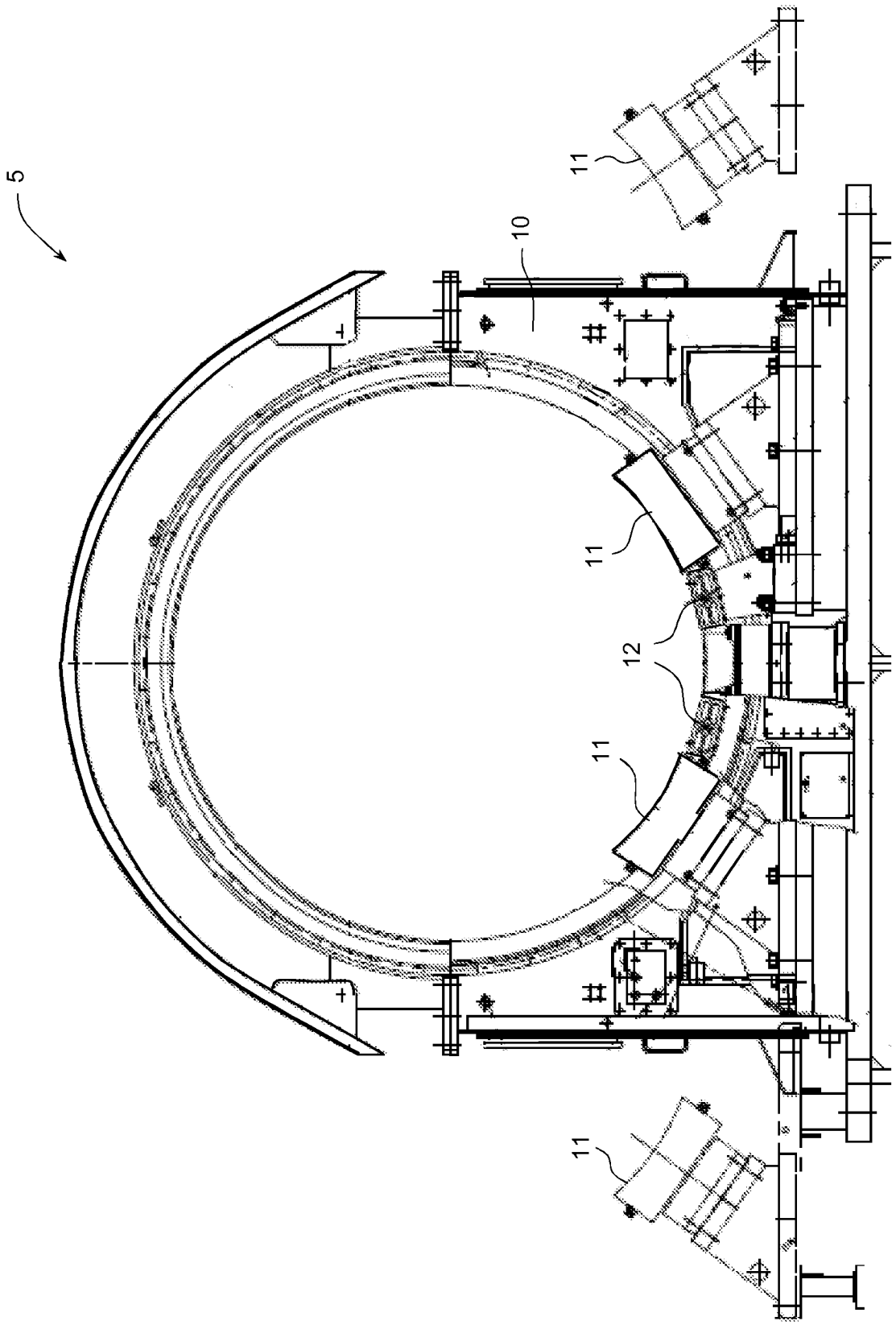


Fig. 3

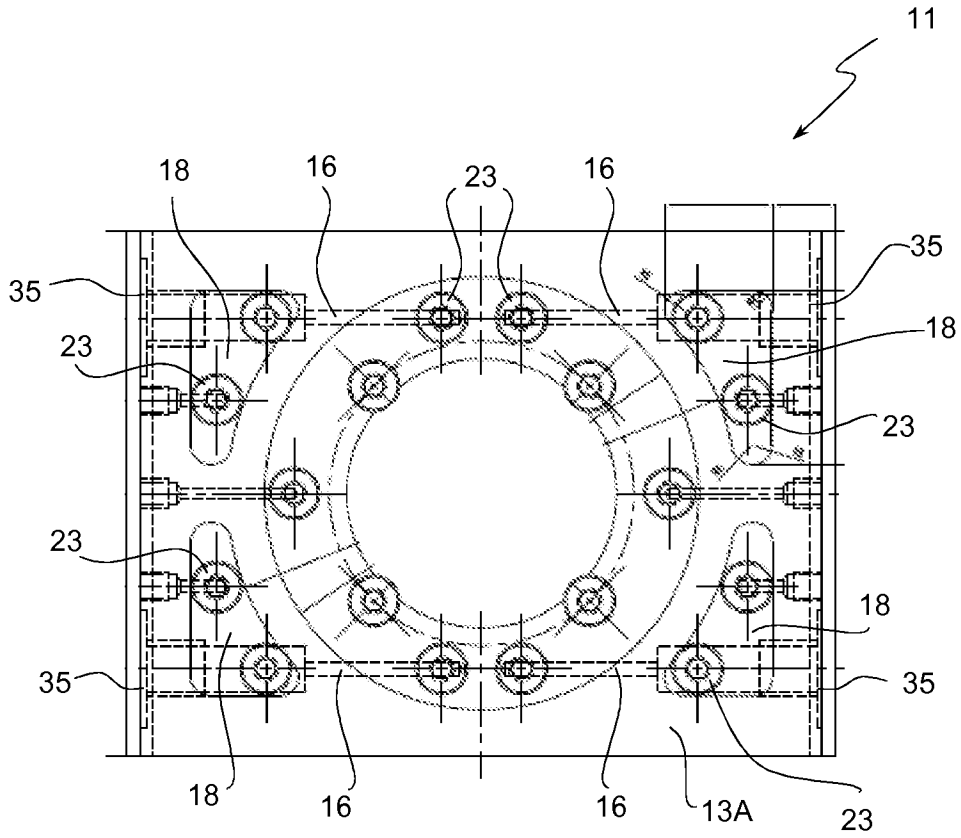


Fig. 4

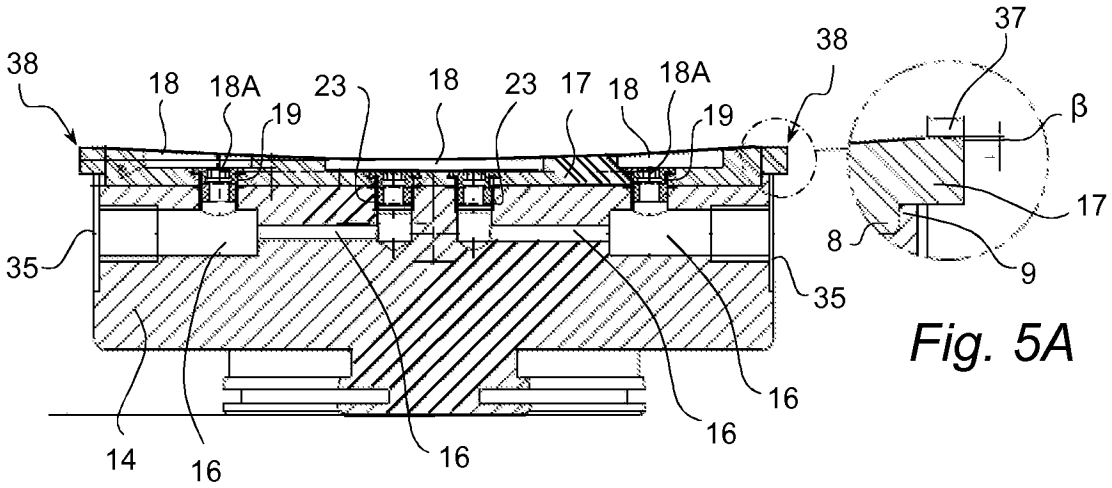


Fig. 5A

Fig. 5

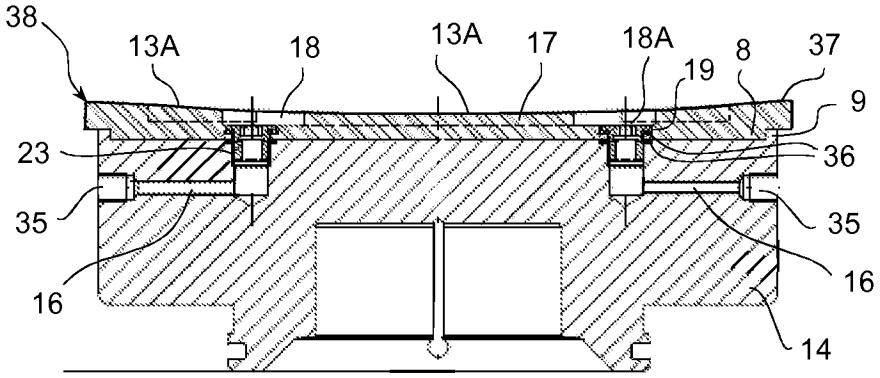


Fig. 6

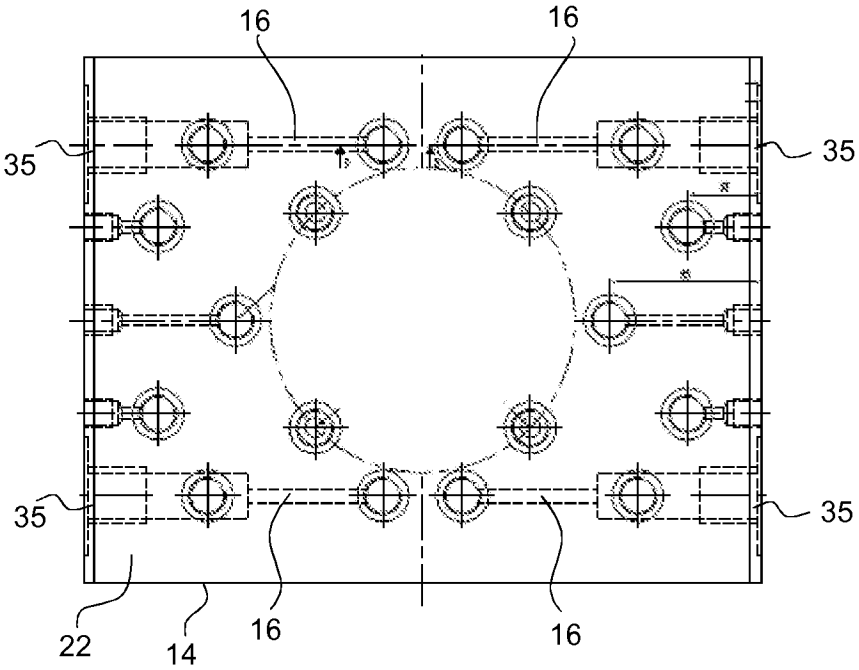


Fig. 7

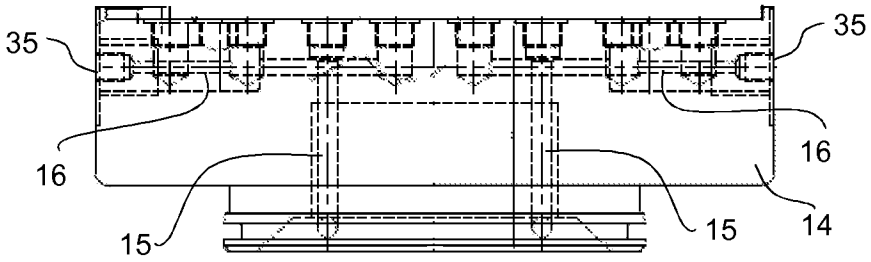


Fig. 8

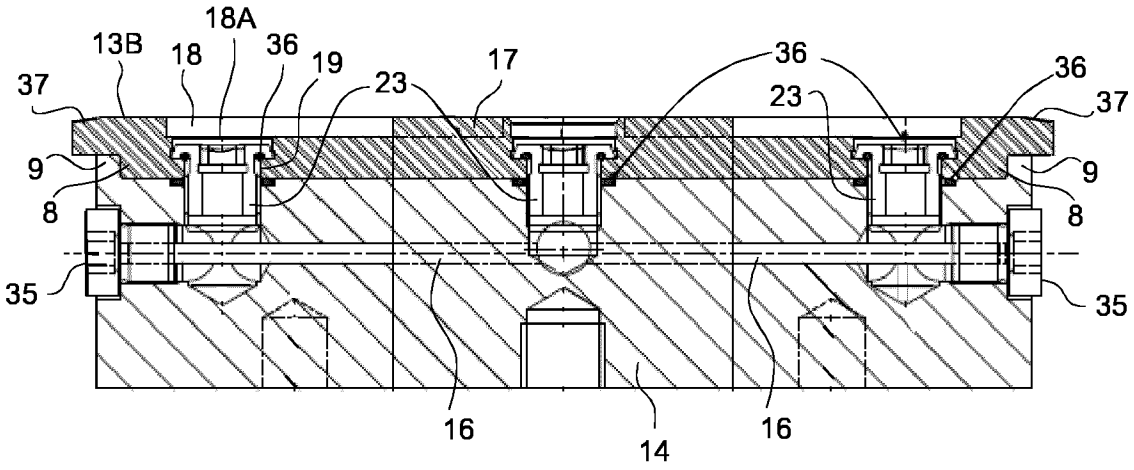

18A
13B
18
36
19
23
17
36
23
36
37
37
9
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9
8
35
35
16
14
16

Fig. 9

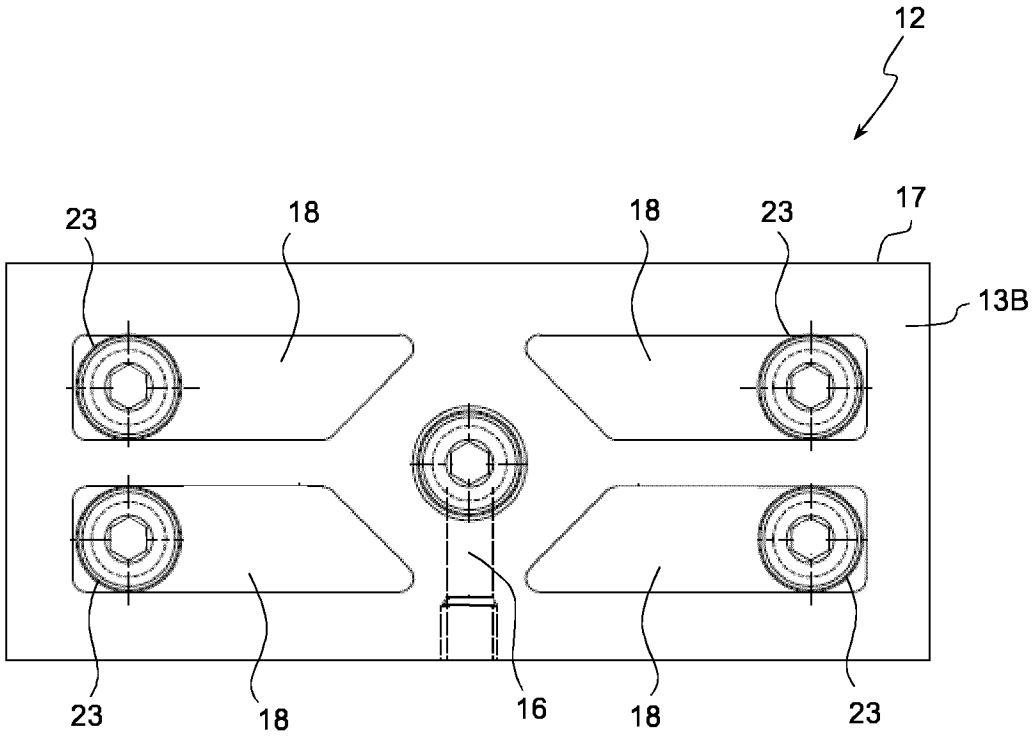

12
23
18
18
23
17
13B
23
18
16
18
23

Fig. 10

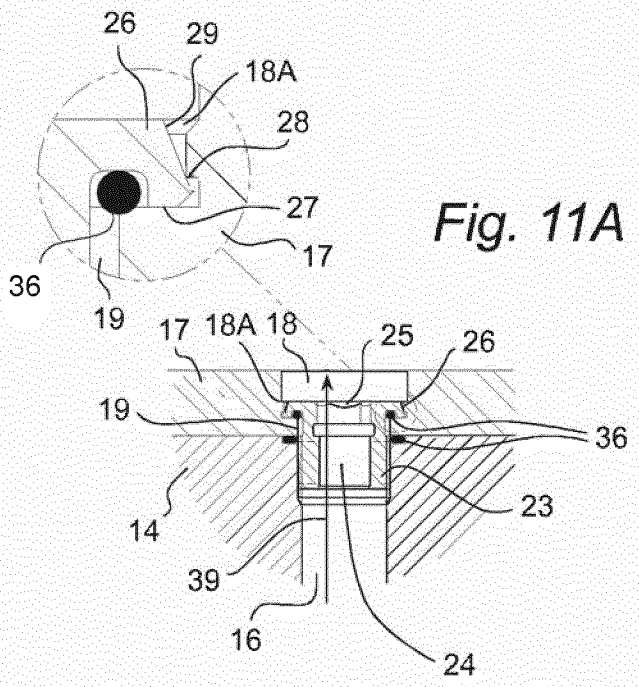


Fig. 11A

Fig. 11

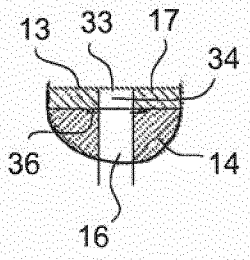


Fig. 12A

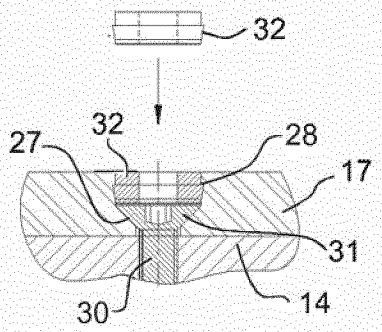


Fig. 12

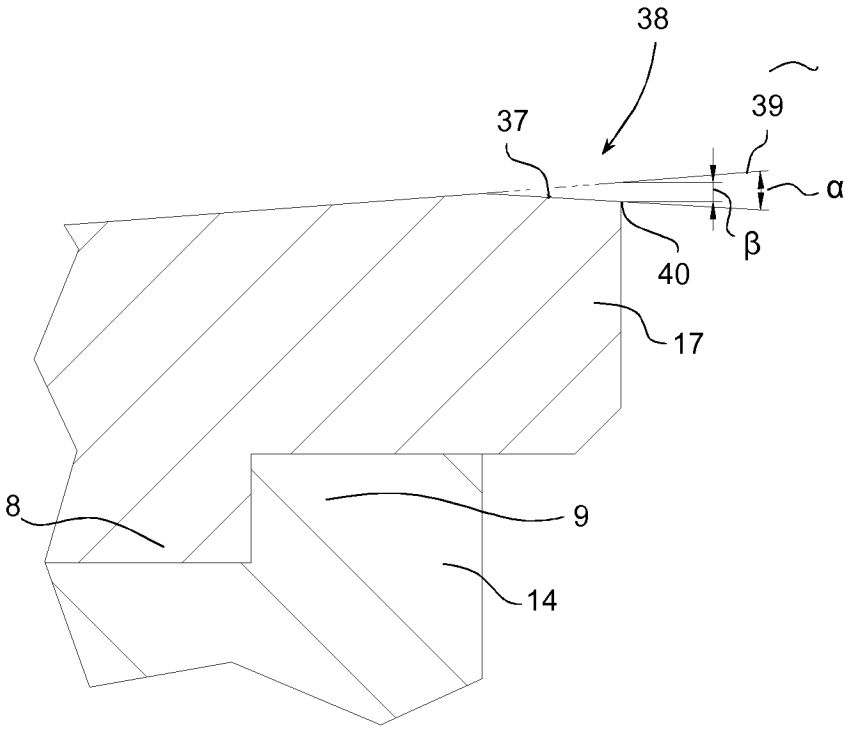


Fig. 13

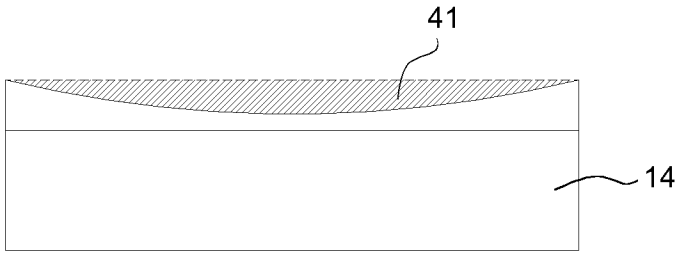


Fig. 14

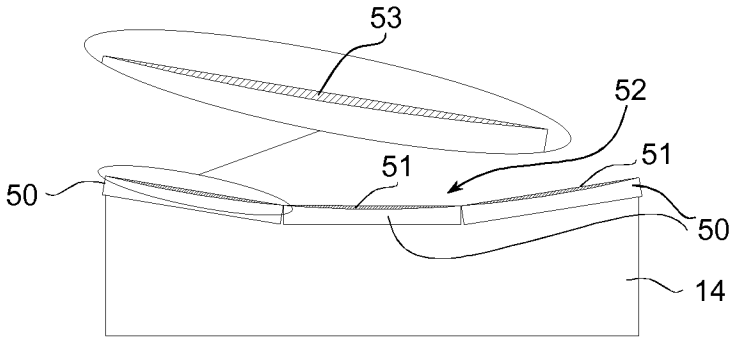


Fig. 15

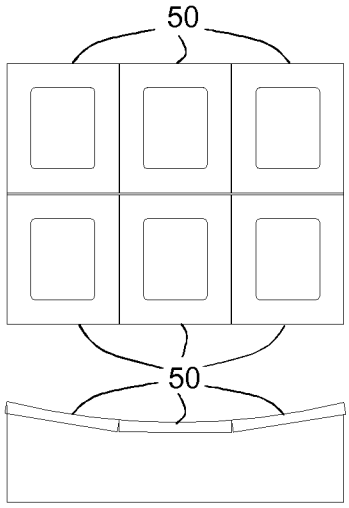


Fig.16

Fig.16A

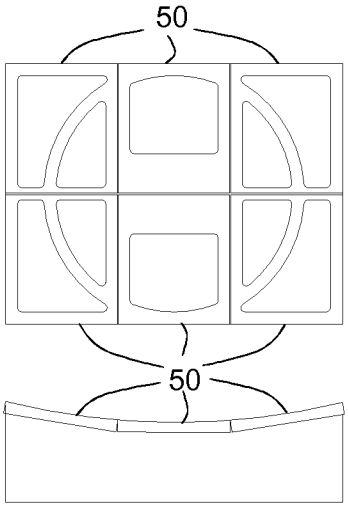


Fig.17

Fig.17A

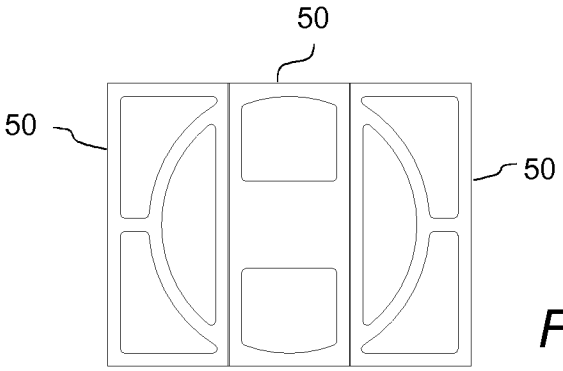


Fig. 18

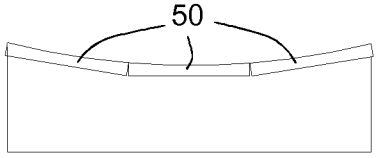


Fig. 18A

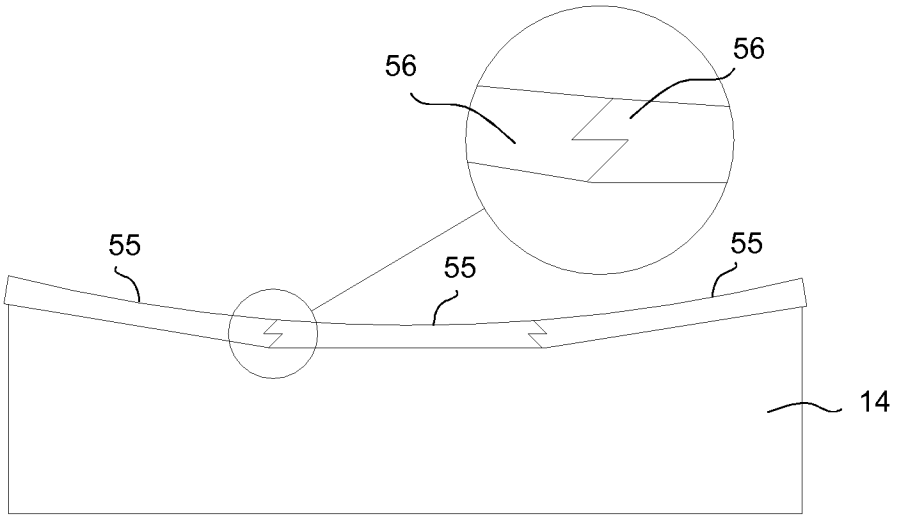


Fig. 19

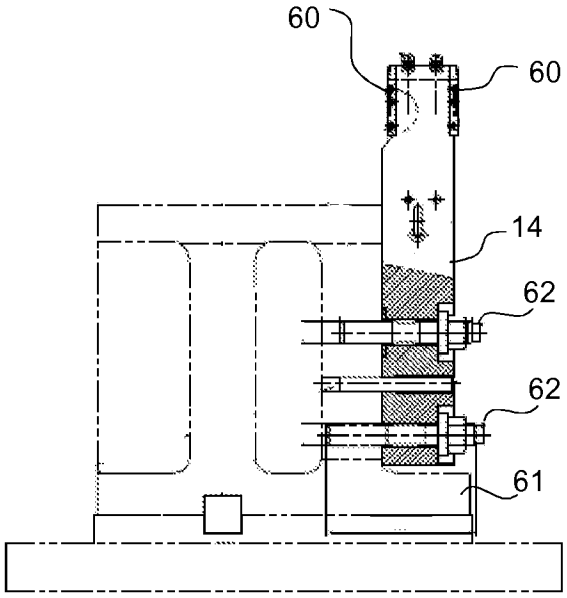
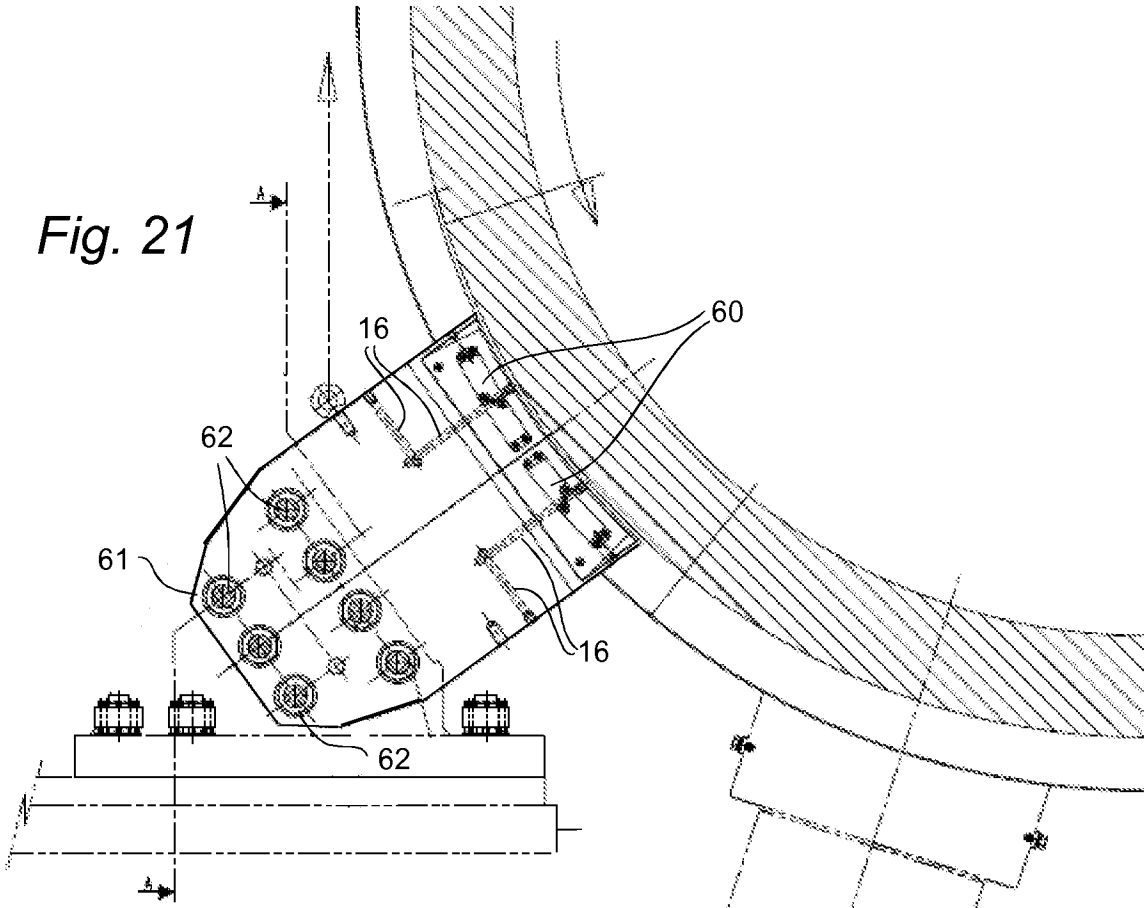


Fig. 22

Fig. 21



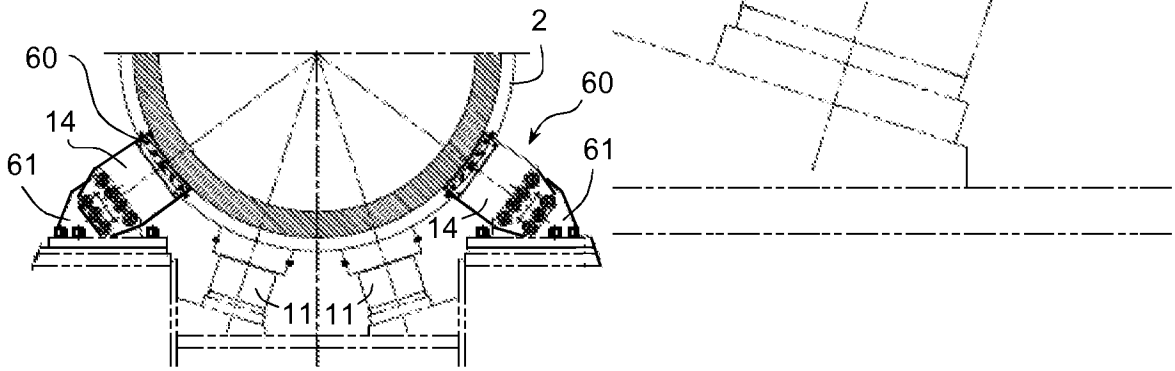


Fig. 20

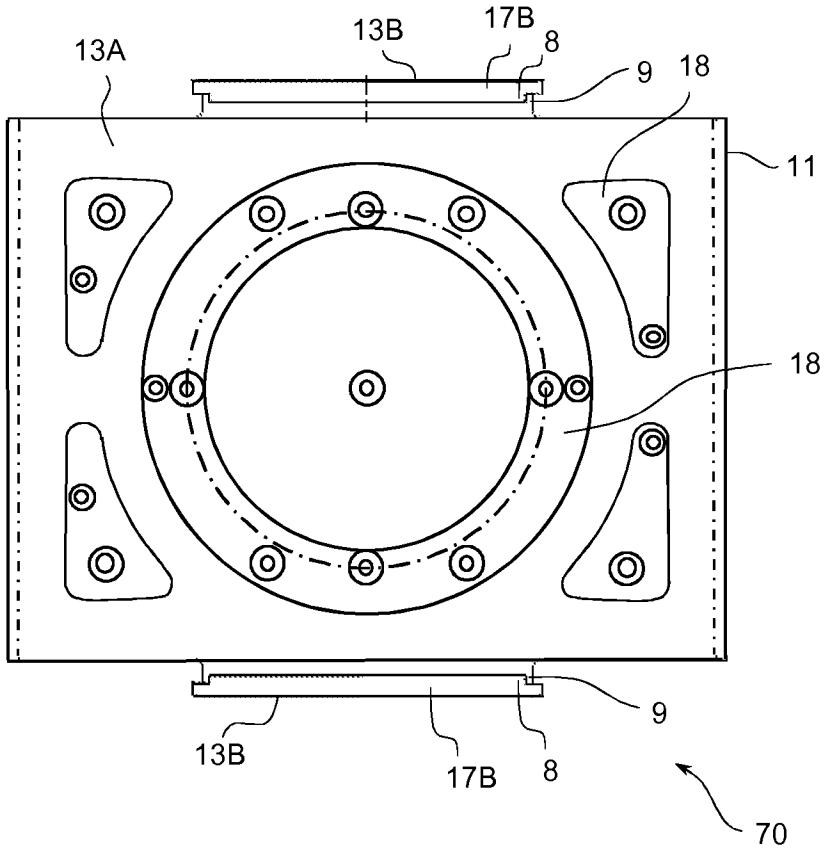


Fig. 23

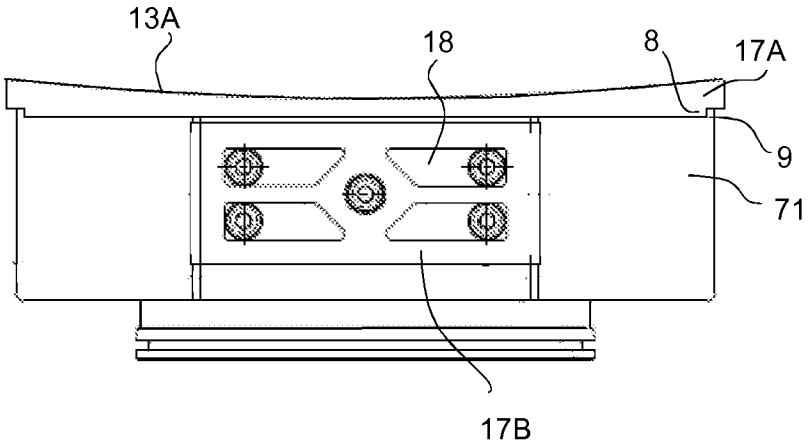


Fig. 24

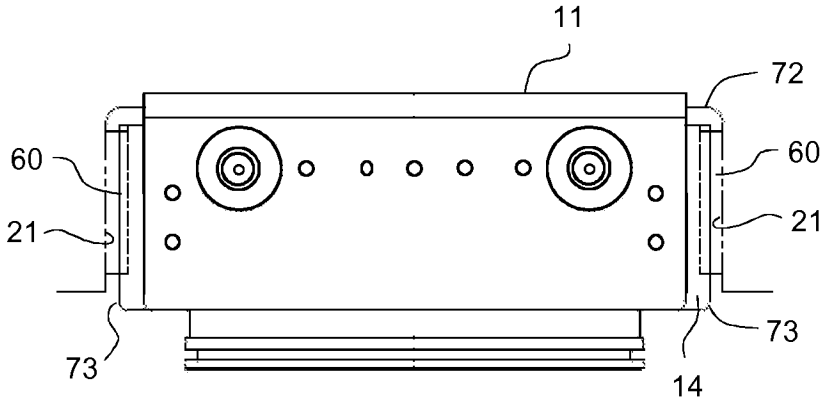


Fig. 25

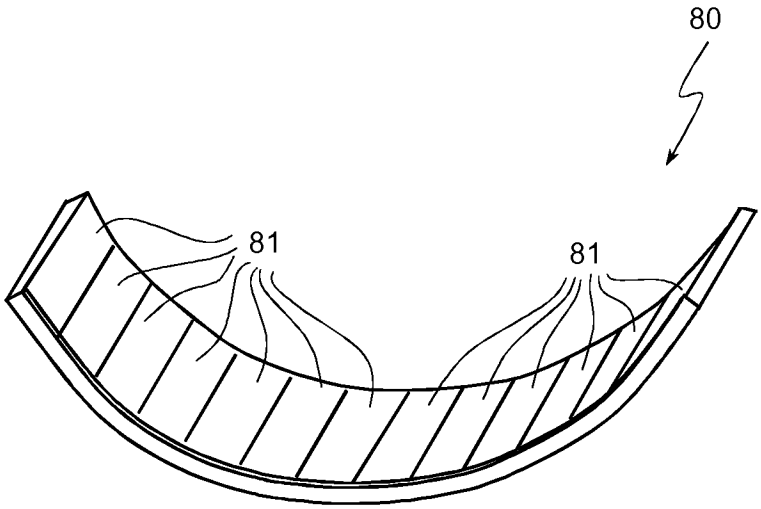


Fig. 26

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Submission number	5992357
Application number	EP13745198.5
Date of receipt	25 January 2018
Receiving Office	European Patent Office, The Hague
Your reference	P-EP93434MN
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Documents submitted	
package-data.xml	ep-sfd-request.xml
epf1038.pdf (1 p.)	DESC-1.pdf\Description as amended clean copy.pdf (28 p.)
DESC-HWA-1.pdf\Description as amended marked up copy.pdf (28 p.)	CLMS-1.pdf\Claims as amended clean copy.pdf (2 p.)
DESC-2.pdf\Claims as amended marked up copy.pdf (5 p.)	DRAW-1.pdf\Drawings as amended figure 9.pdf (1 p.)
EXRE3-1.pdf\Response to EPO.pdf (3 p.)	

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Correction by the EPO of errors in debit instructions filed by eOLF

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Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

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Claims

~~1. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.~~

~~2. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.~~

~~3. The bearing assembly of claim 1 or 2, wherein said polymer bearing pad is removably mounted to said base, wherein said mounting means preferably comprises a mounting portion extending from said polymer bearing pad, wherein said mounting portion preferably comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base, said flange preferably being located at an outer edge of said base.~~

~~4. The bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base, said at least one recess comprises a locking element for retaining said fastener within said at least one recess, preferably a locking tab for retaining a head portion of said fastener, and said at least one~~

fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

5. The bearing assembly of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base, wherein said outer surface is preferably at least one of a partially curved outer surface or a substantially planar outer surface.

6. The bearing assembly of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal, wherein said chamfer preferably has an outer edge that is displaced from a journal when said journal engages said polymer pad.

7. The bearing assembly of any one of the preceding claims, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

8. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal, wherein each of said polymer bearing pads preferably comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

9. The bearing assembly of any one of claims 1 to 7, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads, a first of said polymer bearing pads being mountable to said first surface and a second of said polymer bearing pads being mountable to said second surface.

~~wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and~~

~~said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface,~~

~~wherein said first outer surface is preferably partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is preferably substantially planar such that said second polymer bearing pad acts as an axial bearing.~~

~~10.~~1. A multidirectional fluid bearing for a journal, comprising:

a base (14) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad (17A) mountable to said first surface, said polymer bearing pad (17A) having a first outer surface (13A) and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface (13A), and

a second polymer bearing pad (17B) mountable to said second surface, said second polymer bearing pad (17B) having a second outer surface (13B) and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (13B)

wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

2. The multidirectional fluid bearing of claim 1, wherein said first polymer bearing pad (17A) is removably mounted to said first surface.

~~11.~~3. The multidirectional fluid bearing of claim 1 or 2, wherein ~~and/or~~ said second polymer bearing pad (17B) is removably mounted to said second surface.

4. The multidirectional fluid bearing of any one of claims 1 to ~~3~~ ~~11~~, wherein said first polymer bearing pad (17A) substantially covers said first surface and said second polymer bearing pad (17B) substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.~~,~~

5. The multidirectional fluid bearing of any one of claims 1 to 4, wherein said first outer surface (13A) is ~~preferably~~ partially curved such that said first polymer bearing pad (17A) acts as a radial hydrostatic bearing.~~ and~~

~~12.~~6. The multidirectional fluid bearing of any one of claims 1 to 5, wherein said second outer surface (13B) is ~~preferably~~ substantially planar such that said second polymer bearing pad (17B) acts as an axial bearing.

7. The multidirectional fluid bearing of any one of claims 1 to 6~~12~~, wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises a chamfer (37) at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal (4).~~,~~

~~13.~~8. The multidirectional fluid bearing of claim 7, wherein said chamfer ~~preferably~~ has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

9. The multidirectional fluid bearing of any one of claims 1 to ~~-~~8, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

~~14.~~10. The multidirectional fluid bearing of claim 9, wherein each of said plurality of at least one of said first and second polymer bearing pads (17A, 17B) ~~preferably~~ comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

11. The multidirectional fluid bearing of any one of claims 1 to ~~14~~ 10, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at

least one passage to said at least one recess (18), said at least one fastener being partially received in said at least one passage.

12. The multidirectional fluid bearing of any one of claims 1 to 11, ~~and preferably~~ wherein said base comprises (14) at least one flange (9) for engagement with a mounting portion (8) of at least one of said first and second polymer bearing pads (17A, 17B) to securely mount said at least one polymer bearing pad to said base (14).~~,~~

~~15.~~13. The multidirectional fluid bearing of claim 12, wherein said flange (9) is preferably located at an outer edge of said base.

Field of the Invention

[0001] The present invention relates to a fluid bearing and in a particular a hydrostatic polymeric bearing for use in a mill. The invention has been developed primarily for use as a hydrostatic polymeric bearing in grinding mills and will be described hereinafter by reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use, but also extends to other types of fluid bearings such as hydrodynamic bearings and hybrid bearings (i.e. bearings that use a combination of hydrodynamic and continuous hydrostatic flow for lubrication).

Background of the Invention

[0002] The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its advantages to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an express or implied admission that such art is widely known or forms part of common general knowledge in the field.

[0003] A grinding mill has a mill chamber and two journal shafts, the journals being mounted upon supports for rotation. Typical bearings have two main components; a steel base for mounting to the support and a bearing pad or surface for contact with the mill journal. These mill bearings are installed between the mill journals and the supports so that the mill journals rotate on the bearing pads during operation of the grinding mill.

[0004] The applicant developed a hydrostatic pad bearing system for grinding mills that is currently in use. In this hydrostatic pad bearing system, an external oil supply system pumps high-pressure oil to recesses machined into the bearing so that the oil forms a thin film on the bearing pad surface. The resultant hydraulic pressure is sufficient to completely lift the mill journal off the hydrostatic pads and separate the sliding surfaces. Thus, mill actually “floats” on a film of oil between journal and bearing. As such the bearing will operate under both static and dynamic conditions. Since the surfaces are completely separated and the bearing is self aligning there is no metal-to-metal contact between the bearing surface and the mill journal due to the oil film, thus

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resulting in only low friction. Consequently, maintaining the oil film between the surfaces means that there is virtually no wear in the bearing.

[0005] Despite the advantages conferred by this hydrostatic bearing system, a loss of oil pressure (and thus a reduction in the oil film thickness) can cause failure of the bearings, leading to damage to the bearing pad and/or the mill journal. For example, it can take a few seconds for a grinding mill to stop turning in the event of a power failure, and when this happens there is a high risk of damage to the mill bearing pads or journal surfaces due to a loss of oil reducing the oil film thickness, thereby bringing the journal and bearings into direct metal to metal contact. The consequential downtime for replacement of any damaged bearings and/or journals severely impairs operation of the mill, reducing its efficiency.

[0006] To prevent this type of damage, grinding mill lubrication systems usually have pressure accumulator systems that are typically used to store and deliver high pressure oil to the bearing in the event of a power failure and the oil supply system fails. These pressure accumulators are expensive, require frequent maintenance to ensure that they are at the appropriate pressure level and can interfere with control systems in the mill. Thus, there are increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and then the oil supply ports for delivering high pressure oil to the recesses are then drilled into the base. Bronze is spray welded or cast onto the relevant parts of the steel base to form the bearing pad or lining. Spray welding enables the bronze metal to form a seal with the base. White metal may be used instead of bronze, but is cast onto the base. Due to this manufacturing process, the repair and/or refurbishment of these bearings involves initially cleaning the damaged bearing surface, machining any parts of the steel base and either spray welding the bronze or re-casting the bronze/white metal. This repair process cannot be performed on-site but requires the bearing to be returned to the manufacturer. Consequently, mills must keep a sufficient stock of spare bearings to account for the absence of damaged bearings being repaired. This adds to the maintenance costs of the mill.

[0008] It is an object of the present invention to overcome or substantially ameliorate one or more of the disadvantages of prior art, or at least to provide a useful alternative.

[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] ~~According to a first aspect of the invention, t~~There is provided a polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means for securely mounting said polymer bearing pad to said base.

[0011] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0012] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0013] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[0014] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0015] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0016] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0017] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0018] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0019] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0020] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0021] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0022] ~~According to a second aspect of the invention, t~~There is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

the polymer bearing pad of the first aspect of the present invention mountable to said base.

[0023] Preferably, said polymer bearing pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

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[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] ~~According to a third aspect of the invention, t~~There is provided a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] ~~According to a fourth aspect of the invention, t~~There is provided a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for

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connecting said polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] ~~According to a fifth aspect of the invention, t~~There is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to ~~a sixth aspect of~~ the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first outer surface and said polymer bearing pad substantially covers said second outer surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, least one of said first and second polymer bearing pads comprises a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

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Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

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[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the

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journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to

act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent

any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23 also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the

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event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a “hovercraft” type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20,

21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems

damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the “lead-in” chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the “lead-in” chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the “lead-out” chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of

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the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased “off the shelf” in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural

integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same

reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the

polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Claims

1. A multidirectional fluid bearing for a journal, comprising:

a base (14) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad (17A) mountable to said first surface, said polymer bearing pad (17A) having a first outer surface (13A) and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface (13A), and

a second polymer bearing pad (17B) mountable to said second surface, said second polymer bearing pad (17B) having a second outer surface (13B) and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (13B)

wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

2. The multidirectional fluid bearing of claim 1, wherein said first polymer bearing pad (17A) is removably mounted to said first surface.

3. The multidirectional fluid bearing of claim 1 or 2, wherein said second polymer bearing pad (17B) is removably mounted to said second surface.

4. The multidirectional fluid bearing of any one of claims 1 to 3, wherein said first polymer bearing pad (17A) substantially covers said first surface and said second polymer bearing pad (17B) substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

5. The multidirectional fluid bearing of any one of claims 1 to 4, wherein said first outer surface (13A) is partially curved such that said first polymer bearing pad (17A) acts as a radial hydrostatic bearing.

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6. The multidirectional fluid bearing of any one of claims 1 to 5, wherein said second outer surface (13B) is substantially planar such that said second polymer bearing pad (17B) acts as an axial bearing.

7. The multidirectional fluid bearing of any one of claims 1 to 6, wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises a chamfer (37) at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal (4).

8. The multidirectional fluid bearing of claim 7, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

9. The multidirectional fluid bearing of any one of claims 1 to 8, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

10. The multidirectional fluid bearing of claim 9, wherein each of said plurality of at least one of said first and second polymer bearing pads (17A, 17B) comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

11. The multidirectional fluid bearing of any one of claims 1 to 10, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess (18), said at least one fastener being partially received in said at least one passage.

12. The multidirectional fluid bearing of any one of claims 1 to 11, wherein said base comprises (14) at least one flange (9) for engagement with a mounting portion (8) of at least one of said first and second polymer bearing pads (17A, 17B) to securely mount said at least one polymer bearing pad to said base (14).

13. The multidirectional fluid bearing of claim 12, wherein said flange (9) is preferably located at an outer edge of said base.

Field of the Invention

[0001] The present invention relates to a fluid bearing and in a particular a hydrostatic polymeric bearing for use in a mill. The invention has been developed primarily for use as a hydrostatic polymeric bearing in grinding mills and will be described hereinafter by reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use, but also extends to other types of fluid bearings such as hydrodynamic bearings and hybrid bearings (i.e. bearings that use a combination of hydrodynamic and continuous hydrostatic flow for lubrication).

Background of the Invention

[0002] The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its advantages to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an express or implied admission that such art is widely known or forms part of common general knowledge in the field.

[0003] A grinding mill has a mill chamber and two journal shafts, the journals being mounted upon supports for rotation. Typical bearings have two main components; a steel base for mounting to the support and a bearing pad or surface for contact with the mill journal. These mill bearings are installed between the mill journals and the supports so that the mill journals rotate on the bearing pads during operation of the grinding mill.

[0004] The applicant developed a hydrostatic pad bearing system for grinding mills that is currently in use. In this hydrostatic pad bearing system, an external oil supply system pumps high-pressure oil to recesses machined into the bearing so that the oil forms a thin film on the bearing pad surface. The resultant hydraulic pressure is sufficient to completely lift the mill journal off the hydrostatic pads and separate the sliding surfaces. Thus, mill actually “floats” on a film of oil between journal and bearing. As such the bearing will operate under both static and dynamic conditions. Since the surfaces are completely separated and the bearing is self aligning there is no metal-to-metal contact between the bearing surface and the mill journal due to the oil film, thus

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resulting in only low friction. Consequently, maintaining the oil film between the surfaces means that there is virtually no wear in the bearing.

[0005] Despite the advantages conferred by this hydrostatic bearing system, a loss of oil pressure (and thus a reduction in the oil film thickness) can cause failure of the bearings, leading to damage to the bearing pad and/or the mill journal. For example, it can take a few seconds for a grinding mill to stop turning in the event of a power failure, and when this happens there is a high risk of damage to the mill bearing pads or journal surfaces due to a loss of oil reducing the oil film thickness, thereby bringing the journal and bearings into direct metal to metal contact. The consequential downtime for replacement of any damaged bearings and/or journals severely impairs operation of the mill, reducing its efficiency.

[0006] To prevent this type of damage, grinding mill lubrication systems usually have pressure accumulator systems that are typically used to store and deliver high pressure oil to the bearing in the event of a power failure and the oil supply system fails. These pressure accumulators are expensive, require frequent maintenance to ensure that they are at the appropriate pressure level and can interfere with control systems in the mill. Thus, there are increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and then the oil supply ports for delivering high pressure oil to the recesses are then drilled into the base. Bronze is spray welded or cast onto the relevant parts of the steel base to form the bearing pad or lining. Spray welding enables the bronze metal to form a seal with the base. White metal may be used instead of bronze, but is cast onto the base. Due to this manufacturing process, the repair and/or refurbishment of these bearings involves initially cleaning the damaged bearing surface, machining any parts of the steel base and either spray welding the bronze or re-casting the bronze/white metal. This repair process cannot be performed on-site but requires the bearing to be returned to the manufacturer. Consequently, mills must keep a sufficient stock of spare bearings to account for the absence of damaged bearings being repaired. This adds to the maintenance costs of the mill.

[0008] It is an object of the present invention to overcome or substantially ameliorate one or more of the disadvantages of prior art, or at least to provide a useful alternative.

[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] There is provided a polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means for securely mounting said polymer bearing pad to said base.

[0011] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0012] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0013] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[0014] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0015] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0016] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0017] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0018] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0019] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0020] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0021] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0022] There is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

the polymer bearing pad of the first aspect of the present invention mountable to said base.

[0023] Preferably, said polymer bearing pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] There is provided a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] There is provided a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for

connecting said polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] There is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first outer surface and said polymer bearing pad substantially covers said second outer surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, least one of said first and second polymer bearing pads comprises a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

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[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

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[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the

journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to

act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent

any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23 also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the

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event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a “hovercraft” type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20,

21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems

damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the “lead-in” chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the “lead-in” chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the “lead-out” chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of

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the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased “off the shelf” in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural

integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same

reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the

polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

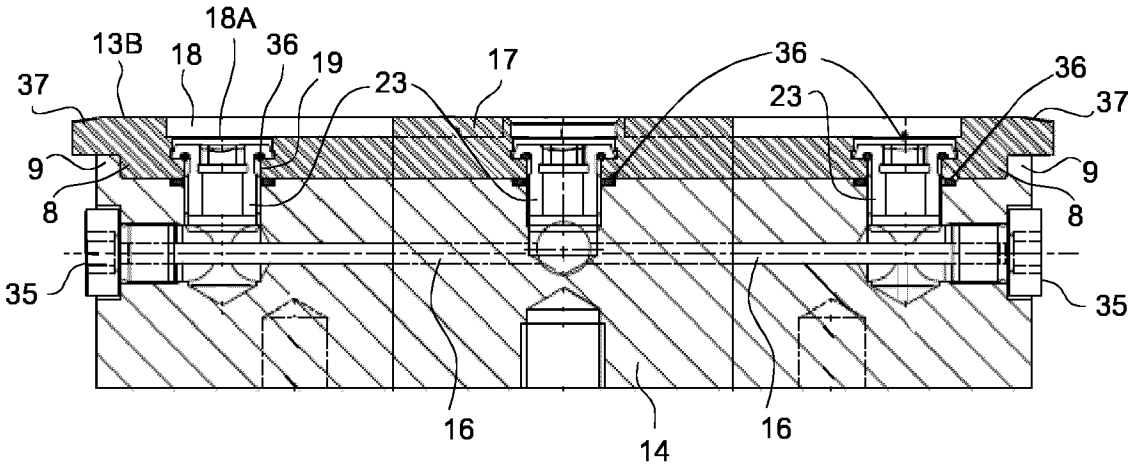


Fig. 9

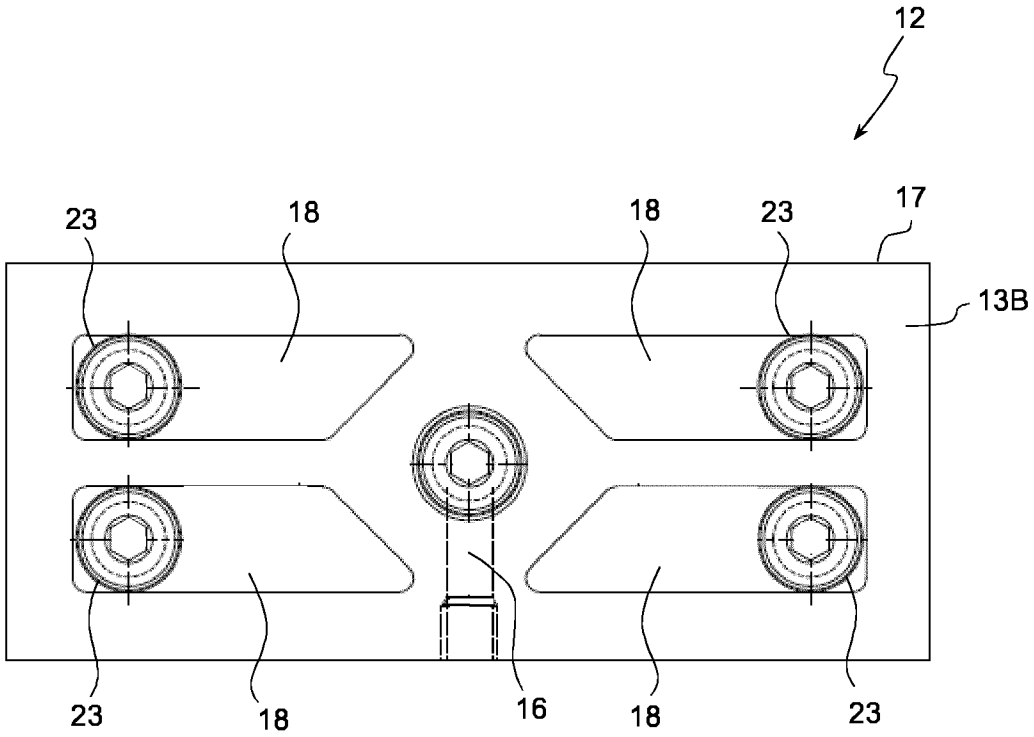


Fig. 10

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European Patent Office
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Letter accompanying subsequently filed items

Representative:

Papula Oy
397
P.O. Box 981
00101 Helsinki
Finland

Phone: +358-9-3480060
Fax: +358-9-34800630
E-mail: western-patents@papula-nevinpat.com

80298 Munich
Germany
Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818
2280 HV Rijswijk
Netherlands
Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin
Germany
Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	13745198.5
Applicant's or representative's reference	P-EP93434MN

	Description of document	Original file name	Assigned file name
1	Amended description (clean copy)	Description as amended clean copy.pdf	DESC-1.pdf
2	Amended description with annotations	Description as amended marked up copy.pdf	DESC-HWA-1.pdf
3	Amended claims (clean copy)	Claims as amended clean copy.pdf	CLMS-1.pdf
4	Amended description (clean copy)	Claims as amended marked up copy.pdf	DESC-2.pdf
5	Amended drawings (clean copy)	Drawings as amended figure 9.pdf	DRAW-1.pdf
6	Reply to examination report	Response to EPO.pdf	EXRE3-1.pdf

	Payment	
1	Method of payment	Not specified

Signatures

Place:	
Date:	**25 January 2018**
Signed by:	**Jarmo Tanskanen 23717**
Association:	**Papula Oy**
Representative name:	**Jarmo Tanskanen**
Capacity:	**(Representative)**

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Papula-Nevinpat
Business ID 0236098-2
VAT number FI02360982

Head office
Mechelininkatu 1 a
FI-00180 Helsinki, Finland

Mail address
POB 981
FI-00101 Helsinki, Finland

Phone
+358 (0)9 348 0060

Fax
+358 (0)9 3480 0630, 3480 0631

E-mail
papula@papula-nevinpat.com
firstname.lastname@papula-nevinpat.com

western-patents@papula-nevinpat.com
eurasian-patents@papula-nevinpat.com
trademarks@papula-nevinpat.com
designs@papula-nevinpat.com
validation@papula-nevinpat.com
annuities@papula-nevinpat.com

Internet
www.papula-nevinpat.com

European Patent Office
D-80298 München
Germany

Our ref: P-EP93434MN
Date: 24 January 2018

European patent application 13745198.5
Applicant: Outotec (Finland) Oy

This is in response to a Communication dated 1 August 2017 pursuant to Article 94(3) EPC concerning the above identified application.

Amendments

The claims filed with entry into the regional phase before the EPO were the result of the merger of previous separate claims (see PCT application as filed). Now introduced amended claims disclose claims that corresponds the claims before said merger and the correspondence is indicated below. No new subject matter has been added.

Pending claims 1-9 have been removed and pending independent claim 10 has been renumbered as new amended claim 1.

Previously presented and currently pending claim 11 has been divided into amended claims 2 (referring to amended claim 1) and 3 (referring to amended claim 1 or 2). The pending claim 11 discloses two features that are separated by the phrase "and/or", indicating that these two features may be separate, which is now the case.

Amended claim 4 corresponds to claim 40 and is supported by paragraph [0053] of the PCT specification as filed.

Amended claim 5 is supported by paragraph [0059] of the PCT specification as filed.

Amended claim 6 is supported by paragraph [0060] of the PCT specification as filed.

Amended claim 7 corresponds to claim 41 and is supported by paragraph [0054] of the PCT specification as filed.

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Amended claim 8 corresponds to claim 42 and is supported by paragraph [0054] of the PCT specification as filed.

Amended claim 9 corresponds to claim 46 and is supported by paragraph [0058] of the PCT specification as filed.

Amended claim 10 corresponds to claim 47 and is supported by paragraph [0058] of the PCT specification as filed.

Amended claim 11 corresponds to claim 44 and is supported by paragraph [0056] of the PCT specification as filed.

Amended claim 12 corresponds to claim 49 and is supported by paragraphs [0024] and [0062] of the PCT specification as filed.

Amended claim 13 corresponds to claim 50 and is supported by paragraphs [0024] and [0062] of the PCT specification as filed.

Figure 9 has been amended to correct placement of reference numeral "23" to point to the bolt.

The description has been brought into conformity with the amended claims.

As the Examiner indicated in the communication, pending independent claim 10 full fills the requirements of the EPC. As amended claim 1 is only renumbered pending claim 10, it is submitted that amended claim 1 full fills also the requirements of the EPC. Amended dependent claims 2-13 refers to amended claim 1 and, therefore, it is believed that they full fill also requirements of the EPC.

Summary

It is believed the application is now in compliance with the EPC. Should the Examiner find any incompliance, we are ready to further specify our comments and/or further amend the application in response to any communication pointing such deficiencies under the European Patent Convention. Should the Examining Division take any adverse decision on this application, the applicant hereby requests, in order of preference, a phone conversation, an informal interview and Oral Proceedings before such decision.

Respectfully

PAPULA OY

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ENC Amended claims clean copy
Amended claims marked up copy
Amended description clean copy
Amended description marked up copy
Amended Figure 9

/spo

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Questions about this communication ?
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Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Date
29.11.17

Reference	Application No./Patent No.
P-EP93434Y	13745198.5 - 1751 / 2867550
Applicant/Proprietor	
Outotec (Finland) Oy	

Extension of time limit pursuant to Rule 132(2) EPC

Examination procedure

With reference to your request, the time limit for replying to the communication pursuant to Article 94(3) EPC dated 01.08.17 has been extended

by 2 months

to a total of 6 months

from the date of notification of the above-mentioned communication.

Please note: To the extent that your request exceeded the above extension, your request has been refused.

Note
The granting of extensions to time limits is governed by the Implementing Regulations to the EPC and the Guidelines for Examination in the EPO, E-VII, 1.6. A request for extension, which would result in the total period set exceeding six months, must be reasoned and supported by evidence.

If no reply to the communication is received in due time, the European patent application will be deemed to be withdrawn (Art. 94(4) EPC).

Important information in case of a PACE request
If a PACE request has been validly filed for the application, the applicant is herewith informed that with the grant of the request for extension of time limit the application is removed from the PACE programme. A second PACE request for that application during the same stage of the procedure will not be processed (see OJ EPO 2015, A93, point 4).

For the Examining Division



Europäisches Patentamt
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Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	5795847
Application number	EP13745198.5
Date of receipt	17 November 2017
Receiving Office	European Patent Office, The Hague
Your reference	P-EP93434MN
Applicant	All applicants as on file
Documents submitted	package-data.xml epf1038.pdf (1 p.) ep-sfd-request.xml EXRE92-1.pdf\Extension request to EPO.pdf (1 p.)
Submitted by	CN=Jarmo Tanskanen 23717
Method of submission	Online
Date and time receipt generated	17 November 2017, 12:22 (CET)
Message Digest	00:43:95:DB:73:3F:99:A2:14:A2:44:C6:A1:94:6F:DC:BD:50:CD:DF

Correction by the EPO of errors in debit instructions filed by eOLF
Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

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FLS v. Metso - IPR2025-00985

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Letter accompanying subsequently filed items

Representative:

Papula Oy
397
P.O. Box 981
00101 Helsinki
Finland

Phone: +358-9-3480060
Fax: +358-9-34800630
E-mail: western-patents@papula-nevinpat.com

80298 Munich
Germany
Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818
2280 HV Rijswijk
Netherlands
Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin
Germany
Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	13745198.5
Applicant's or representative's reference	P-EP93434MN

	Description of document	Original file name	Assigned file name
1	Request for extension of time limit during examination procedure	Extension request to EPO.pdf	EXRE92-1.pdf

	Payment	
1	Mode of payment	Not specified

Signatures

Place:	
Date:	**17 November 2017**
Signed by:	**Jarmo Tanskanen 23717**
Association:	**Papula Oy**
Representative name:	**Jarmo Tanskanen**
Capacity:	**(Representative)**

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PAPULA NEVINPAT
YOUR EXCLUSIVE RIGHT

Papula-Nevinpat
Business ID 0236098-2
VAT number FI02360982

Head office
Mechelininkatu 1 a
FI-00180 Helsinki, Finland

Mail address
POB 981
FI-00101 Helsinki, Finland

Phone
+358 (0)9 348 0060

Fax
+358 (0)9 3480 0630, 3480 0631

E-mail
papula@papula-nevinpat.com
firstname.lastname@papula-nevinpat.com

western-patents@papula-nevinpat.com
eurasian-patents@papula-nevinpat.com
trademarks@papula-nevinpat.com
designs@papula-nevinpat.com
validation@papula-nevinpat.com
annuities@papula-nevinpat.com

Internet
www.papula-nevinpat.com

European Patent Office
D-80298 München
Germany

Our ref: P-EP93434MN
Date: 16 November 2017

European patent application 13745198.5
- Outotec (Finland) Oy

Sirs,

Referring to the communication dated 1 August 2017, we herewith request for an extension of time of two months.

In case this extension is not granted, please inform us immediately thereof.

Respectfully

PAPULA OY

/spo

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he examination is being carried out on the **following application documents**

Description, Pages

1-28	filed with entry into the regional phase before the EPO	

Claims, Numbers

1-15	filed in electronic form on	24-03-2017

Drawings, Sheets

1/13-6/13, 8/13-13/13	filed with entry into the regional phase before the EPO	
7/13	filed in electronic form on	24-03-2017

1 The amendments and arguments of the applicant filed with letter of 24.03.2017 have been carefully considered. Below is a reply thereto.

2 Document DE 27 31 074 (D7) was found in a further search (see Guidelines C-IV, 7.2 and 7.3). A copy of the document is annexed to the communication and the numbering will be adhered to in the rest of the procedure.

3 The subject-matter of independent claim 1 is still considered to lack inventive step within the meaning of Article 56 EPC.

3.1 Referring back to paragraphs 2.1 and 2.2 of the preceding official action dated 30.11.2016, the subject-matter of claim 1 differs from the bearing assembly of GB 1 508 384 (D5) in that the bearing pad is explicitly made of "polymer".

3.2 As argued by the applicant in his letter of 24.03.2017, such a polymer bearing pad is deformable to mould to the journal surface profile (self-moulding) and provide a dampening effect.

3.3 Document D7 however discloses a polymer bearing pad that provides the same advantages.

3.4 In detail, D7 discloses in particular a bearing assembly (3, 4) *suitable* (Guidelines F-IV, 4.13) for supporting a journal (6) of a grinding mill body (1); see especially lines 5-8 of the last paragraph of page 4, in particular "weiter zerkleinert". Said assembly comprises a frame (5) and a plurality of bearings; see figures 5, 6).

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3.5 Moreover the bearing pad described therein consists of polymer material, especially of rubber and PTFE; see lines 7-8 and 10-13 of the last paragraph of page 5.

3.6 The polymer bearing pad thus disclosed is deformable to mould to the journal surface profile (self-moulding) and provide a dampening effect; see page 6, paragraph 3.

3.7 Therefore, on the basis of D5, It would be obvious to the skilled person looking for "self-moulding" bearing pads exhibiting a dampening effect, to manufacture the pads of D5 out of polymer material, or at least of rubber and PTFE, as described in D7. Moreover, such a change in material does not require outstanding manufacturing steps of the recess of the pads of D5.

3.8 The subject-matter of claim 1 thus does not involve an inventive step in view of the combination of D5 and D7.

4 Independent claim 2 differs from claim 1 - and therefore from the combination of D5 and D7 - in that "the base is fixedly mounted to said frame".

4.1 Such a feature is however considered to be a mere constructional detail, i.e. is merely one of several straightforward possibilities which the skilled person would select, depending on the circumstances, without exercising inventive skill, in order to provide a bearing assembly allowing a "self-moulding" and dampening effect of the bearing pads, both effects being already obtained by the polymer bearing pads.

4.2 Alternatively, such a fixed mounting of the base on the frame is disclosed in D6; see column 3, lines 28-38.

4.3 The subject-matter of claim 1 thus does not involve an inventive step in view of the combination of D5 and D7, if necessary in the light of D6.

5 The combination of features of independent claim 10 appears to fulfill the requirements of the EPC.

6 However, the set of three independent claims 1, 2 and 10 as presently on file now lacks conciseness, contrary to the requirement of Article 84 EPC.

6.1 Indeed, under Article 84 in combination with Rule 43(2) EPC, an application may contain more than one independent claim in a particular category only if the subject-matter claimed falls within one or more of the exceptional situations set out in paragraph (a), (b) or (c) of Rule 43(2) EPC. This is not the case in the present application.

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6.2 As confirmed by the Guidelines F-IV, 3.2, these independent claims obviously do not fall under the situation set out in paragraph (b) of the Rule.

6.3 Likewise, the bearing assembly, resp. multidirectional fluid bearing, claimed in said independent claims do not correspond to the situation set out in paragraph (b) of the Rule, see the typical examples of such situation outlined in the mentioned Guidelines.

6.4 Finally, the amount of differences of independent claim 10 on one hand and independent claims 1 and 2 on the other hand is such that said claims do not constitute alternative solutions to the same particular problem. Therefore, claim 10 and claims 1 and 2 do not relate to the situation set out in paragraph (c) of the Rule.

6.5 In the further prosecution of the application, failure to file an amended set of claims which complies with Rule 43(2) EPC, or to submit convincing arguments as to why the current set of claims does in fact comply with these provisions, may lead - including in the framework of the requested Oral Proceedings - to refusal of the application under Article 97(2) EPC.

7 The applicant is invited to file claims which take account of the above comments.

When filing amended claims the applicant should at the same time bring the description into conformity with the amended claims. Care should be taken during revision, especially of the introductory portion and of any statements of problem or advantage, not to add subject-matter which extends beyond the content of the application as originally filed (Article 123(2) EPC).

8 The reference number "23" appears twice in figure 9. It seems that said reference on the right hand side of the figure is erroneous.

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Europäisches Patentamt
European Patent Office
Office européen des brevets

European Patent Office
Postbus 5818
2280 HV Rijswijk
NETHERLANDS
Tel: +31 70 340 2040
Fax: +31 70 340 3016

Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Formalities Officer
Name: Prouteau, Evelyne
Tel: +31 70 340 - 4864
or call
+31 (0)70 340 45 00

Substantive Examiner
Name: Martin, Christophe
Tel: +31 70 340 - 4492

Application No.	Ref.	Date
13 745 198.5 - 1751	P-EP93434Y	01.08.2017
Applicant: Outotec (Finland) Oy		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).

Martin, Christophe
Primary Examiner
For the Examining Division

Enclosure(s): 3 page/s reasons (Form 2906)
DE-2731074-A1

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Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	5143440
Application number	EP13745198.5
Date of receipt	24 March 2017
Receiving Office	European Patent Office, The Hague
Your reference	P-EP93434Y
Applicant	All applicants as on file
Documents submitted	package-data.xml epf1038.pdf (1 p.) CLMS-1.pdf\Amended Claims_Clean.pdf (5 p.) DRAW-1.pdf\Amended Figures page 7.pdf (1 p.) ep-sfd-request.xml EPLETT-1.pdf\Response to EPO.pdf (5 p.) CLMS-HWA-1.pdf\Amended Claims_Marked up.pdf (5 p.)
Submitted by	CN=Jarmo Tanskanen 23717
Method of submission	Online
Date and time receipt generated	24 March 2017, 10:24 (CET)
Message Digest	46:46:DB:16:D2:CC:F3:66:8C:77:74:6A:A6:B8:7A:02:CA:F3:5E:F8

Correction by the EPO of errors in debit instructions filed by eOLF

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Claims

1. A bearing assembly for supporting a journal of a grinding mill body (2), comprising a frame (10) and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad (17) mounted to a base (14), said polymer bearing pad comprising an outer surface (13A, 13B), at least one recess (18) for receiving lubricating fluid from at least one passage of said base (14) and distributing said lubricating fluid to said outer surface (13A, 13B) and mounting means for securely mounting said polymer bearing pad (17) to said base (14), said base (14) also comprising at least one lubricating fluid supply port (15) in fluid communication with said at least one passage, wherein said base (14) is mounted to said frame (10) so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body (2).

2. A bearing assembly for supporting a journal of a grinding mill body (2), comprising a frame (10) and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad (17) mounted to a base (14), said polymer bearing pad (17) comprising an outer surface (13A, 13B), at least one recess (18) for receiving lubricating fluid from at least one passage of said base (14) and distributing said lubricating fluid to said outer surface (13A, 13B) and mounting means for securely mounting said polymer bearing pad (17) to said base (14), said base (14) also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base (14) is fixedly mounted to said frame (10).

3. The bearing assembly of claim 1 or 2, wherein said polymer bearing pad (17) is removably mounted to said base (14), wherein said mounting means preferably comprises a mounting portion (8) extending from said polymer bearing pad (17), wherein said mounting portion (8) preferably comprises a protrusion from a mounting surface opposite to said outer surface (13A, 13B) for engaging a flange (9) of said base (14), said flange (9) preferably being located at an outer edge of said base (14).

4. The bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening (18A) for receiving at least one fastener for mounting said polymer pad (17) to said base (14), said at least one

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recess (18) comprises a locking element for retaining said fastener within said at least one recess (18), preferably a locking tab (28) for retaining a head portion (26) of said fastener, and said at least one fastener comprises a bore (24) for conveying lubricating fluid from said at least one passage to said at least one recess (18).

5. The bearing assembly of any one of the preceding claims, wherein said polymer bearing pad (17) substantially covers an outer surface (22) of said base (14) to create a fluid seal between said polymer bearing pad (17) and said base (14), wherein said outer surface (22) is preferably at least one of a partially curved outer surface or a substantially planar outer surface.

6. The bearing assembly of any one of the preceding claims, further comprising a chamfer (37) at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal (4), wherein said chamfer (37) preferably has an outer edge that is displaced from a journal (4) when said journal (4) engages said polymer pad (17).

7. The bearing assembly of any one of the preceding claims, said at least one recess (18) of said polymer bearing pad (17) comprises at least one interconnecting passage (19) for fluidly connecting said at least one recess (18) to said at least one passage of said base (14).

8. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads (17), wherein said respective outer surfaces (13A, 13B) of said polymer pads form a substantially uniform bearing surface (20, 21) for said journal (4), wherein each of said polymer bearing pads (17) preferably comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

9. The bearing assembly of any one of claims 1 to 7, wherein said base (14) further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads (17), a first of said polymer bearing pads being mountable to said first surface and a second of said polymer bearing pads being mountable to said second surface.

wherein said first polymer bearing pad (17A) comprises a first outer surface (13A) and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad (17B) comprises a second outer surface (13B) and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface,

wherein said first outer surface (13A) is preferably partially curved such that said first polymer bearing pad (17A) acts as a radial hydrostatic bearing and said second outer surface (13B) is preferably substantially planar such that said second polymer bearing pad (17B) acts as an axial bearing.

10. A multidirectional fluid bearing for a journal, comprising:

a base (14) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad (17A) mountable to said first surface, said polymer bearing pad (17A) having a first outer surface (13A) and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface (13A), and

a second polymer bearing pad (17B) mountable to said second surface, said second polymer bearing pad (17B) having a second outer surface (13B) and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (13B)

wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

11. The multidirectional fluid bearing of claim 10, wherein said first polymer bearing pad (17A) is removably mounted to said first surface and/or said second polymer bearing pad (17B) is removably mounted to said second surface.

~~11.~~12. The multidirectional fluid bearing of claim 10 or 11, said first polymer bearing pad (17A) substantially covers said first surface and said second polymer bearing pad (17B) substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base, wherein said first outer surface (13A) is preferably partially curved such that said first polymer bearing pad (17A) acts as a radial hydrostatic bearing and said second outer surface (13B) is preferably substantially planar such that said second polymer bearing pad (17B) acts as an axial bearing.

~~12.~~13. The multidirectional fluid bearing of any one of claims 10 to 12~~r 11~~, wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises a chamfer (37) at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal (4), wherein said chamfer preferably has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

~~13.~~14. The multidirectional fluid bearing of claim 10, wherein there is a plurality of at least one of said first and second polymer bearing pads (17A, 17B), wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface (52) for said journal (4), wherein each of said plurality of at least one of said first and second polymer bearing pads preferably comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

~~14.~~15. The multidirectional fluid bearing of any one of claims 10 to 14~~13~~, ~~wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab, and~~ wherein said at least one fastener

comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess (18), said at least one fastener being partially received in said at least one passage, and preferably wherein said base (14) comprises at least one flange (9) for engagement with a mounting portion (8) of at least one of said first and second polymer bearing pads (17A, 17B) to securely mount said at least one polymer bearing pad to said base (14), wherein said flange (9) is preferably located at an outer edge of said base.

~~15. The multidirectional fluid bearing of any one of claims 10 to 14, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base, wherein said flange is preferably located at an outer edge of said base.~~

Claims

1. A bearing assembly for supporting a journal of a grinding mill body (2), comprising a frame (10) and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad (17) mounted to a base (14), said polymer bearing pad comprising an outer surface (13A, 13B), at least one recess (18) for receiving lubricating fluid from at least one passage of said base (14) and distributing said lubricating fluid to said outer surface (13A, 13B) and mounting means for securely mounting said polymer bearing pad (17) to said base (14), said base (14) also comprising at least one lubricating fluid supply port (15) in fluid communication with said at least one passage, wherein said base (14) is mounted to said frame (10) so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body (2).

2. A bearing assembly for supporting a journal of a grinding mill body (2), comprising a frame (10) and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad (17) mounted to a base (14), said polymer bearing pad (17) comprising an outer surface (13A, 13B), at least one recess (18) for receiving lubricating fluid from at least one passage of said base (14) and distributing said lubricating fluid to said outer surface (13A, 13B) and mounting means for securely mounting said polymer bearing pad (17) to said base (14), said base (14) also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base (14) is fixedly mounted to said frame (10).

3. The bearing assembly of claim 1 or 2, wherein said polymer bearing pad (17) is removably mounted to said base (14), wherein said mounting means preferably comprises a mounting portion (8) extending from said polymer bearing pad (17), wherein said mounting portion (8) preferably comprises a protrusion from a mounting surface opposite to said outer surface (13A, 13B) for engaging a flange (9) of said base (14), said flange (9) preferably being located at an outer edge of said base (14).

4. The bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening (18A) for receiving at least one fastener for mounting said polymer pad (17) to said base (14), said at least one

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recess (18) comprises a locking element for retaining said fastener within said at least one recess (18), preferably a locking tab (28) for retaining a head portion (26) of said fastener, and said at least one fastener comprises a bore (24) for conveying lubricating fluid from said at least one passage to said at least one recess (18).

5. The bearing assembly of any one of the preceding claims, wherein said polymer bearing pad (17) substantially covers an outer surface (22) of said base (14) to create a fluid seal between said polymer bearing pad (17) and said base (14), wherein said outer surface (22) is preferably at least one of a partially curved outer surface or a substantially planar outer surface.

6. The bearing assembly of any one of the preceding claims, further comprising a chamfer (37) at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal (4), wherein said chamfer (37) preferably has an outer edge that is displaced from a journal (4) when said journal (4) engages said polymer pad (17).

7. The bearing assembly of any one of the preceding claims, said at least one recess (18) of said polymer bearing pad (17) comprises at least one interconnecting passage (19) for fluidly connecting said at least one recess (18) to said at least one passage of said base (14).

8. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads (17), wherein said respective outer surfaces (13A, 13B) of said polymer pads form a substantially uniform bearing surface (20, 21) for said journal (4), wherein each of said polymer bearing pads (17) preferably comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

9. The bearing assembly of any one of claims 1 to 7, wherein said base (14) further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

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wherein there is a plurality of said polymer bearing pads (17), a first of said polymer bearing pads being mountable to said first surface and a second of said polymer bearing pads being mountable to said second surface.

wherein said first polymer bearing pad (17A) comprises a first outer surface (13A) and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad (17B) comprises a second outer surface (13B) and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface,

wherein said first outer surface (13A) is preferably partially curved such that said first polymer bearing pad (17A) acts as a radial hydrostatic bearing and said second outer surface (13B) is preferably substantially planar such that said second polymer bearing pad (17B) acts as an axial bearing.

10. A multidirectional fluid bearing for a journal, comprising:

a base (14) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad (17A) mountable to said first surface, said polymer bearing pad (17A) having a first outer surface (13A) and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface (13A), and

a second polymer bearing pad (17B) mountable to said second surface, said second polymer bearing pad (17B) having a second outer surface (13B) and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (13B)

wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

11. The multidirectional fluid bearing of claim 10, wherein said first polymer bearing pad (17A) is removably mounted to said first surface and/or said second polymer bearing pad (17B) is removably mounted to said second surface.

12. The multidirectional fluid bearing of claim 10 or 11, said first polymer bearing pad (17A) substantially covers said first surface and said second polymer bearing pad (17B) substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base, wherein said first outer surface (13A) is preferably partially curved such that said first polymer bearing pad (17A) acts as a radial hydrostatic bearing and said second outer surface (13B) is preferably substantially planar such that said second polymer bearing pad (17B) acts as an axial bearing.

13. The multidirectional fluid bearing of any one of claims 10 to 12, wherein at least one of said first and second polymer bearing pads (17A, 17B) comprises a chamfer (37) at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal (4), wherein said chamfer preferably has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

14. The multidirectional fluid bearing of claim 10, wherein there is a plurality of at least one of said first and second polymer bearing pads (17A, 17B), wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface (52) for said journal (4), wherein each of said plurality of at least one of said first and second polymer bearing pads preferably comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

15. The multidirectional fluid bearing of any one of claims 10 to 14, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess (18), said at least one fastener being partially received in said at least one passage, and preferably wherein said base (14) comprises at least one flange (9) for engagement with a mounting portion (8) of at least one of said first and second polymer bearing pads (17A, 17B) to securely mount

said at least one polymer bearing pad to said base (14), wherein said flange (9) is preferably located at an outer edge of said base.

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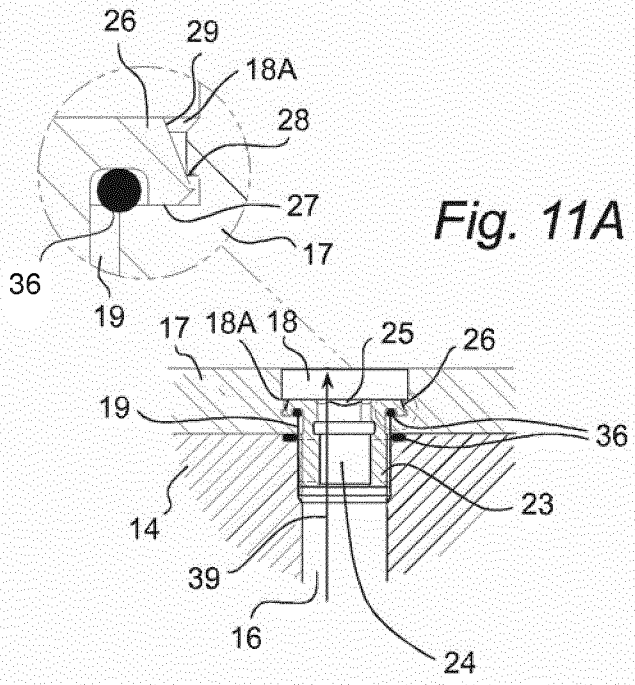


Fig. 11A

Fig. 11

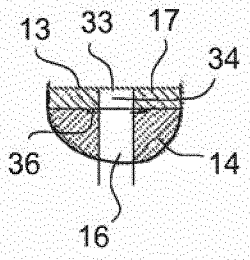


Fig. 12A

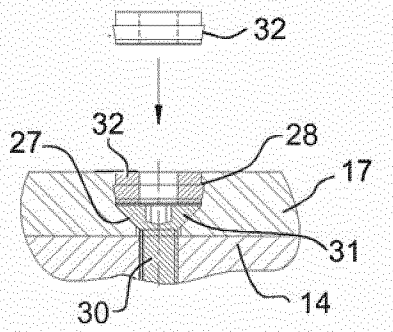


Fig. 12

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Office européen des brevets

Letter accompanying subsequently filed items

Representative:
PAPULA OY
397
P.O. Box 981
Mechelininkatu 1 a
00101 Helsinki
Finland

Phone: +35893480060
Fax: +358934800630
E-mail: western-patents@papula-nevinpat.com

80298 Munich
Germany
Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818
2280 HV Rijswijk
Netherlands
Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin
Germany
Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	13745198.5
Applicant's or representative's reference	P-EP93434Y

	Description of document	Original file name	Assigned file name
1	Letter relating to the search and examination procedure	Response to EPO.pdf	EPLETT-1.pdf
2	Amended claims (clean copy)	Amended Claims_Clean.pdf	CLMS-1.pdf
3	Amended claims with annotations	Amended Claims_Marked up.pdf	CLMS-HWA-1.pdf
4	Amended drawings (clean copy)	Amended Figures page 7.pdf	DRAW-1.pdf

	Payment	
1	Mode of payment	Not specified

Signatures

Place:	
Date:	**23 March 2017**
Signed by:	**Jarmo Tanskanen 23717**
Association:	**PAPULA OY**
Representative name:	**Jarmo Tanskanen**
Capacity:	**(Representative)**

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FLS v. Metso - IPR2025-00985

Papula-Nevinpat
Business ID 0236098-2
VAT number FI02360982

Head office
Mechelininkatu 1 a
FI-00180 Helsinki, Finland

Mail address
POB 981
FI-00101 Helsinki, Finland

Phone
+358 (0)9 348 0060

Fax
+358 (0)9 3480 0630, 3480 0631

E-mail
papula@papula-nevinpat.com
firstname.lastname@papula-nevinpat.com

western-patents@papula-nevinpat.com
eurasian-patents@papula-nevinpat.com
trademarks@papula-nevinpat.com
designs@papula-nevinpat.com
validation@papula-nevinpat.com
annuities@papula-nevinpat.com

Internet
www.papula-nevinpat.com

European Patent Office
D-80298 München
Germany

Our ref: P-EP93434Y
Date: 22 March 2017

European patent application 13745198.5
Applicant: Outotec (Finland) Oy

This is in response to a Communication dated 30 November 2016 pursuant to Article 94(3) EPC concerning the above identified application.

Amendments

The applicant has amended claim 10 to include most of the subject matter of claim 14. Claim 3 has been amended and new claim 11 has been added to recite additional features. The remaining part of claim 14 has been merged with claim 15. Consequential amendments have been made to the claims.

In addition, claim 15 has added the word "said" before "base" and introduced an appropriate antecedent for the mounting portion.

Support for the amendment to claim 3 and new claim 11 is found, for example, at page 18, paragraph [00108] of the specification as filed, which recites that the polymer bearing pad may be removed from the base when damaged. Also, page 25, paragraph [0114] and page 27, paragraph [0123] recite that the polymer bearing pad may be removed from the base for replacement or repair.

Support for the amendment to claim 10 is found, for example, at page 10, paragraphs [0052] and [0055] of the specification as filed.

Figure 11A of the drawings has been amended so that item 34 is replaced with "36" to correct a typographical error, as "34" currently points to the O-ring, which is described as item 36 in the specification – see page 17, paragraph [00106].

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Arguments (Art. 56 EPC)

Claim 1

The Examiner has referred to the reasoning in the International Preliminary Report on Patentability (IPRP) that issued on the corresponding international application in support of his inventive step objection. The reasoning in the IPRP concedes that D5 does not describe a polymer bearing pad but asserts that it would have been obvious to substitute the bearing pads in D5 with polymer bearing pads.

It is submitted that it would not have been obvious for a skilled person to simply substitute the lining 16 in D5 for a polymer bearing pad. There is no disclosure or teaching in D5 to support the inference that the lining 16 can be replaced with a polymer bearing pad.

Nor is it well known to use polymer bearing pads in bearing assemblies for grinding mills. To the contrary, it was conventionally thought that only bronze/white metal linings were suitable for this application due to their resistance to damage and deformation during operation of the grinding mill. As described in the specification as filed at paragraphs [0007] and [0109], prior art systems use steel bases with white metal or bronze linings, of which D5 is an example of this conventional prior art. These white metal/bronze lining arrangements are designed to resist deformation caused by engagement of the bearing pad with the journal surface. By resisting deformation, the white metal/bronze linings protect the bearing from impact damage from the journal. It is submitted that this standard design and purpose for the bearing pads in a grinding mill is universally known and adopted. Accordingly, it is submitted that the inventive insight of the present invention is to use a deformable bearing pad and this approach is contrary to conventional thought in relation to bearing assemblies for grinding mills.

In contrast to this conventional thought, the use of a polymer bearing pad in the claimed invention is designed with the purpose of being deformable to mould to the journal surface profile (self-moulding) and provide a dampening effect – see paragraph [0109], items (1) and (5). Thus, the purpose of the claimed invention is the opposite to the purpose of the linings in the prior art as exemplified by D5. Consequently, to modify the bearing pads in D5 with polymer bearing pads would in fact frustrate the purpose of the bearings in D5 to resist deformation caused by the grinding action of the journal surface. Hence, the person skilled in the art would not consider such a substitution as this is contrary to conventional thought. In effect, D5 teaches away from the invention by requiring the lining to resist deformation using conventional white metal/bronze, instead of being deformable as would occur in a polymer bearing pad.

Moreover, the polymer bearing pad provides technical advantages over conventional bronze/white metal linings as exemplified in D5, as discussed in

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paragraph [0109] of the specification. In particular, the polymer bearing pads are easily replaceable, require much less lubricating fluid, involve less machining (and hence manufacturing costs) due to their self-moulding properties, dampen impact forces on the bearing, assists in aligning the journal on the bearing and cushions the journal. None of these advantages are disclosed or taught in D5. Accordingly, for these reasons, it is submitted that claim 1 is non-obvious over D5.

Claim 2

In relation to this claim, the Examiner again relies on the reasoning in the IPRP to assert that claim 2 is obvious in view of D6. The IPRP conceded that D6 does not describe a polymer bearing pad but asserts that it would have been obvious to substitute the bearing pads in D6 with polymer bearing pads.
Accordingly, the Applicant submits that claim 2 is non-obvious over D6 for at least the same reasons as outlined in respect of claim 1 above.

In addition, it is further submitted that D6 fails to disclose, teach or suggest other features claimed in claim 2. D6 describes a fluid bearing assembly arrangement for a grinding mill drum. Hydrostatic or hydrodynamic bearing shoes 10 support bearing rings 7, 9 of the drum, while a ring gear 11 has axial end faces that act as axial guide surfaces 15, 15a. Two mountings 17, 17a have guide blocks 18, 18a made of bearing material support the axial guide surfaces 15, 15a. Oil supply line 31 provides lubricating oil to the guide blocks 18, 18a.

However, D6 does not disclose (besides a polymer bearing pad) a recess in the bearing pad (being the guide blocks 18, 18a) or a passage in the base (being the mountings 17, 17a) to supply lubricating fluid to the recess, as required by claim 2.

Accordingly, it would not have been obvious to the skilled person to modify both the bearing pad and the base to include a recess and a passage, respectively, in addition to using a polymer bearing pad, since these features are not taught or suggested by D6. Consequently, claim 2 is non-obvious over D6.

Claim 10

The Examiner has further adopted the reasoning in the IPRP to assert that claim 10 is obvious in light of D5 or D6 on the basis that each citation discloses a multidirectional fluid bearing that only lack polymer bearing pads. Again, the Examiner considers that it would have been obvious to substitute the bearing pads in D5 and D6 with a polymer bearing pad to arrive at the invention of claim 10.
Accordingly, the Applicant submits that claim 10 is non-obvious over D5 and D6 for at least the same reasons as outlined in respect of claim 1 above. That

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is, it would not have been obvious to substitute the linings described in D5 and D6 for polymer bearing pads as outlined above.

In addition, it is submitted that neither D5 nor D6 disclose or teach other features recited in claim 10, especially the feature of respective first and second polymer bearing pads covering respective first and second surfaces of the bearing assembly.

The IPRP asserts that Figures 3 and 5 of D5 show a fluid bearing with bearing pads on orthogonal surfaces of a base. However, it is submitted that Figures 3 and 5 merely show that a flange 14 of the lining 16 overhangs each side of the base 10. Thus, the same bearing pad (lining 16) covers one surface and only partly covers another orthogonal surface. In contrast, claim 10 requires separate (first and second) bearing pads covering the separate first and second surfaces. To modify the lining 16 to cover individual surfaces of the base 10 would remove the flanges 14, and so be contrary to the design and function in D5, as the flanges 4 are required to take up axial forces (see page 1, 67 to 70) and control lubrication and the flow of oil (see page 1, lines 71 to 88 and page 2, lines 119 to 123). Accordingly, it is submitted that for this additional reason D5 fails to render claim 10 obvious.

Likewise, the IPRP has not construed D6 correctly, as in this document each fluid bearing only has one bearing pad mounted on one surface of a base. That is, the bearing pad 10 is mounted on a separate base to the guide blocks 18, 18a. Thus, while the bearing pad 10 and guide blocks 18, 18a are mounted on surfaces that are orthogonal to each other, these surfaces are not on the same base, as is required by claim 22. To modify in D6 so that bearing pads are on orthogonal surfaces of the same base would drastically change the design of the bearing assembly in D6 as the bearings are physically displaced from each other to perform their function at different locations of the grinding mill body. Hence, it is submitted that for this additional reason D6 fails to render claim 10 obvious.

In addition, claim 10 has been amended to further recite the features of:

- at least one of said first and second polymer bearing pads comprising at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base; and
- said at least one recess comprising a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

While the Examiner has asserted that these features are taught in D1 and D3, D1 only teaches an opening for receiving a fastener while D3 only teaches a locking tab for a fastener. Neither one of these documents teaches the combination of an opening in a polymer bearing pad to receive a fastener and a locking tab for retaining the head portion of the fastener, where the head potion is tapered.

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In summary, to arrive at claim 10 it would be necessary to modify D5 to have (1) a polymer bearing pad; (2) the lining 16 cover individual surfaces of the base contrary to its intended design; (3) provide an opening for receiving a fastener as taught by D1; (4) provide a locking tab in the recess as taught by D3; and (5) further provide a tapered head portion for the fastener. Given the number of modifications required, it is submitted that it would not have been obvious for one skilled in the art to arrive at claim 10 based on a combination of D5, D1 and D3.

Similarly, to arrive at claim 10 it would be necessary to modify D6 to have (1) a polymer bearing pad; (2) the bearing pads 10 on the same guide block 18 or 18 contrary to its intended design; (3) provide an opening for receiving a fastener as taught by D1; (4) provide a locking tab in the recess as taught by D3; and (5) further provide a tapered head portion for the fastener. Again, given the number of modifications required, it is submitted that it would not have been obvious for one skilled in the art to arrive at claim 10 based on a combination of D6, D1 and D3

Therefore, it is submitted that the combination of features now recited by claim 10 is not rendered obvious by any combination of D5 or D6 with D1 and D3.

Summary

It is believed the application is now in compliance with the EPC. Should the Examiner find any incompliance, we are ready to further specify our comments and/or further amend the application in response to any communication pointing such deficiencies under the European Patent Convention. Should the Examining Division take any adverse decision on this application, the applicant hereby requests, in order of preference, a phone conversation, an informal interview and Oral Proceedings before such decision.

Respectfully,

PAPULA OY

ENCS Amended claims, clean copy
Amended claims, marked-up copy
Amended figure page 7/13

/pku

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The examination is being carried out on the **following application documents**

Description, Pages

1-28 filed with entry into the regional phase before the EPO

Claims, Numbers

1-15 filed with entry into the regional phase before the EPO

Drawings, Sheets

1/13-13/13 filed with entry into the regional phase before the EPO

1 Reference is made to the following documents:

D1 : DE 10 2007 039 364 A1

D2 : WO 90/12216 A

D3 : JP 2006-9968 A

D4 : WO 2012/145217 A1

D5 : GB 1 508 384

D6 : US 4,911,554

2 The present application does not meet the criteria of Article 52(1) EPC, because the subject-matter of independent claim 1 does not involve an inventive step in the sense of Article 56 EPC.

2.1 D5 discloses "a bearing assembly for supporting a journal (12) of a grinding mill body (see page 3, lines 20-27), comprising a frame (17) and a plurality of fluid bearings, said fluid bearings each comprising a ~~*polymer*~~ bearing pad (16) mounted to a base (10), said ~~*polymer*~~ bearing pad (16) comprising an outer surface, at least one recess (18) for receiving lubricating fluid from at least one passage (20) of said base (10) and distributing said lubricating fluid to said outer surface (implicit feature) and mounting means (11, 13) for securely mounting said ~~*polymer*~~ bearing pad (16) to said base (10), said base (10) also comprising at least one lubricating fluid supply port (see figure 2) in fluid communication with said at least one passage (20), wherein said base (10) is mounted to said frame (17) so that said fluid bearings self adjust to changes in the angular position of the journal (12) during operation of said grinding mill body (see page 2, lines 45-54)".

2.2 The subject-matter of claim 1 differs therefrom in that the bearing pad is explicitly made of "polymer".

2.3 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

2.4 The subject-matter of claim 1 therefore lacks inventive step on the basis of D5 and the general knowledge of the skilled person.

3 The present application does not meet the criteria of Article 52(1) EPC, because the subject-matter of independent claim 2 does not involve an inventive step in the sense of Article 56EPC.

3.1 D6 discloses "a bearing assembly for supporting a journal of a grinding mill body (see column 2, lines 28-37), comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a ~~*polymer*~~ bearing pad (18, 18a) mounted to a base (17, 17a), said ~~*polymer*~~ bearing pad (18, 18a) comprising an outer surface, at least one recess for receiving lubricating fluid (implicit feature) from at least one passage of said base (31) (see column 3, line 57-column 4, line 2) and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad (18, 18a) to said base (17, 17a) (implicit feature), said base (17,17a) also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage (see 31), wherein said base (18, 18a) is fixedly mounted to said frame (see column 3, lines 28-38)".

3.2 The subject-matter of claim 2 differs therefrom in that the bearing pad is explicitly made of "polymer".

3.3 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

3.4 The subject-matter of claim 2 therefore lacks inventive step on the basis of D6 and the general knowledge of the skilled person.

4 The present application does not meet the criteria of Article 52(1) EPC, because the subject-matter of independent claim 10 does not involve an inventive step in the sense of Article 56 EPC.

4.1 D5 discloses "a multidirectional fluid bearing for a journal (12), comprising:

a base (10) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports (see figure 2) and a plurality of passages (20) in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first ~~*polymer*~~ bearing pad (16) mountable to said first surface, said ~~*polymer*~~ bearing pad (16) having a first outer surface and at least one recess (18) for receiving lubricating fluid from at least one of said plurality of passages (10) and distributing said lubricating fluid to said first outer surface, and

a ~~*second*~~ polymer bearing pad (16) mountable to said second surface, said second ~~*polymer*~~ bearing pad (16) having a second outer surface and at least one recess (19) for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (see figures 3 and 5)".

4.2 The subject-matter of claim 10 differs therefrom in that the bearing pad is explicitly made of "polymer".

4.3 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

4.4 The subject-matter of claim 10 therefore lacks inventive step on the basis of D5 and the general knowledge of the skilled person.

4.5 The subject-matter of claim 10 also lacks an inventive step in view of D6 (see in particular the orthogonally oriented pads (10 and 18a) in figure 2 of D6). Indeed, the subject-matter of claim 10 differs therefrom in that the bearing pad is explicitly made of "polymer". As argued before, such a difference is considered as being a mere constructional option which is obvious to the skilled person.

5 Dependent claims 3-9 and 11-15 do not contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the EPC in respect of inventive step, the reasons being as follows:

5.1 The features of claim 3 are known from D1, see e.g. the beveled edge of pad (30) in cooperation with the corresponding undercut notch of shoe (5) in figure 3A.

5.2 The features of claim 4 are known from D1, see figures 4A and 4B, as well as page 5/8, left column, lines 5-7 and 23-26..

Moreover, the optional features of said claim 4, i.e. the features introduced by "preferably" which do not necessarily further define the assembly of claim 4, are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028], an automated English translation of which is found here below:

"[0027] Moreover, according to the combination structure 6, after inserting ring 9 in the ring mounting groove¦channel 7 in the decomposition¦degradation state shown in FIG. 3, it can assemble simply in the state shown in FIG. 1 by inserting the hemisphere part 37 in a concave-part 8, and engaging the end face 45 of the hemisphere part 37 with ring 9.

[0028] In addition, as ring 9, an elastic O ring is preferable, However If it is the objective of mere connection, although it is a rigid material -- a diameter-expansion -- free and the diameter reduction -- free E ring or a C-ring may be sufficient. Even if it uses such E ring or a C-ring, it can connect, as that the gap adjustment member 5 may not be dropped off in the static-pressure gas bearing pad 3, and a cost reduction can be intended".

5.3 The features of claim 5 are known from D1, see figure 4A and the material used for the pad (for the first part of the claim), and from D6, see the pads (18, 18a) in figure 2 (for the last part of the claim).

Moreover, the optional features of said claim 5, i.e. the features introduced by "preferably" which do not necessarily further define the assembly of claim 5, are known from D5, see figure 2.

5.4 The features of claim 6 are known from D5, see column 2, lines 83-column 3, line 8; figures 3, 6 and 7.

5.5 The features of claim 7 are known from D5, see figure 2.

5.6 The features of claim 8 are obvious in view of a combination of the teachings of D6 to the arrangement shown in figure 5 of D2.

Moreover, the optional features of said claim 8, i.e. the features introduced by "preferably" which do not necessarily further define the assembly of claim 8 constitute a slight constructional change in the bearing of claim 8 which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

5.7 The features of claims 9 are known from D5 and/or D6, see the reasoning in paragraphs 4.1, 4.5 and 5.3 above.

5.8 The features of claims 11, 12 and 13 have already been discussed w.r.t. claim 5 (corresponding to claim 11), claim 6 (corresponding to claim 12) and claim 8(corresponding to claim 13).

5.9 The features of claim 14 are obtained from a combination of D1 (opening for receiving a fastener, bore for conveying fluid) and D3 (locking tab).

5.10 The features of claim 15 have already been discussed w.r.t. claim 3.

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6 It is not at present apparent which part of the application could serve as a basis for a new, allowable claim. Should the applicant nevertheless regard some particular matter as patentable, an independent claim should be filed taking account of Rule 43(1) EPC. The applicant should also indicate how the subject-matter of the new claim differs from the state of the art and the significance thereof.

Moreover, the features of the claims should be provided with reference signs placed in parentheses to increase the intelligibility of the claims (Rule 43(7) EPC). This applies to both the preamble and characterising portion (see Guidelines F-IV, 4.19).

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FLS v. Metso - IPR2025-00985

Europäisches Patentamt
European Patent Office
Office européen des brevets

European Patent Office
Postbus 5818
2280 HV Rijswijk
NETHERLANDS
Tel: +31 70 340 2040
Fax: +31 70 340 3016

Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Formalities Officer
Name: Prouteau, Evelyne
Tel: +31 70 340 - 4864
or call
+31 (0)70 340 45 00

Substantive Examiner
Name: Martin, Christophe
Tel: +31 70 340 - 4492

Application No.	Ref.	Date
13 745 198.5 - 1751	P-EP93434Y	30.11.2016
Applicant: Outotec (Finland) Oy		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

In case you withdraw the application within the above-mentioned period, the examination fee will be refunded at a rate of 50% (Art. 11 (b) RFees).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).

Registered letter
Exhibit 1027
FLS v. Metso - IPR2025-00985

Martin, Christophe
Primary Examiner
For the Examining Division

Enclosure(s): 5 page/s reasons (Form 2906)

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FLS v. Metso - IPR2025-00985

Europäisches Patentamt
European Patent Office
Office européen des brevets

Application No.: 13745198.5

Substantive examination has started on 24.11.16 (see Notice from the European Patent Office dated 29.01.2013, OJ EPO 2013, 153).

For the Examining Division

Exhibit 1027
FLS v. Metso - IPR2025-00985

Europäisches Patentamt
European Patent Office
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Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	3903314
Application number	EP13745198.5
Date of receipt	11 November 2015
Receiving Office	European Patent Office, The Hague
Your reference	P-EP93434Y
Applicant	All applicants as on file
Documents submitted	package-data.xml epf1038.pdf (1 p.) ep-sfd-request.xml PRSR-NON-1.pdf\Response to EPO.pdf (1 p.)
Submitted by	CN=Anssi Tullila 25666
Method of submission	Online
Date and time receipt generated	11 November 2015, 15:11 (CET)
Message Digest	95:B6:FD:6E:7A:04:F6:B0:78:9F:B1:77:3F:39:55:B2:0A:DD:A0:D4

Correction by the EPO of errors in debit instructions filed by eOLF
Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

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FLS v. Metso - IPR2025-00985

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European Patent Office
Office européen des brevets

Letter accompanying subsequently filed items

Representative:

Papula Oy
397
P.O. Box 981
Mechelininkatu 1 a
00101 Helsinki
Finland

Phone: +358-9-3480060
Fax: +358-9-34800630
E-mail: western-patents@papula-nevinpat.com

80298 Munich
Germany
Tel. +49(0)89 2399-0 | Fax -4465

P.O. Box 5818
NL-2280 HV Rijswijk
Netherlands
Tel. +31(0)70 340-2040 | Fax -3016

10958 Berlin
Germany
Tel. +49(0)30 25901-0 | Fax -840

The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	13745198.5
Applicant's or representative's reference	P-EP93434Y

	Description of document	Original file name	Assigned file name
1	Statement of non-availability of search results required under Rule 141(1) EPC	Response to EPO.pdf	PRSR-NON-1.pdf

Signatures

Place:	**Helsinki**
Date:	**11 November 2015**
Signed by:	**Anssi Tullila 25666**
Association:	**Papula Oy**
Representative name:	**Anssi Tullila**
Capacity:	**(Representative)**

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PAPULA NEVINPAT
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Papula-Nevinpat
Business ID 0236098-2
VAT number FI02360982

Head office
Mechelininkatu 1 a
FI-00180 Helsinki, Finland

Mail address
POB 981
FI-00101 Helsinki, Finland

Phone
+358 (0)9 348 0060

Fax
+358 (0)9 3480 0630, 3480 0631

E-mail
papula@papula-nevinpat.com
firstname.lastname@papula-nevinpat.com

domestic-patents@papula-nevinpat.com
eurasian-patents@papula-nevinpat.com
telecom-papula@papula-nevinpat.com
trademarks@papula-nevinpat.com
designs@papula-nevinpat.com
validation@papula-nevinpat.com
annuities@papula-nevinpat.com

Internet
www.papula-nevinpat.com

European Patent Office
D-80298 München
Germany

Our ref: P-EP93434Y
Date: 11 November 2015

European patent application 13745198.5
Applicant: Outotec (Finland) Oy

This is in response to an Invitation dated 14 October 2015 pursuant to Rule 70b(1) EPC concerning the above identified application.

Please be informed that no search results or Office Actions have been issued in the Australian priority application AU 2012902770.

Respectfully,

PAPULA OY

/pku

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FLS v. Metso - IPR2025-00985

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European Patent Office
80298 MUNICH
GERMANY

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Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Date
14-10-2015

Reference	Application No./Patent No.
P-EP93434Y	13745198.5 - 1751 / 2867550
Applicant/Proprietor	
Outotec (Finland) Oy	

Invitation to file a copy of search results or a statement of non-availability pursuant to Rule 70b(1) EPC

You are hereby requested to file, within a period of **two months** from notification of this invitation,

- a copy of the results of any search carried out by the authority with which the previous application/s from which priority is claimed was/were filed,

or

- a statement indicating that the said search results are not available to you.

The previous application/s concerned is/are the following:

AUA 2012902770

If this information is not filed in due time the European patent application shall be deemed to be withdrawn (Rule 70b(2) EPC, Article 124(2) EPC).

If the present application is a European divisional application:

You need not to reply to the present invitation provided that all relevant search results have already been filed with respect to the parent application.

You need to reply to the present invitation if a statement of non-availability has been filed with respect to the parent application.

For the Examining Division

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Registered letter
EPO Form 2913 01.11 (01/10/15)

Exhibit 1027
FLS v. Metso - IPR2025-00985

Europäisches Patentamt
European Patent Office
Office européen des brevets

European Patent Office
80298 MUNICH
GERMANY

Questions about this communication ?
Contact Customer Services at www.epo.org/contact

Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Date
09.04.15

Reference	Application No./Patent No.
P-EP93434Y	13745198.5 - 1751 / 2867550
Applicant/Proprietor	
Outotec (Finland) Oy	

Communication of European publication number and information on the application of Article 67(3) EPC

The provisional protection under Article 67(1) and (2) EPC in the individual Contracting States becomes effective only when the conditions referred to in Article 67(3) EPC have been fulfilled (for further details, see information brochure of the European Patent Office "National Law relating to the EPC" and additional information in the Official Journal of the European Patent Office).

Pursuant to Article 153(3) EPC the publication under Article 21 PCT of an international application for which the European Patent Office is a designated or elected Office takes the place of the publication of a European patent application.

The bibliographic data of the above-mentioned Euro-PCT application will be published on 06.05.15 in Section I.1 of the European Patent Bulletin. The European publication number is 2867550.

In all future communications to the European Patent Office, please quote the application number plus Directorate number.

For the Examining Division

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European Patent Office
80298 MUNICH
GERMANY

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Contact Customer Services at www.epo.org/contact

Papula Oy
P.O. Box 981
00101 Helsinki
FINLANDE

Date
20.02.15

Reference	Application No./Patent No.
P-EP93434Y	13745198.5 - 1751
Applicant/Proprietor	
Outotec (Finland) Oy	

Communication pursuant to Rules 161(1) and 162 EPC

1. Comments on the written opinion and amendment of the application (R. 161(1) EPC)

The above-mentioned international (Euro-PCT) application has entered the European phase.

The EPO as International Searching Authority and, where a demand under Article 31 PCT was filed, also as International Preliminary Examining Authority has drawn up a written opinion on this application or the EPO as Supplementary International Searching Authority has issued explanations pursuant to Rule 45*bis*.7(e) PCT to the supplementary international search report.

In accordance with Rule 161(1) EPC, you may comment on the written opinion or on the explanations to the supplementary international search report within a **non-extendable period of six months** after notification of the present communication.

Under Articles 28, 41 PCT and Rules 52, 78 PCT the application may be amended before a designated or elected Office, and in accordance with Rule 137(2) EPC the applicant may amend the description, claims and drawings of his own volition together with any comments, corrections or amendments made in response to the communication under Rule 161(1) EPC.

Whether or not you have already done so, you now have a further opportunity to file amended claims or other application documents within the above-mentioned period.

Please note that under Rule 137(2) and (3) EPC as in force from 1 April 2010, you may amend the description, claims and drawings of your own volition in response to this communication, if the international search report has been drawn up on or after 1 April 2010 or the EPO has issued a supplementary international search report. In these cases no further amendments may be made without the consent of the Examining Division. This may be in particular relevant if you have already filed comments/amendments with respect to a written opinion of the International Searching Authority or an international preliminary examination report, or to any explanations pursuant to Rule 45*bis*.7(e) PCT to the supplementary international search report, which however do not address the deficiencies noted therein and you choose not to react to the present communication.

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

The claims applicable on expiry of this period, i.e. those filed on entry into the European phase or in response to the present communication, will form the basis for the calculation of any claims fee to be paid (see p. 2).

Registered letter
EPO Form 1226BB 07.14 (NFS) EUCL (13/02/15)

2. Claims fees under Rule 162 EPC

If the application documents on which the European grant procedure is to be based comprise more than fifteen claims, a claims fee shall be payable for the sixteenth and each subsequent claim within the period provided for in Rule 159(1) EPC.

☑ Based on the application documents currently on file, all necessary claims fees have already been paid (or the documents do not comprise more than 15 claims).

☐ All necessary fees will be debited automatically according to the automatic debit order.

☐ The claims fees due for the claims ..... to ..... were not paid within the above-mentioned period.

Any outstanding claims fee, either based on the current set of claims or on any amended claims to be filed pursuant to Rule 161 EPC (see page 1), may still be validly paid within a **non-extendable period of six months** after notification of this communication (R. 162(2) EPC).

If a payment is made for only some of the claims, you must indicate for which claims it is intended. If a claims fee is not paid in due time, the claim concerned is deemed to be abandoned (R. 162(4) EPC).

If claims fees have already been paid, but on expiry of the above-mentioned period there is a new set of claims containing fewer fee-incurring claims than before, the claims fees in excess of those due under Rule 162(2), second sentence EPC will be refunded (R. 162(3) EPC).

The claims fee is currently

EUR 235 for the 16th and each subsequent claim up to the limit of 50
EUR 580 for the 51st and each subsequent claim

Note to users of the automatic debiting procedure
Unless the EPO receives prior instructions to the contrary, the fees for all claims incurring fees will be debited on the last day of the period for payment. For further details see the Arrangements for the automatic debiting procedure, Annex A.1 to the ADA, Point 6.1(d), Supplementary publication 4 - OJ EPO 2014.

Important information concerning fee amounts
Following any amendment to the Rules relating to Fees, the amount(s) mentioned in this communication may be different from the amount(s) **actually due on the date of payment.** The latest version of the Schedule of fees and expenses, published as a Supplement to the Official Journal of the EPO, is also available on the EPO website (**www.epo.org**) and can be found under **www.epo.org/schedule-of-fees**, which allows the viewing, downloading and searching for individual fee amounts, both current and previous.
Please note that procedural fees are usually adjusted every two years, on even years, with effect from 1 April.

Payments by cheque delivered or sent direct to the EPO are no longer accepted as from 1 April 2008 (see OJ EPO 2007, 626).

For the Examining Division



Exhibit 1027
FLS v. Metso - IPR2025-00985

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European Patent Office
80298 MUNICH
GERMANY

Questions about this communication ?
Contact Customer Services at www.epo.org/contact

TATE, Chris
187 Delgrado Parade,
Iluka, Western Australia 6018
AUSTRALIE

Date
13.02.15

Reference	Application No./Patent No.
	13745198.5 - 1751
Applicant/Proprietor	
Outotec (Finland) Oy	

Notification of the data mentioned in Rule 19(3) EPC

In the above-identified patent application you are designated as inventor/co-inventor.
Pursuant to Rule 19(3) EPC the following data are notified herewith:

DATE OF FILING	: 28.06.13
PRIORITY	: AU/28.06.12/ AUA 2012902770
TITLE	: IMPROVEMENTS IN FLUID BEARINGS
DESIGNATED STATES	: AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

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GERMANY

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Contact Customer Services at www.epo.org/contact

BELKE, Jeffrey, Victor
11 Cowrie Cresent,
Mt Pleasant, Western Australia 6018
AUSTRALIE

Date
13.02.15

Reference	Application No./Patent No.
	13745198.5 - 1751
Applicant/Proprietor	
Outotec (Finland) Oy	

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80298 MUNICH
GERMANY

Questions about this communication ?
Contact Customer Services at www.epo.org/contact

GREEN, Nicholas, John
98a Toorak Road,
Rivervale, Western Australia 6018
AUSTRALIE

Date
13.02.15

Reference	Application No./Patent No.
	13745198.5 - 1751
Applicant/Proprietor	
Outotec (Finland) Oy	

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BRAITHWAITE, Daniel
5/17 Herta Road,
Innaloo, Western Australia 6018
AUSTRALIE

Date
13.02.15

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European Patent Office
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GERMANY

Questions about this communication ?
Contact Customer Services at www.epo.org/contact

VAAGE, Knut
Middlethunsgate 23,
0368 Oslio
NORVEGE

Date
13.02.15

Reference	Application No./Patent No.
	13745198.5 - 1751
Applicant/Proprietor	
Outotec (Finland) Oy	

Notification of the data mentioned in Rule 19(3) EPC

In the above-identified patent application you are designated as inventor/co-inventor.
Pursuant to Rule 19(3) EPC the following data are notified herewith:

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80298 MUNICH
GERMANY

Questions about this communication ?
Contact Customer Services at www.epo.org/contact

HARRISON, Oscar
35 Campsbourne Street,
Balcatta, Western Australia 6018
AUSTRALIE

Date
13.02.15

Reference	Application No./Patent No.
	13745198.5 - 1751
Applicant/Proprietor	
Outotec (Finland) Oy	

Notification of the data mentioned in Rule 19(3) EPC

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European Patent Office
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Acknowledgement of receipt

We hereby acknowledge receipt of the form for entry into the European phase (EPO as designated or elected Office) as follows:

Submission number	3273118
PCT application number	PCT/IB2013/055305
EP application number	13745198.5
Date of receipt	27 January 2015
Receiving Office	European Patent Office, The Hague
Your reference	P-EP93434Y
Applicant	
Country	
Documents submitted	package-data.xml application-body.xml AMSPECEPO-1.pdf\Clean claim set - European Regional phase.pdf (4 p.) ep-euro-pct.xml epf1200.pdf (5 p.)
Submitted by	CN=Anssi Tullila 25666
Method of submission	Online
Date and time receipt generated	27 January 2015, 15:40 (CET)
Message Digest	E1:20:5C:44:D9:F9:ED:BA:8F:51:C1:C0:30:83:41:91:67:89:A5:BB

Correction by the EPO of errors in debit instructions filed by eOLF

Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82,

Exhibit 1027
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OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

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Claims

1. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

2. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

3. The bearing assembly of claim 1 or 2, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad, wherein said mounting portion preferably comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base, said flange preferably being located at an outer edge of said base.

4. The bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base, said at least one recess comprises a locking element for retaining said fasterner within said at least onen recess, preferably a locking tab for retaining a head portion of said fastener, and said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

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5. The bearing assembly of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base, wherein said outer surface is preferably at least one of a partially curved outer surface or a substantially planar outer surface.

6. The bearing assembly of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal, wherein said chamfer preferably has an outer edge that is displaced from a journal when said journal engages said polymer pad.

7. The bearing assembly of any one of the preceding claims, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

8. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal, wherein each of said polymer bearing pads preferably comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

9. The bearing assembly of any one of claims 1 to 7, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads, a first of said polymer bearing pads being mountable to said first surface and a second of said polymer bearing pads being mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface,

wherein said first outer surface is preferably partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is preferably substantially planar such that said second polymer bearing pad acts as an axial bearing.

10. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

11. The multidirectional fluid bearing of claim 10, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base, wherein said first outer surface is preferably partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is preferably substantially planar such that said second polymer bearing pad acts as an axial bearing.

12. The multidirectional fluid bearing of claim 10 or 11, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal, wherein said chamfer preferably has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

13. The multidirectional fluid bearing of claim 10, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal, wherein each of said plurality of at least one of said first and second polymer bearing pads preferably comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

14. The multidirectional fluid bearing of any one of claims 10 to 13, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab, and wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

15. The multidirectional fluid bearing of any one of claims 10 to 14, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base, wherein said flange is preferably located at an outer edge of said base.

Europäisches Patentamt
European Patent Office
Office européen des brevets

Entry into the European phase (EPO as designated or elected Office)

To the European Patent Office

European application number	EP13745198.5
PCT application number	PCT/IB2013/055305
PCT publication number	WO2014002060
Applicant's or representative's reference	P-EP93434Y
International Filing Date	28.06.2013
International Searching Authority (ISA)	EP
International Preliminary Examining Authority (IPEA)	EP

1. Applicant

Indications concerning the applicant(s) are contained in the international publication or were recorded by the International Bureau after the international publication. ☒

Changes which have not yet been recorded by the International Bureau are set out here: ☐

2. Representative

Representative 1

This is the representative who will be listed in the European Patent Register and to whom notifications will be sent.

Name:	Papula Oy
Association No.:	397
Address of place of business:	P.O. Box P.O. Box 981
	POB 981
	00101 Helsinki,
	Finland
Telephone:	+358-9-3480060
Fax:	+358-9-34800630
E-mail:	western-patents@papula-nevinpat.com

3. Authorisation

Representative 1

An individual authorisation is attached. ☐

A general authorisation has been registered under No: ☐

A general authorisation has been filed, but not yet registered. ☐

The authorisation filed with the EPO as PCT receiving Office expressly includes the European phase. ☐

4. Request for examination

Examination of the application under Art. 94 EPC is hereby requested. The examination fee is being (has been, will be) paid. ☒

Request for examination in an admissible non-EPO language: ☐

The applicant waives his right to be asked under Rule 70(2) EPC whether he wishes to proceed further with the application. ☐

The/Each applicant hereby declares that he is an entity or a natural person under Rule 6(4) EPC. ☐

5. Copies

Additional copies of the documents cited in the supplementary European search report are requested. ☐

Number of additional sets of copies

6. Documents intended for proceedings before the EPO

Number of claims on entry into the European phase: 15

6.1 Proceedings before the EPO as designated Office (PCT I) are to be based on the following documents:

Exhibit 1027
FLS v. Metso - IPR2025-00985

the application documents published by the International Bureau (with all claims, description and drawings), where applicable with amended claims under Art. 19 PCT	☐
unless replaced by the amendments attached.	☐
Where necessary, clarifications should be attached as `Other documents`	
6.2 Proceedings before the EPO as elected Office (PCT II) are to be based on the following documents:	
the documents on which the international preliminary examination report is based, including any annexes	☐
unless replaced by the amendments attached.	☒
Where necessary, clarifications should be attached as `Other documents`	
If the EPO as International Preliminary Examining Authority has been supplied with test reports, these may be used as the basis of proceedings before the EPO.	☒
6.3 A copy of the results of the search carried out by the authority with which the previous application(s) whose priority is claimed was (were) filed is attached (R. 141(1) EPC).	☐
6.4 The applicant waives his right to the communication under Rules 161(1) or (2) and 162 EPC.	☐
7. Translations	
Translations in one of the official languages of the EPO (English, French, German) are attached as crossed below:	☐
** In proceedings before the EPO as designated or elected Office (PCT I + II):*	
Translation of the international application (description, claims, any text in the drawings) as originally filed, of the abstract as published and of any indication under Rule 13bis.3 and 13bis.4 PCT regarding biological material	☐
Translation of the priority application(s) (to be filed only at the EPO's request, Rule 53(3) EPC)	☐
It is hereby declared that the international application as originally filed is a complete translation of the previous application (Rule 53(3) EPC)	☐
** In addition, in proceedings before the EPO as designated Office (PCT I):*	
Translation of amended claims and any statement under Art. 19 PCT, if the claims as amended are to form the basis for the proceedings before the EPO (see Section 6).	☐
** In addition, in proceedings before the EPO as elected Office (PCT II):*	
Translation of annexes to the international preliminary examination report	☐
8. Biological material	
The invention uses and/or relates to biological material deposited under Rule 31 EPC.	☐
The particulars referred to in Rule 31(1)(c) EPC (if not yet known, the depositary institution and the identification reference(s)) [number, symbols, etc.] of the depositor) are given in the international publication or in the translation submitted in Section 7 on:	☐
page(s) / line(s)	
The receipt(s) of deposit issued by the depositary institution	
is (are) enclosed.	☐
will be filed later.	☐
Waiver of the right to an undertaking from the requester pursuant to Rule 33(2) EPC attached.	☐
9. Nucleotide and amino acid sequences	
The international application discloses nucleotide and/or amino acid sequences.	☐
9.1 The sequence listing was filed under Rule 5.2(a) PCT, or furnished to the EPO as ISA under Rule 13ter.1(a) PCT, or is otherwise available to the EPO, in computer-readable format in accordance with WIPO ST.25.	☐
9.2	
The sequence listing is attached in computer-readable format in accordance with WIPO Standard ST.25	☐
The sequence listing is attached in PDF format.	☐

The sequence listing does not include matter which goes beyond the content of the application as filed.	☐

10. Designation of contracting states

All the contracting states party to the EPC at the time of filing of the international patent application and designated in the international application are deemed to be designated (see Article 79(1) EPC).	☒

11. Extension/Validation

This application is deemed to be a request to extend the effects of the European patent application and the European patent granted in respect of it to all non-contracting states to the EPC designated in the international application with which extension or validation agreements were in force on the date on which the application was filed. However, the request is deemed withdrawn if the extension fee or the validation fee, whichever is applicable, is not paid within the prescribed time limit.	☐
11.1 It is intended to pay the extension fee(s) for the following state(s):	
11.2 It is intended to pay the validation fee(s) for the following state(s):	
Not applicable	
Note: Under the automatic debiting procedure, extension and/or validation fees will be debited only for states indicated here unless the EPO is instructed otherwise before expiry of the period for payment.	

12. List of enclosed documents

	Description of document	Original file name	Assigned file name
1	Combined Amendments	Clean claim set - European Regional phase.pdf	AMSPECEPO-1.pdf

13. Mode of payment: Debit from deposit account ☒

Currency	EUR
The European Patent Office is hereby authorised, to debit from the deposit account with the EPO any fees and costs indicated on the fees page.	
Deposit account number	28150011
Account holder	Papula Oy

14. Any refunds should be made to the following EPO deposit account: ☒

Number and account holder	Papula Oy, 28150011

15. Fees

		Factor/reduction applied	Fee schedule	Amount to be paid
15-1	002 Fee for a European search - Applications filed on/after 01.07.2005	-1285	1 285.00	0.00
15-2	005e Designation fee - For all contracting States designated for applications filed on/after 01.04.2009	1	580.00	580.00
15-3	006e Examination fee - For applications filed before 01.07.2005 and for international applications filed on/after 01.07.2005 without supplementary European search report	0.5	1 805.00	902.50
15-4	015 Claims fee - For the 16th to the 50th claim	0	235.00	0.00
15-5	15e Claims fee - For the 51st and each subsequent claim	0	580.00	0.00
15-6	020 Filing fee - entry EP phase - online	1	120.00	120.00
15-7	520 Additional filing fee for the 36th and each subsequent page - entry into EP phase	11	15.00	165.00
	Total:		EUR	**1 767.50**

16. Annotations

17. Signature(s) of applicant(s) or representative

Place: **Helsinki**

Date: **27 January 2015**

Exhibit 1027
FLS v. Metso - IPR2025-00985

Signed by:	Anssi Tullila 25666
Association:	Papula Oy
Capacity:	(Representative)

Exhibit 1027
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Table for section 6 of Form 1200.3

In accordance with the Notice from the European Patent Office dated 26 January 2009 concerning the 2009 fee structure (OJ EPO 2009, 118, and Guidelines for Examination in the EPO, April 2009, A-III, 13.2), the amount of the additional fee (Art. 2, item 1a, Rules relating to Fees) for the pages of this European patent application is calculated as follows:

Documents intended for proceedings before the EPO (R. 159 (1) (b) EPC) and for calculating the additional fee (Art. 2, item 1a, RFees):

		Page(s) from ... to ...	Number of pages
Description:	Amendments under Art. 34 PCT	1-28	28
Claims:	Amendments filed on entry into European phase	29-32	4
Drawings:	International application as published	33-45	13
Abstract:	Default count: one page		1
Total number of pages			46
Fee-exempt pages (Art. 2, item 1a, RFees)			-35
Number of pages to be paid for			11
			(x 15 EUR per page)
Total amount payable		EUR	165

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[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

[0011] A second aspect of the present invention provides a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

[0012] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

[0013] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0014] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[0015] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0016] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0017] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0018] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0019] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0020] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0021] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0022] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0023] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] There is disclosed a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] Also disclosed is a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for connecting said

polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] Also further disclosed is a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to a third aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably,, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this

embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23

also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a "hovercraft" type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there

is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both

outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the "lead-in" chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the "lead-in" chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the "lead-out" chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased "off the shelf" in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and

kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped

recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from

the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing in a bearing assembly, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the

invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Claims

1. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

2. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

3. The bearing assembly of claim 1 or 2, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad.

4. The bearing assembly of claim 3, wherein said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base.

5. The bearing assembly of claim 4, wherein said flange is located at an outer edge of said base.

6. The bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base.

7. The bearing assembly of claim 6, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess.

8. The bearing assembly of claim 6 or 7, wherein said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

9. The bearing assembly of claim 7, further comprising a plug for engagement with said head portion and said at least one recess.

10. The bearing assembly of claim 6, further comprising a locking element for retaining said at least one fastener within said at least one recess.

11. The bearing assembly of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

12. The bearing assembly of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

13. The bearing assembly of claim 12, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

14. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

15. The bearing assembly of any one of claims 1 to 13, wherein said outer surface is substantially planar.

16. The bearing assembly of any one of the preceding claims, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

17. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

18. The bearing assembly of claim 17, wherein each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

19. The bearing assembly of any one of claims 1 to 16, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads, a first of said polymer bearing pads being mountable to said first surface and a second of said polymer bearing pads being mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

20. The bearing assembly of claim 19, wherein said first surface is orthogonal to said second surface.

21. The fluid bearing of claim 19 or 20, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic

bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

22. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

23. The multidirectional fluid bearing of claim 22, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

24. The multidirectional fluid bearing of claim 22 or 23, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

25. The multidirectional fluid bearing of claim 24, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

26. The multidirectional fluid bearing of claim 22, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

27. The multidirectional fluid bearing of claim 26, wherein each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

28. The multidirectional fluid bearing of any one of claims 22 to 27, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

29. The multidirectional fluid bearing of claim 28, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

30. The multidirectional fluid bearing of any one of claims 22 to 29, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

31. The multidirectional fluid bearing of claim 30, wherein said flange is located at an outer edge of said base.

32. The multidirectional fluid bearing of any one of claims 22 to 31, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 74861WOP00	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/IB2013/055305	International filing date *(day/month/year)* 28.06.2013	Priority date *(day/month/year)* 28.06.2012

International Patent Classification (IPC) or national classification and IPC
INV. F16C32/06

Applicant
Outotec Oyj

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 8 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *(sent to the applicant and to the International Bureau)* a total of 36 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and/or sheets containing rectifications authorized by this Authority, unless those sheets were superseded or cancelled, and any accompanying letters (see Rules 46.5, 66.8, 70.16, 91.2, and Section 607 of the Administrative Instructions).
      ☐ sheets containing rectifications, where the decision was made by this Authority not to take them into account because they were not authorized by or notified to this Authority at the time when this Authority began to draw up this report, and any accompanying letters (Rules 66.4bis, 70.2(e), 70.16 and 91.2).
      ☐ superseded sheets and any accompanying letters, where this Authority either considers that the superseding sheets contain an amendment that goes beyond the disclosure in the international application as filed, or the superseding sheets were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in item 4 of Box No. I and the Supplemental Box (see Rule 70.16(b)).
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see paragraph 3*bis* of Annex C of the Administrative Instructions).

4. This report contains indications relating to the following items:
   - ☒ Box No. I Basis of the report
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☒ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☒ Box No. VIII Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22.04.2014	08.10.2014

Name and mailing address of the international preliminary examining authority:

European Patent Office P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk - Pays Bas
Tel. +31 70 340 - 2040
Fax: +31 70 340 - 3016

Authorized officer

Martin, Christophe

Telephone No. +31 70 340-4492

Exhibit 1027
FLS v. Metso - IPR2025-00985

Box No. I Basis of the report

1. With regard to the **language**, this report is based on

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3(a) and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4(a))
   - ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a) and (b))

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1, 2	as originally filed	
3-28	filed with the letter of	22-04-2014

Claims, Numbers

1-32	filed with the letter of	22-04-2014

Drawings, Sheets

1/13-13/13	as originally filed	

☐ a sequence listing - see Supplemental Box Relating to Sequence Listing.

3. ☒ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☒ the claims, Nos. 33-52
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (c-bis)):
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:

5. ☐ This report has been established:
   - ☐ taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rules 66.1(d-bis) and 70.2(e)).
   - ☐ without taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91(Rules 66.4bis and 70.2(e)).

Exhibit 1027
FLS v. Metso - IPR2025-00985

6. ☒ With regard to top-up searches (Rules 66.1 ter and 70.2(f)):
   ☒ A top-up search was carried out by this Authority on 29.09.2014 (all discovered documents are listed in the Supplemental Box Relating to Top-up Search).
   ☐ No top-up search was carried out by this Authority.

7. ☐ Supplementary international search report(s) from Authority(ies) has/have been received and taken into account in establishing this report (Rule 45bis.8(b) and (c)).

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-32
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-32
Industrial applicability (IA)	Yes:	Claims	1-32
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Box No. VI Certain documents cited

1. Certain published documents (Rule 70.10)

   and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Exhibit 1027
FLS v. Metso - IPR2025-00985

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 The attention of the applicant is drawn to the time limit for reply specified on the cover sheet of the present written opinion.

2 Reference is made to the following documents:

D1 : DE 10 2007 039 364 A1

D2 : WO 90/12216 A

D3 : JP 2006-9968 A

D4 : WO 2012/145217 A1

3 Furthermore, due to the extensive amendments filed by the applicant in reply to the international search report, a further search has been considered necessary, especially in the field of grinding mills. This search has revealed the following documents, a copy of which is attached to the present written opinion.

D5 : GB 1 508 384

D6 : US 4,911,554

4 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 1 does not involve an inventive step in the sense of Article 33(3) PCT.

4.1 D5 discloses "a bearing assembly for supporting a journal (12) of a grinding mill body (see page 3, lines 20-27), comprising a frame (17) and a plurality of fluid bearings, said fluid bearings each comprising a ~~*polymer*~~ bearing pad (16) mounted to a base (10), said ~~*polymer*~~ bearing pad (16) comprising an outer surface, at least one recess (18) for receiving lubricating fluid from at least one passage (20) of said base (10) and distributing said lubricating fluid to said outer surface (implicit feature) and mounting means (11, 13) for securely mounting said ~~*polymer*~~ bearing pad (16) to said base (10), said base (10) also comprising at least one lubricating fluid supply port (see figure 2) in fluid communication with said at least one passage (20), wherein said base (10) is mounted to said frame (17) so that said fluid bearings self adjust to changes in the angular position of the journal (12) during operation of said grinding mill body (see page 2, lines 45-54)".

4.1.1 The subject-matter of claim 1 differs therefrom in that the bearing pad is explicitly made of "polymer".

4.1.2 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

4.2 The subject-matter of claim 1 therefore lacks inventive step on the basis of D5 and the general knowledge of the skilled person.

5 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 2 does not involve an inventive step in the sense of Article 33(3) PCT.

5.1 D6 discloses "a bearing assembly for supporting a journal of a grinding mill body (see column 2, lines 28-37), comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a ~~*polymer*~~ bearing pad (18, 18a) mounted to a base (17, 17a), said ~~*polymer*~~ bearing pad (18, 18a) comprising an outer surface, at least one recess for receiving lubricating fluid (implicit feature) from at least one passage of said base (31) (see column 3, line 57-column 4, line 2) and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad (18, 18a) to said base (17, 17a) (implicit feature), said base (17, 17a)also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage (see 31), wherein said base (18, 18a) is fixedly mounted to said frame (see column 3, lines 28-38)".

5.1.1 The subject-matter of claim 2 differs therefrom in that the bearing pad is explicitly made of "polymer".

5.1.2 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

5.2 The subject-matter of claim 2 therefore lacks inventive step on the basis of D6 and the general knowledge of the skilled person.

6 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 22 does not involve an inventive step in the sense of Article 33(3) PCT.

6.1 D5 discloses "a multidirectional fluid bearing for a journal (12), comprising:

a base (10) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports (see figure 2) and a plurality of passages (20) in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first ~~*polymer*~~ bearing pad (16) mountable to said first surface, said ~~*polymer*~~ bearing pad (16) having a first outer surface and at least one recess (18) for receiving lubricating fluid from at least one of said plurality of passages (10) and distributing said lubricating fluid to said first outer surface, and

a ~~*second*~~ polymer bearing pad (16) mountable to said second surface, said second ~~*polymer*~~ bearing pad (16) having a second outer surface and at least one recess (19) for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (see figures 3 and 5)".

6.2 The subject-matter of claim 22 differs therefrom in that the bearing pad is explicitly made of "polymer".

6.2.1 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

6.3 The subject-matter of claim 22 therefore lacks inventive step on the basis of D5 and the general knowledge of the skilled person.

6.4 The subject-matter of claim 22 also lacks an inventive step in view of D6 (see in particular the orthogonally oriented pads (10 and 18a) in figure 2 of D6). Indeed, the subject-matter of claim 22 differs therefrom in that the bearing pad is explicitly made of "polymer". As argued before, such a difference is considered as being a mere constructional option which is obvious to the skilled person.

7 Dependent claims 3-21 and 23-32 do not contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step, the reasons being as follows:

7.1 The features of claims 3-5 are known from D1, see e.g. the beveled edge of pad (30) in cooperation with the corresponding undercut notch of shoe (5) in figure 3A.

7.2 The features of claim 6 are known from D1, see figures 4A and 4B.

7.3 The features of claim 7 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028], an automated English translation of which is found here below:

"[0027] Moreover, according to the combination structure 6, after inserting ring 9 in the ring mounting groove¦channel 7 in the decomposition¦degradation state shown in FIG. 3, it can assemble simply in the state shown in FIG. 1 by inserting the hemisphere part 37 in a concave-part 8, and engaging the end face 45 of the hemisphere part 37 with ring 9.

[0028] In addition, as ring 9, an elastic O ring is preferable, However If it is the objective of mere connection, although it is a rigid material -- a diameter-expansion -- free and the diameter reduction -- free E ring or a C-ring may be sufficient. Even if it uses such E ring or a C-ring, it can connect, as that the gap adjustment member 5 may not be dropped off in the static-pressure gas bearing pad 3, and a cost reduction can be intended".

7.4 The features of claim 8 are known from D1, see Figure 4A and page 5/8, left column, lines 5-7 and 23-26.

7.5 The features of claim 9 are known or derivable from D1, see the schematically represented sleeve like plug under the head of elements "17" in Figure 4B.

7.6 The features of claim 10 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028].

7.7 The features of claim 11 are known from D1, see figure 4A and the material used for the pad.

7.8 The features of claims 12 and 13 are known from D5, see column 2, lines 83-column 3, line 8; figures 3, 6 and 7.

7.9 The features of claim 14 are known from D5, see figure 2.

7.10 The features of claim 15 are implicitly known from D6, see the pads (18, 18a) in figure 2.

7.11 The features of claim 16 are known from D5, see figure 2.

7.12 The features of claim 17 are obvious in view of a combination of the teachings of D6 to the arrangement shown in figure 5 of D2.

7.13 In claim 18 a slight constructional change in the bearing of claim 17 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

7.14 The features of claims 19-21 are known from D5 and/or D6, see the reasoning in paragraphs 5.1 to 5.4 above.

7.15 The features of claims 23-26, have already been discussed w.r.t. claim 11 (corresponding to claim 23), claim 12 (corresponding to claim 24), claim 13 (corresponding to claim 25), claim 17 (corresponding to claim 26).

7.16 In claim 27 a slight constructional change in the bearing of claim 26 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

7.17 The features of claim 28 are obtained from a combination of D1 (opening for receiving a fastener) and D3 (locking tab).

7.18 The features of claims 29-32 have already been discussed w.r.t. claim 8 (corresponding to claim 29), claim 4 (corresponding to claim 30), claim 5 (corresponding to claim 31), 21 (corresponding to claim 32).

Re Item VI

Certain documents cited

Application No Patent No	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date *(valid claim)* *(day/month/year)*
WO 2012/145217 A1	26.10.2012	12.04.2012	19.04.2011

Re Item VIII

Certain observations on the international application

8 Since originally filed claim 18, on which present claim 9 is based, depends on originally filed claim 16, on which present claim 8 is based, present claim 9 should depend on present claim 8 and not on present claim 7.

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ABN 58 855 816 942

International Preliminary Examining Authority
European Patent Office
P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk – Pays Bas
THE NETHERLANDS

22 April 2014

Our Ref: 74861WOP00

Attention: Christophe Martin

Contact: Andrew Lowe

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

STATEMENT OF AMENDMENTS – ARTICLE 34

Complete Specification

Description

1. Cancel pages 3 to 28 now on file and replace with new pages 3 to 28.

Claims

2. Cancel pages 29 to 36 now on file and replace with new pages 29 to 33.

DATED this 22nd day of April 2014
OUTOTEC OYJ

Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com www.ShelstonIP.com fax +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

Shelston IP

Confidential Communication
Facsimile No. +31 70 340 3016
CONFIRMATION BY MAIL

ABN 58 855 816 942

International Preliminary Examining Authority
European Patent Office
P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk – Pays Bas
THE NETHERLANDS

CONFIRMATION

Attention: Christophe Martin

22 April 2014

Our Ref: 74861WOP00

Contact: Andrew Lowe

Dear Sirs

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

We refer to the First Written Opinion of the International Preliminary Examining Authority mailed on 30 October 2013 in respect of the above application.

Article 34 amendments

Pursuant to Article 34, the Applicant requires the International Preliminary Examining Authority to take into account the amendments on the enclosed replacement pages as set forth on the attached Statement of Amendments.

The proposed amendments have cancelled claims 11 to 13, 25, 26 to 38, 45, 48 and 51.

Claims 1 to 10 and 14 to 24 have been reworded and are now directed to a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising a base and the polymer bearing pad of original claim 1 mounted to the base. Support for this amendment is found at page 14, paragraph [0093] of the specification as filed

Claim 1 has also been amended claim to define that the base is mounted to the frame so that the fluid bearings self adjust to changes in the angular position of the journal during operation of the grinding mill body. Support for this amendment is found at page 14, paragraph [0094] of the specification as filed.

A new claim 2 has been added, which also defines a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising the polymer bearing pad of original claim 1 mounted to the base. New claim 2, however, defines that the base is fixedly mounted to the frame. Support for this amendment is found at page 24, paragraph [0113] of the specification as filed.

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@SheltonIP.com **www.SheltonIP.com** **fax** +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

Claim 39 has been amended to include the subject matter of original claim 51, and has now been renumbered as claim 22. Support for this amendment is found at page 11, paragraph [0061] and page 25, paragraph [0114] of the specification as filed

As a result, claims 2 to 10, 14 to 24, 40 to 44, 46, 47, 49, 50 and 52 have been renumbered as new claims 3 to 21 and 23 to 32.

Some clarifying amendments have also been made to claims 20, 22, 40, 46 and 47, now new claims 17, 19, 23, 26 and 27.

It is submitted that the proposed amendments are supported by the specification as filed and favourable consideration is requested.

Response to written opinion

In response to the Written Opinion, the Applicant submits that invention as now claimed is novel and involves an inventive step over the cited prior art referred to in Box V, and the claims no longer have the clarity problems noted in Box VIII.

Box V - novelty and inventive step

Of the claims that are now pending in the international application, the following documents have been cited by the Examiner as being relevant to novelty and inventive step:

D1: DE 10 2007 039 364 (Metso Paper)

D2: WO 90/12216 (Vickers plc)

D3: JP 2006-9968A (Oiles Industry Co Ltd)

It is submitted that claims 1 to 21 are novel and involve an inventive step over the cited prior art. Independent claims 1 and 2 now define a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising a polymer bearing pad mounted to a base.

Claim 1 further defines that the base is mounted to the frame so that the fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body. It is submitted that none of the cited prior art, especially D1, discloses or teaches this claimed feature.

D1 discloses a bearing pad 30 for a flexible sheet 10 forming a nip with a roller 2 in a paper or cardboard making machine. The bearing pad is mounted on a shoe 5, 31 that is supported by a piston 4 movably located in a shaft or axle 3. The axle 3 has a central well 15' that acts as a supply for lubricating fluid to be delivered to recesses 22 in the pad 30. The piston 4 operates to move the bearing pad 30 and shoe 5, 31 in a radial direction into engagement the flexible sheet 10, thus applying a pressure or force to the sheet 10 against the nip roller 2.

As such, it is submitted that any movement of the roller 2 relative to the sheet 10 and bearing pad 30, including its angular position, can only be adjusted for by operating the piston 4 so that the bearing pad 30 re-engages the roller 2 and pinch the flexible sheet 10. Hence, it is submitted that changes in angular position need to be manually corrected by operating the piston 4 – the fluid bearing comprising the bearing pad 30 and the shoe 5, 31 cannot correct for changes in the angular position of the roller 2 on its own. As a consequence, the fluid bearing does not stabilise the sheet 10 or roller 2 in an axial position, but rather allows the sheet 10 to "float" on the axle part 3 and applies a force to the internal surface of the sheet 10 so that a pressure is maintained against the roller 2.

By way of contrast, the bearing assembly of the claimed invention has the base of the fluid bearing mounted to the frame so that the fluid bearing self-adjusts to changes in the angular position of the journal shaft 4; ie. the fluid bearing is self-aligning on its own in response to movements of the journal shaft 4. Thus, the bearing assembly of the claimed invention acts to positively locate the supported journal shaft 4 in a fixed position such that mating precision components can be correctly located. As a consequence, the invention of claim 1 has the technical advantage of avoiding the need for manual

adjustment in response to changes in the angular position of the journal or a mechanical device such as a piston to perform that adjustment.

It is submitted that the skilled person would not be able to modify the arrangement of D1 to arrive at the technical solution defined in amended claim 1, since this would involve substantial redesign to take into account the removal of the piston arrangement disclosed in D1. Furthermore, it is submitted that there is no teaching in D1 that would motivate the skilled person to consider or attempt such a modification of such a central element of the designed bearing arrangement as taught in that document. Thus, it is submitted that claim 1 has an inventive step over D1.

Likewise, claim 2 defines that the base is fixedly mounted to the frame, whereas in D1 the shoe 5, 31 is able to move in a radial direction relative to the shaft 3 via the piston 4. Therefore, it is submitted that D1 fails to teach the technical solution proposed by claim 2, and in fact teaches the opposite arrangement – a moveable mounting of the shoe 5, 31 to the "base", being the shaft 3. Thus, for the same reasons outlined above, it is submitted that claim 2 also has an inventive step over D1.

Since the teaching in D3 relates only to particular fastening arrangements for mounting the bearing pad to the base, it is submitted that a combination of D1 with D3 would also fail to render the claimed invention obvious for the same reasons stated above.

Thus, it is submitted that claims 1 to 21 involve an inventive step over the cited prior art.

In relation to claims 22 to 32, it is also submitted that these claims involve an inventive step over D1 and D2, the Examiner having previously conceded that original claim 39 was novel.

Claim 22 now includes the subject matter of original claims 39 and 51. It is submitted that a combination of D1 and D2 fails to disclose or teach the claimed multidirectional fluid bearing having polymer bearing pads mounted to orthogonal surfaces of a base.

D1 only discloses a polymer bearing pad that supports a load in a single radial direction. Therefore, there is no disclosure or teaching of using the polymer bearing pad for supporting loads in multiple directions.

D2 describes a thrust bearing or shoe and particular reference is made to Figure 4 which shows multiple bearings 10a, 10b arranged on a thrust ring or disc that rotates with a shaft. The shoes or bearing pads 10a, 10b are arranged on opposite faces of the disc 44. Thus, in D2 the surfaces supporting the bearing pads face in opposing directions and are in axial alignment (ie. coaxial). Therefore, there is no disclosure or teaching of an orthogonal arrangement of the surfaces upon which are mounted the bearing pads.

Hence, it is submitted that a combination of D1 and D2 would not lead the skilled person to the claimed invention. It is submitted that the skilled person reading D1 and D2 would simply mount the polymer bearing pads on the opposed, axially aligned surfaces taught in D2, rather than arrive at the multidirectional bearing as now claimed.

It is also submitted that there is no motivation for the skilled person to modify the coaxial arrangement of the surfaces in D2 to orthogonal surfaces because there is no teaching or suggestion to do so in either D1 or D2, especially as D2 is solely concerned with axial loads (albeit in opposite directions) along the single, same axis.

By contrast, the multidirectional fluid bearing of claim 22 is concerned with supporting loads from orthogonal directions, particularly the radial and axial loads of a journal shaft connected to the mill body.

Thus, it is submitted that D1 and D2 would teach away from the claimed invention. Therefore, it is submitted that claims 22 to 32 involve an inventive step over the cited prior art.

Box VIII – certain observations

It is submitted that the cancellation of claims 35, 36, 45 and 48 have rendered the objections at items 14.3, 14.4, 14.6 and 14.8 moot.

In relation to items 14.1 and 14.2, it is submitted that the redefinition of claim 1 as a bearing assembly comprising, *inter alia*, a polymer bearing pad and base has resolved the objections against claims 6, 15 and 16 (now claims 11, 16 and 8, respectively).

Similarly, it is submitted that the amendments to claim 40 (now claim 23) have overcome the objection at item 14.5 by correcting the references to "first outer surface", "second outer surface" and "said polymer bearing pad" to "first surface", "second surface" and "said second polymer bearing pad", respectively.

In reply to item 14.7, claim 46 (now claim 26) has clarified that there is a plurality of at least one of the first and second polymer bearing pads. Accordingly, it is submitted that this objection has now been overcome.

Thus, in conclusion, it is submitted that all of the observations made in Box VIII have now been resolved.

Closing comments

As the Examiner's objections have now been overcome, the Applicant requests a clear and favourable International Preliminary Report on Patentability.

Yours respectfully
Shelston IP



Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

Europäisches Patentamt
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European Patent Office
80298 MUNICH
GERMANY

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SHELSTON IP
Shelston IP
Level 21, 60 Margaret Street
Sydney, New South Wales 2000
AUSTRALIE

Date
07.11.14

Reference	Application No./Patent No.
	13745198.5 - 1751 PCT/IB2013055305
Applicant/Proprietor	
Outotec (Finland) Oy	

Entry into the European phase before the European Patent Office

The following information describes the procedural steps required for entry into the European phase before the European Patent Office (EPO). You are advised to read it carefully because failure to take the necessary action in due time can lead to a loss of rights.

1. The above mentioned international patent application has been given the **European application No. 13745198.5**.

2. Applicants **without a residence or their principal place of business** in an EPC Contracting State may themselves initiate European processing of their international applications, provided they do so before expiry of the 31st month from the priority date.

   During the European phase before the EPO as designated or elected Office, however, such applicants **must** be represented by a professional representative (Art. 133(2) and Art. 134(1) and (8) EPC).

   Where, at the expiry of the time period laid down in Rule 163(5) EPC, the requirements of Article 133(2) EPC have not been complied with, the European patent application will be **refused**, pursuant to Rule 163(6) EPC.

   Please note that a professional representative authorised to act before the EPO and who acted for the applicant during the international phase does not automatically become the representative for the European phase. Applicants are therefore strongly advised to appoint in good time any representative they wish to initiate the European phase for them; otherwise the EPO has to send all communications directly to the applicant.

3. Applicants **with a residence or their principal place of business** in an EPC Contracting State are not obliged to appoint for the European phase a professional representative authorised to act before the EPO. However, in view of the complexity of the procedure it is recommended that they do so.

4. Applicants and professional representatives are also strongly advised to initiate the European phase using **EPO Form 1200**. It is available free of charge from the EPO or via the EPO website at **www.epo.org**. Similarly, it can be or generated with the Online Filing software, obtainable free of charge from the EPO (**www.epoline.org**) The use of the form is not compulsory.

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5. Applicants wishing to use an address for correspondence which is different from the address of their seat or residence are advised to indicate this address in Box 1 of EPO Form 1200. When acting as designated or elected Office, the EPO will accept an address for correspondence only if no professional representative must be or is appointed (Art. 133 and 134 EPC). This address must be the applicant's own address and must be located in an EPC Contracting State. Any address for correspondence accepted for the procedure in the international phase which does not fulfil those conditions will not be accepted in the procedure before the EPO in the European phase.

6. Where the EPO acts as designated or elected Office (Art. 22(1) and (3) and 39(1) PCT), to enter the European phase before the EPO, the **following acts** must be performed by the applicant within **31 months** from the date of filing of the international application or (where applicable) the earliest priority date:

   a) Supply a translation of the international application into an EPO official language, if the International Bureau did not publish the application in such language (Art. 22(1) PCT and R. 159(1)(a) EPC);

   b) Specify the application documents, as originally filed or as amended, on which the European grant procedure is to be based (R. 159(1)(b) EPC);

   c) Pay the filing fee and, where applicable, the additional fee for a European patent application comprising more than 35 pages (R. 159(1)(c) EPC, Art. 2, items 1, 1a Rules relating to Fees);

   d) Pay the search fee where a supplementary European search report has to be drawn up (R. 159(1)(e) EPC);

   e) Pay the designation fee if the time limit laid down in Rule 39(1) EPC (i.e. six months after publication of the international search report) has expired before the 31-month period pursuant to Rule 159(1) EPC (R. 159(1)(d) EPC);

   f) File the written request for examination and pay the examination fee if the time limit laid down in Rule 70(1) EPC has expired before the 31-month period pursuant to Rule 159(1) EPC (R. 159(1)(f) EPC);

   g) Pay the renewal fee in respect of the third year, if the fee has fallen due (see Rule 51(1) EPC) before expiry of the 31-month period pursuant to Rule 159(1) EPC (R. 159(1)(g) EPC);

   h) File, where applicable, the certificate of exhibition referred to in Article 55(2) and Rule 25 EPC (R. 159(1)(h) EPC);

   i) Pay the claims fees for the sixteenth and each subsequent claim when the application documents on which the European grant procedure is to be based comprise more than fifteen claims (R. 162(1) EPC). For applications entering the European phase on or after 1 April 2009, a higher amount is payable for the 51st and each subsequent claim (Decision of the Administrative Council of 14 December 2007 amending the Rules relating to Fees, OJ EPO 2008, 10).

   If either the translation of the international application or the request for examination is not filed in time, or if the filing fee, the additional fee, the search fee, the designation fee or the examination fee is not paid in due time, the application shall be deemed to be withdrawn (R. 160(1) EPC).

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7. Payment of fees

An up-to-date guidance for the payment of fees, expenses and prices and a list of the euro accounts of the European Patent Organisation are published in each issue of the Official Journal of the EPO. The guidance includes inter alia a reference to the latest version of the Schedule of fees and expenses where the amounts of fees are set out.

The Schedule of fees and expenses, published as a Supplementary publication to the Official Journal of the EPO, is also available on the EPO website (**www.epo.org**) and can be found under **www.epo.org/schedule-of-fees**, which allows the viewing, downloading and searching for individual fee amounts, both current and previous.

Applicants should always check the fee amounts applying at the time of payment.

Payments can be validly made by any person. Permissible methods of payment are laid down in Article 5 Rules relating to Fees. Please note that payment cannot be made by cheque sent to the EPO.

For information on the calculation of the additional fee for applications comprising more than 35 pages, see Notice from the European Patent Office dated 26 January 2009 concerning the 2009 fee structure (OJ EPO 2009, 118), Notice supplementing the notice from the European Patent Office dated 26 January 2009 concerning the 2009 fee structure (OJ EPO 2009, 338) and Guidelines for Examination in the EPO, April 2010, A-III, 13.2.

For an overview of search and examination fees, see Notice from the European Patent Office dated 10 February 2014 (OJ EPO 2014, A31). Fee information is also published on the EPO website under **www.epo.org/fees.**

8. Restoration of priority right

Where the international application contains a priority claim to an earlier application and it has been filed within two months from the expiration of the 12-month priority period, a request for restoration before the EPO as designated Office (R. 49*ter*.2 PCT) applies under the following circumstances:

a) No request for restoration filed before the receiving Office (RO) during the international phase (R. 26*bis*.3 PCT)
b) Negative decision by the RO irrespective of the criterion applied (due care/ unintentionality)
c) Positive decision by the RO based on the unintentionality criterion.

For a request to be admissible, it must be filed and the requisite fee must be paid (R. 49*ter*.2(b)(iii) and R. 49*ter*.2(d) PCT) within one month from the applicable time limit under Article 22 PCT for entering the regional phase (R. 49*ter*.2(b)(i) PCT). The request for restoration also needs to state the reasons for the failure to file the international application within the priority period (Rule 49*ter*.2(b)(ii) PCT).

9. If the applicant had appointed a representative during the application's international phase, the present Form will be sent to the representative, asking him to inform the applicant accordingly.
All subsequent communications will be sent to the applicant, or - if the EPO is informed of his appointment in time - to the applicant's European representative.

10. For more details about time limits and procedural acts before the EPO as designated or elected Office, see the EPO brochure "How to get an European patent", Guide for applicants - Part 2, PCT procedure before the EPO - "Euro-PCT" (EPO PCT Guide). This brochure, the list of professional representatives before the EPO, Form 1200 and details of the latest fees are available on the Internet under **http://www.epo.org**.

Exhibit 1027
FLS v. Metso - IPR2025-00985

11. **Programme for accelerated prosecution of European patent applications - "PACE"**

Applicants wishing to accelerate proceedings before the EPO as designated or elected Office may request accelerated search and/or examination under the PACE programme (Notice from the European Patent Office dated 4 May 2010 concerning the programme for accelerated prosecution of European patent applications - "PACE", OJ EPO 2010, 352). To be as effective as possible, this should preferably be requested immediately on entry into the European phase.

Receiving Section



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16 October 2014 (16.10.2014)

Applicant's or agent's file reference
74861WOP00

IMPORTANT NOTIFICATION

International application No.
PCT/IB2013/055305

International filing date *(day/month/year)*
28 June 2013 (28.06.2013)

1. The following indications appeared on record concerning:

☒ the applicant ☐ the inventor ☐ the agent ☐ the common representative

Name and Address
OUTOTEC (FINLAND) OY
Puolikkotie 10
FI-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address
OUTOTEC (FINLAND) OY
Rauhalanpuisto 9
FI-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.:
Facsimile No.:
E-mail address:
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☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 910 06 10

Authorized officer
Bellour Veronique
e-mail ro.ib@wipo.int
Telephone No. +4122 338 8602

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FI-02230 Espoo
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E-mail address:

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☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address
OUTOTEC (FINLAND) OY
Rauhalanpuisto 9
FI-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.:
Facsimile No.:
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The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 910 06 10

Authorized officer
Bellour Veronique
e-mail ro.ib@wipo.int
Telephone No. +4122 338 8602

Exhibit 1027
17M2GCLA4DNAN2K0
FLS v. Metso - IPR2025-00985

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ABN 58 855 816 942

International Preliminary Examining Authority
European Patent Office
P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk – Pays Bas
THE NETHERLANDS

22 April 2014

Our Ref: 74861WOP00

Attention: Christophe Martin

Contact: Andrew Lowe

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

STATEMENT OF AMENDMENTS – ARTICLE 34

Complete Specification

Description

1. Cancel pages 3 to 28 now on file and replace with new pages 3 to 28.

Claims

2. Cancel pages 29 to 36 now on file and replace with new pages 29 to 33.

DATED this 22nd day of April 2014
OUTOTEC OYJ

Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com www.ShelstonIP.com fax +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

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Facsimile No. +31 70 340 3016
CONFIRMATION BY MAIL

ABN 58 855 816 942

International Preliminary Examining Authority
European Patent Office
P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk – Pays Bas
THE NETHERLANDS

CONFIRMATION

Attention: Christophe Martin

22 April 2014

Our Ref: 74861WOP00

Contact: Andrew Lowe

Dear Sirs

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

We refer to the First Written Opinion of the International Preliminary Examining Authority mailed on 30 October 2013 in respect of the above application.

Article 34 amendments

Pursuant to Article 34, the Applicant requires the International Preliminary Examining Authority to take into account the amendments on the enclosed replacement pages as set forth on the attached Statement of Amendments.

The proposed amendments have cancelled claims 11 to 13, 25, 26 to 38, 45, 48 and 51.

Claims 1 to 10 and 14 to 24 have been reworded and are now directed to a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising a base and the polymer bearing pad of original claim 1 mounted to the base. Support for this amendment is found at page 14, paragraph [0093] of the specification as filed

Claim 1 has also been amended claim to define that the base is mounted to the frame so that the fluid bearings self adjust to changes in the angular position of the journal during operation of the grinding mill body. Support for this amendment is found at page 14, paragraph [0094] of the specification as filed.

A new claim 2 has been added, which also defines a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising the polymer bearing pad of original claim 1 mounted to the base. New claim 2, however, defines that the base is fixedly mounted to the frame. Support for this amendment is found at page 24, paragraph [0113] of the specification as filed.

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@SheltonIP.com **www.SheltonIP.com** **fax** +61 2 9241 4666
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Claim 39 has been amended to include the subject matter of original claim 51, and has now been renumbered as claim 22. Support for this amendment is found at page 11, paragraph [0061] and page 25, paragraph [0114] of the specification as filed

As a result, claims 2 to 10, 14 to 24, 40 to 44, 46, 47, 49, 50 and 52 have been renumbered as new claims 3 to 21 and 23 to 32.

Some clarifying amendments have also been made to claims 20, 22, 40, 46 and 47, now new claims 17, 19, 23, 26 and 27.

It is submitted that the proposed amendments are supported by the specification as filed and favourable consideration is requested.

Response to written opinion

In response to the Written Opinion, the Applicant submits that invention as now claimed is novel and involves an inventive step over the cited prior art referred to in Box V, and the claims no longer have the clarity problems noted in Box VIII.

Box V - novelty and inventive step

Of the claims that are now pending in the international application, the following documents have been cited by the Examiner as being relevant to novelty and inventive step:

D1: DE 10 2007 039 364 (Metso Paper)

D2: WO 90/12216 (Vickers plc)

D3: JP 2006-9968A (Oiles Industry Co Ltd)

It is submitted that claims 1 to 21 are novel and involve an inventive step over the cited prior art. Independent claims 1 and 2 now define a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising a polymer bearing pad mounted to a base.

Claim 1 further defines that the base is mounted to the frame so that the fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body. It is submitted that none of the cited prior art, especially D1, discloses or teaches this claimed feature.

D1 discloses a bearing pad 30 for a flexible sheet 10 forming a nip with a roller 2 in a paper or cardboard making machine. The bearing pad is mounted on a shoe 5, 31 that is supported by a piston 4 movably located in a shaft or axle 3. The axle 3 has a central well 15' that acts as a supply for lubricating fluid to be delivered to recesses 22 in the pad 30. The piston 4 operates to move the bearing pad 30 and shoe 5, 31 in a radial direction into engagement the flexible sheet 10, thus applying a pressure or force to the sheet 10 against the nip roller 2.

As such, it is submitted that any movement of the roller 2 relative to the sheet 10 and bearing pad 30, including its angular position, can only be adjusted for by operating the piston 4 so that the bearing pad 30 re-engages the roller 2 and pinch the flexible sheet 10. Hence, it is submitted that changes in angular position need to be manually corrected by operating the piston 4 – the fluid bearing comprising the bearing pad 30 and the shoe 5, 31 cannot correct for changes in the angular position of the roller 2 on its own. As a consequence, the fluid bearing does not stabilise the sheet 10 or roller 2 in an axial position, but rather allows the sheet 10 to "float" on the axle part 3 and applies a force to the internal surface of the sheet 10 so that a pressure is maintained against the roller 2.

By way of contrast, the bearing assembly of the claimed invention has the base of the fluid bearing mounted to the frame so that the fluid bearing self-adjusts to changes in the angular position of the journal shaft 4; ie. the fluid bearing is self-aligning on its own in response to movements of the journal shaft 4. Thus, the bearing assembly of the claimed invention acts to positively locate the supported journal shaft 4 in a fixed position such that mating precision components can be correctly located. As a consequence, the invention of claim 1 has the technical advantage of avoiding the need for manual

adjustment in response to changes in the angular position of the journal or a mechanical device such as a piston to perform that adjustment.

It is submitted that the skilled person would not be able to modify the arrangement of D1 to arrive at the technical solution defined in amended claim 1, since this would involve substantial redesign to take into account the removal of the piston arrangement disclosed in D1. Furthermore, it is submitted that there is no teaching in D1 that would motivate the skilled person to consider or attempt such a modification of such a central element of the designed bearing arrangement as taught in that document. Thus, it is submitted that claim 1 has an inventive step over D1.

Likewise, claim 2 defines that the base is fixedly mounted to the frame, whereas in D1 the shoe 5, 31 is able to move in a radial direction relative to the shaft 3 via the piston 4. Therefore, it is submitted that D1 fails to teach the technical solution proposed by claim 2, and in fact teaches the opposite arrangement – a moveable mounting of the shoe 5, 31 to the "base", being the shaft 3. Thus, for the same reasons outlined above, it is submitted that claim 2 also has an inventive step over D1.

Since the teaching in D3 relates only to particular fastening arrangements for mounting the bearing pad to the base, it is submitted that a combination of D1 with D3 would also fail to render the claimed invention obvious for the same reasons stated above.

Thus, it is submitted that claims 1 to 21 involve an inventive step over the cited prior art.

In relation to claims 22 to 32, it is also submitted that these claims involve an inventive step over D1 and D2, the Examiner having previously conceded that original claim 39 was novel.

Claim 22 now includes the subject matter of original claims 39 and 51. It is submitted that a combination of D1 and D2 fails to disclose or teach the claimed multidirectional fluid bearing having polymer bearing pads mounted to orthogonal surfaces of a base.

D1 only discloses a polymer bearing pad that supports a load in a single radial direction. Therefore, there is no disclosure or teaching of using the polymer bearing pad for supporting loads in multiple directions.

D2 describes a thrust bearing or shoe and particular reference is made to Figure 4 which shows multiple bearings 10a, 10b arranged on a thrust ring or disc that rotates with a shaft. The shoes or bearing pads 10a, 10b are arranged on opposite faces of the disc 44. Thus, in D2 the surfaces supporting the bearing pads face in opposing directions and are in axial alignment (ie. coaxial). Therefore, there is no disclosure or teaching of an orthogonal arrangement of the surfaces upon which are mounted the bearing pads.

Hence, it is submitted that a combination of D1 and D2 would not lead the skilled person to the claimed invention. It is submitted that the skilled person reading D1 and D2 would simply mount the polymer bearing pads on the opposed, axially aligned surfaces taught in D2, rather than arrive at the multidirectional bearing as now claimed.

It is also submitted that there is no motivation for the skilled person to modify the coaxial arrangement of the surfaces in D2 to orthogonal surfaces because there is no teaching or suggestion to do so in either D1 or D2, especially as D2 is solely concerned with axial loads (albeit in opposite directions) along the single, same axis.

By contrast, the multidirectional fluid bearing of claim 22 is concerned with supporting loads from orthogonal directions, particularly the radial and axial loads of a journal shaft connected to the mill body.

Thus, it is submitted that D1 and D2 would teach away from the claimed invention. Therefore, it is submitted that claims 22 to 32 involve an inventive step over the cited prior art.

Box VIII – certain observations

It is submitted that the cancellation of claims 35, 36, 45 and 48 have rendered the objections at items 14.3, 14.4, 14.6 and 14.8 moot.

In relation to items 14.1 and 14.2, it is submitted that the redefinition of claim 1 as a bearing assembly comprising, *inter alia*, a polymer bearing pad and base has resolved the objections against claims 6, 15 and 16 (now claims 11, 16 and 8, respectively).

Similarly, it is submitted that the amendments to claim 40 (now claim 23) have overcome the objection at item 14.5 by correcting the references to "first outer surface", "second outer surface" and "said polymer bearing pad" to "first surface", "second surface" and "said second polymer bearing pad", respectively.

In reply to item 14.7, claim 46 (now claim 26) has clarified that there is a plurality of at least one of the first and second polymer bearing pads. Accordingly, it is submitted that this objection has now been overcome.

Thus, in conclusion, it is submitted that all of the observations made in Box VIII have now been resolved.

Closing comments

As the Examiner's objections have now been overcome, the Applicant requests a clear and favourable International Preliminary Report on Patentability.

Yours respectfully
Shelston IP



Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

[0011] A second aspect of the present invention provides a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

[0012] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

[0013] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0014] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[0015] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0016] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0017] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0018] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0019] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0020] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0021] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0022] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0023] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] There is disclosed a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] Also disclosed is a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for connecting said

polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] Also further disclosed is a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to a third aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably,, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this

embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23

also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a "hovercraft" type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there

is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both

outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the "lead-in" chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the "lead-in" chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the "lead-out" chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased "off the shelf" in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and

kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped

recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from

the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing in a bearing assembly, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the

invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Claims

1. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

2. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

3. The bearing assembly of claim 1 or 2, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad.

4. The bearing assembly of claim 3, wherein said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base.

5. The bearing assembly of claim 4, wherein said flange is located at an outer edge of said base.

6. The bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base.

7. The bearing assembly of claim 6, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess.

8. The bearing assembly of claim 6 or 7, wherein said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

9. The bearing assembly of claim 7, further comprising a plug for engagement with said head portion and said at least one recess.

10. The bearing assembly of claim 6, further comprising a locking element for retaining said at least one fastener within said at least one recess.

11. The bearing assembly of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

12. The bearing assembly of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

13. The bearing assembly of claim 12, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

14. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

15. The bearing assembly of any one of claims 1 to 13, wherein said outer surface is substantially planar.

16. The bearing assembly of any one of the preceding claims, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

17. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

18. The bearing assembly of claim 17, wherein each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

19. The bearing assembly of any one of claims 1 to 16, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads, a first of said polymer bearing pads being mountable to said first surface and a second of said polymer bearing pads being mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

20. The bearing assembly of claim 19, wherein said first surface is orthogonal to said second surface.

21. The fluid bearing of claim 19 or 20, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic

bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

22. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

23. The multidirectional fluid bearing of claim 22, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

24. The multidirectional fluid bearing of claim 22 or 23, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

25. The multidirectional fluid bearing of claim 24, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

26. The multidirectional fluid bearing of claim 22, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

27. The multidirectional fluid bearing of claim 26, wherein each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

28. The multidirectional fluid bearing of any one of claims 22 to 27, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

29. The multidirectional fluid bearing of claim 28, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

30. The multidirectional fluid bearing of any one of claims 22 to 29, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

31. The multidirectional fluid bearing of claim 30, wherein said flange is located at an outer edge of said base.

32. The multidirectional fluid bearing of any one of claims 22 to 31, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 74861WOP00	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/IB2013/055305	International filing date *(day/month/year)* 28.06.2013	Priority date *(day/month/year)* 28.06.2012

International Patent Classification (IPC) or national classification and IPC
INV. F16C32/06

Applicant
Outotec Oyj

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 8 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *(sent to the applicant and to the International Bureau)* a total of 36 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and/or sheets containing rectifications authorized by this Authority, unless those sheets were superseded or cancelled, and any accompanying letters (see Rules 46.5, 66.8, 70.16, 91.2, and Section 607 of the Administrative Instructions).
      ☐ sheets containing rectifications, where the decision was made by this Authority not to take them into account because they were not authorized by or notified to this Authority at the time when this Authority began to draw up this report, and any accompanying letters (Rules 66.4bis, 70.2(e), 70.16 and 91.2).
      ☐ superseded sheets and any accompanying letters, where this Authority either considers that the superseding sheets contain an amendment that goes beyond the disclosure in the international application as filed, or the superseding sheets were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in item 4 of Box No. I and the Supplemental Box (see Rule 70.16(b)).
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see paragraph 3*bis* of Annex C of the Administrative Instructions).

4. This report contains indications relating to the following items:
   - ☒ Box No. I Basis of the report
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☒ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☒ Box No. VIII Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22.04.2014	08.10.2014

Name and mailing address of the international preliminary examining authority:

European Patent Office P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk - Pays Bas
Tel. +31 70 340 - 2040
Fax: +31 70 340 - 3016

Authorized officer

Martin, Christophe

Telephone No. +31 70 340-4492

Exhibit 1027
FLS v. Metso - IPR2025-00985

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 The attention of the applicant is drawn to the time limit for reply specified on the cover sheet of the present written opinion.

2 Reference is made to the following documents:

D1 : DE 10 2007 039 364 A1

D2 : WO 90/12216 A

D3 : JP 2006-9968 A

D4 : WO 2012/145217 A1

3 Furthermore, due to the extensive amendments filed by the applicant in reply to the international search report, a further search has been considered necessary, especially in the field of grinding mills. This search has revealed the following documents, a copy of which is attached to the present written opinion.

D5 : GB 1 508 384

D6 : US 4,911,554

4 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 1 does not involve an inventive step in the sense of Article 33(3) PCT.

4.1 D5 discloses "a bearing assembly for supporting a journal (12) of a grinding mill body (see page 3, lines 20-27), comprising a frame (17) and a plurality of fluid bearings, said fluid bearings each comprising a ~~*polymer*~~ bearing pad (16) mounted to a base (10), said ~~*polymer*~~ bearing pad (16) comprising an outer surface, at least one recess (18) for receiving lubricating fluid from at least one passage (20) of said base (10) and distributing said lubricating fluid to said outer surface (implicit feature) and mounting means (11, 13) for securely mounting said ~~*polymer*~~ bearing pad (16) to said base (10), said base (10) also comprising at least one lubricating fluid supply port (see figure 2) in fluid communication with said at least one passage (20), wherein said base (10) is mounted to said frame (17) so that said fluid bearings self adjust to changes in the angular position of the journal (12) during operation of said grinding mill body (see page 2, lines 45-54)".

4.1.1 The subject-matter of claim 1 differs therefrom in that the bearing pad is explicitly made of "polymer".

4.1.2 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

4.2 The subject-matter of claim 1 therefore lacks inventive step on the basis of D5 and the general knowledge of the skilled person.

5 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 2 does not involve an inventive step in the sense of Article 33(3) PCT.

5.1 D6 discloses "a bearing assembly for supporting a journal of a grinding mill body (see column 2, lines 28-37), comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a ~~*polymer*~~ bearing pad (18, 18a) mounted to a base (17, 17a), said ~~*polymer*~~ bearing pad (18, 18a) comprising an outer surface, at least one recess for receiving lubricating fluid (implicit feature) from at least one passage of said base (31) (see column 3, line 57-column 4, line 2) and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad (18, 18a) to said base (17, 17a) (implicit feature), said base (17, 17a)also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage (see 31), wherein said base (18, 18a) is fixedly mounted to said frame (see column 3, lines 28-38)".

5.1.1 The subject-matter of claim 2 differs therefrom in that the bearing pad is explicitly made of "polymer".

5.1.2 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

5.2 The subject-matter of claim 2 therefore lacks inventive step on the basis of D6 and the general knowledge of the skilled person.

6 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 22 does not involve an inventive step in the sense of Article 33(3) PCT.

6.1 D5 discloses "a multidirectional fluid bearing for a journal (12), comprising:

a base (10) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports (see figure 2) and a plurality of passages (20) in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first ~~*polymer*~~ bearing pad (16) mountable to said first surface, said ~~*polymer*~~ bearing pad (16) having a first outer surface and at least one recess (18) for receiving lubricating fluid from at least one of said plurality of passages (10) and distributing said lubricating fluid to said first outer surface, and

a ~~*second*~~ polymer bearing pad (16) mountable to said second surface, said second ~~*polymer*~~ bearing pad (16) having a second outer surface and at least one recess (19) for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (see figures 3 and 5)".

6.2 The subject-matter of claim 22 differs therefrom in that the bearing pad is explicitly made of "polymer".

6.2.1 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

6.3 The subject-matter of claim 22 therefore lacks inventive step on the basis of D5 and the general knowledge of the skilled person.

6.4 The subject-matter of claim 22 also lacks an inventive step in view of D6 (see in particular the orthogonally oriented pads (10 and 18a) in figure 2 of D6). Indeed, the subject-matter of claim 22 differs therefrom in that the bearing pad is explicitly made of "polymer". As argued before, such a difference is considered as being a mere constructional option which is obvious to the skilled person.

7 Dependent claims 3-21 and 23-32 do not contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step, the reasons being as follows:

7.1 The features of claims 3-5 are known from D1, see e.g. the beveled edge of pad (30) in cooperation with the corresponding undercut notch of shoe (5) in figure 3A.

7.2 The features of claim 6 are known from D1, see figures 4A and 4B.

7.3 The features of claim 7 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028], an automated English translation of which is found here below:

"[0027] Moreover, according to the combination structure 6, after inserting ring 9 in the ring mounting groove¦channel 7 in the decomposition¦degradation state shown in FIG. 3, it can assemble simply in the state shown in FIG. 1 by inserting the hemisphere part 37 in a concave-part 8, and engaging the end face 45 of the hemisphere part 37 with ring 9.

[0028] In addition, as ring 9, an elastic O ring is preferable, However If it is the objective of mere connection, although it is a rigid material -- a diameter-expansion -- free and the diameter reduction -- free E ring or a C-ring may be sufficient. Even if it uses such E ring or a C-ring, it can connect, as that the gap adjustment member 5 may not be dropped off in the static-pressure gas bearing pad 3, and a cost reduction can be intended".

7.4 The features of claim 8 are known from D1, see Figure 4A and page 5/8, left column, lines 5-7 and 23-26.

7.5 The features of claim 9 are known or derivable from D1, see the schematically represented sleeve like plug under the head of elements "17" in Figure 4B.

7.6 The features of claim 10 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028].

7.7 The features of claim 11 are known from D1, see figure 4A and the material used for the pad.

7.8 The features of claims 12 and 13 are known from D5, see column 2, lines 83-column 3, line 8; figures 3, 6 and 7.

7.9 The features of claim 14 are known from D5, see figure 2.

7.10 The features of claim 15 are implicitly known from D6, see the pads (18, 18a) in figure 2.

7.11 The features of claim 16 are known from D5, see figure 2.

7.12 The features of claim 17 are obvious in view of a combination of the teachings of D6 to the arrangement shown in figure 5 of D2.

7.13 In claim 18 a slight constructional change in the bearing of claim 17 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

7.14 The features of claims 19-21 are known from D5 and/or D6, see the reasoning in paragraphs 5.1 to 5.4 above.

7.15 The features of claims 23-26, have already been discussed w.r.t. claim 11 (corresponding to claim 23), claim 12 (corresponding to claim 24), claim 13 (corresponding to claim 25), claim 17 (corresponding to claim 26).

7.16 In claim 27 a slight constructional change in the bearing of claim 26 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

7.17 The features of claim 28 are obtained from a combination of D1 (opening for receiving a fastener) and D3 (locking tab).

7.18 The features of claims 29-32 have already been discussed w.r.t. claim 8 (corresponding to claim 29), claim 4 (corresponding to claim 30), claim 5 (corresponding to claim 31), 21 (corresponding to claim 32).

Re Item VI

Certain documents cited

Application No Patent No	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date *(valid claim)* *(day/month/year)*
WO 2012/145217 A1	26.10.2012	12.04.2012	19.04.2011

Re Item VIII

Certain observations on the international application

8 Since originally filed claim 18, on which present claim 9 is based, depends on originally filed claim 16, on which present claim 8 is based, present claim 9 should depend on present claim 8 and not on present claim 7.

Box No. I Basis of the report

1. With regard to the **language**, this report is based on

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3(a) and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4(a))
   - ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a) and (b))

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1, 2	as originally filed	
3-28	filed with the letter of	22-04-2014

Claims, Numbers

1-32	filed with the letter of	22-04-2014

Drawings, Sheets

1/13-13/13	as originally filed	

☐ a sequence listing - see Supplemental Box Relating to Sequence Listing.

3. ☒ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☒ the claims, Nos. 33-52
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (c-bis)):
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:

5. ☐ This report has been established:
   - ☐ taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rules 66.1(d-bis) and 70.2(e)).
   - ☐ without taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91(Rules 66.4bis and 70.2(e)).

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6. ☒ With regard to top-up searches (Rules 66.1 ter and 70.2(f)):
   - ☒ A top-up search was carried out by this Authority on 29.09.2014 (all discovered documents are listed in the Supplemental Box Relating to Top-up Search).
   - ☐ No top-up search was carried out by this Authority.

7. ☐ Supplementary international search report(s) from Authority(ies) has/have been received and taken into account in establishing this report (Rule 45bis.8(b) and (c)).

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-32
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-32
Industrial applicability (IA)	Yes:	Claims	1-32
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Box No. VI Certain documents cited

1. Certain published documents (Rule 70.10)

   and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

The International Bureau of WIPO
34, chemin des Colombettes
CH - 1211 Geneva 20
Switzerland

PCT

NOTIFICATION CONCERNING
DOCUMENTS TRANSMITTED

Date of mailing
(day/month/year) 08.10.2014

International application No: PCT/IB2013/055305

This International Preliminary Examining Authority transmits herewith the following documents:

1. ☐ demand (Rule 61.1(a)).

2. ☒ copy of the international preliminary examination report and its annexes (Rule 71.1).

3. ☐ _____ other documents *(specify)*:

Name and mailing address of the international preliminary examining authority:

European Patent Office P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk - Pays Bas
Tel. +31 70 340 - 2040
Fax: +31 70 340 - 3016

Authorized Officer

Fontana Balparda, E

Tel. +31 70 340-2442

Exhibit 1027
FLS v. Metso - IPR2025-00985

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

SHELSTON IP
60 Margaret Street
Sydney, NSW 2000
AUSTRALIE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	08.10.2014

Applicant's or agent's file reference	**IMPORTANT NOTIFICATION**
74861WOP00	

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB2013/055305	28.06.2013	28.06.2012

Applicant
Outotec Oyj

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary report on patentability and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary report on patentability. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed inventions is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

Name and mailing address of the international preliminary examining authority:

European Patent Office P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk - Pays Bas
Tel. +31 70 340 - 2040
Fax: +31 70 340 - 3016

Authorized Officer

Fontana Balparda, E

Tel. +31 70 340-2442

Exhibit 1027
FLS v. Metso - IPR2025-00985

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

SHELSTON IP
60 Margaret Street
Sydney, NSW 2000
AUSTRALIE

PCT

WRITTEN OPINION OF THE INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

(PCT Rule 66)

Date of mailing *(day/month/year)*	13.08.2014
Applicant's or agent's file reference 74861WOP00	**REPLY DUE** within 1 month(s) from the above date of mailing

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB2013/055305	28.06.2013	28.06.2012

International Patent Classification (IPC) or both national classification and IPC
INV. F16C32/06

Applicant
Outotec Oyj

1. ☒ The written opinion established by the International Searching Authority:
   ☒ is ☐ is not
   considered to be a written opinion of the International Preliminary Examining Authority.

2. This second opinion contains indications relating to the following items:
   - ☒ Box No. I Basis of the opinion
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☒ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☒ Box No. VIII Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

   When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(e).
   How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 55.3 and 66.8.
   Also: For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4*bis*. For an informal communication with the examiner, see Rule 66.6. For an additional opportunity to submit amendments, see Rule 66.4.
   If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary report on patentability (Chapter II of the PCT) must be established according to Rule 69.2 is: 28.10.2014

Name and mailing address of the international preliminary examining authority:	Authorized Officer
European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Fax: +31 70 340 - 3016	Martin, Christophe Telephone No. +31 70 340-4492

Form PCT/IPEA/408 (Cover Sheet) (July 2011)
Exhibit 1027
FLS v. Metso - IPR2025-00985

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 The attention of the applicant is drawn to the time limit for reply specified on the cover sheet of the present written opinion.

2 Reference is made to the following documents:

D1 : DE 10 2007 039 364 A1

D2 : WO 90/12216 A

D3 : JP 2006-9968 A

D4 : WO 2012/145217 A1

3 Furthermore, due to the extensive amendments filed by the applicant in reply to the international search report, a further search has been considered necessary, especially in the field of grinding mills. This search has revealed the following documents, a copy of which is attached to the present written opinion.

D5 : GB 1 508 384

D6 : US 4,911,554

4 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 1 does not involve an inventive step in the sense of Article 33(3) PCT.

4.1 D5 discloses "a bearing assembly for supporting a journal (12) of a grinding mill body (see page 3, lines 20-27), comprising a frame (17) and a plurality of fluid bearings, said fluid bearings each comprising a ~~*polymer*~~ bearing pad (16) mounted to a base (10), said ~~*polymer*~~ bearing pad (16) comprising an outer surface, at least one recess (18) for receiving lubricating fluid from at least one passage (20) of said base (10) and distributing said lubricating fluid to said outer surface (implicit feature) and mounting means (11, 13) for securely mounting said ~~*polymer*~~ bearing pad (16) to said base (10), said base (10) also comprising at least one lubricating fluid supply port (see figure 2) in fluid communication with said at least one passage (20), wherein said base (10) is mounted to said frame (17) so that said fluid bearings self adjust to changes in the angular position of the journal (12) during operation of said grinding mill body (see page 2, lines 45-54)".

4.1.1 The subject-matter of claim 1 differs therefrom in that the bearing pad is explicitly made of "polymer".

4.1.2 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

4.2 The subject-matter of claim 1 therefore lacks inventive step on the basis of D5 and the general knowledge of the skilled person.

5 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 2 does not involve an inventive step in the sense of Article 33(3) PCT.

5.1 D6 discloses "a bearing assembly for supporting a journal of a grinding mill body (see column 2, lines 28-37), comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a ~~*polymer*~~ bearing pad (18, 18a) mounted to a base (17, 17a), said ~~*polymer*~~ bearing pad (18, 18a) comprising an outer surface, at least one recess for receiving lubricating fluid (implicit feature) from at least one passage of said base (31) (see column 3, line 57-column 4, line 2) and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad (18, 18a) to said base (17, 17a) (implicit feature), said base (17, 17a)also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage (see 31), wherein said base (18, 18a) is fixedly mounted to said frame (see column 3, lines 28-38)".

5.1.1 The subject-matter of claim 2 differs therefrom in that the bearing pad is explicitly made of "polymer".

5.1.2 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

5.2 The subject-matter of claim 2 therefore lacks inventive step on the basis of D6 and the general knowledge of the skilled person.

6 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 22 does not involve an inventive step in the sense of Article 33(3) PCT.

6.1 D5 discloses "a multidirectional fluid bearing for a journal (12), comprising:

a base (10) having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports (see figure 2) and a plurality of passages (20) in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first ~~*polymer*~~ bearing pad (16) mountable to said first surface, said ~~*polymer*~~ bearing pad (16) having a first outer surface and at least one recess (18) for receiving lubricating fluid from at least one of said plurality of passages (10) and distributing said lubricating fluid to said first outer surface, and

a ~~*second*~~ polymer bearing pad (16) mountable to said second surface, said second ~~*polymer*~~ bearing pad (16) having a second outer surface and at least one recess (19) for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface (see figures 3 and 5)".

6.2 The subject-matter of claim 22 differs therefrom in that the bearing pad is explicitly made of "polymer".

6.2.1 Such a difference is considered as being a mere constructional option which is obvious to the skilled person.

6.3 The subject-matter of claim 22 therefore lacks inventive step on the basis of D5 and the general knowledge of the skilled person.

6.4 The subject-matter of claim 22 also lacks an inventive step in view of D6 (see in particular the orthogonally oriented pads (10 and 18a) in figure 2 of D6). Indeed, the subject-matter of claim 22 differs therefrom in that the bearing pad is explicitly made of "polymer". As argued before, such a difference is considered as being a mere constructional option which is obvious to the skilled person.

7 Dependent claims 3-21 and 23-32 do not contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step, the reasons being as follows:

7.1 The features of claims 3-5 are known from D1, see e.g. the beveled edge of pad (30) in cooperation with the corresponding undercut notch of shoe (5) in figure 3A.

7.2 The features of claim 6 are known from D1, see figures 4A and 4B.

7.3 The features of claim 7 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028], an automated English translation of which is found here below:

"[0027] Moreover, according to the combination structure 6, after inserting ring 9 in the ring mounting groove¦channel 7 in the decomposition¦degradation state shown in FIG. 3, it can assemble simply in the state shown in FIG. 1 by inserting the hemisphere part 37 in a concave-part 8, and engaging the end face 45 of the hemisphere part 37 with ring 9.

[0028] In addition, as ring 9, an elastic O ring is preferable, However If it is the objective of mere connection, although it is a rigid material -- a diameter-expansion -- free and the diameter reduction -- free E ring or a C-ring may be sufficient. Even if it uses such E ring or a C-ring, it can connect, as that the gap adjustment member 5 may not be dropped off in the static-pressure gas bearing pad 3, and a cost reduction can be intended".

7.4 The features of claim 8 are known from D1, see Figure 4A and page 5/8, left column, lines 5-7 and 23-26.

7.5 The features of claim 9 are known or derivable from D1, see the schematically represented sleeve like plug under the head of elements "17" in Figure 4B.

7.6 The features of claim 10 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028].

7.7 The features of claim 11 are known from D1, see figure 4A and the material used for the pad.

7.8 The features of claims 12 and 13 are known from D5, see column 2, lines 83-column 3, line 8; figures 3, 6 and 7.

7.9 The features of claim 14 are known from D5, see figure 2.

7.10 The features of claim 15 are implicitly known from D6, see the pads (18, 18a) in figure 2.

7.11 The features of claim 16 are known from D5, see figure 2.

7.12 The features of claim 17 are obvious in view of a combination of the teachings of D6 to the arrangement shown in figure 5 of D2.

7.13 In claim 18 a slight constructional change in the bearing of claim 17 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

7.14 The features of claims 19-21 are known from D5 and/or D6, see the reasoning in paragraphs 5.1 to 5.4 above.

7.15 The features of claims 23-26, have already been discussed w.r.t. claim 11 (corresponding to claim 23), claim 12 (corresponding to claim 24), claim 13 (corresponding to claim 25), claim 17 (corresponding to claim 26).

7.16 In claim 27 a slight constructional change in the bearing of claim 26 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

7.17 The features of claim 28 are obtained from a combination of D1 (opening for receiving a fastener) and D3 (locking tab).

7.18 The features of claims 29-32 have already been discussed w.r.t. claim 8 (corresponding to claim 29), claim 4 (corresponding to claim 30), claim 5 (corresponding to claim 31), 21 (corresponding to claim 32).

Re Item VI

Certain documents cited

Application No Patent No	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date *(valid claim)* *(day/month/year)*
WO 2012/145217 A1	26.10.2012	12.04.2012	19.04.2011

Re Item VIII

Certain observations on the international application

8 Since originally filed claim 18, on which present claim 9 is based, depends on originally filed claim 16, on which present claim 8 is based, present claim 9 should depend on present claim 8 and not on present claim 7.

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into ,
   which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3(a) and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4(a))
   - ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a) and (b))

2. With regard to the elements of the international application, this opinion has been established on the basis of *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed")*:

Description, Pages

1, 2	as originally filed	
3-28	filed with the letter of	22-04-2014

Claims, Numbers

1-32	filed with the letter of	22-04-2014

Drawings, Sheets

1/13-13/13	as originally filed

   ☐ a sequence listing - see Supplemental Box Relating to Sequence Listing.

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:

4. ☐ This opinion has been established as if (some of) the amendments listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (c-bis)):
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:

5. ☐ This opinion has been established:
   - ☐ taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 66.1(d-bis)).
   - ☐ without taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 66.4bis).

Exhibit 1027
FLS v. Metso - IPR2025-00985

6. ☐ Supplementary international search report(s) from Authority(ies) have been received and taken into account in drawing up this opinion (Rule 45bis.8(b) and (c)).

Box No. V Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	No:	Claims	
Inventive step (IS)	No:	Claims	1-32
Industrial applicability (IA)	No:	Claims	

2. Citations and explanations:

see separate sheet

Box No. VI Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Exhibit 1027
FLS v. Metso - IPR2025-00985

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

SHELSTON IP
60 Margaret Street
Sydney, NSW 2000
AUSTRALIE

PCT

WRITTEN OPINION OF THE INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

(PCT Rule 66)

Date of mailing *(day/month/year)*	13.08.2014
Applicant's or agent's file reference: 74861WOP00	REPLY DUE within 1 month(s) from the above date of mailing
International application No.: PCT/IB2013/055305	International filing date *(day/month/year)*: 28.06.2013
Priority date *(day/month/year)*: 28.06.2012	
International Patent Classification (IPC) or both national classification and IPC: INV. F16C32/06	
Applicant: Outotec Oyj	

1. ☒ The written opinion established by the International Searching Authority:
   ☒ is ☐ is not
   considered to be a written opinion of the International Preliminary Examining Authority.

2. This second opinion contains indications relating to the following items:
   - ☒ Box No. I Basis of the opinion
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☒ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☒ Box No. VIII Certain observations on the international application

3. The applicant is hereby invited to reply to this opinion.

   When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(e).
   How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 55.3 and 66.8.
   Also: For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4*bis*. For an informal communication with the examiner, see Rule 66.6. For an additional opportunity to submit amendments, see Rule 66.4.

   If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary report on patentability (Chapter II of the PCT) must be established according to Rule 69.2 is: 28.10.2014

Name and mailing address of the international preliminary examining authority:	Authorized Officer
European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Fax: +31 70 340 - 3016	Martin, Christophe Telephone No. +31 70 340-4492

Form PCT/IPEA/408 (Cover sheet) (July 2011)

Duration: 12.08.2014 06:32:26 - 12.08.2014 06:33:18. This page 2 of 2 was completed at 12.08.2014 06:33:18.
Received at the EPO on Aug 12, 2014 06:33:18. Page 2 of 2
FLS v. Metso - IPR2025-00985

Shelston IP

AUSTRALIAN IP FIRM OF THE YEAR 2013

URGENT

Confidential Facsimile Transmission

To	**International Preliminary Examining Authority** **European Patent Office** **P.B. 5818 Patentlaan 2** **NL-28280HV Rijswijk** **The Netherlands**
Attention	**Christophe Martin**
Facsimile No.	**+31 70 340 4966,** **+31 70 340 3016**
From	**Andrew Lowe**
Date Sent	**12 August 2014**
Our Reference	**74861WOP00**
Pages sent, *1*+ 1	

Dear Sirs

Re: PCT Patent Application No. PCT/IB2013/055305
to us today. Unfortunately, only the first page of the fax was received (See attached copy).

We therefore request that you please re-transmit the Written Opinion to us as a matter of urgency in view of the one (1) month deadline for replying to the Written Opinion.

We thank you for prompt attention to this matter and look forward to hearing from you shortly.

Yours respectfully
Shelston IP

Andrew Lowe
Registered Patent Attorney
Email: AndrewLowe@ShelstonIP.com

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ EP

PCT

EPO - Munich 81

20. Mai 2014

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:

The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty.

For International Preliminary Examining Authority use only

IPEA/EP Identification of IPEA	22-04-2014 Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION		Applicant's or agent's file reference 74861WOP00
International application No. PCT/IB2013/055305	International filing date *(day/month/year)* 28 June 2013 (28.06.2013)	(Earliest) Priority date *(day/month/year)* 28 June 2012 (28.06.2012)
Title of invention Improvements in fluid bearings		

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*	Telephone No. +358 205 29211
Outotec Oyj Puolikkotie 10 02230 Espoo Finland	Facsimile No. +358 205 292988
	Applicant's registration No. with the Office

E-mail authorization: Marking one of the check-boxes below authorizes the International Bureau and the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send notifications issued in respect of this international application if those offices are willing to do so.

☐ as advance copies followed by paper notifications; or ☐ exclusively in electronic form (no paper notifications will be sent).

E-mail address: _____

State *(that is, country)* of nationality: FI	State *(that is, country)* of residence: FI

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BRAITHWAITE, Daniel
5/17 Hertha Road
Innaloo, Western Australia 6018
Australia

State *(that is, country)* of nationality: AU	State *(that is, country)* of residence: AU

☒ Further applicants are indicated on a continuation sheet.

International application No.
PCT/IB2013/055305

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
BELKE, Jeffrey Victor
11 Cowrie Cresent
Mt Pleasant, Western AustraLia 6153
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
GREEN, Nicholas John
98a Toorak Road
Rivervale, Western Australia 6103
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
TATE, Chris
187 Delgado Parade
Iluka, Western Australia 6028
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
HARRISON, Oscar
35 Campsbourne Street
Balcatta, Western Australia 6021
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

☒ Further applicants are indicated on another continuation sheet.

International application No.
PCT/IB2013/055305

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

VAAGE, Knut
Middlethunsgate 23
0368 Oslo
Norway

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
NO	NO

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

☐ Further applicants are indicated on another continuation sheet.

Exhibit 1027
FLS v. Metso - IPR2025-00985

International application No.
PCT/IB2013/055305

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is ☒ agent ☐ common representative

and ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.

☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Shelston IP
60 Margaret Street
Sydney NSW 2000
AUSTRALIA

Telephone No.
+61 2 9777 1111

Facsimile No.
+61 2 9241 4666

Agent's registration No. with the Office

E-mail authorization: Marking one of the check-boxes below authorizes the International Bureau and the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send notifications issued in respect of this international application if those offices are willing to do so.

☒ as advance copies followed by paper notifications; or ☐ exclusively in electronic form (no paper notifications will be sent).

E-mail address: email@ShelstonIP.com

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination **to start on the basis of:**

☐ the international application as originally filed

the description ☐ as originally filed
☒ as amended under Article 34

the claims ☐ as originally filed
☐ as amended under Article 19
☒ as amended under Article 34

the drawings ☒ as originally filed
☐ as amended under Article 34

2. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. ☐ Where the IPEA wishes to start the international preliminary examination at the same time as the international search in accordance with Rule 69.1(b), the applicant requests the IPEA **to postpone** the start of the international preliminary examination until the expiration of the applicable time limit under Rule 69.1(d).

4. ☐ The applicant expressly wishes the international preliminary examination **to start earlier** than at the expiration of the applicable time limit under Rule 54*bis*.1(a).

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

☒ which is the language in which the international application was filed.

☐ which is the language of a translation furnished for the purposes of international search.

☐ which is the language of publication of the international application.

☐ which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The filing of this demand constitutes the election of all Contracting States which are designated and are bound by Chapter II of the PCT.

International application No.
PCT/IB2013/055305

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

			For International Preliminary Examining Authority use only: received	not received
1. translation of international application	:	sheets	☐	☐
2. amendments under Article 34	:	sheets	☐	☐
3. letter accompanying the amendments under Article 34 (Rule 66.8)	:	sheets	☐	☐
4. copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
5. copy of the letter accompanying the amendments under Article 19 (Rules 46.5(b) and 53.9)	:	sheets	☐	☐
6. copy (or, where applicable, translation) of any statement under Article 19 (Rule 62.1(ii))	:	sheets	☐	☐
7. other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ original separate power of attorney
3. ☐ original general power of attorney
4. ☐ copy of general power of attorney; reference number, if any:
5. ☐ sequence listing in electronic form
6. ☐ other *(specify)*: _____

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).



Andrew Lowe
Shelston IP

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND: 22-04-2014

2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):

3. ☒ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply.

   ☒ The applicant has been informed accordingly.

4. ☐ The date of receipt of the demand is WITHIN the time limit of 19 months from the priority date as extended by virtue of Rule 80.5.

5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.

6. ☐ The date of receipt of the demand is AFTER the expiration of the time limit under Rule 54*bis*.1(a) and item 7 or 8, below, does not apply.

7. ☐ The date of receipt of the demand is WITHIN the time limit under Rule 54*bis*.1(a) as extended by virtue of Rule 80.5.

8. ☐ Although the date of receipt of the demand is after the expiration of the time limit under Rule 54*bis*.1(a), the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

WESTERN UNION business solutions

Outgoing Payment Confirmation

Tax Invoice/Transaction Confirmation

Confirmation Number: **AOTR3170950**

Account Number: **SH1111**
Order Date: **23 juin 2014**

Payment Instructions

Item Number	AOTR3170950-1
Transaction Type	Electronic Funds Transfer
Foreign Currency	EUR
Foreign Amount	2,419.00
Exchange Rate	0.666600
Fee	0.00
Beneficiary Name	EUROPEAN PATENT OFFICE
Account Number	DE20700800000333880000
Beneficiary Bank	COMMERZBANK AKTIENGESELLSCHAFT
Beneficiary Bank Address	PROMENADEPLATZ 7 MUNICH BAYERN
Country	Germany
SWIFT Code	DRESDEFF700
Routing Code	
Payment Reference	Appl. #PCT/2013/055305 re Invitation to Pay dated 11/6/2014 - File 74861WOP00
Settlement Method	Direct Debit
Amount Due to	3,628.86 AUD

Western Union Business Solutions (Australia) Pty Limited ("WUBS") hereby confirms the details of this transaction entered into between You and WUBS (the "Transaction") on the Order Date specified above. The terms and conditions between You and WUBS (the "Agreement"), a copy of which You have previously received, govern all aspects of this Transaction.

Western Union Business Solutions (Australia) Pty Limited,
Level 12, 1 Margaret Street Sydney, NSW 2000 Australia Phone: +61285857000 Fax: 1800 065 937
ABN : 24 150 129 749 | AFSL No. 404092

Foreign exchange services are provided in Australia by Western Union Business Solutions (Australia) Pty Limited, a company within the Western Union Business Solutions division of The Western Union Company. Western Union Business Solutions (Australia) Pty Limited is a wholly-owned subsidiary of The Western Union Company, a world-wide leader in consumer and business payments and financial services.

Shelston ip

ABN 58 855 816 942

Confidential Communication
Fax No. +49 89 2399 4465
Page 1 of 2
CONFIRMATION BY MAIL

EPO - Munich
27
30. Juni 2014

European Patent Office
D-80298
MUNICH, GERMANY

23 June 2014

Our Ref: 74861WOP00

Contact: Andrew Lowe

Attention : Annik Appelen

Dear Sirs

CONFIRMATION

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec (Finland) Oy
Title: Improvements in fluid bearings

We refer to Form PCT/IPEA/440 Invitation to Pay Prescribed Fees that issued on 11 June 2014.

We now confirm payment of the outstanding International Preliminary Examination and handling fees of €2,419 to EPO's bank account and enclose a copy of the remittance receipt for your records.

We look forward to receiving your acknowledgement of the Demand for IPE.

Yours respectfully
Shelston IP

Andrew Lowe
Registered Patent Attorney
Email: AndrewLowe@ShelstonIP.com

Encl. Confirmation of remittance

CC by facsimile: Facsimile No. +41 22 910 06 10
International Bureau of WIPO
34 chemin des Colombettes
1211 Geneva 20
SWITZERLAND

Attention: Cécile Chatel, Authorised Officer

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com www.ShelstonIP.com fax +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

Shelston IP

ABN 58 855 816 942

Confidential CommunicationConfidential Communication
Fax No. +49 89 2399 4465
Page 1 of 2
CONFIRMATION BY MAIL

European Patent Office
D-80298
MUNICH, GERMANY

23 June 2014

Our Ref: 74861WOP00

Attention : Annik Appelen

Contact: Andrew Lowe

Dear Sirs

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec (Finland) Oy
Title: Improvements in fluid bearings

We refer to Form PCT/IPEA/440 Invitation to Pay Prescribed Fees that issued on 11 June 2014.

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Yours respectfully
Shelston IP



Andrew Lowe
Registered Patent Attorney
Email: AndrewLowe@ShelstonIP.com

Encl. Confirmation of remittance

CC by facsimile: Facsimile No. +41 22 910 06 10
International Bureau of WIPO
34 chemin des Colombettes
1211 Geneva 20
SWITZERLAND

Attention: Cécile Chatel, Authorised Officer

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com **www**.ShelstonIP.com **fax** +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

Exhibit 1027
FLS v. Metso - IPR2025-00985
Duration: 23.06.2014 11:40:29 - 23.06.2014 11:41:09. This page 1 of 2 was completed at 23.06.2014 11:40:42.
Received at the EPO on Jun 23, 2014 11:41:09. Page 1 of 2

WESTERN UNION business solutions

Outgoing Payment Confirmation

Tax Invoice/Transaction Confirmation

Confirmation Number: **AOTR3170950**

Account Number: **SH1111**
Order Date: **23 juin 2014**

Payment Instructions

Item Number	AOTR3170950-1
Transaction Type	Electronic Funds Transfer
Foreign Currency	EUR
Foreign Amount	2,419.00
Exchange Rate	0.666600
Fee	0.00
Beneficiary Name	EUROPEAN PATENT OFFICE
Account Number	DE20700800000333880000
Beneficiary Bank	COMMERZBANK AKTIENGESELLSCHAFT
Beneficiary Bank Address	PROMENADEPLATZ 7 MUNICH BAYERN
Country	Germany
SWIFT Code	DRESDEFF700
Routing Code	
Payment Reference	Appl. #PCT/2013/055305 re Invitation to Pay dated 11/6/2014 - File 74861WOP00
Settlement Method	Direct Debit
Amount Due to	3,628.86 AUD

Western Union Business Solutions (Australia) Pty Limited ("WUBS") hereby confirms the details of this transaction entered into between You and WUBS (the "Transaction") on the Order Date specified above. The terms and conditions between You and WUBS (the "Agreement"), a copy of which You have previously received, govern all aspects of this Transaction.

Western Union Business Solutions (Australia) Pty Limited,
Level 12, 1 Margaret Street Sydney, NSW 2000 Australia Phone: +61285857000 Fax: 1800 065 937
ABN : 24 150 129 749 | AFSL No. 404092

Foreign exchange services are provided in Australia by Western Union Business Solutions (Australia) Pty Limited, a company within the Western Union Business Solutions division of The Western Union Company. Western Union Business Solutions (Australia) Pty Limited is a wholly-owned subsidiary of The Western Union Company, a world-wide leader in consumer and business payments and financial services.

Copy for (IPEA-EP) 34
PATENT COOPERATION TREATY

ADVANCE E-MAIL

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92*bis*.1 and Administrative Instructions, Section 422)

To:

SHELSTON IP
Shelston IP
Level 21, 60 Margaret Street
Sydney, New South Wales 2000
AUSTRALIE

Date of mailing *(day/month/year)*
10 June 2014 (10.06.2014)

Applicant's or agent's file reference
74861WOP00

IMPORTANT NOTIFICATION

International application No.
PCT/IB2013/055305

International filing date *(day/month/year)*
28 June 2013 (28.06.2013)

1. The following indications appeared on record concerning:

☒ the applicant ☐ the inventor ☐ the agent ☐ the common representative

Name and Address
OUTOTEC OYJ
Puolikkotie 10
FI-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☒ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address
OUTOTEC (FINLAND) OY
Puolikkotie 10
FI-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:
☐ Notifications by e-mail authorized

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☐ the receiving Office
☐ the International Searching Authority
☐ the Authority(ies) specified for supplementary search
☒ the International Preliminary Examining Authority
☐ the designated Offices concerned
☒ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 910 06 10

Authorized officer
Santiago Hortensia
e-mail ro.ib@wipo.int
Telephone No. +4122 338 9588

Exhibit 1027
IPR2025-00985
FLS v. Metso - IPR2025-00985

Copy for (EO-EP) 30

PATENT COOPERATION TREATY

ADVANCE E-MAIL

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92*bis*.1 and Administrative Instructions, Section 422)

To:

SHELSTON IP
Shelston IP
Level 21, 60 Margaret Street
Sydney, New South Wales 2000
AUSTRALIE

Date of mailing *(day/month/year)*
10 June 2014 (10.06.2014)

Applicant's or agent's file reference
74861WOP00

IMPORTANT NOTIFICATION

International application No.
PCT/IB2013/055305

International filing date *(day/month/year)*
28 June 2013 (28.06.2013)

1. The following indications appeared on record concerning:

☒ the applicant ☐ the inventor ☐ the agent ☐ the common representative

Name and Address
OUTOTEC OYJ
Puolikkotie 10
FI-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☒ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address
OUTOTEC (FINLAND) OY
Puolikkotie 10
FI-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:
☐ Notifications by e-mail authorized

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☐ the receiving Office
☐ the International Searching Authority
☐ the Authority(ies) specified for supplementary search
☒ the International Preliminary Examining Authority
☐ the designated Offices concerned
☒ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 910 06 10

Authorized officer
Santiago Hortensia
e-mail ro.ib@wipo.int
Telephone No. +4122 338 9588

Form PCT/IB/306 (January 2009)

Exhibit 1027
1/LV5K7PKGZU2YQ0
FLS v. Metso - IPR2025-00985

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

To:
SHELSTON IP
60 Margaret Street
Sydney, NSW 2000
AUSTRALIE

REGISTERED MAIL

INVITATION TO PAY PRESCRIBED FEES TOGETHER WITH LATE PAYMENT FEE

(PCT Rule 58*bis*)

Date of mailing *(day/month/year)*	11-06-2014
Applicant's or agent's file reference 74861WOP00	**PAYMENT DUE** within **ONE MONTH** from the above date of mailing
International application No. PCT/IB2013/055305	International filing date *(day/month/year)* 28 June 2013 (28-06-2013)
Applicant Outotec Oyj et al.	

1. This International Preliminary Examining Authority has found that the **prescribed fees** (that is, preliminary examination and handling fees) have not been paid (in full), within the time limit prescribed under Rules 57 and 58 (see below for details of the calculation).

2. The applicant is hereby **invited**, within the time limit indicated above, **to pay the total amount due indicated below:**

Preliminary examination fee		EUR 1.930,00	P
Handling fee *	+	EUR 163,00	H
Total fees payable	=	EUR 2.093,00	
Amount paid	−	EUR 0,00	
Total unpaid fees	=	EUR 2.093,00	

\+ EUR 326,00 (Late payment fee) = EUR 2.419,00 (Total amount due)

* *Applicants from certain States are entitled to a reduction of 90% of the handling fee. Where the applicant is (or all applicants are) so entitled, the amount to be entered at H is 10% of the handling fee. See Notes to the Fee Calculation Sheet annexed to the Demand Form. PCT/IPEA/401, for details.*

3. **Failure to pay** the total amount due within the time limit indicated above may result in this Authority declaring that the demand is considered as if it had not been submitted (Rule 58*bis*.1(b)).

4. Additional observations *(if any)*:

A copy of this invitation has been sent to the International Bureau.

Name and mailing address of the IPEA European Patent Office D-80298 Munich Tel. (+49-89) 2399-0 Fax: (+49-89) 2399-4465	Authorized officer Appelen, Annik

Europäisches Patentamt • European Patent Office • Office européen des brevets

Form PCT/IPEA/440 (July 2008)

Exhibit 1027
FLS v. Metso - IPR2025-00985

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Article 31(7) and Rule 61.2)

To:

European Patent Office
Postbus 5818
Patentlaan 2
NL-2280 HV RIJSWIJK
PAYS-BAS
in its capacity as elected Office

Date of mailing *(day/month/year)* 15 May 2014 (15.05.2014)	
International application No. PCT/IB2013/055305	Applicant's or agent's file reference 74861WOP00
International filing date *(day/month/year)* 28 June 2013 (28.06.2013)	Priority date *(day/month/year)* 28 June 2012 (28.06.2012)
Applicant OUTOTEC OYJ et al	

1. The designated Office is hereby notified of its election made in the demand filed with the International Preliminary Examining Authority on:
22 April 2014 (22.04.2014)

2. The election ☒ was
☐ was not
made before the expiration of 19 months from the priority date (PCT Article 39(1)(a)).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 338 8270

Authorized officer
Cécile Chatel

e-mail: ro.ib@wipo.int

Exhibit 1027

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ EP

PCT

EPO - Munich 81

20. Mai 2014

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:

The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty.

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION

Applicant's or agent's file reference: 74861WOP00

International application No.	International filing date *(day/month/year)*	(Earliest) Priority date *(day/month/year)*
PCT/IB2013/055305	28 June 2013 (28.06.2013)	28 June 2012 (28.06.2012)

Title of invention: Improvements in fluid bearings

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Outotec Oyj
Puolikkotie 10
02230 Espoo
Finland

Telephone No.: +358 205 29211

Facsimile No.: +358 205 292988

Applicant's registration No. with the Office:

E-mail authorization: Marking one of the check-boxes below authorizes the International Bureau and the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send notifications issued in respect of this international application if those offices are willing to do so.

☐ as advance copies followed by paper notifications; or ☐ exclusively in electronic form (no paper notifications will be sent).

E-mail address: _____

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
FI	FI

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BRAITHWAITE, Daniel
5/17 Hertha Road
Innaloo, Western Australia 6018
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

☒ Further applicants are indicated on a continuation sheet.

International application No.
PCT/IB2013/055305

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
BELKE, Jeffrey Victor
11 Cowrie Cresent
Mt Pleasant, Western AustraLia 6153
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
GREEN, Nicholas John
98a Toorak Road
Rivervale, Western Australia 6103
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
TATE, Chris
187 Delgado Parade
Iluka, Western Australia 6028
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
HARRISON, Oscar
35 Campsbourne Street
Balcatta, Western Australia 6021
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

☒ Further applicants are indicated on another continuation sheet.

International application No.
PCT/IB2013/055305

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
VAAGE, Knut
Middlethunsgate 23
0368 Oslo
Norway

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
NO	NO

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

☐ Further applicants are indicated on another continuation sheet.

Exhibit 1027
FLS v. Metso - IPR2025-00985

International application No.
PCT/IB2013/055305

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is ☒ agent ☐ common representative

and ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.

☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Shelston IP
60 Margaret Street
Sydney NSW 2000
AUSTRALIA

Telephone No.
+61 2 9777 1111

Facsimile No.
+61 2 9241 4666

Agent's registration No. with the Office

E-mail authorization: Marking one of the check-boxes below authorizes the International Bureau and the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send notifications issued in respect of this international application if those offices are willing to do so.

☒ as advance copies followed by paper notifications; or ☐ exclusively in electronic form (no paper notifications will be sent).

E-mail address: email@ShelstonIP.com

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination **to start on the basis of:**

☐ the international application as originally filed

the description ☐ as originally filed
☒ as amended under Article 34

the claims ☐ as originally filed
☐ as amended under Article 19
☒ as amended under Article 34

the drawings ☒ as originally filed
☐ as amended under Article 34

2. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. ☐ Where the IPEA wishes to start the international preliminary examination at the same time as the international search in accordance with Rule 69.1(b), the applicant requests the IPEA **to postpone** the start of the international preliminary examination until the expiration of the applicable time limit under Rule 69.1(d).

4. ☐ The applicant expressly wishes the international preliminary examination **to start earlier** than at the expiration of the applicable time limit under Rule 54*bis*.1(a).

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

☒ which is the language in which the international application was filed.

☐ which is the language of a translation furnished for the purposes of international search.

☐ which is the language of publication of the international application.

☐ which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The filing of this demand constitutes the election of all Contracting States which are designated and are bound by Chapter II of the PCT.

International application No.
PCT/IB2013/055305

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

			For International Preliminary Examining Authority use only: received	not received
1. translation of international application	:	sheets	☐	☐
2. amendments under Article 34	:	sheets	☐	☐
3. letter accompanying the amendments under Article 34 (Rule 66.8)	:	sheets	☐	☐
4. copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
5. copy of the letter accompanying the amendments under Article 19 (Rules 46.5(b) and 53.9)	:	sheets	☐	☐
6. copy (or, where applicable, translation) of any statement under Article 19 (Rule 62.1(ii))	:	sheets	☐	☐
7. other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ original separate power of attorney
3. ☐ original general power of attorney
4. ☐ copy of general power of attorney; reference number, if any:
5. ☐ sequence listing in electronic form
6. ☐ other *(specify)*: _____

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).



Andrew Lowe
Shelston IP

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:

2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):

3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply.
   ☐ The applicant has been informed accordingly.
4. ☐ The date of receipt of the demand is WITHIN the time limit of 19 months from the priority date as extended by virtue of Rule 80.5.
5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.
6. ☐ The date of receipt of the demand is AFTER the expiration of the time limit under Rule 54*bis*.1(a) and item 7 or 8, below, does not apply.
7. ☐ The date of receipt of the demand is WITHIN the time limit under Rule 54*bis*.1(a) as extended by virtue of Rule 80.5.
8. ☐ Although the date of receipt of the demand is after the expiration of the time limit under Rule 54*bis*.1(a), the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

Shelston ip

Confidential Communication
Facsimile No. +49 89 2399 4465
CONFIRMATION BY MAIL

EPO - Munich
81
20. Mai 2014

ABN 58 855 816 942

International Preliminary Examining Authority
European Patent Office
D-80298
Munich GERMANY

15 May 2014

Our Ref: 74861WOP00

Attention: Annik Appelen

Contact: Andrew Lowe

Dear Sirs

CONFIRMATION

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

We refer to the Invitation to Correct Defects in the Demand mailed 30 April 2014 and enclose a fresh Demand form which indicates all the Applicants for this PCT application.

It is submitted that the defect in the Demand for International Preliminary Examination has now been corrected.

We also look forward to receiving an official notification concerning payment of the prescribed fees for International Preliminary Examination.

Yours respectfully
Shelston IP

Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

Encl. Demand for IPE

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com **www**.ShelstonIP.com **fax** +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ EP

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty.

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION

Applicant's or agent's file reference: 74861WOP00

International application No.	International filing date *(day/month/year)*	(Earliest) Priority date *(day/month/year)*
PCT/IB2013/055305	28 June 2013 (28.06.2013)	28 June 2012 (28.06.2012)

Title of invention
Improvements in fluid bearings

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Outotec Oyj
Puolikkotie 10
02230 Espoo
Finland

Telephone No.: +358 205 29211

Facsimile No.: +358 205 292988

Applicant's registration No. with the Office:

E-mail authorization: Marking one of the check-boxes below authorizes the International Bureau and the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send notifications issued in respect of this international application if those offices are willing to do so.

☐ as advance copies followed by paper notifications; or ☐ exclusively in electronic form (no paper notifications will be sent).

E-mail address: _____

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
FI	FI

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BRAITHWAITE, Daniel
5/17 Hertha Road
Innaloo, Western Australia 6018
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

☒ Further applicants are indicated on a continuation sheet.

Duration: 15.05.2014 02:20:13 - 15.05.2014 02:21:46. This page 2 of 6 was completed at 15.05.2014 02:21:46.
Received at the EPO on May 15, 2014 02:21:46. Page 2 of 6

Sheet No. .2

International application No.
PCT/IB2013/055305

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
BELKE, Jeffrey Victor
11 Cowrie Cresent
Mt Pleasant, Western AustraLia 6153
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
GREEN, Nicholas John
98a Toorak Road
Rivervale, Western Australia 6103
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
TATE, Chris
187 Delgado Parade
Iluka, Western Australia 6028
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
HARRISON, Oscar
35 Campsbourne Street
Balcatta, Western Australia 6021
Australia

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
AU	AU

☒ Further applicants are indicated on another continuation sheet.

Sheet No. .3

International application No.
PCT/IB2013/055305

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
VAAGE, Knut
Middlethunsgate 23
0368 Oslo
Norway

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
NO	NO

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

☐ Further applicants are indicated on another continuation sheet.

Form PCT/IPEA/401 (continuation sheet) (16 September 2012) *See Notes to the demand form*

Duration: 15.05.2014 02:20:13 - 15.05.2014 02:21:46. This page 4 of 6 was completed at 15.05.2014 02:21:46.
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Received at the EPO on May 15, 2014 02:21:46. Page 4 of 6

Sheet No. 4

International application No.
PCT/IB2013/055305

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is ☒ agent ☐ common representative

and ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.

☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Shelston IP
60 Margaret Street
Sydney NSW 2000
AUSTRALIA

Telephone No.
+61 2 9777 1111

Facsimile No.
+61 2 9241 4666

Agent's registration No. with the Office

E-mail authorization: Marking one of the check-boxes below authorizes the International Bureau and the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send notifications issued in respect of this international application if those offices are willing to do so.

☒ as advance copies followed by paper notifications; or ☐ exclusively in electronic form (no paper notifications will be sent).

E-mail address: email@ShelstonIP.com

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination **to start on the basis of:**

☐ the international application as originally filed

the description ☐ as originally filed
☒ as amended under Article 34

the claims ☐ as originally filed
☐ as amended under Article 19
☒ as amended under Article 34

the drawings ☒ as originally filed
☐ as amended under Article 34

2. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. ☐ Where the IPEA wishes to start the international preliminary examination at the same time as the international search in accordance with Rule 69.1(b), the applicant requests the IPEA **to postpone** the start of the international preliminary examination until the expiration of the applicable time limit under Rule 69.1(d).

4. ☐ The applicant expressly wishes the international preliminary examination **to start earlier** than at the expiration of the applicable time limit under Rule 54*bis*.1(a).

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

☒ which is the language in which the international application was filed.

☐ which is the language of a translation furnished for the purposes of international search.

☐ which is the language of publication of the international application.

☐ which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The filing of this demand constitutes the election of all Contracting States which are designated and are bound by Chapter II of the PCT.

Form PCT/IPEA/401 (second sheet) (16 September 2012) *See Notes to the demand form*

Duration: 15.05.2014 02:20:13 - 15.05.2014 02:21:46. This page 5 of 6 was completed at 15.05.2014 02:21:46.
FLS v. Metso - IPR2025-00985
Received at the EPO on May 15, 2014 02:21:46. Page 5 of 6

Sheet No. .5

International application No.
PCT/IB2013/055305

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

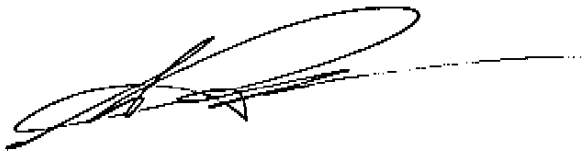
			For International Preliminary Examining Authority use only: received	not received
1. translation of international application	:	sheets	☐	☐
2. amendments under Article 34	:	sheets	☐	☐
3. letter accompanying the amendments under Article 34 (Rule 66.8)	:	sheets	☐	☐
4. copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
5. copy of the letter accompanying the amendments under Article 19 (Rules 46.5(b) and 53.9)	:	sheets	☐	☐
6. copy (or, where applicable, translation) of any statement under Article 19 (Rule 62.1(ii))	:	sheets	☐	☐
7. other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ original separate power of attorney
3. ☐ original general power of attorney
4. ☐ copy of general power of attorney; reference number, if any:
5. ☐ sequence listing in electronic form
6. ☐ other *(specify)*: _____

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).



Andrew Lowe
Shelston IP

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:

2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):

3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply.
   ☐ The applicant has been informed accordingly.
4. ☐ The date of receipt of the demand is WITHIN the time limit of 19 months from the priority date as extended by virtue of Rule 80.5.
5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.
6. ☐ The date of receipt of the demand is AFTER the expiration of the time limit under Rule 54*bis*.1(a) and item 7 or 8, below, does not apply.
7. ☐ The date of receipt of the demand is WITHIN the time limit under Rule 54*bis*.1(a) as extended by virtue of Rule 80.5.
8. ☐ Although the date of receipt of the demand is after the expiration of the time limit under Rule 54*bis*.1(a), the delay in arrival is EXCUSED pursuant to Rule 82.

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Demand received from IPEA on:

Duration: 15.05.2014 02:20:13 - 15.05.2014 02:21:46. This page 6 of 6 was completed at 15.05.2014 02:21:46 Received at the EPO on May 15, 2014 02:21:46. Page 6 of 6

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Confidential Communication
Facsimile No. +49 89 2399 4465
CONFIRMATION BY MAIL

ABN 58 865 816 942

International Preliminary Examining Authority
European Patent Office
D-80298
Munich GERMANY

15 May 2014

Our Ref: 74861WOP00

Attention: Annik Appelen

Contact: Andrew Lowe

Dear Sirs

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

We refer to the Invitation to Correct Defects in the Demand mailed 30 April 2014 and enclose a fresh Demand form which indicates all the Applicants for this PCT application.

It is submitted that the defect in the Demand for International Preliminary Examination has now been corrected.

We also look forward to receiving an official notification concerning payment of the prescribed fees for International Preliminary Examination.

Yours respectfully
Shelston IP

Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

Encl. Demand for IPE

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com www.ShelstonIP.com fax +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

Exhibit 1027
FLS v. Metso - IPR2025-00985
Duration: 15.05.2014 02:20:13 - 15.05.2014 02:21:46. This page 1 of 6 was completed at 15.05.2014 02:20:26
Received at the EPO on May 15, 2014 02:21:46. Page 1 of 6

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ABN 58 855 816 942

International Preliminary Examining Authority
European Patent Office
P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk – Pays Bas
THE NETHERLANDS

22 April 2014

Our Ref: 74861WOP00

Attention: Christophe Martin

Contact: Andrew Lowe

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

STATEMENT OF AMENDMENTS – ARTICLE 34

Complete Specification

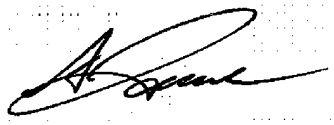
Description

1. Cancel pages 3 to 28 now on file and replace with new pages 3 to 28.

Claims

2. Cancel pages 29 to 36 now on file and replace with new pages 29 to 33.

DATED this 22nd day of April 2014
OUTOTEC OYJ



Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com **www**.ShelstonIP.com **fax** +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

Exhibit 1027
FLS v. Metso - IPR2025-00985

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Confidential Facsimile Transmission

URGENT

To	International Preliminary Examining Authority European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk – Pays Bas THE NETHERLANDS
Attention	**Christophe Martin**
Facsimile No.	+31 70 340 3016
From	Andrew Lowe
Date Sent	22 April 2014
Our Reference	74861WOP00
Pages sent:	1+ 74

CONFIRMATION

Message

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

We refer to this application in which the EPO is the International Searching Authority and has issued an ISR and Written Opinion dated 30 October 2013.

We now attach a Demand for International Preliminary Examinaiton, and a response to the Written Opinion with amendments under Article 34.

Please kindly acknowledge receipt of this facsimile by return fax (+61-2-92414666) or by email to AndrewLowe@ShelstonIP.com.

We look forward to receiving the Invitation to Pay the Prescribed fees and acknowledgement of the Demand for IPE and response.

Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ EP

EPO - DG 2

05. 05. 2014

43

PCT

DEMAND

CHAPTER II

under Article 31 of the Patent Cooperation Treaty:

The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty.

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION

Applicant's or agent's file reference: 74861WOP00

International application No.	International filing date *(day/month/year)*	(Earliest) Priority date *(day/month/year)*
PCT/IB2013/055305	28 June 2013 (28.06.2013)	28 June 2012 (28.06.2012)

Title of invention: Improvements in fluid bearings

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Outotec Oyj
Puolikkotie 10
02230 Espoo
Finland

Telephone No.: 0011 358 205 29211

Facsimile No.: (358205) 292988

Applicant's registration No. with the Office:

☐ **E-mail authorization:** Marking this check-box authorizes the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send, if the Authority so wishes, advance copies of notifications in respect of this international application. (*See also the Notes to Box No. II.*)

E-mail address:

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
FI	FI

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

☐ Further applicants are indicated on a continuation sheet.

International application No.
PCT/IB2013/055305

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is ☒ agent ☐ common representative

and ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.

☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*	Telephone No. (612) 9777 1111
Shelston IP 60 Margaret Street Sydney NSW 2000 AUSTRALIA	Facsimile No. (612) 9241 4666
	Applicant's registration No. with the Office
☒ **E-mail authorization:** Marking this check-box authorizes the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send, if the Authority so wishes, advance copies of notifications in respect of this international application. (*See also the Notes to Box No. II.*)	E-mail address email@ShelstonIP.com

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination **to start on the basis of:**

☐ the international application as originally filed

the description ☐ as originally filed
☒ as amended under Article 34

the claims ☐ as originally filed
☐ as amended under Article 19 (together with any accompanying statement)
☒ as amended under Article 34

the drawings ☒ as originally filed
☐ as amended under Article 34

2. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. ☐ Where the IPEA wishes to start the international preliminary examination at the same time as the international search in accordance with Rule 69.1(b), the applicant requests the IPEA **to postpone** the start of the international preliminary examination until the expiration of the applicable time limit under Rule 69.1(d).

4. ☐ The applicant expressly wishes the international preliminary examination **to start earlier** than at the expiration of the applicable time limit under Rule 54*bis*.1(a).

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

☒ which is the language in which the international application was filed.

☐ which is the language of a translation furnished for the purposes of international search.

☐ which is the language of publication of the international application.

☐ which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The filing of this demand constitutes the election of all Contracting States which are designated and are bound by Chapter II of the PCT.

International application No.
PCT/IB2013/055305

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

				For International Preliminary Examining Authority use only: received	not received
1.	translation of international application	:	sheets	☐	☐
2.	amendments under Article 34	:	sheets	☐	☐
3.	copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
4.	copy (or, where required, translation) of statement under Article 19	:	sheets	☐	☐
5.	letter	:	sheets	☐	☐
6.	other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ original separate power of attorney
3. ☐ original general power of attorney
4. ☐ copy of general power of attorney; reference number, if any:
5. ☐ statement explaining lack of signature
6. ☐ sequence listing in electronic form
7. ☐ other *(specify)*:

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).



Andrew Lowe
Shelston IP

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:

2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):

3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply.
   ☐ The applicant has been informed accordingly.
4. ☐ The date of receipt of the demand is WITHIN the time limit of 19 months from the priority date as extended by virtue of Rule 80.5.
5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.
6. ☐ The date of receipt of the demand is AFTER the expiration of the time limit under Rule 54*bis*.1(a) and item 7 or 8, below, does not apply.
7. ☐ The date of receipt of the demand is WITHIN the time limit under Rule 54*bis*.1(a) as extended by virtue of Rule 80.5.
8. ☐ Although the date of receipt of the demand is after the expiration of the time limit under Rule 54*bis*.1(a), the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

Claims

1. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

2. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

3. The bearing assembly of claim 1 or 2, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad.

4. The bearing assembly of claim 3, wherein said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base.

5. The bearing assembly of claim 4, wherein said flange is located at an outer edge of said base.

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6. The bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base.

7. The bearing assembly of claim 6, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess.

8. The bearing assembly of claim 6 or 7, wherein said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

9. The bearing assembly of claim 7, further comprising a plug for engagement with said head portion and said at least one recess.

10. The bearing assembly of claim 6, further comprising a locking element for retaining said at least one fastener within said at least one recess.

11. The bearing assembly of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

12. The bearing assembly of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

13. The bearing assembly of claim 12, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

14. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

15. The bearing assembly of any one of claims 1 to 13, wherein said outer surface is substantially planar.

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16. The bearing assembly of any one of the preceding claims, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

17. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

18. The bearing assembly of claim 17, wherein each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

19. The bearing assembly of any one of claims 1 to 16, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads, a first of said polymer bearing pads being mountable to said first surface and a second of said polymer bearing pads being mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

20. The bearing assembly of claim 19, wherein said first surface is orthogonal to said second surface.

21. The fluid bearing of claim 19 or 20, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic

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FLS v. Metso - IPR2025-00985

bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

22. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

23. The multidirectional fluid bearing of claim 22, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

24. The multidirectional fluid bearing of claim 22 or 23, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

25. The multidirectional fluid bearing of claim 24, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

26. The multidirectional fluid bearing of claim 22, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

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27. The multidirectional fluid bearing of claim 26, wherein each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

28. The multidirectional fluid bearing of any one of claims 22 to 27, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

29. The multidirectional fluid bearing of claim 28, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

30. The multidirectional fluid bearing of any one of claims 22 to 29, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

31. The multidirectional fluid bearing of claim 30, wherein said flange is located at an outer edge of said base.

32. The multidirectional fluid bearing of any one of claims 22 to 31, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

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Claims

1. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad ~~for a fluid bearing,~~ comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base ~~of said fluid bearing~~ and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

2. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

~~2.~~3. The ~~polymer bearing pad~~bearing assembly of claim 1 or 2, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad.

4. The ~~polymer bearing pad~~bearing assembly of claim ~~2~~ 3, wherein said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base.

~~3.~~5. The bearing assembly of claim 4, wherein said flange is located at an outer edge of said base.

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~~4.~~6. The ~~polymer bearing pad~~bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base.

7. The ~~polymer bearing pad~~bearing assembly of claim 6, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess.

~~5.~~8. The bearing assembly of claim 6 or 7, wherein said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

9. The bearing assembly of claim 7, further comprising a plug for engagement with said head portion and said at least one recess.

10. The bearing assembly of claim 6, further comprising a locking element for retaining said at least one fastener within said at least one recess.

~~6.~~11. The ~~polymer bearing pad~~bearing assembly of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

~~7.~~12. The ~~polymer bearing pad~~bearing assembly of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

~~8.~~13. The ~~polymer bearing pad~~bearing assembly of claim 12, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

~~9.~~14. The ~~polymer bearing pad~~bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

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~~10.~~15. The ~~polymer bearing pad~~bearing assembly of any one of claims 1 to 13, wherein said outer surface is substantially planar.

~~11. The polymer bearing pad of any one of the preceding claims, further comprising at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.~~

~~12. A fluid bearing for a journal, comprising:~~

~~a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and~~

~~the polymer bearing pad of any one of the preceding claims mountable to said base.~~

~~13. The fluid bearing of claim 12, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.~~

~~14. The fluid bearing of claim 13, wherein said flange is located at an outer edge of said base.~~

~~15.~~16. The ~~fluid bearing~~bearing assembly of any one of the preceding claims ~~10 to 14~~, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

~~16. The fluid bearing of any one of claims 10 to 15, further comprising at least one fastener for mounting said polymer bearing pad to said base, said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.~~

~~17. The fluid bearing of claim 16, wherein said at least one recess has a locking tab for retaining said head portion within said at least one recess.~~

~~18. The fluid bearing of claim 16, further comprising a plug for engagement with said head portion and said at least one recess.~~

~~19. The fluid bearing of claim 16 or 18, further comprising a locking element for retaining said at least one fastener within said at least one recess.~~

~~20.~~17. The ~~fluid bearing~~bearing assembly of any one of the preceding claims ~~12 to 19~~, further comprising a plurality of said polymer bearing pads, wherein said respective outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

~~21.~~18. The ~~fluid bearing~~bearing assembly of claim 17, wherein each of said polymer bearing pads ~~-~~comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

~~22.~~19. The ~~fluid bearing~~bearing assembly of any one of claims 1 to ~~21~~ 16, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads, a first of said polymer bearing pads ~~is~~being mountable to said first surface and a second of said polymer bearing pads ~~is~~being mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

~~23.~~20. The ~~fluid bearing~~bearing assembly of claim 19, wherein said first surface is orthogonal to said second surface.

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~~24.~~21. The fluid bearing of claim 19 or 20, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

~~25. The fluid bearing of any one of claims 12 to 21, wherein said fluid bearing is at least one of a radial hydrostatic bearing, a self-aligning radial hydrostatic bearing, a fixedly mounted radial hydrostatic bearing, a hydrostatic slipper bearing, an axial bearing, a self-aligning axial hydrostatic bearing and a fixedly mounted axial hydrostatic bearing.~~

~~26. A method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.~~

~~27. The method of claim 26, wherein said mounting means forming step comprises machining said polymer pad to form a mounting portion extending from said polymer pad.~~

~~28. The method of claim 26, wherein said mounting means forming step comprises drilling, punching, cutting or machining an opening in said at least one recess to receive at least one fastener.~~

~~29. The method of claim 26 or 28, further comprising chamfering an outer edge of said polymer pad.~~

~~30. The method of any one of claims 26 to 29, wherein said at least one recess forming step comprises machining said at least one recess in said polymer pad and machining at least one interconnecting passage to interconnect said at least one recess to said base.~~

~~31. A method of making a fluid bearing for a journal, comprising:~~

providing a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port and at least one flange;

making a polymer bearing pad in accordance with the method of any one of claims 26 to 30, and

mounting said polymer bearing pad to said base.

32. The method of claim 31, wherein said mounting step comprising mechanically fastening said polymer bearing pad to said base.

33. The method of claim 31 or 32, wherein there are a plurality of said polymer pads, said method further comprising connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal.

34. The method of claim 33, further comprising forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

35. The method of claim 33 or 34, wherein said further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

36. A fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

~~37. The fluid bearing of claim 36, wherein said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.~~

~~38. The fluid bearing of claim 36 or 37, wherein said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.~~

~~39.~~22. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to~~,~~ a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

~~40.~~23. The multidirectional fluid bearing of claim 22, said first polymer bearing pad substantially covers said first ~~outer~~ surface and said second polymer bearing pad substantially covers said second ~~outer~~ surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

~~41.~~24. The multidirectional fluid bearing of claim 22 or 23, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

~~42.~~25. The multidirectional fluid bearing of claim 24, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

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~~43. The multidirectional fluid bearing of any one of claims 39 to 42, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.~~

~~44. The multidirectional fluid bearing of any one of claims 39 to 43, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.~~

~~45. The multidirectional fluid bearing of any one of claims 39 to 42, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, and further comprising a locking element for retaining said at least one fastener within said at least one recess.~~

~~46.~~26. The multidirectional fluid bearing of ~~any one of~~ claim~~s~~ 22 ~~to 45~~, wherein there is a plurality of at least one of said first and second polymer bearing pads ~~comprises a plurality of said polymer bearing pads~~, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

~~47.~~27. The multidirectional fluid bearing of claim 26, wherein each of said plurality of at least one of said first and second polymer bearing pads ~~comprises~~ at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

28. The multidirectional fluid bearing of any one of claims 22 to 27, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab

for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

29. The multidirectional fluid bearing of claim 28, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

~~48. The multidirectional fluid bearing of claim 39, wherein at least one of said first polymer bearing pad and said second polymer bearing pad comprises said polymer bearing pad of any one of claims 1 to 11.~~

~~49.~~30. The multidirectional fluid bearing of any one of claims ~~22~~48 to 29, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

~~50.~~31. The multidirectional fluid bearing of claim 30, wherein said flange is located at an outer edge of said base.

~~51. The multidirectional fluid bearing of any one of claims 39 to 50, wherein said first surface is orthogonal to said second surface.~~

~~52.~~32. The multidirectional fluid bearing of any one of claims 22 to ~~51~~31, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

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[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

[0011] A second aspect of the present invention provides a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

[0012] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0013] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0014] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[0015] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0016] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0017] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0018] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0019] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

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[0020] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0021] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0022] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0023] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

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[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] There is disclosed a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

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[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] Also disclosed is a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for connecting said

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polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] Also further disclosed is a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to a third aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

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[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably,, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

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Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

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[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

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[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this

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embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

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[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

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[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23

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also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a "hovercraft" type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there

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is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both

outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the "lead-in" chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the "lead-in" chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the "lead-out" chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

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[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased "off the shelf" in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and

kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped

recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from

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the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

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[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing in a bearing assembly, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the

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invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

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[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body~~a polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means for securely mounting said polymer bearing pad to said base~~.

~~[0010]~~[0011] A second aspect of the present invention provides a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

~~[0011]~~[0012] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in

an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

~~[0012]~~[0013] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

~~[0013]~~[0014] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

~~[0014]~~[0015] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

~~[0015]~~[0016] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

~~[0016]~~[0017] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

~~[0017]~~[0018] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

~~[0018]~~[0019] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately

0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

~~[0019]~~[0020] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

~~[0020]~~[0021] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

~~[0021]~~[0022] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

~~[0022] According to a second aspect of the invention, there is provided a fluid bearing for a journal, comprising:~~

~~a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and~~

~~the polymer bearing pad of the first aspect of the present invention mountable to said base.~~

[0023] Preferably, ~~said polymer bearing pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect,~~ said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

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[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

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[0037] ~~According to a third aspect of the invention, t~~There is ~~provid~~disclosed a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] ~~According to a fourth aspect of the invention, there is provided~~Also disclosed is a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

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[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for connecting said polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] Also further disclosed is ~~ccording to a fifth aspect of the invention, there is provided a~~ fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to a third ~~sixth~~ aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to~~,~~ a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

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[0053] Preferably, said first polymer bearing pad substantially covers said first ~~outer~~ surface and said second polymer bearing pad substantially covers said second ~~outer~~ surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, ~~least one of said first and second polymer bearing pads comprises~~ there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

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[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably, ~~said first surface is orthogonal to said second surface. In one preferred form~~, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

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[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

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[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The

fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no

pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23 also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil

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collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

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(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a "hovercraft" type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and

installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the "lead-in" chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the "lead-in"

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chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the "lead-out" chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional

manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased "off the shelf" in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining

the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is

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running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing in a bearing assembly, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair.

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Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

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NL-2280 HV Rijswijk – Pays Bas
THE NETHERLANDS

CONFIRMATION

Attention: Christophe Martin

22 April 2014

Our Ref: 74861WOP00

Contact: Andrew Lowe

Dear Sirs

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

We refer to the First Written Opinion of the International Preliminary Examining Authority mailed on 30 October 2013 in respect of the above application.

Article 34 amendments

Pursuant to Article 34, the Applicant requires the International Preliminary Examining Authority to take into account the amendments on the enclosed replacement pages as set forth on the attached Statement of Amendments.

The proposed amendments have cancelled claims 11 to 13, 25, 26 to 38, 45, 48 and 51.

Claims 1 to 10 and 14 to 24 have been reworded and are now directed to a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising a base and the polymer bearing pad of original claim 1 mounted to the base. Support for this amendment is found at page 14, paragraph [0093] of the specification as filed

Claim 1 has also been amended claim to define that the base is mounted to the frame so that the fluid bearings self adjust to changes in the angular position of the journal during operation of the grinding mill body. Support for this amendment is found at page 14, paragraph [0094] of the specification as filed.

A new claim 2 has been added, which also defines a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising the polymer bearing pad of original claim 1 mounted to the base. New claim 2, however, defines that the base is fixedly mounted to the frame. Support for this amendment is found at page 24, paragraph [0113] of the specification as filed.

Sydney	Brisbane	Newcastle	Auckland
Level 21	7 Clunies Ross Court	Level 1, IDC House	Level 13, AA Building
60 Margaret Street	Brisbane Technology Park	University Drive	99 Albert Street
Sydney, NSW 2000	Eight Mile Plains, QLD 4113	Callaghan, NSW 2308	Auckland 1010
Australia	Australia	Australia	New Zealand
T +61 2 9777 1111	**T** +61 7 3147 8020	**T** +61 2 4921 7366	**T** +64 9 638 5300

email@SheltonIP.com **www**.SheltonIP.com **fax** +61 2 9241 4666
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Claim 39 has been amended to include the subject matter of original claim 51, and has now been renumbered as claim 22. Support for this amendment is found at page 11, paragraph [0061] and page 25, paragraph [0114] of the specification as filed

As a result, claims 2 to 10, 14 to 24, 40 to 44, 46, 47, 49, 50 and 52 have been renumbered as new claims 3 to 21 and 23 to 32.

Some clarifying amendments have also been made to claims 20, 22, 40, 46 and 47, now new claims 17, 19, 23, 26 and 27.

It is submitted that the proposed amendments are supported by the specification as filed and favourable consideration is requested.

Response to written opinion

In response to the Written Opinion, the Applicant submits that invention as now claimed is novel and involves an inventive step over the cited prior art referred to in Box V, and the claims no longer have the clarity problems noted in Box VIII.

Box V - novelty and inventive step

Of the claims that are now pending in the international application, the following documents have been cited by the Examiner as being relevant to novelty and inventive step:

D1: DE 10 2007 039 364 (Metso Paper)

D2: WO 90/12216 (Vickers plc)

D3: JP 2006-9968A (Oiles Industry Co Ltd)

It is submitted that claims 1 to 21 are novel and involve an inventive step over the cited prior art. Independent claims 1 and 2 now define a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising a polymer bearing pad mounted to a base.

Claim 1 further defines that the base is mounted to the frame so that the fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body. It is submitted that none of the cited prior art, especially D1, discloses or teaches this claimed feature.

D1 discloses a bearing pad 30 for a flexible sheet 10 forming a nip with a roller 2 in a paper or cardboard making machine. The bearing pad is mounted on a shoe 5, 31 that is supported by a piston 4 movably located in a shaft or axle 3. The axle 3 has a central well 15' that acts as a supply for lubricating fluid to be delivered to recesses 22 in the pad 30. The piston 4 operates to move the bearing pad 30 and shoe 5, 31 in a radial direction into engagement the flexible sheet 10, thus applying a pressure or force to the sheet 10 against the nip roller 2.

As such, it is submitted that any movement of the roller 2 relative to the sheet 10 and bearing pad 30, including its angular position, can only be adjusted for by operating the piston 4 so that the bearing pad 30 re-engages the roller 2 and pinch the flexible sheet 10. Hence, it is submitted that changes in angular position need to be manually corrected by operating the piston 4 – the fluid bearing comprising the bearing pad 30 and the shoe 5, 31 cannot correct for changes in the angular position of the roller 2 on its own. As a consequence, the fluid bearing does not stabilise the sheet 10 or roller 2 in an axial position, but rather allows the sheet 10 to "float" on the axle part 3 and applies a force to the internal surface of the sheet 10 so that a pressure is maintained against the roller 2.

By way of contrast, the bearing assembly of the claimed invention has the base of the fluid bearing mounted to the frame so that the fluid bearing self-adjusts to changes in the angular position of the journal shaft 4; ie. the fluid bearing is self-aligning on its own in response to movements of the journal shaft 4. Thus, the bearing assembly of the claimed invention acts to positively locate the supported journal shaft 4 in a fixed position such that mating precision components can be correctly located. As a consequence, the invention of claim 1 has the technical advantage of avoiding the need for manual

adjustment in response to changes in the angular position of the journal or a mechanical device such as a piston to perform that adjustment.

It is submitted that the skilled person would not be able to modify the arrangement of D1 to arrive at the technical solution defined in amended claim 1, since this would involve substantial redesign to take into account the removal of the piston arrangement disclosed in D1. Furthermore, it is submitted that there is no teaching in D1 that would motivate the skilled person to consider or attempt such a modification of such a central element of the designed bearing arrangement as taught in that document. Thus, it is submitted that claim 1 has an inventive step over D1.

Likewise, claim 2 defines that the base is fixedly mounted to the frame, whereas in D1 the shoe 5, 31 is able to move in a radial direction relative to the shaft 3 via the piston 4. Therefore, it is submitted that D1 fails to teach the technical solution proposed by claim 2, and in fact teaches the opposite arrangement – a moveable mounting of the shoe 5, 31 to the "base", being the shaft 3. Thus, for the same reasons outlined above, it is submitted that claim 2 also has an inventive step over D1.

Since the teaching in D3 relates only to particular fastening arrangements for mounting the bearing pad to the base, it is submitted that a combination of D1 with D3 would also fail to render the claimed invention obvious for the same reasons stated above.

Thus, it is submitted that claims 1 to 21 involve an inventive step over the cited prior art.

In relation to claims 22 to 32, it is also submitted that these claims involve an inventive step over D1 and D2, the Examiner having previously conceded that original claim 39 was novel.

Claim 22 now includes the subject matter of original claims 39 and 51. It is submitted that a combination of D1 and D2 fails to disclose or teach the claimed multidirectional fluid bearing having polymer bearing pads mounted to orthogonal surfaces of a base.

D1 only discloses a polymer bearing pad that supports a load in a single radial direction. Therefore, there is no disclosure or teaching of using the polymer bearing pad for supporting loads in multiple directions.

D2 describes a thrust bearing or shoe and particular reference is made to Figure 4 which shows multiple bearings 10a, 10b arranged on a thrust ring or disc that rotates with a shaft. The shoes or bearing pads 10a, 10b are arranged on opposite faces of the disc 44. Thus, in D2 the surfaces supporting the bearing pads face in opposing directions and are in axial alignment (ie. coaxial). Therefore, there is no disclosure or teaching of an orthogonal arrangement of the surfaces upon which are mounted the bearing pads.

Hence, it is submitted that a combination of D1 and D2 would not lead the skilled person to the claimed invention. It is submitted that the skilled person reading D1 and D2 would simply mount the polymer bearing pads on the opposed, axially aligned surfaces taught in D2, rather than arrive at the multidirectional bearing as now claimed.

It is also submitted that there is no motivation for the skilled person to modify the coaxial arrangement of the surfaces in D2 to orthogonal surfaces because there is no teaching or suggestion to do so in either D1 or D2, especially as D2 is solely concerned with axial loads (albeit in opposite directions) along the single, same axis.

By contrast, the multidirectional fluid bearing of claim 22 is concerned with supporting loads from orthogonal directions, particularly the radial and axial loads of a journal shaft connected to the mill body.

Thus, it is submitted that D1 and D2 would teach away from the claimed invention. Therefore, it is submitted that claims 22 to 32 involve an inventive step over the cited prior art.

Box VIII – certain observations

It is submitted that the cancellation of claims 35, 36, 45 and 48 have rendered the objections at items 14.3, 14.4, 14.6 and 14.8 moot.

In relation to items 14.1 and 14.2, it is submitted that the redefinition of claim 1 as a bearing assembly comprising, *inter alia*, a polymer bearing pad and base has resolved the objections against claims 6, 15 and 16 (now claims 11, 16 and 8, respectively).

Similarly, it is submitted that the amendments to claim 40 (now claim 23) have overcome the objection at item 14.5 by correcting the references to "first outer surface", "second outer surface" and "said polymer bearing pad" to "first surface", "second surface" and "said second polymer bearing pad", respectively.

In reply to item 14.7, claim 46 (now claim 26) has clarified that there is a plurality of at least one of the first and second polymer bearing pads. Accordingly, it is submitted that this objection has now been overcome.

Thus, in conclusion, it is submitted that all of the observations made in Box VIII have now been resolved.

Closing comments

As the Examiner's objections have now been overcome, the Applicant requests a clear and favourable International Preliminary Report on Patentability.

Yours respectfully
Shelston IP



Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

PATENT COOPERATION TREATY

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INVITATION TO CORRECT DEFECTS IN THE DEMAND

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Applicant's or agent's file reference 74861WOP00	Date of mailing *(day/month/year)* 30-04-2014
International application No. PCT/IB2013/055305	**REPLY DUE** within **ONE MONTH** from the above date of mailing. See also below. International filing date *(day/month/year)* 28 June 2013 (28-06-2013)
Applicant Outotec Oyj et al.	

The applicant is hereby **invited** within the time limit indicated above **to correct the following defects** which this International Preliminary Examining Authority has found in the demand for international preliminary examination:

1. ☐ It does not permit identification of the international application to which it relates (Rule 60.1(b)).
2. ☐ It does not contain the required petition (Rules 53.2(a)(i) and 53.3).
3. ☐ It does not contain the required indications concerning the agent as specified in the Annex (Rules 53.2(a)(ii) and 53.5).
4. ☐ It does not contain the required indications concerning the international application as specified in the Annex (Rules 53.2(a)(iii) and 53.6).
5. ☐ It is not submitted in the required language which is: _____ (Rule 55.1).
6. ☐ It is not made on the printed form (rule 53.1(a)).
7. ☐ It is presented as a computer print-out the particulars of which do not comply with the Administrative Instructions (Rule 53.1(a)).
8. ☒ It does not contain the required indications concerning the applicant as specified in the Annex (Rules 53.2(a)(ii), 53.4 and 60.1(a-*bis*)).
9. ☐ It does not contain the required signature as specified in the Annex (Rules 53.2(b), 53.8, 60.1(a-*ter*) and 90.4).
10. ☐ Other observations *(if necessary)*:

Effects of the date of receipt of the corrections on the date of receipt of the demand:

(i) If the defect noted under item 1 is corrected within the time limit indicated above, the demand will be considered to have been received on the date when the corrections are received (Rule 60.1(b)).
If that date is later than the expiration of 19 months from the priority date, entry into the national phase before the elected Offices will **NOT** be postponed until the expiration of 30 months from the priority date, but only in respect of **some designated Offices.** In respect of **other designated Offices,** the time limit of 30 months (or later) may apply even if that date of receipt is later than the expiration of 19 months. See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicants's Guide*, Volume II, National Chapters and the WIPO Internet site.
If that date is later than the expiration of the time limit referred to in Rule 54*bis*.1(a), the demand shall be considered as if had not been submitted and this Authority shall so declare.

(ii) If the defects noted under items 2 to 9 are corrected within the time limit indicated above, the demand shall be considered as if it had been received on the actual filing date (Rule 60.1(b)).

Effect of failure to correct the defects within the time limit indicated above:

In the case of defects noted under items 1 to 9, this Authority will declare that the demand is considered as if it had not been submitted.

A copy of this Invitation has been sent to the International Bureau.

Name and mailing address of the IPEA European Patent Office D-80298 Munich Tel. (+49-89) 2399-0 Fax: (+49-89) 2399-4465	Authorized officer Appelen, Annik Tel: (+31-70)340-4846

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Form PCT/IPEA/404 (16 September 2012)

Exhibit 1027
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ANNEX TO
FORM PCT/IPEA/404

International application No.
PCT/IB2013/055305

Continuation of item 3: As to indications concerning **the agent** (Rules 53.2(a)(ii) and 53.5), the demand:

a. ☐ does not properly indicate the agent's name *(specify)*:

b. ☐ does not indicate the agent's address.

c. ☐ does not properly indicate the agent's address *(specify)*:

Continuation of item 4: As to indications concerning **the international application,** the demand does not indicate:

a. ☐ the international filing date.

b. ☐ the international application number.

c. ☐ the name of the receiving Office, where the international application number was not known to the applicant at the time the demand was filed.

d. ☐ the title of the invention.

Continuation of item 8: As to indications concerning **the applicant*** (Rules 53.2(a)(ii), 53.4 and 60.1(a-*bis*)), the demand:

a. ☒ does not indicate all the applicants.

b. ☐ does not properly indicate the applicant's name *(specify)*:

c. ☐ does not indicate the applicant's address.

d. ☐ does not properly indicate the applicant's address *(specify)*:

e. ☐ does not indicate the applicant's nationality.

f. ☐ does not indicate the applicant's residence.

* Although Rule 53.2(a)(ii) requires indications concerning the applicant, or if there are several applicants, of each of them, for the purposes of Rule 53.4, if there is more than one applicant, it shall be sufficient that the required indications be provided in respect of one of them who has the right according to Rule 54.2 to make a demand (Rule 60.1(a-*bis*)).

Continuation of item 9: As to requirements concerning **signature** (Rules 53.2(b), 53.8, 60.1(a-*ter*) and 90.4), the demand:

a. ☐ is not signed by the applicant or, if there is more than one applicant, by at least one of them*.

b. ☐ is signed by what appears to be an agent/common representative, but the demand is not accompanied by a power of attorney signed by at least one of the applicants.

* Although Rule 53.2(b) requires that all applicants must sign the demand, for the purposes of Rule 53.8, if there is more than one applicant, it shall be sufficient that the demand be signed by one of them (Rule 60.1(a-*ter*)).

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

To:

SHELSTON IP
60 Margaret Street
Sydney, NSW 2000
AUSTRALIE

NOTIFICATION OF RECEIPT OF DEMAND BY COMPETENT INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

(PCT Rules 59.3(e) and 61.1(b), first sentence and Administrative Instructions, Section 601(a))

Date of mailing *(day/month/year)*	28-04-2014
Applicant's or agent's file reference 74861WOP00	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB2013/055305	28 June 2013 (28-06-2013)	28 June 2012 (28-06-2012)

Applicant

Outotec Oyj et al.

1. The applicant is hereby **notified** that this International Preliminary Examining Authority considers the following date as the date of receipt of the demand for international preliminary examination of the international application:

22 April 2014 (22-04-2014)

2. This date of receipt is:

- [X] the actual date of receipt of the demand by this Authority (Rule 61.1(b)).
- [ ] the actual date of receipt of the demand on behalf of this Authority (Rule 59.3(e)).
- [ ] the date on which this Authority has, in response to the invitation to correct defects in the demand (Form PCT/IPEA/404), received the required corrections.

3. [X] **ATTENTION:** That date of receipt is **after** the expiration of 19 months from the priority date. Consequently, in respect of some Offices, the demand does not have the effect of postponing the entry into the national phase until 30 months from the priority date (or later in some Offices) (Article 39(1)) and the acts for entry into the national phase must therefore be performed within 20 months from the priority date (or later in some Offices). **However,** in respect of some other Offices, the time limit of 30 months (or later) may nevertheless apply. See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide,* Volume II, National Chapters and the WIPO Internet site.

- [ ] *(If applicable)* This notification confirms the information given by telephone, facsimile transmission or in person on:

4. Only where paragraph 3 applies, a copy of this notification has been sent to the International Bureau.

Name and mailing address of the IPEA	Authorized officer
European Patent Office D-80298 Munich Tel. (+49-89) 2399-0 Fax: (+49-89) 2399-4465	Appelen, Annik Tel: (+31-70)340-4846

Europäisches Patentamt • European Patent Office • Office européen des brevets

Form PCT/IPEA/402 (April 2002; reprint January 2004)

Exhibit 1027
FLS v. Metso - IPR2025-00985

Shelston ip

Confidential Facsimile Transmission

URGENT

To	International Preliminary Examining Authority European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk – Pays Bas THE NETHERLANDS
Attention	**Christophe Martin**
Facsimile No.	+31 70 340 3016
From	Andrew Lowe
Date Sent	22 April 2014
Our Reference	74861WOP00
Pages sent:	1+ 74

Message

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

We refer to this application in which the EPO is the International Searching Authority and has issued an ISR and Written Opinion dated 30 October 2013.

We now attach a Demand for International Preliminary Examinaiton, and a response to the Written Opinion with amendments under Article 34.

Please kindly acknowledge receipt of this facsimile by return fax (+61-2-92414666) or by email to AndrewLowe@ShelstonIP.com.

We look forward to receiving the Invitation to Pay the Prescribed fees and acknowledgement of the Demand for IPE and response.

Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ EP

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty.

For International Preliminary Examining Authority use only

Identification of IPEA IPEA/EP	Date of receipt of DEMAND 22-04-2014

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION		Applicant's or agent's file reference 74861WOP00
International application No. PCT/IB2013/055305	International filing date *(day/month/year)* 28 June 2013 (28.06.2013)	(Earliest) Priority date *(day/month/year)* 28 June 2012 (28.06.2012)
Title of invention Improvements in fluid bearings		

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*	Telephone No. 0011 358 205 29211
Outotec Oyj Puolikkotie 10 02230 Espoo Finland	Facsimile No. (358205) 292988
	Applicant's registration No. with the Office
☐ **E-mail authorization:** Marking this check-box authorizes the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send, if the Authority so wishes, advance copies of notifications in respect of this international application. *(See also the Notes to Box No. II.)*	E-mail address

State *(that is, country)* of nationality: FI	State *(that is, country)* of residence: FI

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

☐ Further applicants are indicated on a continuation sheet.

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Sheet No. 2.

International application No.
PCT/IB2013/055305

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is ☒ agent ☐ common representative

and ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.

☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*	Telephone No. (612) 9777 1111
Shelston IP 60 Margaret Street Sydney NSW 2000 AUSTRALIA	Facsimile No. (612) 9241 4666
	Applicant's registration No. with the Office
☒ **E-mail authorization:** Marking this check-box authorizes the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send, if the Authority so wishes, advance copies of notifications in respect of this international application. *(See also the Notes to Box No. II.)*	E-mail address email@ShelstonIP.com

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination **to start on the basis of:**

☐ the international application as originally filed

the description ☐ as originally filed
☒ as amended under Article 34

the claims ☐ as originally filed
☐ as amended under Article 19 (together with any accompanying statement)
☒ as amended under Article 34

the drawings ☒ as originally filed
☐ as amended under Article 34

2. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. ☐ Where the IPEA wishes to start the international preliminary examination at the same time as the international search in accordance with Rule 69.1(b), the applicant requests the IPEA **to postpone** the start of the international preliminary examination until the expiration of the applicable time limit under Rule 69.1(d).

4. ☐ The applicant expressly wishes the international preliminary examination **to start earlier** than at the expiration of the applicable time limit under Rule 54*bis*.1(a).

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

☒ which is the language in which the international application was filed.

☐ which is the language of a translation furnished for the purposes of international search.

☐ which is the language of publication of the international application.

☐ which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The filing of this demand constitutes the election of all Contracting States which are designated and are bound by Chapter II of the PCT.

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Sheet No. 3

International application No.
PCT/IB2013/055305

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

				For International Preliminary Examining Authority use only: received	not received
1.	translation of international application	:	sheets	☐	☐
2.	amendments under Article 34	:	sheets	☐	☐
3.	copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
4.	copy (or, where required, translation) of statement under Article 19	:	sheets	☐	☐
5.	letter	:	sheets	☐	☐
6.	other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ original separate power of attorney
3. ☐ original general power of attorney
4. ☐ copy of general power of attorney; reference number, if any:
5. ☐ statement explaining lack of signature
6. ☐ sequence listing in electronic form
7. ☐ other *(specify)*:

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).

Andrew Lowe
Shelston IP

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND: 22-04-2014

2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):

3. ☒ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply.
   ☒ The applicant has been informed accordingly.
4. ☐ The date of receipt of the demand is WITHIN the time limit of 19 months from the priority date as extended by virtue of Rule 80.5.
5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.
6. ☐ The date of receipt of the demand is AFTER the expiration of the time limit under Rule 54*bis*.1(a) and item 7 or 8, below, does not apply.
7. ☐ The date of receipt of the demand is WITHIN the time limit under Rule 54*bis*.1(a) as extended by virtue of Rule 80.5.
8. ☐ Although the date of receipt of the demand is after the expiration of the time limit under Rule 54*bis*.1(a), the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

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Claims

1. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

2. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

3. The bearing assembly of claim 1 or 2, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad.

4. The bearing assembly of claim 3, wherein said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base.

5. The bearing assembly of claim 4, wherein said flange is located at an outer edge of said base.

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6. The bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base.

7. The bearing assembly of claim 6, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess.

8. The bearing assembly of claim 6 or 7, wherein said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

9. The bearing assembly of claim 7, further comprising a plug for engagement with said head portion and said at least one recess.

10. The bearing assembly of claim 6, further comprising a locking element for retaining said at least one fastener within said at least one recess.

11. The bearing assembly of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

12. The bearing assembly of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

13. The bearing assembly of claim 12, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

14. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

15. The bearing assembly of any one of claims 1 to 13, wherein said outer surface is substantially planar.

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AMENDED SHEET 2014 06 57.53v. Metso - IPR2025-00985
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16. The bearing assembly of any one of the preceding claims, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

17. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

18. The bearing assembly of claim 17, wherein each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

19. The bearing assembly of any one of claims 1 to 16, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads, a first of said polymer bearing pads being mountable to said first surface and a second of said polymer bearing pads being mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

20. The bearing assembly of claim 19, wherein said first surface is orthogonal to said second surface.

21. The fluid bearing of claim 19 or 20, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic

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bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

22. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

23. The multidirectional fluid bearing of claim 22, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

24. The multidirectional fluid bearing of claim 22 or 23, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

25. The multidirectional fluid bearing of claim 24, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

26. The multidirectional fluid bearing of claim 22, wherein there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

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27. The multidirectional fluid bearing of claim 26, wherein each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

28. The multidirectional fluid bearing of any one of claims 22 to 27, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

29. The multidirectional fluid bearing of claim 28, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

30. The multidirectional fluid bearing of any one of claims 22 to 29, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

31. The multidirectional fluid bearing of claim 30, wherein said flange is located at an outer edge of said base.

32. The multidirectional fluid bearing of any one of claims 22 to 31, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

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Claims

1. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad ~~for a fluid bearing,~~ comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base ~~of said fluid bearing~~ and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

2. A bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

~~2.~~3. The ~~polymer bearing pad~~bearing assembly of claim 1 or 2, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad.

4. The ~~polymer bearing pad~~bearing assembly of claim ~~2~~ 3, wherein said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base.

~~3.~~5. The bearing assembly of claim 4, wherein said flange is located at an outer edge of said base.

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~~4.~~6. The ~~polymer bearing pad~~bearing assembly of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base.

7. The ~~polymer bearing pad~~bearing assembly of claim 6, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess.

~~5.~~8. The bearing assembly of claim 6 or 7, wherein said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

9. The bearing assembly of claim 7, further comprising a plug for engagement with said head portion and said at least one recess.

10. The bearing assembly of claim 6, further comprising a locking element for retaining said at least one fastener within said at least one recess.

~~6.~~11. The ~~polymer bearing pad~~bearing assembly of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

~~7.~~12. The ~~polymer bearing pad~~bearing assembly of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

~~8.~~13. The ~~polymer bearing pad~~bearing assembly of claim 12, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

~~9.~~14. The ~~polymer bearing pad~~bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

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~~10.~~15. The ~~polymer bearing pad~~bearing assembly of any one of claims 1 to 13, wherein said outer surface is substantially planar.

~~11. The polymer bearing pad of any one of the preceding claims, further comprising at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.~~

~~12. A fluid bearing for a journal, comprising:~~

~~a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and~~

~~the polymer bearing pad of any one of the preceding claims mountable to said base.~~

~~13. The fluid bearing of claim 12, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.~~

~~14. The fluid bearing of claim 13, wherein said flange is located at an outer edge of said base.~~

~~15.~~16. The ~~fluid bearing~~bearing assembly of any one of the preceding claims ~~10 to 14~~, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

~~16. The fluid bearing of any one of claims 10 to 15, further comprising at least one fastener for mounting said polymer bearing pad to said base, said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.~~

~~17. The fluid bearing of claim 16, wherein said at least one recess has a locking tab for retaining said head portion within said at least one recess.~~

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~~18. The fluid bearing of claim 16, further comprising a plug for engagement with said head portion and said at least one recess.~~

~~19. The fluid bearing of claim 16 or 18, further comprising a locking element for retaining said at least one fastener within said at least one recess.~~

~~20.~~17. The ~~fluid bearing~~bearing assembly of any one of the preceding claims ~~12 to 19~~, further comprising a plurality of said polymer bearing pads, wherein said respective outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

~~21.~~18. The ~~fluid bearing~~bearing assembly of claim 17, wherein each of said polymer bearing pads ~~-~~comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

~~22.~~19. The ~~fluid bearing~~bearing assembly of any one of claims 1 to ~~21~~ 16, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

wherein there is a plurality of said polymer bearing pads, a first of said polymer bearing pads ~~is~~being mountable to said first surface and a second of said polymer bearing pads ~~is~~being mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

~~23.~~20. The ~~fluid bearing~~bearing assembly of claim 19, wherein said first surface is orthogonal to said second surface.

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24.21. The fluid bearing of claim 19 or 20, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

~~25. The fluid bearing of any one of claims 12 to 21, wherein said fluid bearing is at least one of a radial hydrostatic bearing, a self-aligning radial hydrostatic bearing, a fixedly-mounted radial hydrostatic bearing, a hydrostatic slipper bearing, an axial bearing, a self-aligning axial hydrostatic bearing and a fixedly mounted axial hydrostatic bearing.~~

~~26. A method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.~~

~~27. The method of claim 26, wherein said mounting means forming step comprises machining said polymer pad to form a mounting portion extending from said polymer pad.~~

~~28. The method of claim 26, wherein said mounting means forming step comprises drilling, punching, cutting or machining an opening in said at least one recess to receive at least one fastener.~~

~~29. The method of claim 26 or 28, further comprising chamfering an outer edge of said polymer pad.~~

~~30. The method of any one of claims 26 to 29, wherein said at least one recess forming step comprises machining said at least one recess in said polymer pad and machining at least one interconnecting passage to interconnect said at least one recess to said base.~~

~~31. A method of making a fluid bearing for a journal, comprising:~~

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~~providing a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port and at least one flange;~~

~~making a polymer bearing pad in accordance with the method of any one of claims 26 to 30, and~~

~~mounting said polymer bearing pad to said base.~~

~~32. The method of claim 31, wherein said mounting step comprising mechanically fastening said polymer bearing pad to said base.~~

~~33. The method of claim 31 or 32, wherein there are a plurality of said polymer pads, said method further comprising connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal.~~

~~34. The method of claim 33, further comprising forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.~~

~~35. The method of claim 33 or 34, wherein said further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.~~

~~36. A fluid bearing for a journal, comprising:~~

~~a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and~~

~~a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,~~

~~said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.~~

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~~37. The fluid bearing of claim 36, wherein said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.~~

~~38. The fluid bearing of claim 36 or 37, wherein said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.~~

~~39.~~22. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to~~,~~ a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

~~40.~~23. The multidirectional fluid bearing of claim 22, said first polymer bearing pad substantially covers said first ~~outer~~ surface and said second polymer bearing pad substantially covers said second ~~outer~~ surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

~~41.~~24. The multidirectional fluid bearing of claim 22 or 23, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

~~42.~~25. The multidirectional fluid bearing of claim 24, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

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~~43. The multidirectional fluid bearing of any one of claims 39 to 42, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.~~

~~44. The multidirectional fluid bearing of any one of claims 39 to 43, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.~~

~~45. The multidirectional fluid bearing of any one of claims 39 to 42, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, and further comprising a locking element for retaining said at least one fastener within said at least one recess.~~

~~46.~~26. The multidirectional fluid bearing of ~~any one of~~ claim~~s~~ 22 ~~to 45~~, wherein there is a plurality of at least one of said first and second polymer bearing pads ~~comprises a plurality of said polymer bearing pads~~, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal.

~~47.~~27. The multidirectional fluid bearing of claim 26, wherein each of said plurality of at least one of said first and second polymer bearing pads ~~comprises~~ at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

28. The multidirectional fluid bearing of any one of claims 22 to 27, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab

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for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

29. The multidirectional fluid bearing of claim 28, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

~~48. The multidirectional fluid bearing of claim 39, wherein at least one of said first polymer bearing pad and said second polymer bearing pad comprises said polymer bearing pad of any one of claims 1 to 11.~~

~~49.~~30. The multidirectional fluid bearing of any one of claims 22~~48~~ to 29, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

~~50.~~31. The multidirectional fluid bearing of claim 30, wherein said flange is located at an outer edge of said base.

~~51. The multidirectional fluid bearing of any one of claims 39 to 50, wherein said first surface is orthogonal to said second surface.~~

~~52.~~32. The multidirectional fluid bearing of any one of claims 22 to ~~51~~31, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

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[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill bodya polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means for securely mounting said polymer bearing pad to said base.

[0010][0011] A second aspect of the present invention provides a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

[0011][0012] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in

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an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

[~~0012~~][0013] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[~~0013~~][0014] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[~~0014~~][0015] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[~~0015~~][0016] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[~~0016~~][0017] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[~~0017~~][0018] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[~~0018~~][0019] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately

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0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

~~[0019]~~[0020] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

~~[0020]~~[0021] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

~~[0021]~~[0022] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

~~[0022] According to a second aspect of the invention, there is provided a fluid bearing for a journal, comprising:~~

~~a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and~~

~~the polymer bearing pad of the first aspect of the present invention mountable to said base.~~

[0023] Preferably, ~~said polymer bearing pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect,~~ said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

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[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

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[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

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[0037] ~~According to a third aspect of the invention, t~~There is ~~provid~~disclosed a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] ~~According to a fourth aspect of the invention, there is provided~~Also disclosed is a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

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[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for connecting said polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] Also further disclosed is ~~ccording to a fifth aspect of the invention, there is provided~~ a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

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a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to a third ~~sixth~~ aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to~~,~~ a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

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[0053] Preferably, said first polymer bearing pad substantially covers said first ~~outer~~ surface and said second polymer bearing pad substantially covers said second ~~outer~~ surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, ~~least one of said first and second polymer bearing pads comprises~~ there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

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[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably, ~~said first surface is orthogonal to said second surface. In one preferred form~~, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

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[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

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[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

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[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

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[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The

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fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no

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pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23 also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil

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collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

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(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a "hovercraft" type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and

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installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the "lead-in" chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the "lead-in"

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chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the "lead-out" chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional

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manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased "off the shelf" in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining

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the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

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[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is

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running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

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[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing in a bearing assembly, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair.

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Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

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[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is mounted to said frame so that said fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body.

[0011] A second aspect of the present invention provides a bearing assembly for supporting a journal of a grinding mill body, comprising a frame and a plurality of fluid bearings, said fluid bearings each comprising a polymer bearing pad mounted to a base, said polymer bearing pad comprising an outer surface, at least one recess for receiving lubricating fluid from at least one passage of said base and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base, said base also comprising at least one lubricating fluid supply port in fluid communication with said at least one passage, wherein said base is fixedly mounted to said frame.

[0012] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

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[0013] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0014] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[0015] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0016] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0017] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0018] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0019] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

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[0020] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0021] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0022] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0023] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

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[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

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a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] There is disclosed a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

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[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] Also disclosed is a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for connecting said

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polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] Also further disclosed is a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

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[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to a third aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface orthogonal to a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first surface and said second polymer bearing pad substantially covers said second surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

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[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, there is a plurality of at least one of said first and second polymer bearing pads, wherein said respective outer surfaces of said plurality of at least one of said first and second polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said plurality of at least one of said first and second polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably,, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

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Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

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[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

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[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this

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embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

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[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

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[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23

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also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14. The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

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(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a "hovercraft" type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there

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is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both

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outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the "lead-in" chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the "lead-in" chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the "lead-out" chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

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[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased "off the shelf" in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and

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kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped

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recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from

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the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

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[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

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[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing in a bearing assembly, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the

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invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

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P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk – Pays Bas
THE NETHERLANDS

22 April 2014

Our Ref: 74861WOP00

Contact: Andrew Lowe

Attention: Christophe Martin

Dear Sirs

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

We refer to the First Written Opinion of the International Preliminary Examining Authority mailed on 30 October 2013 in respect of the above application.

Article 34 amendments

Pursuant to Article 34, the Applicant requires the International Preliminary Examining Authority to take into account the amendments on the enclosed replacement pages as set forth on the attached Statement of Amendments.

The proposed amendments have cancelled claims 11 to 13, 25, 26 to 38, 45, 48 and 51.

Claims 1 to 10 and 14 to 24 have been reworded and are now directed to a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising a base and the polymer bearing pad of original claim 1 mounted to the base. Support for this amendment is found at page 14, paragraph [0093] of the specification as filed

Claim 1 has also been amended claim to define that the base is mounted to the frame so that the fluid bearings self adjust to changes in the angular position of the journal during operation of the grinding mill body. Support for this amendment is found at page 14, paragraph [0094] of the specification as filed.

A new claim 2 has been added, which also defines a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising the polymer bearing pad of original claim 1 mounted to the base. New claim 2, however, defines that the base is fixedly mounted to the frame. Support for this amendment is found at page 24, paragraph [0113] of the specification as filed.

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com www.ShelstonIP.com fax +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

Exhibit 1027
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Claim 39 has been amended to include the subject matter of original claim 51, and has now been renumbered as claim 22. Support for this amendment is found at page 11, paragraph [0061] and page 25, paragraph [0114] of the specification as filed

As a result, claims 2 to 10, 14 to 24, 40 to 44, 46, 47, 49, 50 and 52 have been renumbered as new claims 3 to 21 and 23 to 32.

Some clarifying amendments have also been made to claims 20, 22, 40, 46 and 47, now new claims 17, 19, 23, 26 and 27.

It is submitted that the proposed amendments are supported by the specification as filed and favourable consideration is requested.

Response to written opinion

In response to the Written Opinion, the Applicant submits that invention as now claimed is novel and involves an inventive step over the cited prior art referred to in Box V, and the claims no longer have the clarity problems noted in Box VIII.

Box V - novelty and inventive step

Of the claims that are now pending in the international application, the following documents have been cited by the Examiner as being relevant to novelty and inventive step:

D1: DE 10 2007 039 364 (Metso Paper)

D2: WO 90/12216 (Vickers plc)

D3: JP 2006-9968A (Oiles Industry Co Ltd)

It is submitted that claims 1 to 21 are novel and involve an inventive step over the cited prior art. Independent claims 1 and 2 now define a bearing assembly comprising a frame and a plurality of fluid bearings, each fluid bearing comprising a polymer bearing pad mounted to a base.

Claim 1 further defines that the base is mounted to the frame so that the fluid bearings self adjust to changes in the angular position of the journal during operation of said grinding mill body. It is submitted that none of the cited prior art, especially D1, discloses or teaches this claimed feature.

D1 discloses a bearing pad 30 for a flexible sheet 10 forming a nip with a roller 2 in a paper or cardboard making machine. The bearing pad is mounted on a shoe 5, 31 that is supported by a piston 4 movably located in a shaft or axle 3. The axle 3 has a central well 15' that acts as a supply for lubricating fluid to be delivered to recesses 22 in the pad 30. The piston 4 operates to move the bearing pad 30 and shoe 5, 31 in a radial direction into engagement the flexible sheet 10, thus applying a pressure or force to the sheet 10 against the nip roller 2.

As such, it is submitted that any movement of the roller 2 relative to the sheet 10 and bearing pad 30, including its angular position, can only be adjusted for by operating the piston 4 so that the bearing pad 30 re-engages the roller 2 and pinch the flexible sheet 10. Hence, it is submitted that changes in angular position need to be manually corrected by operating the piston 4 – the fluid bearing comprising the bearing pad 30 and the shoe 5, 31 cannot correct for changes in the angular position of the roller 2 on its own. As a consequence, the fluid bearing does not stabilise the sheet 10 or roller 2 in an axial position, but rather allows the sheet 10 to "float" on the axle part 3 and applies a force to the internal surface of the sheet 10 so that a pressure is maintained against the roller 2.

By way of contrast, the bearing assembly of the claimed invention has the base of the fluid bearing mounted to the frame so that the fluid bearing self-adjusts to changes in the angular position of the journal shaft 4; ie. the fluid bearing is self-aligning on its own in response to movements of the journal shaft 4. Thus, the bearing assembly of the claimed invention acts to positively locate the supported journal shaft 4 in a fixed position such that mating precision components can be correctly located. As a consequence, the invention of claim 1 has the technical advantage of avoiding the need for manual

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adjustment in response to changes in the angular position of the journal or a mechanical device such as a piston to perform that adjustment.

It is submitted that the skilled person would not be able to modify the arrangement of D1 to arrive at the technical solution defined in amended claim 1, since this would involve substantial redesign to take into account the removal of the piston arrangement disclosed in D1. Furthermore, it is submitted that there is no teaching in D1 that would motivate the skilled person to consider or attempt such a modification of such a central element of the designed bearing arrangement as taught in that document. Thus, it is submitted that claim 1 has an inventive step over D1.

Likewise, claim 2 defines that the base is fixedly mounted to the frame, whereas in D1 the shoe 5, 31 is able to move in a radial direction relative to the shaft 3 via the piston 4. Therefore, it is submitted that D1 fails to teach the technical solution proposed by claim 2, and in fact teaches the opposite arrangement – a moveable mounting of the shoe 5, 31 to the "base", being the shaft 3. Thus, for the same reasons outlined above, it is submitted that claim 2 also has an inventive step over D1.

Since the teaching in D3 relates only to particular fastening arrangements for mounting the bearing pad to the base, it is submitted that a combination of D1 with D3 would also fail to render the claimed invention obvious for the same reasons stated above.

Thus, it is submitted that claims 1 to 21 involve an inventive step over the cited prior art.

In relation to claims 22 to 32, it is also submitted that these claims involve an inventive step over D1 and D2, the Examiner having previously conceded that original claim 39 was novel.

Claim 22 now includes the subject matter of original claims 39 and 51. It is submitted that a combination of D1 and D2 fails to disclose or teach the claimed multidirectional fluid bearing having polymer bearing pads mounted to orthogonal surfaces of a base.

D1 only discloses a polymer bearing pad that supports a load in a single radial direction. Therefore, there is no disclosure or teaching of using the polymer bearing pad for supporting loads in multiple directions.

D2 describes a thrust bearing or shoe and particular reference is made to Figure 4 which shows multiple bearings 10a, 10b arranged on a thrust ring or disc that rotates with a shaft. The shoes or bearing pads 10a, 10b are arranged on opposite faces of the disc 44. Thus, in D2 the surfaces supporting the bearing pads face in opposing directions and are in axial alignment (ie. coaxial). Therefore, there is no disclosure or teaching of an orthogonal arrangement of the surfaces upon which are mounted the bearing pads.

Hence, it is submitted that a combination of D1 and D2 would not lead the skilled person to the claimed invention. It is submitted that the skilled person reading D1 and D2 would simply mount the polymer bearing pads on the opposed, axially aligned surfaces taught in D2, rather than arrive at the multidirectional bearing as now claimed.

It is also submitted that there is no motivation for the skilled person to modify the coaxial arrangement of the surfaces in D2 to orthogonal surfaces because there is no teaching or suggestion to do so in either D1 or D2, especially as D2 is solely concerned with axial loads (albeit in opposite directions) along the single, same axis.

By contrast, the multidirectional fluid bearing of claim 22 is concerned with supporting loads from orthogonal directions, particularly the radial and axial loads of a journal shaft connected to the mill body.

Thus, it is submitted that D1 and D2 would teach away from the claimed invention. Therefore, it is submitted that claims 22 to 32 involve an inventive step over the cited prior art.

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Box VIII – certain observations

It is submitted that the cancellation of claims 35, 36, 45 and 48 have rendered the objections at items 14.3, 14.4, 14.6 and 14.8 moot.

In relation to items 14.1 and 14.2, it is submitted that the redefinition of claim 1 as a bearing assembly comprising, *inter alia*, a polymer bearing pad and base has resolved the objections against claims 6, 15 and 16 (now claims 11, 16 and 8, respectively).

Similarly, it is submitted that the amendments to claim 40 (now claim 23) have overcome the objection at item 14.5 by correcting the references to "first outer surface", "second outer surface" and "said polymer bearing pad" to "first surface", "second surface" and "said second polymer bearing pad", respectively.

In reply to item 14.7, claim 46 (now claim 26) has clarified that there is a plurality of at least one of the first and second polymer bearing pads. Accordingly, it is submitted that this objection has now been overcome.

Thus, in conclusion, it is submitted that all of the observations made in Box VIII have now been resolved.

Closing comments

As the Examiner's objections have now been overcome, the Applicant requests a clear and favourable International Preliminary Report on Patentability.

Yours respectfully
Shelston IP



Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

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THE NETHERLANDS

22 April 2014

Our Ref: 74861WOP00

Attention: Christophe Martin

Contact: Andrew Lowe

PCT Patent Application No. PCT/IB2013/055305
Applicant: Outotec Oyj
Title: Improvements in fluid bearings

STATEMENT OF AMENDMENTS – ARTICLE 34

Complete Specification

Description

1. Cancel pages 3 to 28 now on file and replace with new pages 3 to 28.

Claims

2. Cancel pages 29 to 36 now on file and replace with new pages 29 to 33.

DATED this 22nd day of April 2014
OUTOTEC OYJ

Andrew Lowe
Registered Patent Attorney
Email: *AndrewLowe@ShelstonIP.com*

Sydney
Level 21
60 Margaret Street
Sydney, NSW 2000
Australia
T +61 2 9777 1111

Brisbane
7 Clunies Ross Court
Brisbane Technology Park
Eight Mile Plains, QLD 4113
Australia
T +61 7 3147 8020

Newcastle
Level 1, IDC House
University Drive
Callaghan, NSW 2308
Australia
T +61 2 4921 7366

Auckland
Level 13, AA Building
99 Albert Street
Auckland 1010
New Zealand
T +64 9 638 5300

email@ShelstonIP.com **www**.ShelstonIP.com **fax** +61 2 9241 4666
Australian and New Zealand Patent and Trade Mark Attorneys in association with Shelston IP Lawyers

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I, ALITA CLARK, PATENT AND PLANT BREEDERS RIGHTS ADMINISTRATION (PPBRA) hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2012902770 for a patent by OUTOTEC OYJ as filed on 28 June 2012.

WITNESS my hand this
Second day of July 2013

ALITA CLARK
PATENT AND PLANT BREEDERS
RIGHTS ADMINISTRATION (PPBRA)

2012902770 28 Jun 2012

AUSTRALIA

PATENTS ACT 1990

PROVISIONAL SPECIFICATION

FOR THE INVENTION ENTITLED:-

"Improvements in fluid bearings"

The invention is described in the following statement:-

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Field of the Invention

[0001] The present invention relates to a fluid bearing and in a particular a hydrostatic polymeric bearing for use in a mill. The invention has been developed primarily for use as a hydrostatic polymeric bearing in grinding mills and will be described hereinafter by reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use, but also extends to other types of fluid bearings such as hydrodynamic bearings and hybrid bearings (i.e. bearings that use a combination of hydrodynamic and continuous hydrostatic flow for lubrication).

Background of the Invention

[0002] The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its advantages to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an express or implied admission that such art is widely known or forms part of common general knowledge in the field.

[0003] A grinding mill has a mill chamber and two journal shafts, the journals being mounted upon supports for rotation. Typical bearings have two main components; a steel base for mounting to the support and a bearing pad or surface for contact with the mill journal. These mill bearings are installed between the mill journals and the supports so that the mill journals rotate on the bearing pads during operation of the grinding mill.

[0004] The applicant developed a hydrostatic pad bearing system for grinding mills that is currently in use. In this hydrostatic pad bearing system, an external oil supply system pumps high-pressure oil to recesses machined into the bearing so that the oil forms a thin film on the bearing pad surface. The resultant hydraulic pressure is sufficient to completely lift the mill journal off the hydrostatic pads and separate the sliding surfaces. Thus, mill actually "floats" on a film of oil between journal and bearing. As such the bearing will operate under both static and dynamic conditions. Since the surfaces are completely separated and the bearing is self aligning there is no metal-to-metal contact between the bearing surface and the mill journal due to the oil film, thus

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resulting in only low friction. Consequently, maintaining the oil film between the surfaces means that there is virtually no wear in the bearing.

[0005] Despite the advantages conferred by this hydrostatic bearing system, a loss of oil pressure (and thus a reduction in the oil film thickness) can cause failure of the bearings, leading to damage to the bearing pad and/or the mill journal. For example, it can take a few seconds for a grinding mill to stop turning in the event of a power failure, and when this happens there is a high risk of damage to the mill bearing pads or journal surfaces due to a loss of oil reducing the oil film thickness, thereby bringing the journal and bearings into direct metal to metal contact. The consequential downtime for replacement of any damaged bearings and/or journals severely impairs operation of the mill, reducing its efficiency.

[0006] To prevent this type of damage, grinding mill lubrication systems usually have pressure accumulator systems that are typically used to store and deliver high pressure oil to the bearing in the event of a power failure and the oil supply system fails. These pressure accumulators are expensive, require frequent maintenance to ensure that they are at the appropriate pressure level and can interfere with control systems in the mill. Thus, there are increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and then the oil supply ports for delivering high pressure oil to the recesses are then drilled into the base. Bronze is spray welded or cast onto the relevant parts of the steel base to form the bearing pad or lining. Spray welding enables the bronze metal to form a seal with the base. White metal may be used instead of bronze, but is cast onto the base. Due to this manufacturing process, the repair and/or refurbishment of these bearings involves initially cleaning the damaged bearing surface, machining any parts of the steel base and either spray welding the bronze or re-casting the bronze/white metal. This repair process cannot be performed on-site but requires the bearing to be returned to the manufacturer. Consequently, mills must keep a sufficient stock of spare bearings to account for the absence of damaged bearings being repaired. This adds to the maintenance costs of the mill.

[0008] It is an object of the present invention to overcome or substantially ameliorate one or more of the disadvantages of prior art, or at least to provide a useful alternative.

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[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a polymer pad for a fluid bearing, comprising an outer surface and at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, wherein said polymer pad is mountable to said base.

[0011] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

[0012] Preferably, said polymer pad substantially covers an outer surface of said base to create a fluid seal between said polymer pad and said base.

[0013] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0014] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0015] Preferably, said polymer pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0016] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

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[0017] Preferably, said polymer pad comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0018] Preferably, said polymer pad comprises at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In a particularly preferred form, each of said polymer pads has at least one lateral connecting portion.

[0019] Preferably, said polymer pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0020] According to a second aspect of the invention, there is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer pad mountable to said base, said polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface.

[0021] Preferably, said polymer pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0022] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0023] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic

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bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0024] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0025] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0026] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0027] Preferably, said at least one fastener is substantially retained within said recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0028] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0029] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion.

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[0030] Preferably, said base further comprises a first surface, a second surface and a plurality of said passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface, and

said polymer pad comprises a first polymer pad mountable to said first surface and a second polymer pad mountable to said second surface,

wherein said first polymer pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0031] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0032] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0033] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0034] According to a third aspect of the invention, there is provided a method of making a polymer bearing pad for a fluid bearing, comprising the steps of forming a polymer pad having an outer surface and forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface.

[0035] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

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[0036] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0037] According to a fourth aspect of the invention, there is provided a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer pad to said base.

[0038] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0039] Preferably, said mounting step comprising mechanically fastening said polymer pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0040] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer pads such that said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer pad for connecting said polymer pad to an adjacent polymer pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer pad.

[0041] Preferably, said forming step further comprises the steps of selecting one or more polymer pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer pad.

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[0042] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0043] According to a fifth aspect of the invention, there is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0044] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0045] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer pad.

[0046] Preferably, the bearing pad is composed of a polymer material. More preferably, the polymer material includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0047] Preferably, said fluid bearing is a hydrostatic bearing.

[0048] According to a sixth aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

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a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0049] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0050] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0051] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0052] Preferably, said first polymer pad and said second polymer pad have the preferred features of the abovementioned aspects of the invention.

[0053] Preferably, said lubricating fluid includes oil or water.

Brief Description of the Drawings

[0054] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0055] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0056] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

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[0057] Figure 3 is a front view of the bearing assembly of Figure 2;

[0058] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0059] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0060] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0061] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0062] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0063] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0064] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0065] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0066] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0067] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0068] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0069] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

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[0070] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0071] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0072] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0073] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0074] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0075] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0076] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0077] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0078] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0079] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0080] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

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[0081] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0082] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0083] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0084] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0085] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

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[0086] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A.

[0087] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0088] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1.

[0089] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[0090] A bolt 23 used to mount the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal

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hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings.

[0091] The bolt 23 is inserted into the oil gallery 16 and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[0092] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[0093] In either fastening arrangement, separate sealing threads 35 and O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A.

[0094] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. For example, a pump could provide oil to two or more bearings 11, 12 in parallel using relief valves also in parallel, through which a flow of oil maintains a constant pressure to the bearing pads

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17. This arrangement tends to facilitate load sharing between the bearings 11, 12 and maintains a constant bearing pressure rather than a fairly constant lubricant film thickness. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[0095] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the shock and so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[0096] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate any surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or

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desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a "hovercraft" type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen any excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism

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(such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[0097] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also the damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[0098] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[0099] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the "lead-in" chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A,

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13B of the hydrostatic bearing. The inventors believe that the oil held by the "lead-in" chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the "lead-out" chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional

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manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased "off the shelf" in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

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[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either fastener system as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are glued together so that the slats 55 to form a complete polymer pad 17. In this variation, each polymeric slat 55 is cleaned and their outer surfaces are roughened by way of cut-wire blasting to form the teeth 56. The polymer pads 55 are then mounted to the base 14 using either fastener system as described in relation to Figures 4 to 10. Once in position, glue is applied at adjacent surfaces of the polymer slats and their teeth 56. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing that such bearings are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that by segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50, this reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

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[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the

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polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

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[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0121] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0122] By providing a polymer bearing pad for a hydrostatic bearing, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of mechanical fasteners to mount the polymer pad 17 to the base 14.

[0123] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use

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of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0124] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0125] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

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Claims

1. A polymer pad for a fluid bearing, comprising an outer surface and at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, wherein said polymer pad is mountable to said base.

2. A fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer pad mountable to said base, said polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface.

3. A method of making a polymer bearing pad for a fluid bearing, comprising the steps of forming a polymer pad having an outer surface and forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface.

4. A method of making a fluid bearing for a journal, comprising:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer pad to said base.

5. A fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

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6. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

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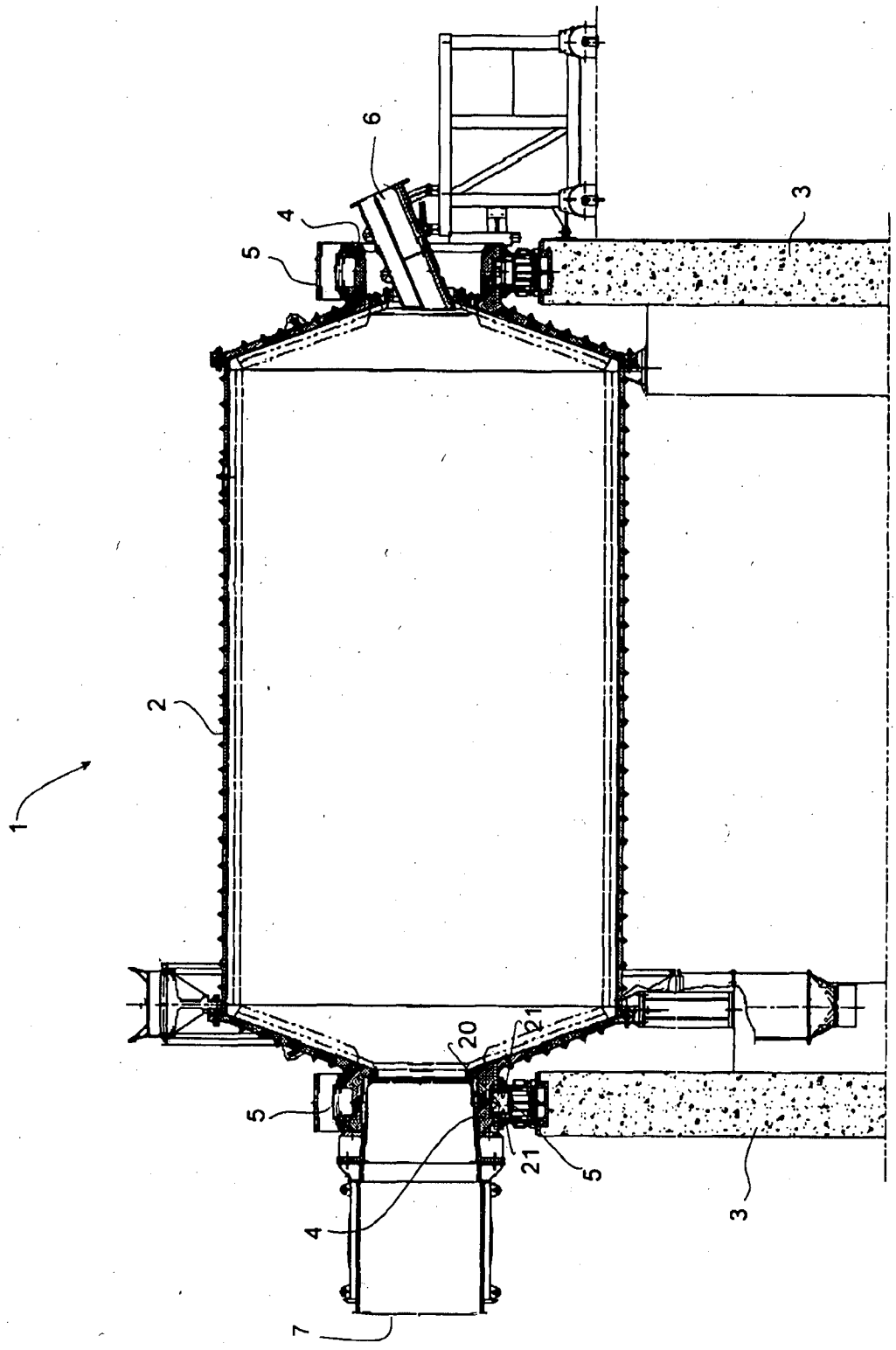


Fig. 1

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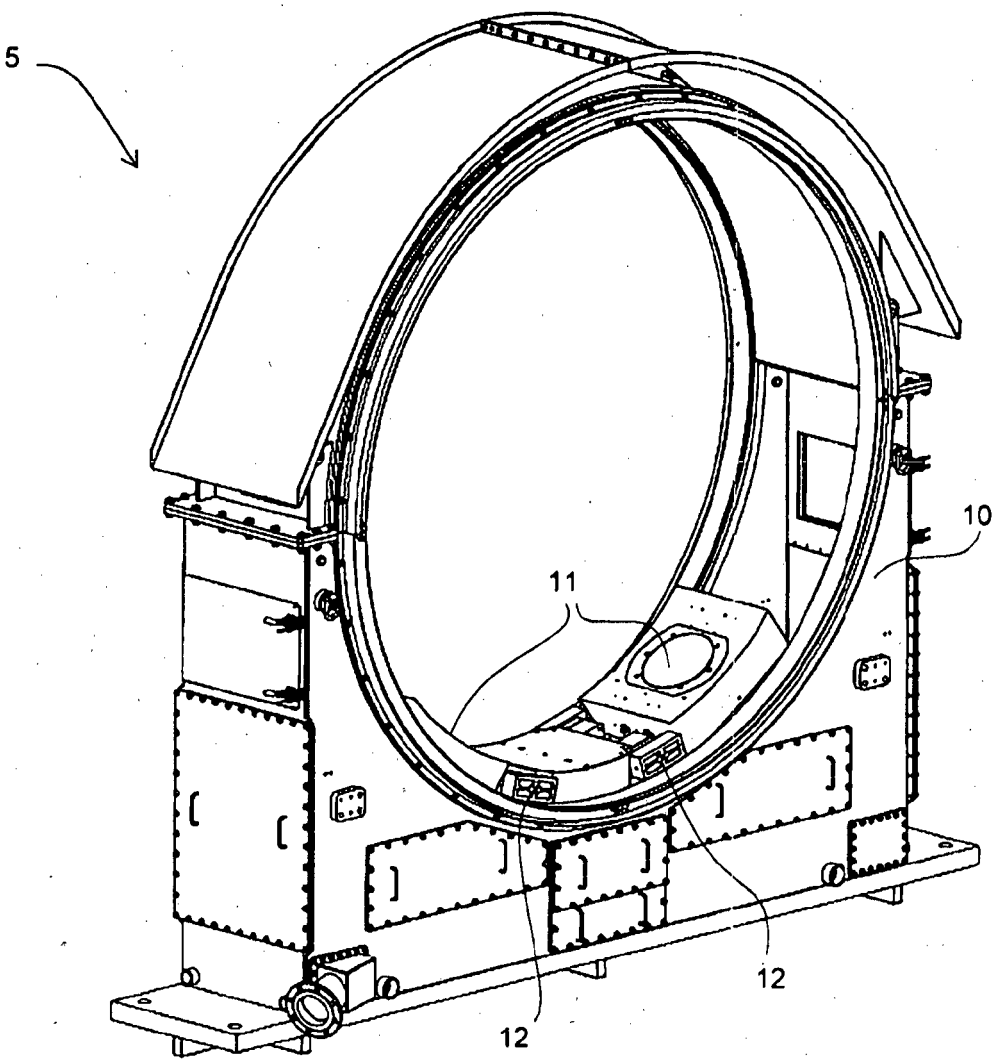


Fig. 2

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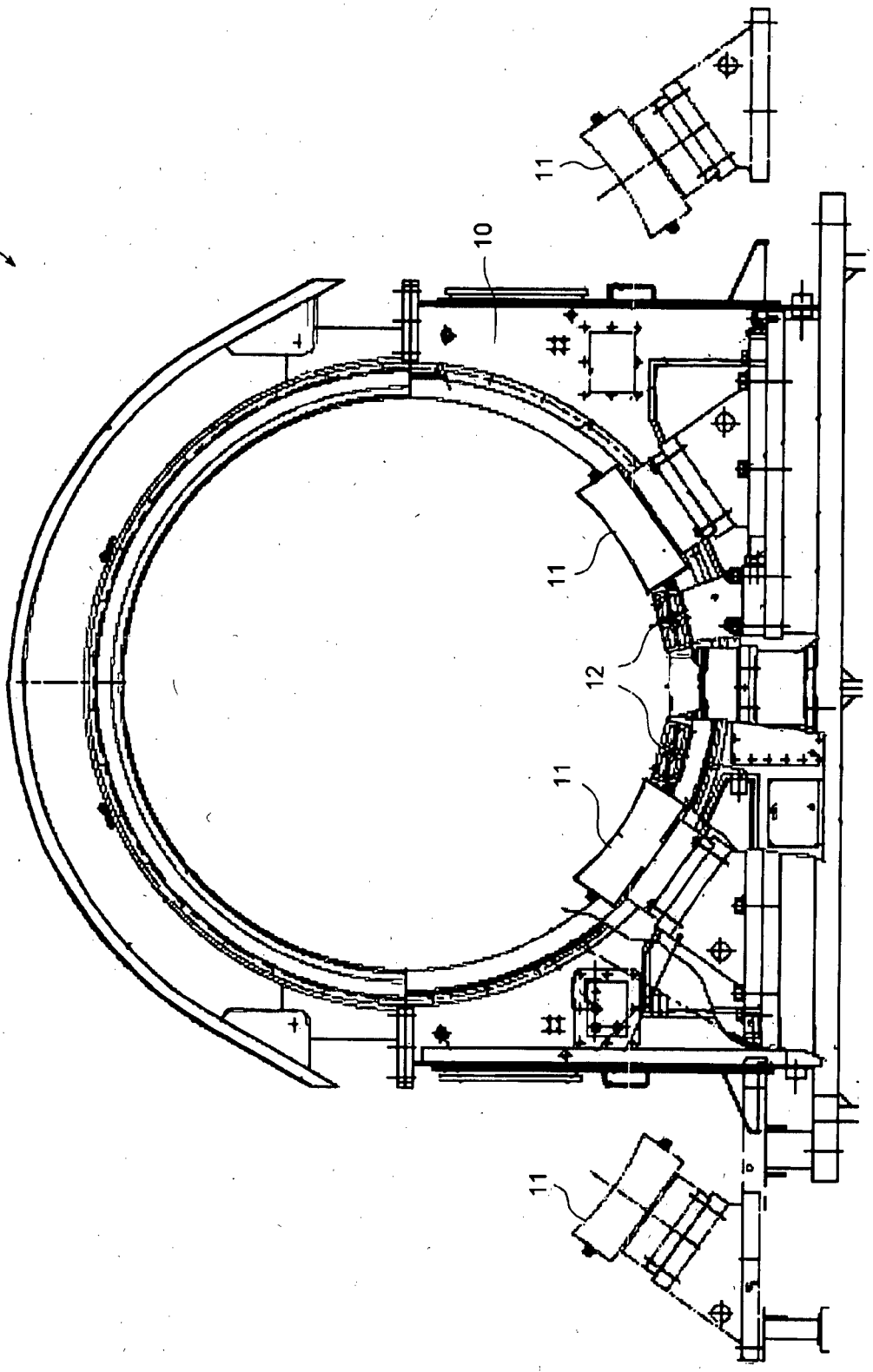


Fig. 3

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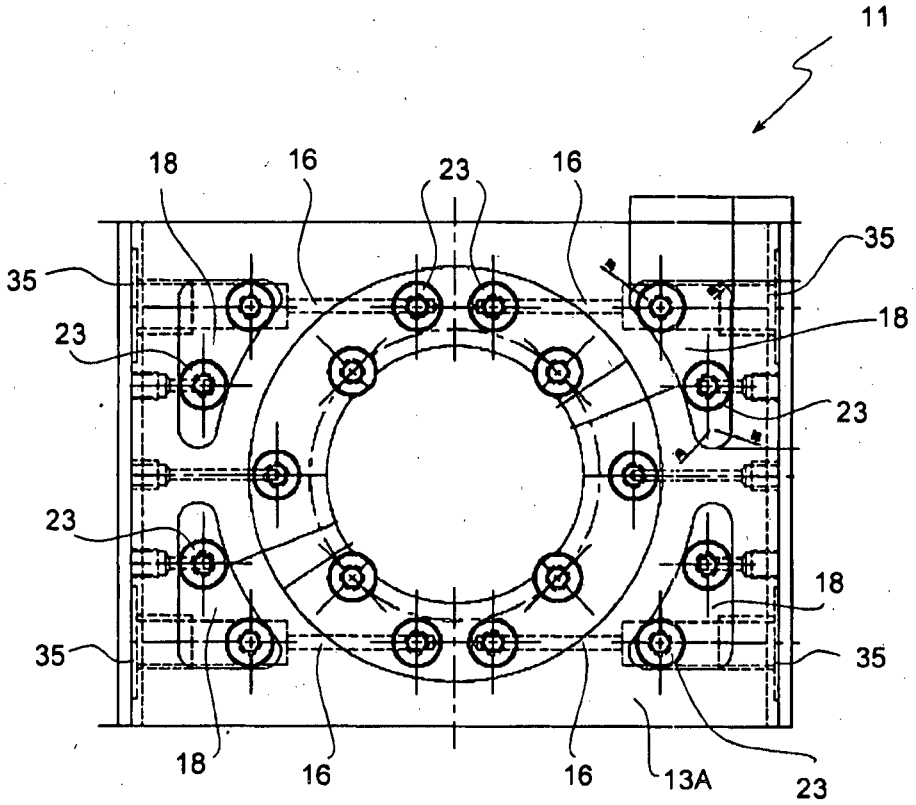


Fig. 4

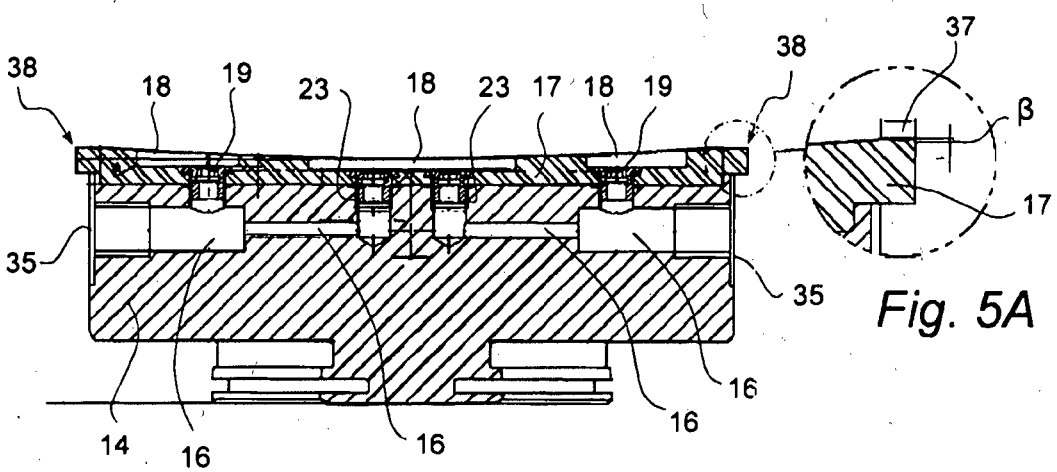


Fig. 5A

Fig. 5

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2012902770

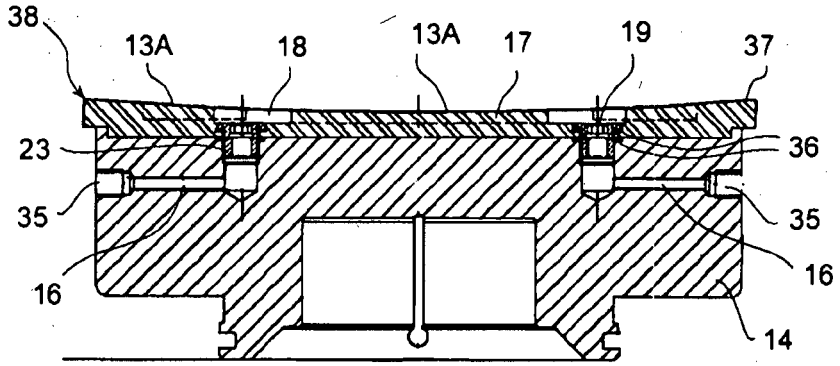


Fig. 6

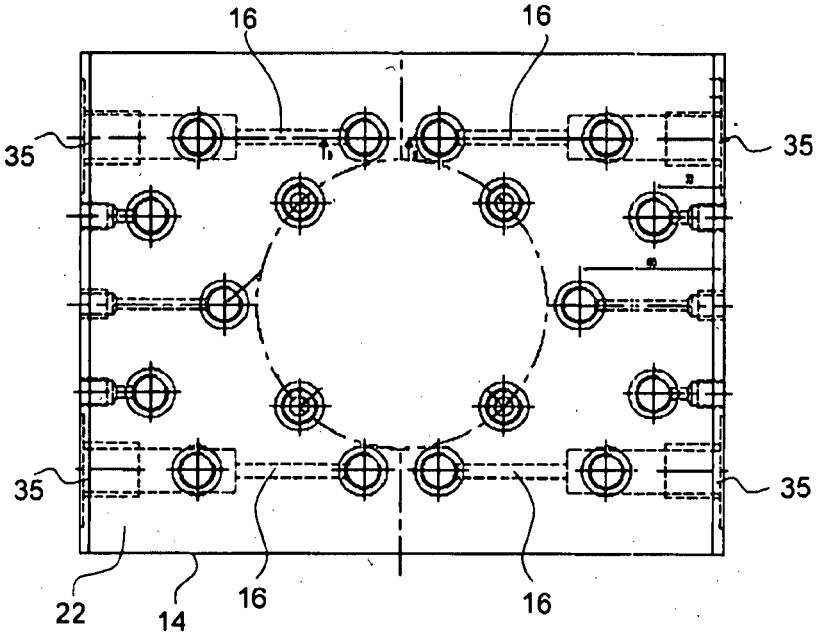


Fig. 7

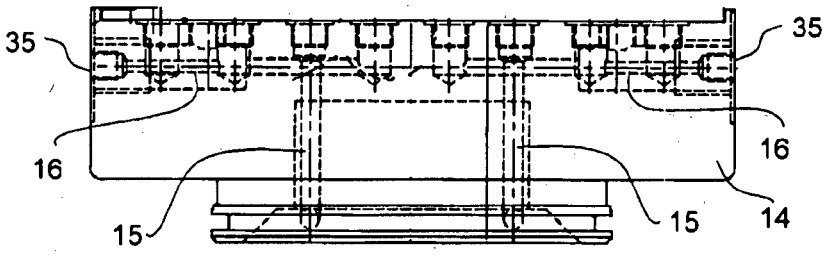


Fig. 8

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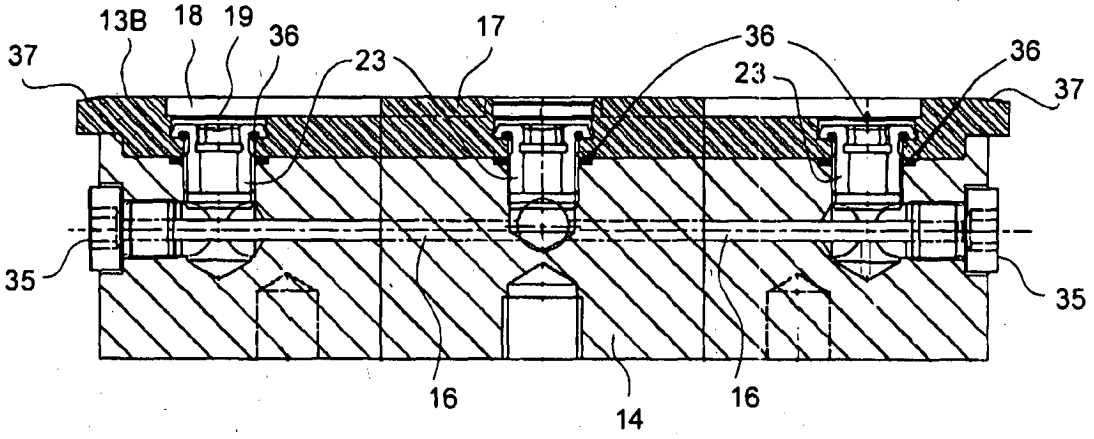


Fig. 9

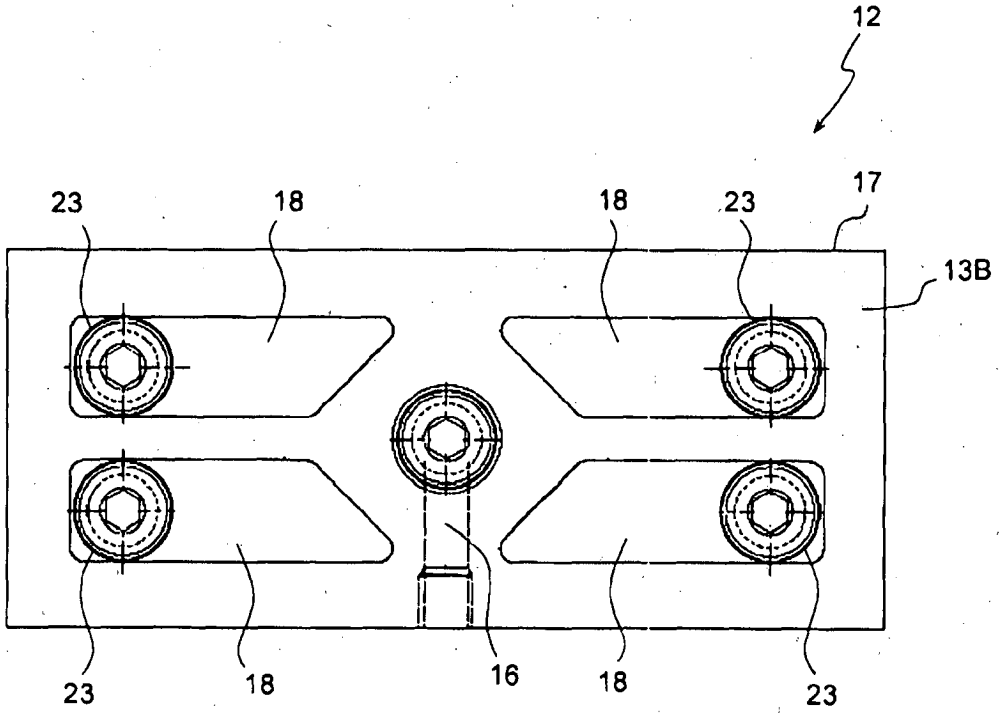


Fig. 10

Exhibit 1027
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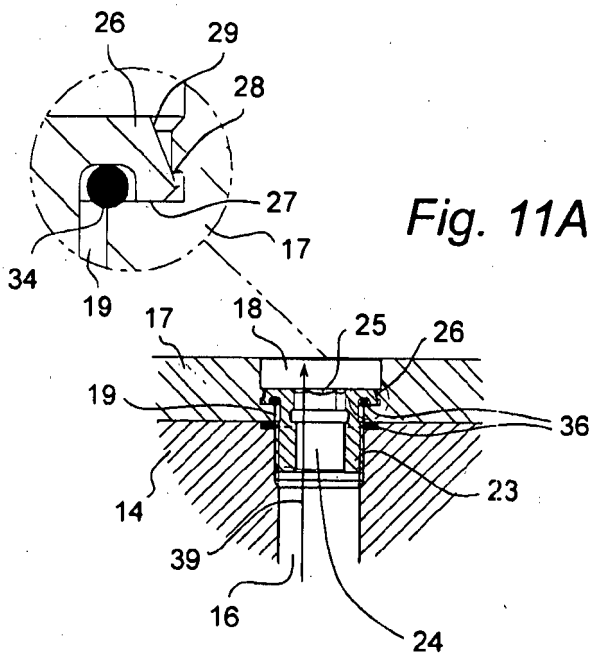


Fig. 11A

Fig. 11

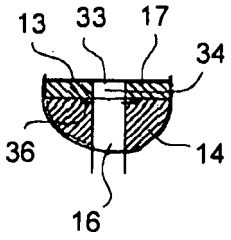


Fig. 12A

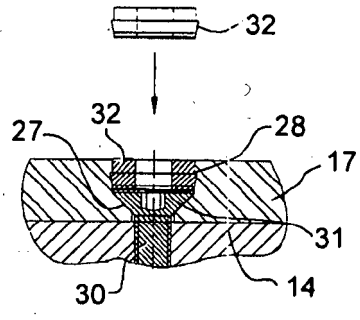


Fig. 12

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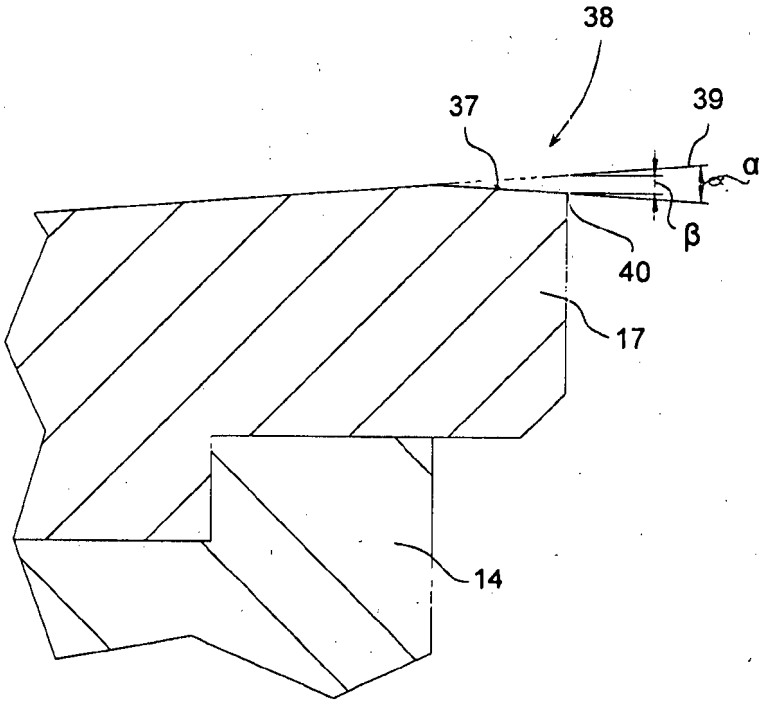


Fig. 13

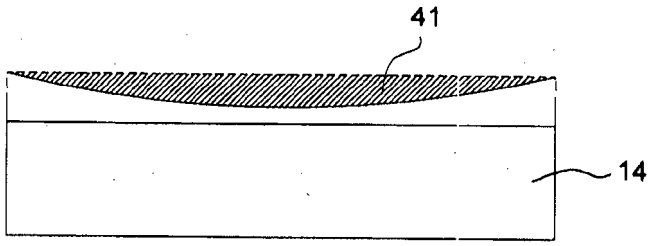


Fig. 14

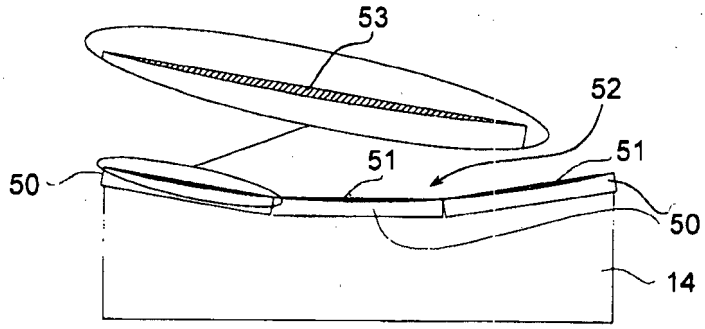


Fig. 15

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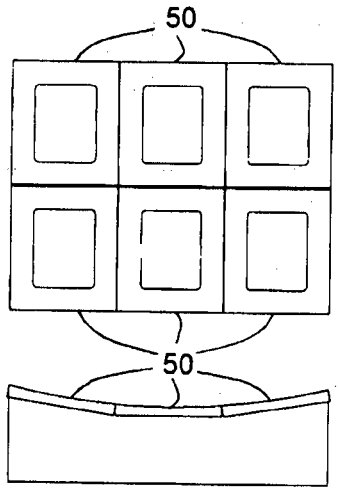


Fig.16

Fig.16A

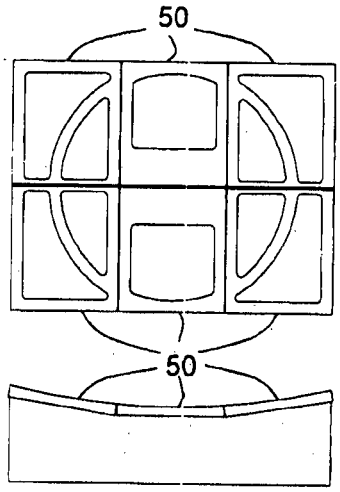


Fig.17

Fig.17A

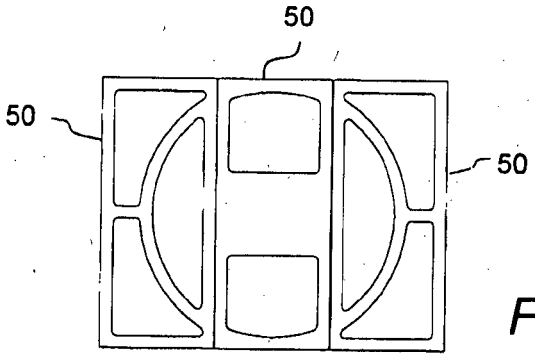


Fig. 18

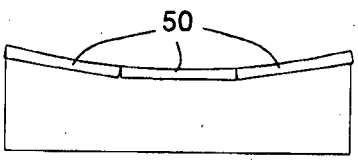


Fig. 18A

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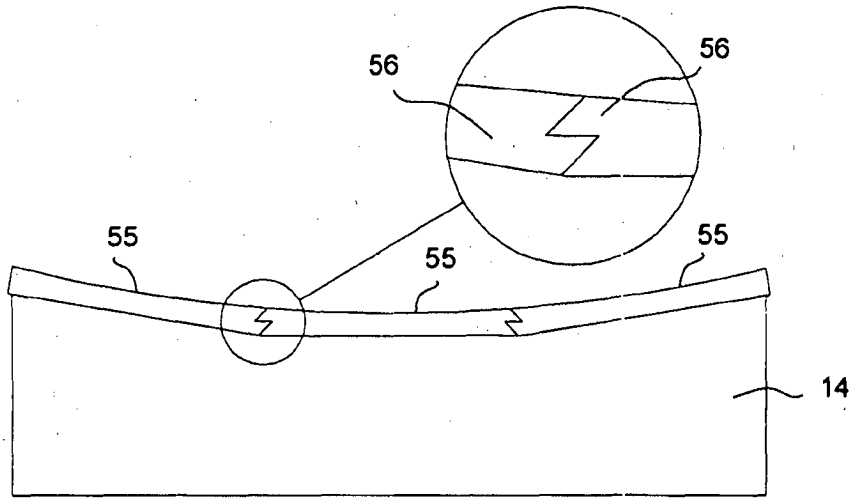


Fig. 19

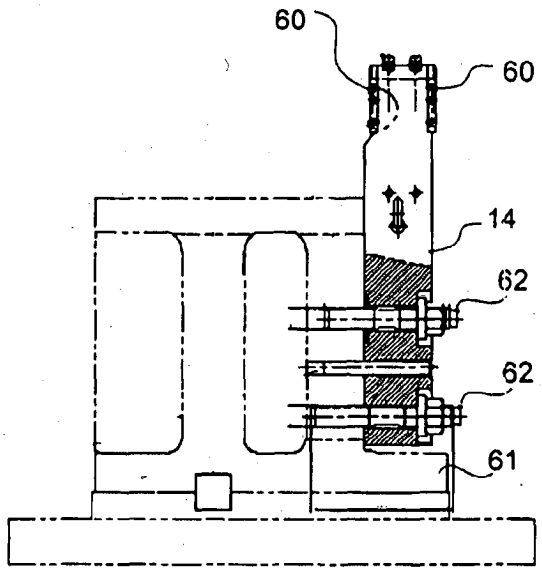


Fig. 22

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Fig. 21

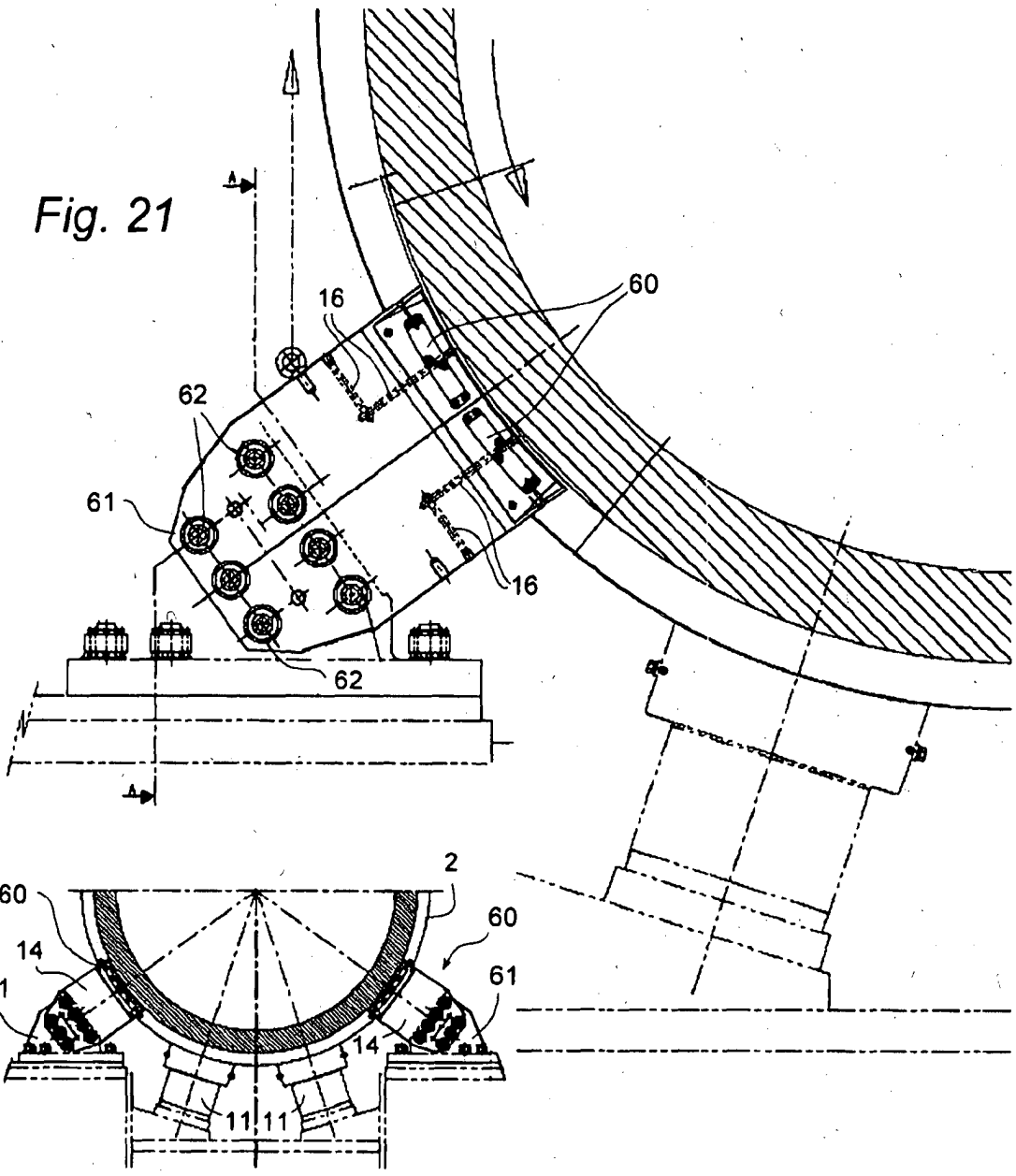


Fig. 20

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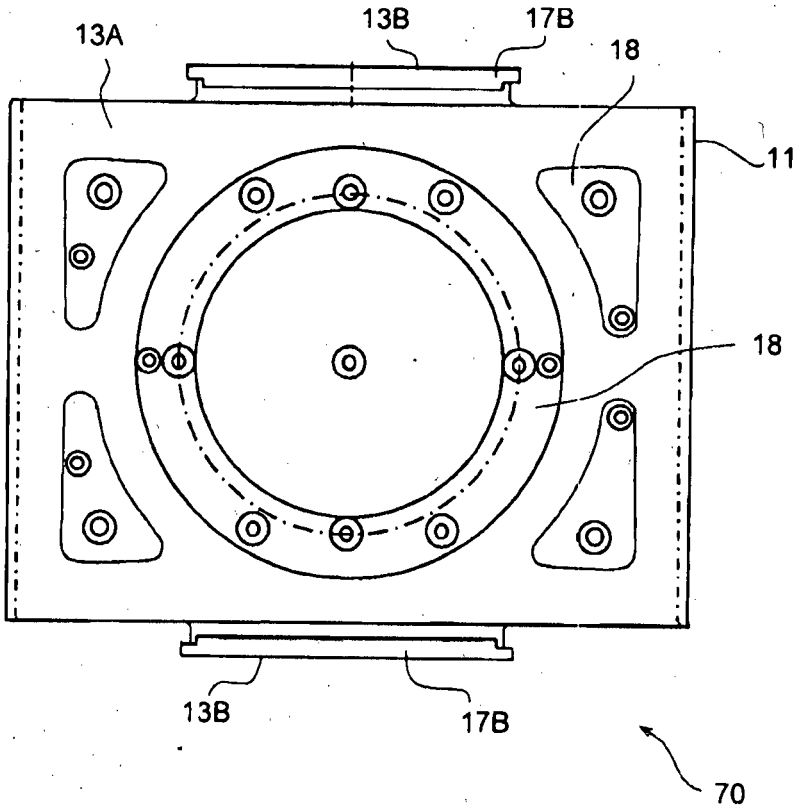


Fig. 23

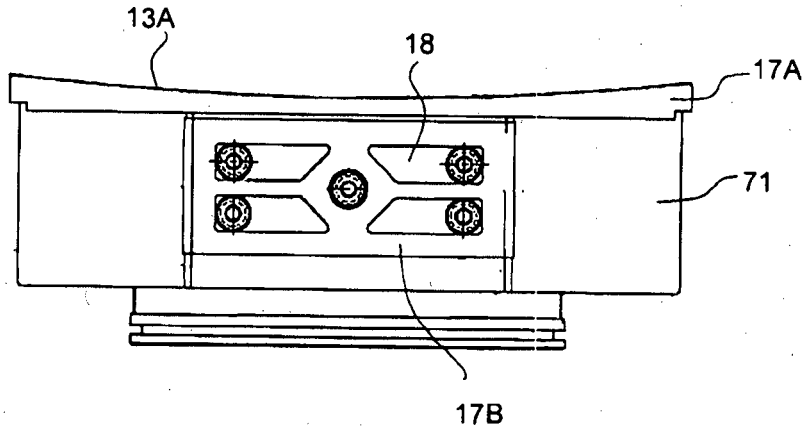


Fig. 24

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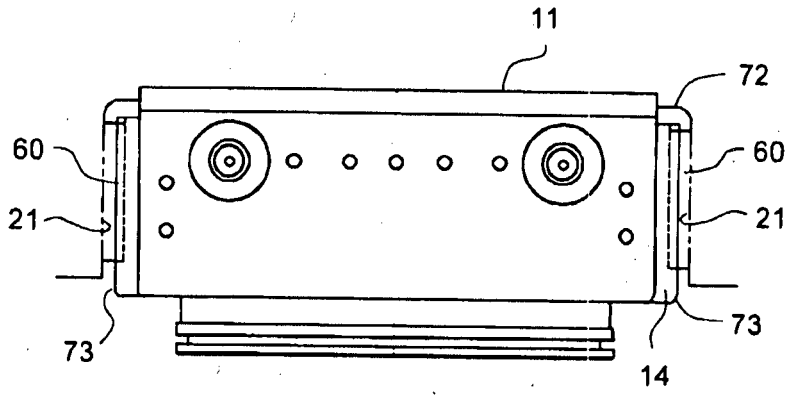


Fig. 25

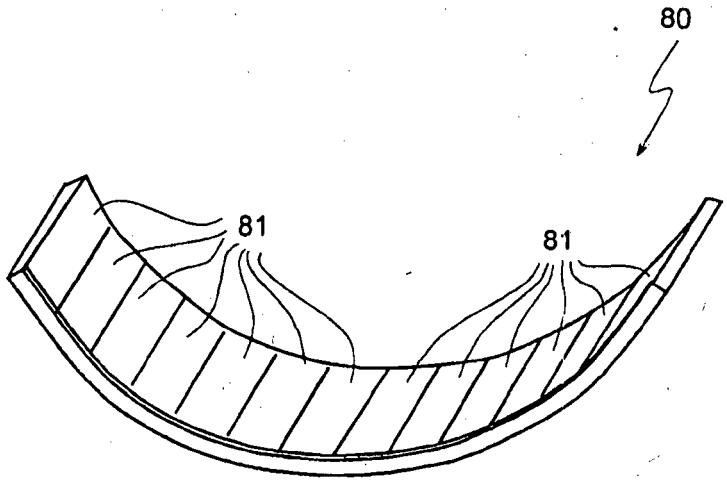


Fig. 26

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/055305

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16C32/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2007 039364 A1 (METSO PAPER INC [FI]) 6 March 2008 (2008-03-06)	1-4,6-9, 12-16, 18, 25-32, 36,38
Y	page 4, right-hand column, line 27 - line 30 paragraph [0025]; figures 3A-4C	5,10,11, 17, 19-24, 33-35, 39-52

Y	WO 90/12216 A1 (VICKERS PLC [GB]) 18 October 1990 (1990-10-18)	10,20, 22-24, 39-42, 44,46, 48-52
	page 9, line 20 - line 36; claims 1-3,9-14; figures	

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 October 2013	30/10/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Martin, Christophe

Exhibit 1027
FLS v. Metso - IPR2025-00985

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006 009968 A (OILES INDUSTRY CO LTD) 12 January 2006 (2006-01-12) paragraph [0027] - paragraph [0028]; figures 1-3	5,17,19, 43,45
Y,P	WO 2012/145217 A1 (US SYNTHETIC CORP [US]; COOLEY CRAIG H [US]; SEXTON TIMOTHY N [US]) 26 October 2012 (2012-10-26) page 2, line 19 - page 3, line 3; figures 1c-3	11,21, 33-35,47

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2013/055305

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 9, 10, 12-20, 24-28, 30-33, 40, 43-46, 49, 50, 52

   Bearing pad, bearing and method characterized by mounting means.

   ---

2. claims: 7-10, 20, 24, 25, 29, 30, 33, 35-38, 40-42, 46, 52

   Bearing pad, bearing and method characterized by a chamfer.

   ---

3. claims: 9-11, 20, 21, 24, 25, 30, 33, 34, 40, 46, 47, 52

   Bearing pad, bearing and method characterized by lateral connecting portions.

   ---

4. claims: 9, 10, 20, 22-25, 30, 33, 39, 40, 46, 48, 51, 52

   Bearing pad, bearing and method characterized by first and second surfaces of the bearing base.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102007039364 A1	06-03-2008	AT 504091 A2	15-03-2008
		DE 102007039364 A1	06-03-2008
		FI 20065532 A	29-02-2008
WO 9012216 A1	18-10-1990	AU 5419590 A	05-11-1990
		EP 0466762 A1	22-01-1992
		GB 2230305 A	17-10-1990
		WO 9012216 A1	18-10-1990
JP 2006009968 A	12-01-2006	JP 4483430 B2	16-06-2010
		JP 2006009968 A	12-01-2006
WO 2012145217 A1	26-10-2012	US 8545103 B1	01-10-2013
		US 2013192899 A1	01-08-2013
		WO 2012145217 A1	26-10-2012

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
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(43) International Publication Date
3 January 2014 (03.01.2014)

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(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2012902770 28 June 2012 (28.06.2012) AU

(71) Applicant: **OUTOTEC OYJ** [FI/FI]; Puolikkotie 10, FI-02230 Espoo (FI).

(72) Inventors; and
(71) Applicants *(for US only)*: **BRAITHWAITE, Daniel** [AU/AU]; 5/17 Hertha Road, Innaloo, Western Australia 6018 (AU). **BELKE, Jeffrey, Victor** [AU/AU]; 11 Cowrie Cresent, Mt Pleasant, Western Australia 6153 (AU). **GREEN, Nicholas John** [AU/AU]; 98a Toorak Road, Rivervale, Western Australia 6103 (AU). **TATE, Chris** [AU/AU]; 187 Delgado Parade, Iluka, Western Australia 6028 (AU). **HARRISON, Oscar** [AU/AU]; 35 Campsbourne Street, Balcatta, Western Australia 6021 (AU). **VAAGE, Knut** [NO/NO]; Middlethunsgate 23, N-0368 Oslo (NO).

(74) Agent: **SHELSTON IP**; Shelston IP, Level 21, 60 Margaret Street, Sydney, New South Wales 2000 (AU).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title**: IMPROVEMENTS IN FLUID BEARINGS

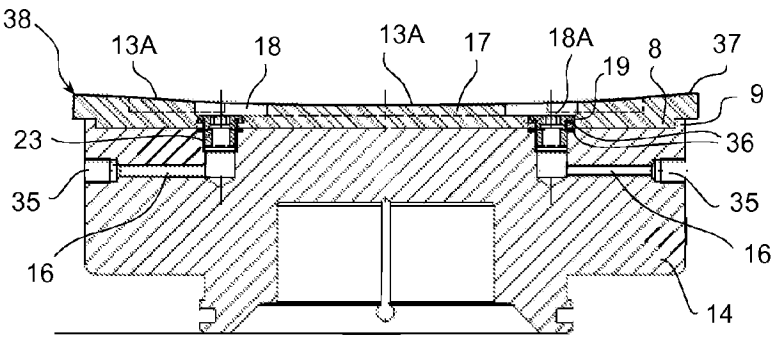


Fig. 6

(57) **Abstract**: The present invention provides improvements to a fluid bearing (11, 12) for a journal (4), one being a polymer bearing pad (17) comprising an outer surface (13), at least one recess (18) for receiving lubricating fluid from a base (14) of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means (8, 8A) for securely mounting said polymer bearing pad to said base. Other improvements include a fluid bearing (11, 12) comprising the polymer bearing pad (17), methods of making the polymer bearing pad and fluid bearing, a fluid bearing comprising a polymer bearing pad (17) having a chamfer (37) and a multidirectional fluid bearing (70).

WO 2014/002060 A1

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"Improvements in fluid bearings"

Field of the Invention

[0001] The present invention relates to a fluid bearing and in a particular a hydrostatic polymeric bearing for use in a mill. The invention has been developed primarily for use as a hydrostatic polymeric bearing in grinding mills and will be described hereinafter by reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use, but also extends to other types of fluid bearings such as hydrodynamic bearings and hybrid bearings (i.e. bearings that use a combination of hydrodynamic and continuous hydrostatic flow for lubrication).

Background of the Invention

[0002] The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its advantages to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an express or implied admission that such art is widely known or forms part of common general knowledge in the field.

[0003] A grinding mill has a mill chamber and two journal shafts, the journals being mounted upon supports for rotation. Typical bearings have two main components; a steel base for mounting to the support and a bearing pad or surface for contact with the mill journal. These mill bearings are installed between the mill journals and the supports so that the mill journals rotate on the bearing pads during operation of the grinding mill.

[0004] The applicant developed a hydrostatic pad bearing system for grinding mills that is currently in use. In this hydrostatic pad bearing system, an external oil supply system pumps high-pressure oil to recesses machined into the bearing so that the oil forms a thin film on the bearing pad surface. The resultant hydraulic pressure is sufficient to completely lift the mill journal off the hydrostatic pads and separate the sliding surfaces. Thus, mill actually “floats” on a film of oil between journal and bearing. As such the bearing will operate under both static and dynamic conditions. Since the surfaces are completely separated and the bearing is self aligning there is no metal-to-metal contact between the bearing surface and the mill journal due to the oil film, thus

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resulting in only low friction. Consequently, maintaining the oil film between the surfaces means that there is virtually no wear in the bearing.

[0005] Despite the advantages conferred by this hydrostatic bearing system, a loss of oil pressure (and thus a reduction in the oil film thickness) can cause failure of the bearings, leading to damage to the bearing pad and/or the mill journal. For example, it can take a few seconds for a grinding mill to stop turning in the event of a power failure, and when this happens there is a high risk of damage to the mill bearing pads or journal surfaces due to a loss of oil reducing the oil film thickness, thereby bringing the journal and bearings into direct metal to metal contact. The consequential downtime for replacement of any damaged bearings and/or journals severely impairs operation of the mill, reducing its efficiency.

[0006] To prevent this type of damage, grinding mill lubrication systems usually have pressure accumulator systems that are typically used to store and deliver high pressure oil to the bearing in the event of a power failure and the oil supply system fails. These pressure accumulators are expensive, require frequent maintenance to ensure that they are at the appropriate pressure level and can interfere with control systems in the mill. Thus, there are increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and then the oil supply ports for delivering high pressure oil to the recesses are then drilled into the base. Bronze is spray welded or cast onto the relevant parts of the steel base to form the bearing pad or lining. Spray welding enables the bronze metal to form a seal with the base. White metal may be used instead of bronze, but is cast onto the base. Due to this manufacturing process, the repair and/or refurbishment of these bearings involves initially cleaning the damaged bearing surface, machining any parts of the steel base and either spray welding the bronze or re-casting the bronze/white metal. This repair process cannot be performed on-site but requires the bearing to be returned to the manufacturer. Consequently, mills must keep a sufficient stock of spare bearings to account for the absence of damaged bearings being repaired. This adds to the maintenance costs of the mill.

[0008] It is an object of the present invention to overcome or substantially ameliorate one or more of the disadvantages of prior art, or at least to provide a useful alternative.

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[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means for securely mounting said polymer bearing pad to said base.

[0011] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0012] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0013] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[0014] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to

said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0015] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0016] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0017] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0018] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0019] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0020] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0021] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0022] According to a second aspect of the invention, there is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

the polymer bearing pad of the first aspect of the present invention mountable to said base.

[0023] Preferably, said polymer bearing pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

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said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] According to a third aspect of the invention, there is provided a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming

step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] According to a fourth aspect of the invention, there is provided a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for connecting said polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer

bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] According to a fifth aspect of the invention, there is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

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[0052] According to a sixth aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first outer surface and said polymer bearing pad substantially covers said second outer surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

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[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, least one of said first and second polymer bearing pads comprises a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

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[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but

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can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer

pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads

generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23 also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14.

The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a “hovercraft” type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there

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is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both

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outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the “lead-in” chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the “lead-in” chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the “lead-out” chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

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[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased “off the shelf” in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and

kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped

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recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from

the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

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[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

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[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the

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invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Claims

1. A polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base.

2. The polymer bearing pad of claim 1, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad.

3. The polymer bearing pad of claim 2, wherein said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base.

4. The polymer bearing pad of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base.

5. The polymer bearing pad of claim 4, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess.

6. The polymer bearing pad of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

7. The polymer bearing pad of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

8. The polymer bearing pad of claim 7, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

9. The polymer bearing pad of any one of the preceding claims, wherein said outer surface is partially curved. .

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10. The polymer bearing pad of any one of claims 1 to 8, wherein said outer surface is substantially planar.

11. The polymer bearing pad of any one of the preceding claims, further comprising at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

12. A fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

the polymer bearing pad of any one of the preceding claims mountable to said base.

13. The fluid bearing of claim 12, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

14. The fluid bearing of claim 13, wherein said flange is located at an outer edge of said base.

15. The fluid bearing of any one of claims 10 to 14, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

16. The fluid bearing of any one of claims 10 to 15, further comprising at least one fastener for mounting said polymer bearing pad to said base, said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

17. The fluid bearing of claim 16, wherein said at least one recess has a locking tab for retaining said head portion within said at least one recess.

18. The fluid bearing of claim 16, further comprising a plug for engagement with said head portion and said at least one recess.

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19. The fluid bearing of claim 16 or 18, further comprising a locking element for retaining said at least one fastener within said at least one recess.

20. The fluid bearing of any one of claims 12 to 19, further comprising a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

21. The fluid bearing of claim 20, wherein each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

22. The fluid bearing of any one of claims 12 to 21, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

23. The fluid bearing of claim 22, wherein said first surface is orthogonal to said second surface.

24. The fluid bearing of claim 22 or 23, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

25. The fluid bearing of any one of claims 12 to 21, wherein said fluid bearing is at least one of a radial hydrostatic bearing, a self-aligning radial hydrostatic bearing, a

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fixedly mounted radial hydrostatic bearing, a hydrostatic slipper bearing, an axial bearing, a self-aligning axial hydrostatic bearing and a fixedly mounted axial hydrostatic bearing.

26. A method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

27. The method of claim 26, wherein said mounting means forming step comprises machining said polymer pad to form a mounting portion extending from said polymer pad.

28. The method of claim 26, wherein said mounting means forming step comprises drilling, punching, cutting or machining an opening in said at least one recess to receive at least one fastener.

29. The method of claim 26 or 28, further comprising chamfering an outer edge of said polymer pad.

30. The method of any one of claims 26 to 29, wherein said at least one recess forming step comprises machining said at least one recess in said polymer pad and machining at least one interconnecting passage to interconnect said at least one recess to said base.

31. A method of making a fluid bearing for a journal, comprising:

providing a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port and at least one flange;

making a polymer bearing pad in accordance with the method of any one of claims 26 to 30, and

mounting said polymer bearing pad to said base.

32. The method of claim 31, wherein said mounting step comprising mechanically fastening said polymer bearing pad to said base.

33. The method of claim 31 or 32, wherein there are a plurality of said polymer pads, said method further comprising connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal.

34. The method of claim 33, further comprising forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

35. The method of claim 33 or 34, wherein said further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

36. A fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

37. The fluid bearing of claim 36, wherein said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

38. The fluid bearing of claim 36 or 37, wherein said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

39. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

40. The multidirectional fluid bearing of claim 39, said first polymer bearing pad substantially covers said first outer surface and said polymer bearing pad substantially covers said second outer surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

41. The multidirectional fluid bearing of claim 40, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

42. The multidirectional fluid bearing of claim 41, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

43. The multidirectional fluid bearing of any one of claims 39 to 42, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

44. The multidirectional fluid bearing of any one of claims 39 to 43, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

45. The multidirectional fluid bearing of any one of claims 39 to 42, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, and further comprising a locking element for retaining said at least one fastener within said at least one recess.

46. The multidirectional fluid bearing of any one of claims 39 to 45, wherein at least one of said first and second polymer bearing pads comprises a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

47. The fluid bearing of claim 46, wherein each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

48. The multidirectional fluid bearing of claim 39, wherein at least one of said first polymer bearing pad and said second polymer bearing pad comprises said polymer bearing pad of any one of claims 1 to 11.

49. The multidirectional fluid bearing of claim 48, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

50. The multidirectional fluid bearing of claim 49, wherein said flange is located at an outer edge of said base.

51. The multidirectional fluid bearing of any one of claims 39 to 50, wherein said first surface is orthogonal to said second surface.

52. The multidirectional fluid bearing of any one of claims 39 to 51, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

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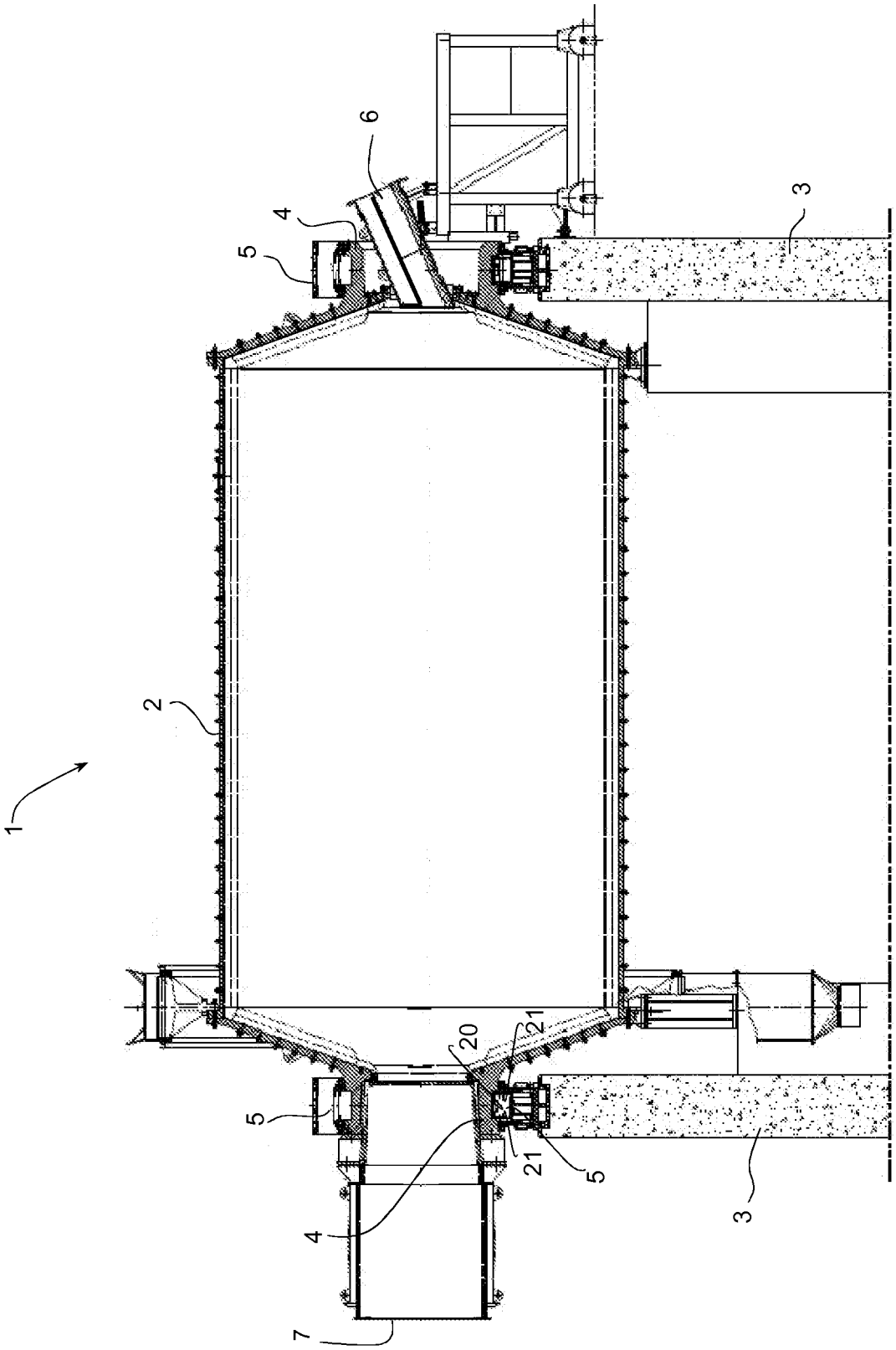


Fig. 1

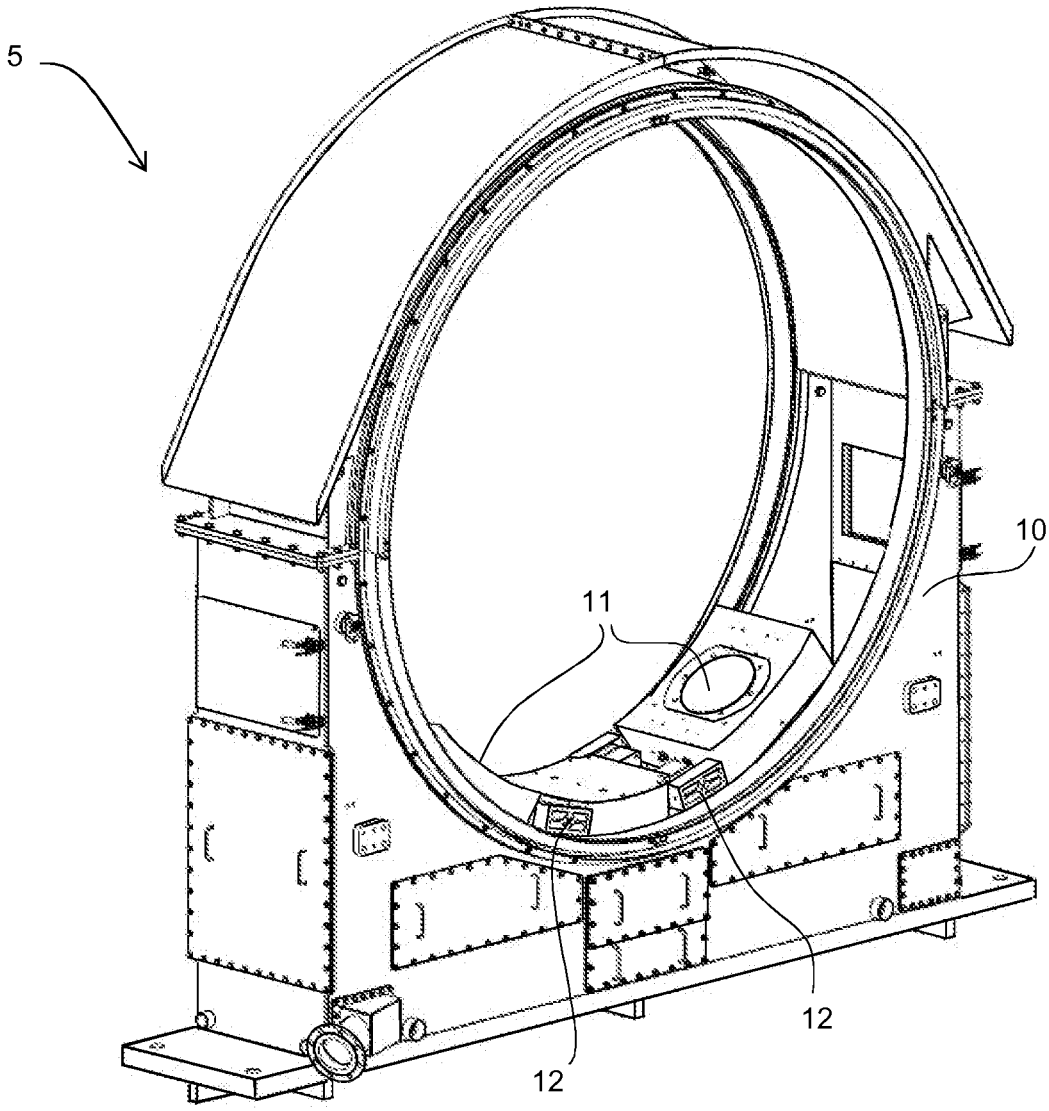


Fig. 2

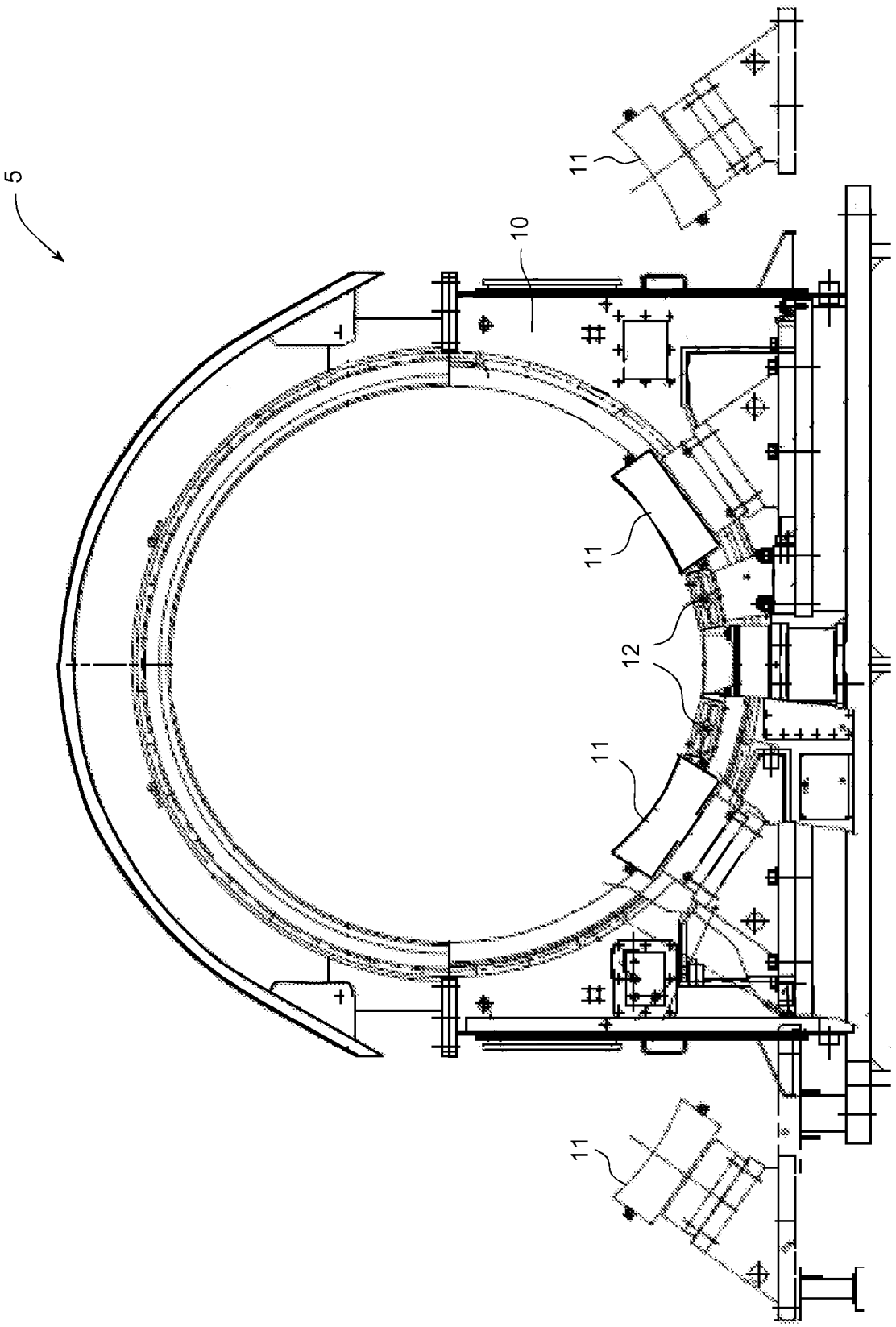


Fig. 3

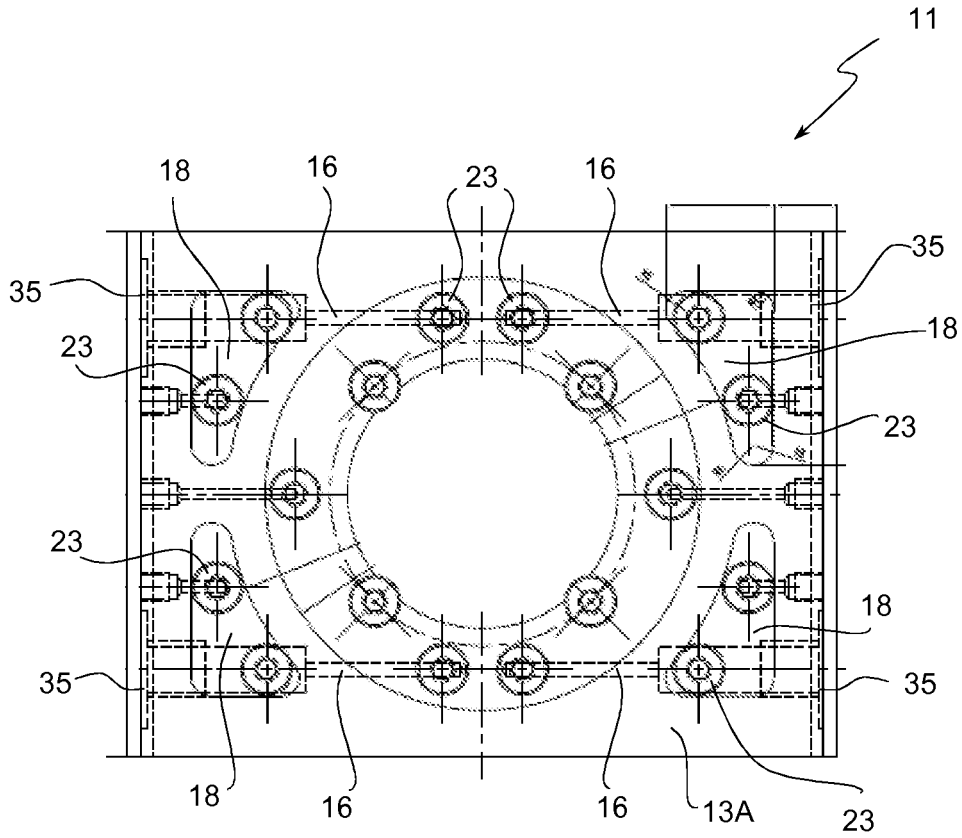


Fig. 4

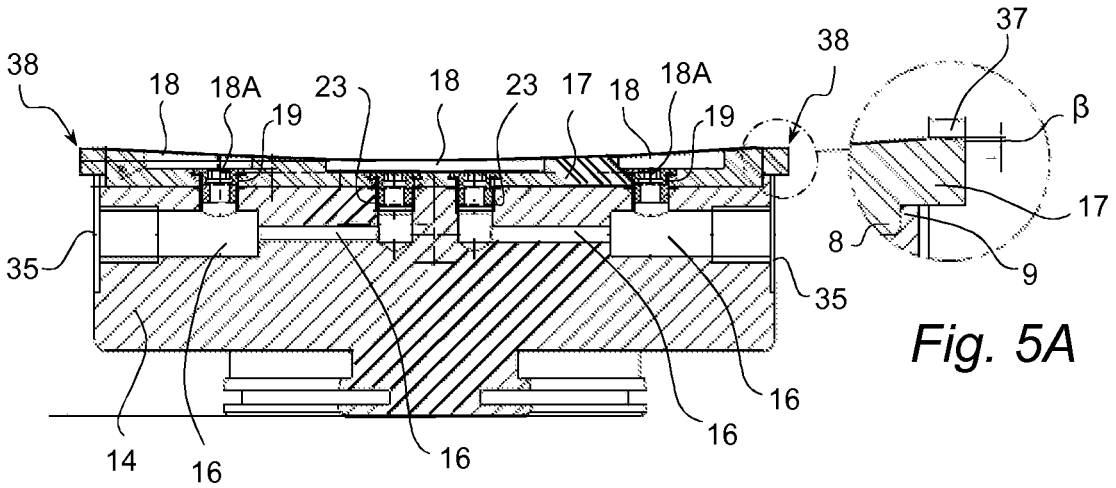


Fig. 5A

Fig. 5

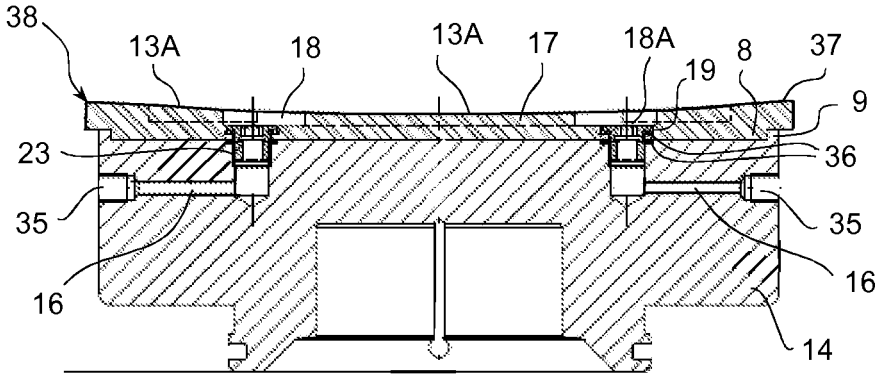


Fig. 6

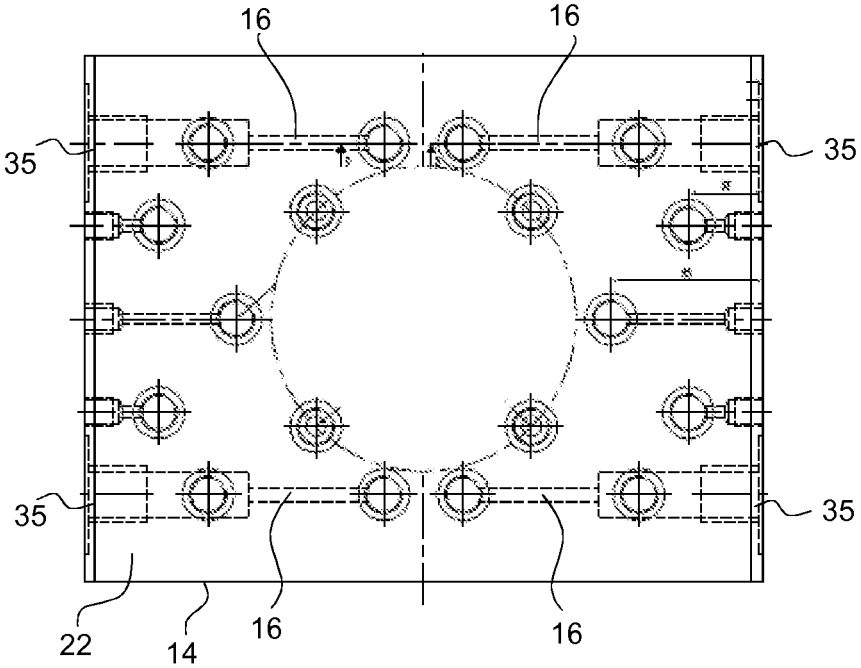


Fig. 7

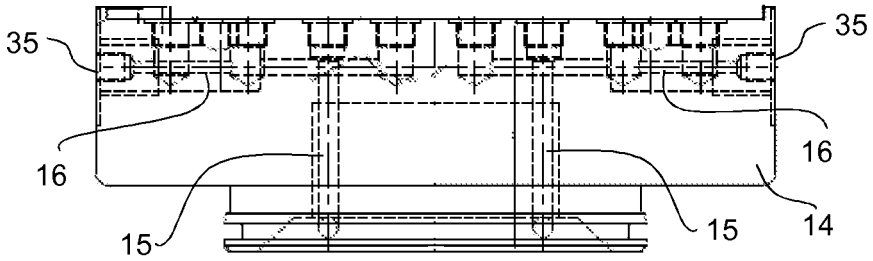


Fig. 8

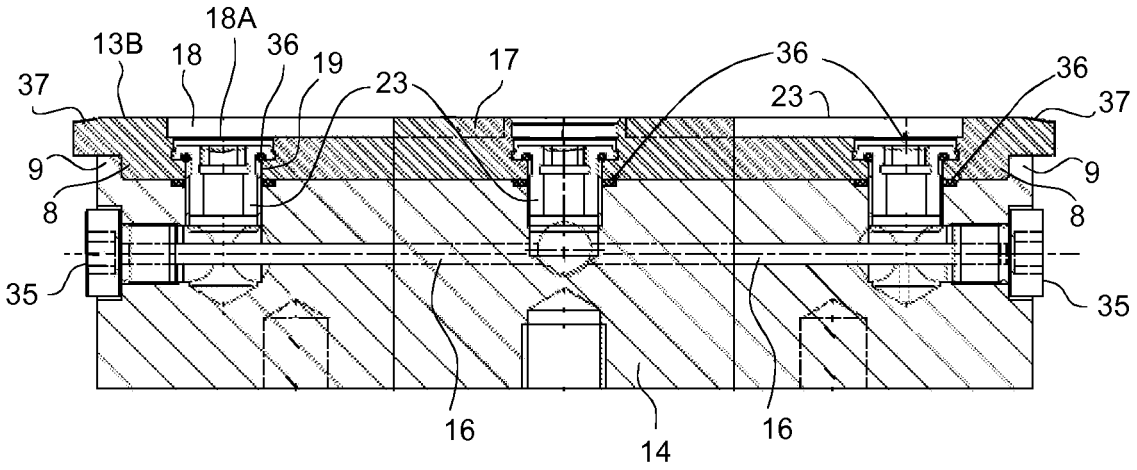

18A
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Fig. 9

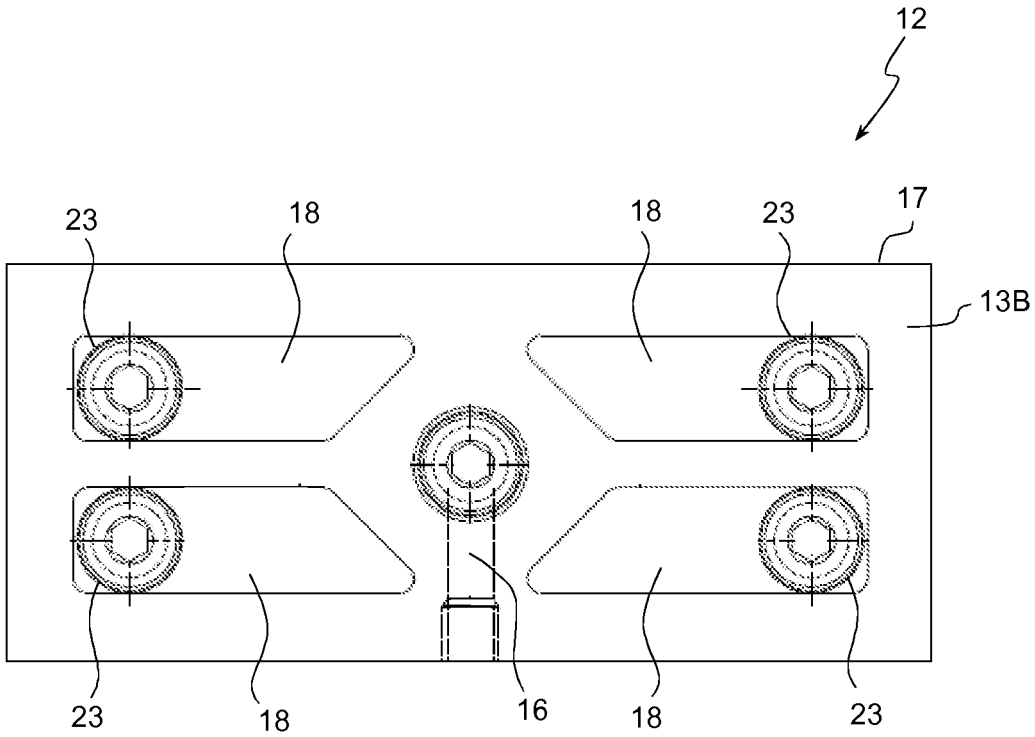

12
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13B
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Fig. 10

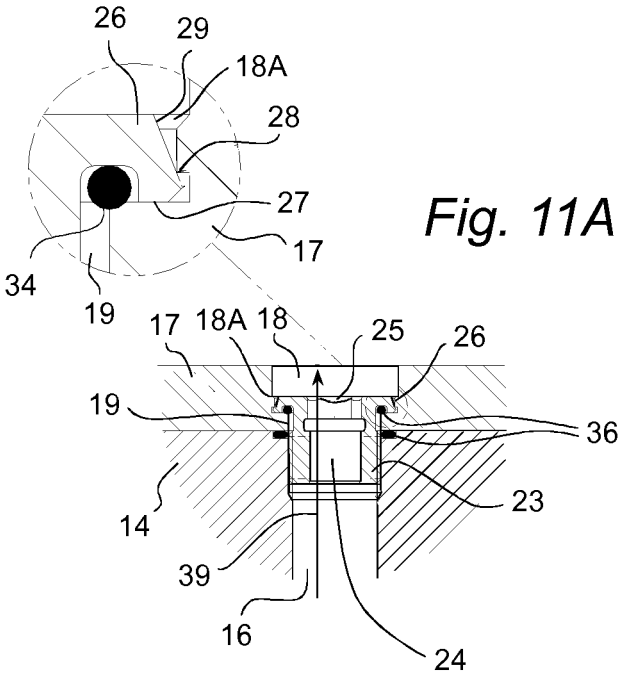


Fig. 11A

Fig. 11

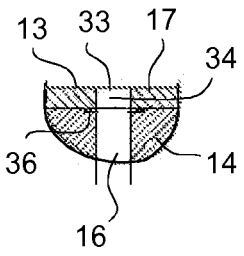


Fig. 12A

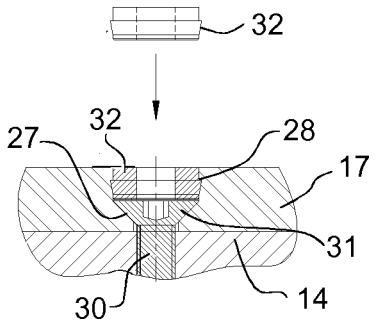


Fig. 12

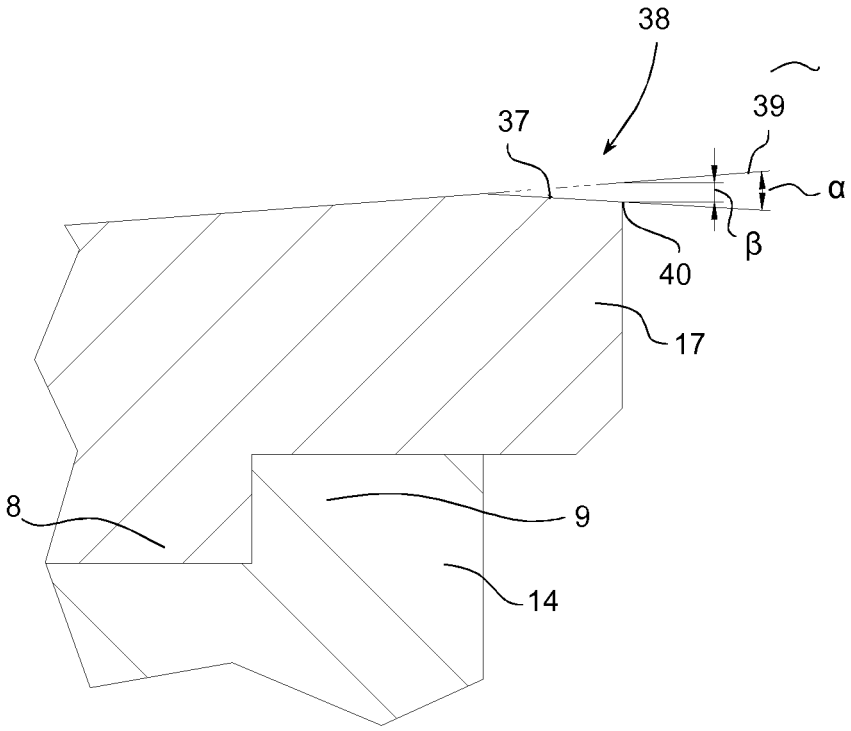


Fig. 13

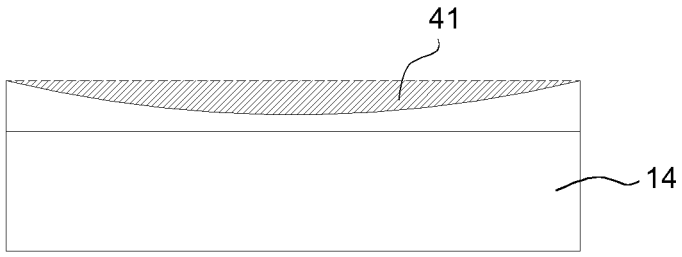


Fig. 14

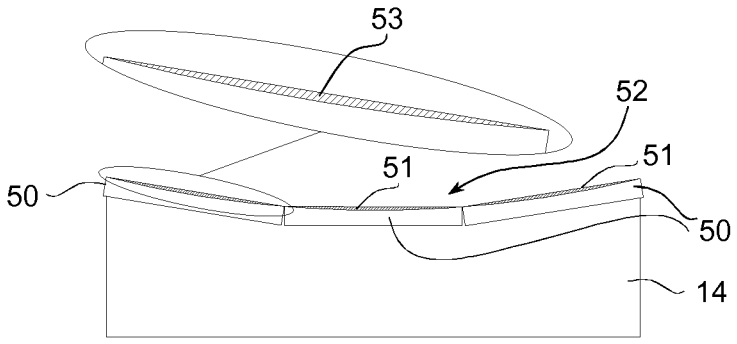


Fig. 15

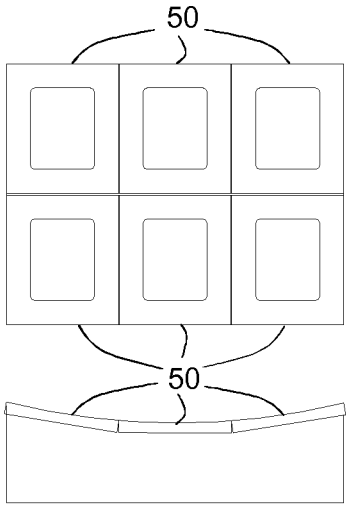


Fig.16

Fig.16A

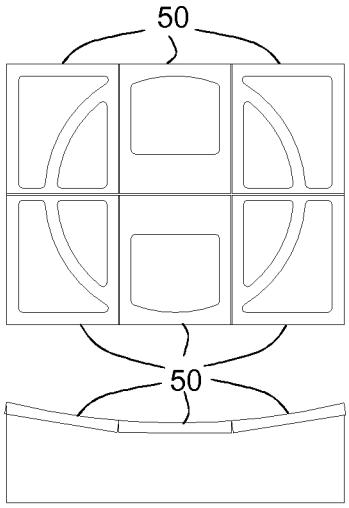


Fig.17

Fig.17A

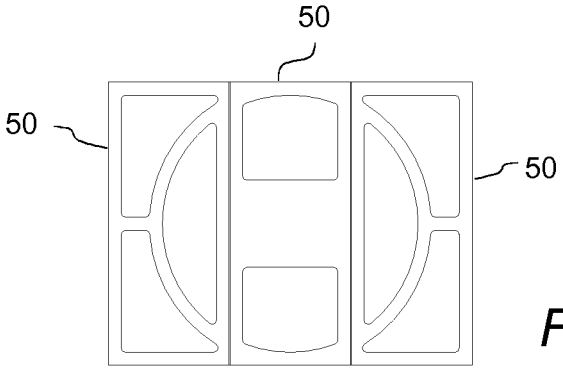


Fig. 18

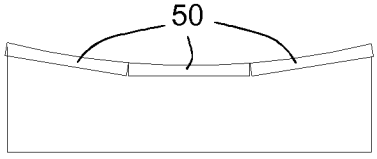


Fig. 18A

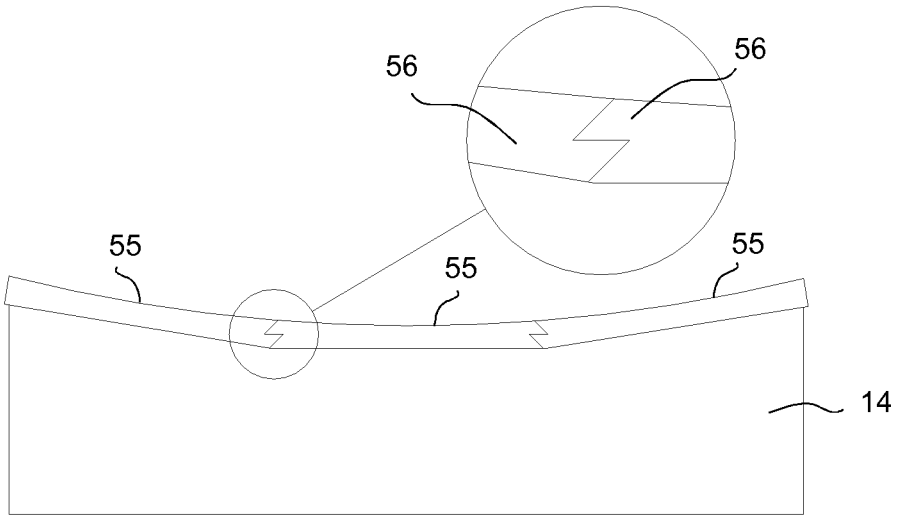


Fig. 19

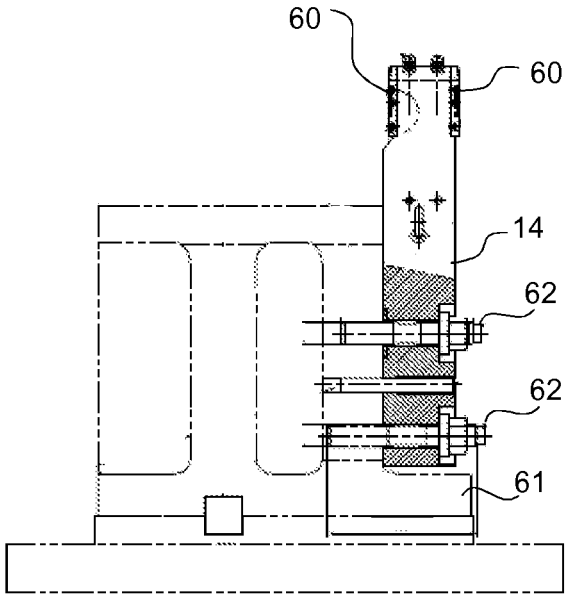


Fig. 22

Fig. 21

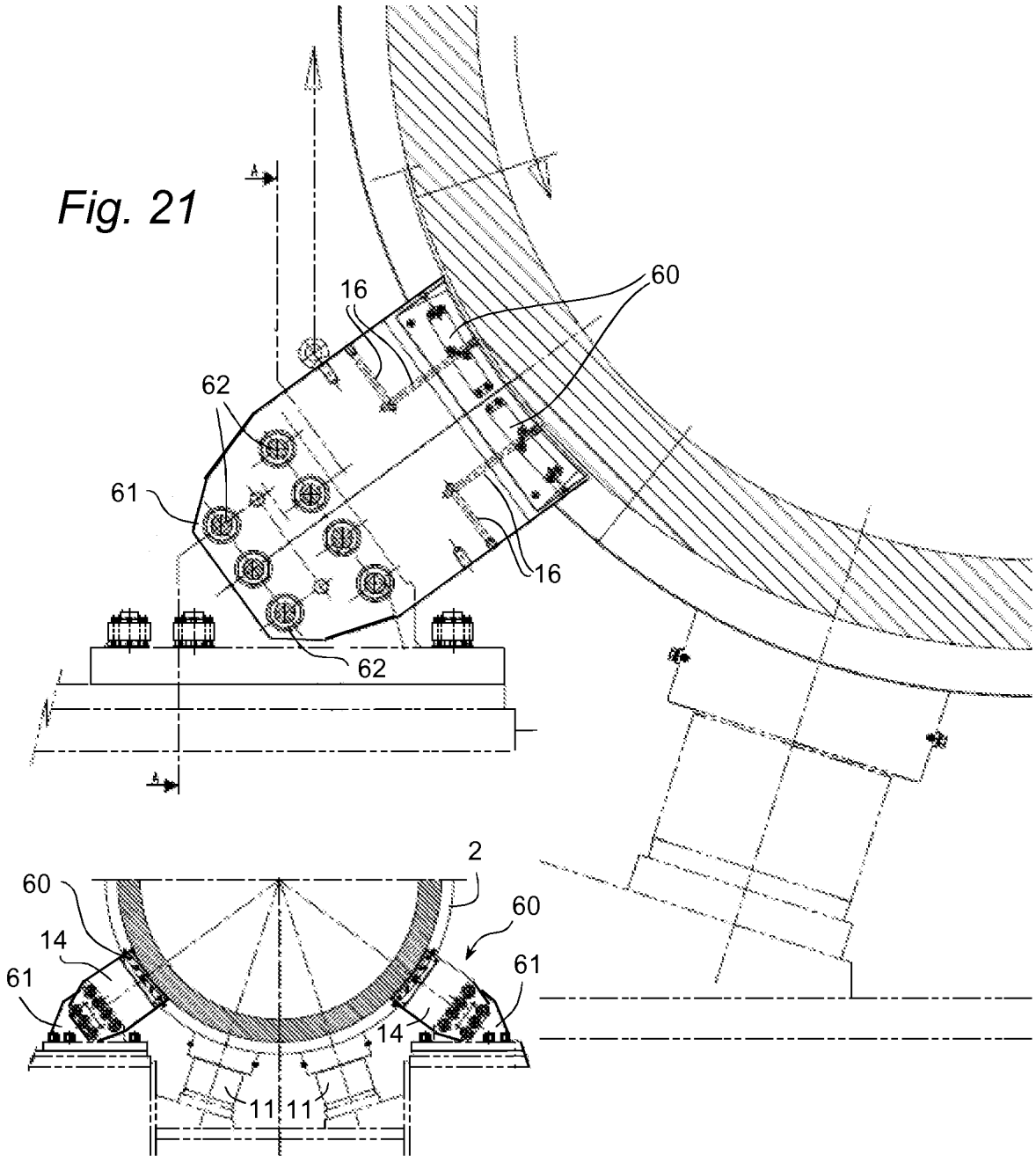


Fig. 20

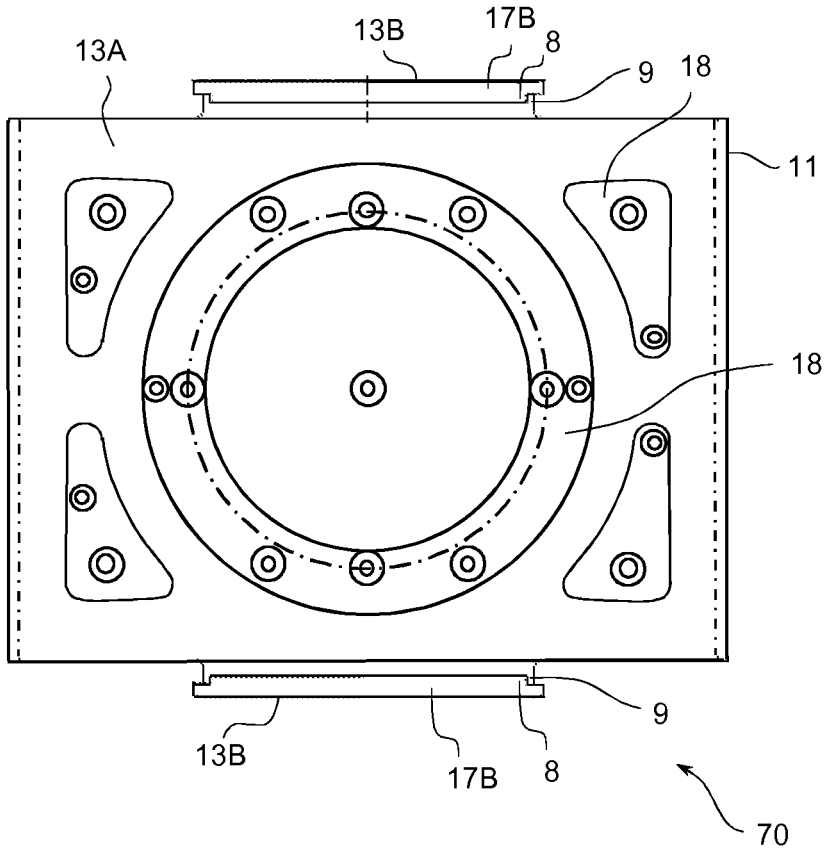


Fig. 23

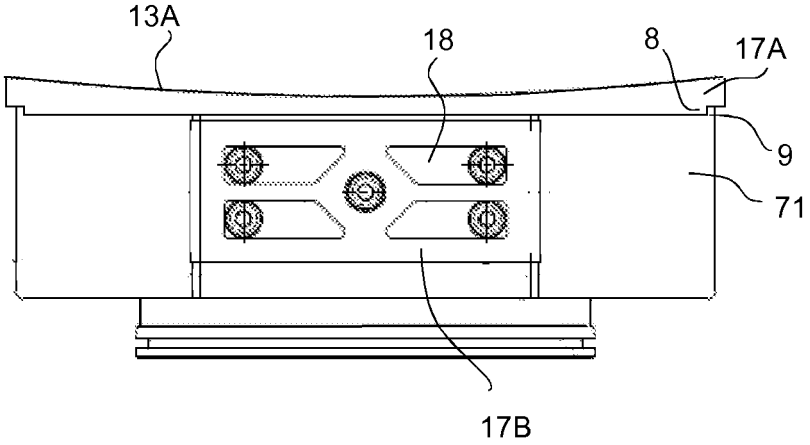


Fig. 24

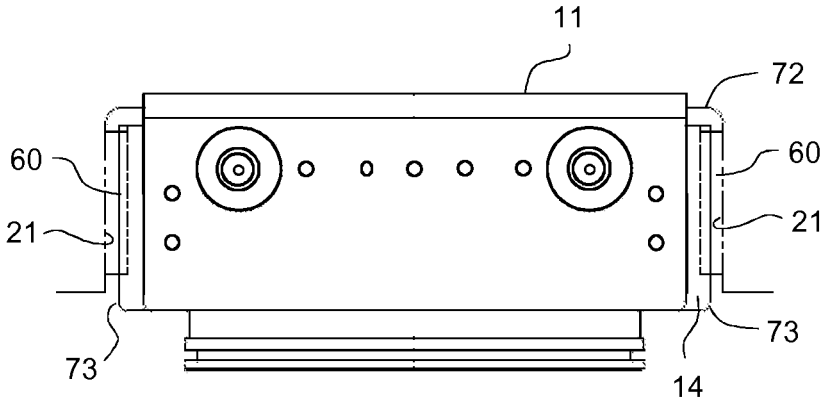


Fig. 25

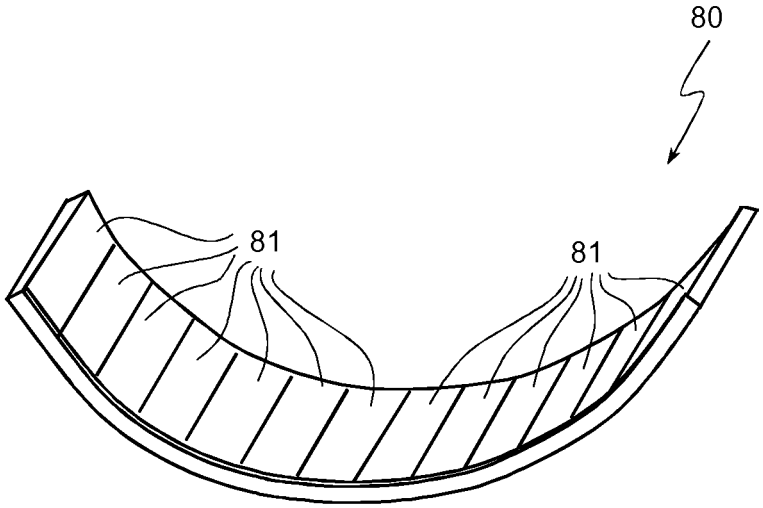


Fig. 26

Copy for (ISA-EP) 33
PATENT COOPERATION TREATY

ADVANCE E-MAIL

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION RELATING TO
DECLARATION MADE UNDER PCT RULE 4.17

(PCT Rules 26*ter* and 48.2(a)(x)
and Administrative Instructions, Section 419)

To:

SHELSTON IP
Shelston IP
Level 21, 60 Margaret Street
Sydney, New South Wales 2000
AUSTRALIE

Date of mailing *(day/month/year)* 28 October 2013 (28.10.2013)	
Applicant's or agent's file reference 74861WOP00	**IMPORTANT NOTIFICATION**
International application No. PCT/IB2013/055305	International filing date *(day/month/year)* 28 June 2013 (28.06.2013)
Applicant OUTOTEC OYJ et al	

1. The applicant is hereby **notified** of the following regarding the declaration indicated below in respect of BELKE, Jeffrey, Victor ; BRAITHWAITE, Daniel ; GREEN, Nicholas John ; HARRISON, Oscar ; TATE, Chris ; VAAGE, Knut :

   (i) ☐ declaration as to the identity of the inventor (Rules 4.17(i) and 51*bis*.1(a)(i) and Section 211)

   (ii) ☐ declaration as to the applicant's entitlement, as at the international filing date, to apply for or be granted a patent (Rules 4.17(ii) and 51*bis*.1(a)(ii) and Section 212)

   (iii) ☐ declaration as to the applicant's entitlement, as at the international filing date, to claim priority of the earlier application (Rules 4.17(iii) and 51*bis*.1(a)(iii) and Section 213)

   (iv) ☒ declaration of inventorship (for the purposes of the designation of the United States of America) (Rules 4.17(iv) and 51*bis*.1(a)(iv) and Section 214)

   (v) ☐ declaration as to non-prejudicial disclosures or exceptions to lack of novelty (Rules 4.17(v) and 51*bis*.1(a)(v) and Section 215)

2. ☒ **Addition or correction of the declaration within the time limit under Rule 26*ter*.1.**

   The added or corrected declaration was received on 14 October 2013 (14.10.2013) , which was within the time limit under Rule 26*ter*.1.

   Any declaration referred to under items 1(i) to (v), whether or not the declaration complies with Rule 4.17, will be published as part of the international application pursuant to Rule 48.2(a)(x).

3. ☐ **Failure to add or correct the declaration within the time limit under Rule 26*ter*.1.**

   The declaration was received on which was **after** the expiration of the time limit under Rule 26*ter*.1; therefore, that declaration, as added or corrected, referred to under items 1(i) to (v) will **not** be published as part of the international application, and any signed declaration referred to under item 1(iv) is attached. **Such declaration should be submitted by the applicant directly to the designated Office(s) concerned.**

4. The applicant's attention is drawn to Rule 51*bis*.2 which provides that the designated Office shall not, unless it may reasonably doubt the veracity of the declaration concerned, require any document or evidence relating to the subject matter of any declaration complying with Rule 4.17(i) to (iv) which is contained in the request or submitted to the International Bureau or directly to the designated Office. Note, however, that Rule 51*bis*.2 may not apply in respect of certain States. For further information, see Notes to the request form, Box No. VIII.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 910 06 10

Authorized officer
Grolier David
e-mail ro.ib@wipo.int
Telephone No. +4122 338 8698

NOTIFICATION RELATING TO DECLARATION MADE UNDER PCT RULE 4.17

Date of mailing *(day/month/year)*
28 October 2013 (28.10.2013)

5. A copy of this notification is being sent to the receiving Office and the International Searching Authority.

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished:

   a. (means)

   ☐ on paper

   ☐ in electronic form

   b. (time)

   ☐ in the international application as filed

   ☐ together with the international application in electronic form

   ☐ subsequently to this Authority for the purposes of search

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Box No. II Priority

1. ☒ The validity of the priority claim has not been considered because the International Searching Authority does not have in its possession a copy of the earlier application whose priority has been claimed or, where required, a translation of that earlier application. This opinion has nevertheless been established on the assumption that the relevant date (Rules 43*bis*.1 and 64.1) is the claimed priority date.

2. ☐ This opinion has been established as if no priority had been claimed due to the fact that the priority claim has been found invalid (Rules 43*bis*.1 and 64.1). Thus for the purposes of this opinion, the international filing date indicated above is considered to be the relevant date.

3. Additional observations, if necessary:

Box No. IV Lack of unity of invention

1. ☐ In response to the invitation (Form PCT/ISA/206) to pay additional fees, the applicant has, within the applicable time limit:

   ☐ paid additional fees

   ☐ paid additional fees under protest and, where applicable, the protest fee

   ☐ paid additional fees under protest but the applicable protest fee was not paid

   ☐ not paid additional fees

2. ☒ This Authority found that the requirement of unity of invention is not complied with and chose not to invite the applicant to pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rule 13.1, 13.2 and 13.3 is

   ☐ complied with

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, this report has been established in respect of the following parts of the international application:

   ☒ all parts.

   ☐ the parts relating to claims Nos.

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	5, 10, 11, 17, 19-24, 33-35, 37, 39-52
	No:	Claims	1-4, 6-9, 12-16, 18, 25-32, 36, 38
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-52
Industrial applicability (IA)	Yes:	Claims	1-52
	No:	Claims	

2. Citations and explanations

   see separate sheet

Box No. VI Certain documents cited

1. Certain published documents (Rules 43*bis*.1 and 70.10)

   and / or

2. Non-written disclosures (Rules 43*bis*.1 and 70.9)

   see form 210

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB2013/055305	28.06.2013	28.06.2012

International Patent Classification (IPC) or both national classification and IPC
INV. F16C32/06

Applicant
OUTOTEC OYJ

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☒ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☒ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☒ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notifed the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA:	Date of completion of this opinion	Authorized Officer
European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Fax: +31 70 340 - 3016	see form PCT/ISA/210	Martin, Christophe Telephone No. +31 70 340-4492

Exhibit 1027
FLS v. Metso - IPR2025-00985

Re Item IV

Lack of unity of invention

1 The application documents clearly show that the elements "mounting means", "chamfer", "lateral connecting portions" and "first and second surfaces" solve unrelated technical problems, viz. mounting a pad on its corresponding base by means of the "mounting means", constituting a lubricant reservoir by means of the "chamfer", constituting a variable pad surface by means of the "lateral connecting portions", constituting a bearing with more than one bearing surface by means of the base "first and second surfaces". Since these elements are themselves different from one another, they are considered to *a priori* affect the unity of invention of the set of claims. However, the search could be carried out for all these elements without the need - *at the search stage* - to raise non-unity objections pursuant Rule 13 PCT. In particular, the groups of inventions made of independent claims 1 and 26 (Group I), independent claim 36 (Group II), independent claim 39 (Group III) are not unitary *a priori.*

1.1 The "mounting means" are more specifically the subject of claims 1-6, 12-19, 26-28, 31, 32, 43-45, 49 and 50.

1.2 The "chamfer" are more specifically the subject of claims 7, 8, 29, 35-38, 41 and 42.

1.3 The "lateral connecting portions" are more specifically the subject of claims 11, 21, 34 and 47.

1.4 The "first and second surfaces" are more specifically the subject of claims 22, 23, 39, 48 and 51.

1.5 The claims 9, 10, 20, 24, 25, 30, 33, 40, 46 and 52 merely relate to general aspects of the pads, respectively bearings.

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

2 Reference is made to the following documents:

D1 : DE 10 2007 039 364 A1

D2 : WO 90/12216 A

D3 : JP 2006-9968 A

D4 : WO 2012/145217 A1

3 The present application does not meet the criteria of Article 33(2) PCT, because the subject-matter of claim independent 1 is not new.

3.1 D1 discloses "a polymer *(see page 5/8, left column, lines 9-15)* bearing pad (32) *(see figure 4B)* for a fluid bearing, comprising an outer surface *(see figure 4A)*, at least one recess (22) for receiving lubricating fluid *(see page 4/8, right column, lines 27-30; figures 3A and 4A)* from a base (31) of said fluid bearing and distributing said lubricating fluid to said outer surface (32) and mounting means *(see page 5/8, left column, lines 23-26)* for securely mounting said polymer bearing pad (32) to said base (31)".

3.2 The subject-matter of claim 1 is therefore not new in view of D1.

4 Dependent claims 2-25 do not contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step:

4.1 The features of claims 2 and 3 are known from D1, see e.g. the beveled edge of pad (30) in cooperation with the corresponding undercut notch of shoe (5) in figure 3A.

4.2 The features of claim 4 are known from D1, see figures 4A and 4B.

4.3 The features of claim 5 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028], an automated English translation of which is found here below:

"[0027] Moreover, according to the combination structure 6, after inserting ring 9 in the ring mounting groove¦channel 7 in the decomposition¦degradation state shown in FIG. 3, it can assemble simply in the state shown in FIG. 1 by inserting the hemisphere part 37 in a concave-part 8, and engaging the end face 45 of the hemisphere part 37 with ring 9.

[0028] In addition, as ring 9, an elastic O ring is preferable, However If it is the objective of mere connection, although it is a rigid material -- a diameter-expansion -- free and the diameter reduction -- free E ring or a C-ring may be sufficient. Even if it uses such E ring or a C-ring, it can connect, as that the gap adjustment member 5 may not be dropped off in the static-pressure gas bearing pad 3, and a cost reduction can be intended".

4.4 The features of claim 6 are known from D1, see figure 4A and the material used for the pad.

4.5 The features of claims 7 and 8 are implicitly known and/or derivable from e.g. figure 4B of D1, see the surface whereto the reference "32" points in said figure.

4.6 The features of claim 9 are known from D1, see figure 4B.

4.7 The features of claim 10 are from D2, see the figures, and readily applicable to the pad of D1.

4.8 In claim 11 a slight constructional change in the pad of claim 1 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

4.9 The features of claim 12 are known from D1, see figures 3A and 4A, especially the base (5, 31) with the "fluid port" and "passage" (15, 15").

4.10 The features of claims 13 and 14 are known from D1, see the undercut notch of shoe (5) in figure 3A.

4.11 The features of claim 15 are known from D1, see figures 4A and 4B.

4.12 The features of claim 16 are known from D1, see Figure 4A and page 5/8, left column, lines 5-7 and 23-26.

4.13 The features of claim 17 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028].

4.14 The features of claim 18 are known or derivable from D1, see the schematically represented sleeve like plug under the head of elements "17" in Figure 4B.

4.15 The features of claim 19 are a well-known means for retaining the head portion of a fastener in a recess and fi their equivalent in D3, see paragraphs [0027] and [0028]

4.16 The features of claim 20 are obvious in view of an application of the teachings of D1 to the arrangement shown in figure 5 of D2.

4.17 In claim 21 a slight constructional change in the bearing of claim 20 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

4.18 The features of claims 22-24 are obvious in view of an application of the teachings of D1 to the arrangement shown in figure 5 of D2.

4.19 The features of claim 25 are known from D1, see figures 3A, 4A, or of D2, see e.g. claim 1.

5 The present application does not meet the criteria of Article 33(2) PCT, because the subject-matter of independent claim 26 is not new.

5.1 The features of claim 26 are indeed implicitly known from D1, because the pad of figures 4A and 4B thereof exhibits the features resulting from the method of claim 26.

6 Likewise, dependent claims 27-35 do not contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, because the steps claimed therein are widely known to the skilled person and/ or implicitly known from D1, and result in the features shown in figure 4A of said D1.

7 In claims 33-34 a slight constructional change in the method of claim 31 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

8 In claim 35 a slight constructional change in the method of claim 33 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen and in view also of D1, see e.g. in figure 4B the surface whereto the reference "32" points in said figure.

9 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 36 is not new in the sense of Article 33(2) PCT and/or does not involve an inventive step in the sense of Article 33(3) PCT.

9.1 The configuration of the fluid bearing claimed in said claim 36 is indeed known from D1, including the chamfer (see in figure 4B the surface whereto the reference "32" points). That the chamfer retains a lubricating fluid and transfers it to the journal - besides the fact that this defines a use of the chamfer and not an unambiguous constructional aspect defining the claimed fluid bearing - is in any case considered as implicitly known and/or derivable from D1 due to the use of the pad of figure 4B understood from the curved shape of the outer surface of the pad and its relation to the roll jacket (10) such as shown in figure 3A.

10 Dependent claims 37 and 38 do not contain any additional features which, in combination with the features of any claim to which it refers, meet the requirements of the PCT in respect of novelty and/or inventive step:

10.1 In claim 37 a slight constructional change in the bearing of claim 36 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

10.2 The features of claim 38 are known from D1, see figure 4A.

11 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claim 39 does not involve an inventive step in the sense of Article 33(3) PCT.

11.1 The general configuration of the claimed fluid bearing is known from D2, see figure 5, and the details (especially the recess and fluid passages) of the pads are known from D1 and may be applied to the bearing of D2, thereby arriving at the claimed fluid bearing. Hence the lack of inventive step of the subject-matter of claim 39.

12 Likewise, dependent claims 40-52 do not contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step.

12.1 The features of claims 40-42, 44, 46, 48-52 have been already discussed w.r.t. claim 6 (corresponding to claim 40), claims 7 and 36 (corresponding to claim 41), 8 (corresponding to claim 42), 16 (corresponding to claim 44), 20 (corresponding to claim 46), 1-11 (corresponding to claim 48), 13 (corresponding to claim 49), 14 (corresponding to claim 50), 23 (corresponding to claim 51), 24 (corresponding to claim 52).

12.2 The features of claims 43 and 45, which claims are basically redundant with one another, are obtained from a combination of D1 (opening for receiving a fastener) and D3 (locking tab).

12.3 In claim 47 a slight constructional change in the bearing of claim 46 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.

Re Item VI

Certain documents cited

Application No Patent No	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date *(valid claim)* *(day/month/year)*
WO 2012/145217 A1	26.10.2012	12.04.2012	19.04.2011

-

Re Item VII

Certain defects in the international application

13 The features of the claims have not been not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

Re Item VIII

Certain observations on the international application

14 The application does not meet the requirements of Article 6 PCT, because claims 6, 15, 16, 35, 36, 40, 43, 45, 46 and 48 are not clear:

14.1 Some of the features in the apparatus claim 6 relate to a method of using the pad rather than clearly defining the pad in terms of its technical features, see the expression "covers" whereas the base is not part of the claimed pad. The intended limitations are therefore not clear from this claim.

14.2 Claims 15 and 16 may not depend on claims 10 or 11, since the claims 10 and 11 do not relate to the base of the bearing.

14.3 Claim 35 does not define to what "further" relates.

14.4 Claim 36, if not considered as non-unitary with respect to at least claim 12, is redundant with the former combination of claims 1, 7 and 12, thereby constituting a set of claims lacking conciseness.

14.5 Claim 40 is not clearly worded, since the first polymer bearing pad having a first (resp. second) outer surface (see claim 39 on which claim 40 depends) cannot be such that it "covers said first (resp. second) outer surface" and since the "said polymer bearing pad" said to be substantially covering said second outer surface is not further defined relative to the first and second polymer bearing pads.

14.6 Claims 43 and 45 are redundant with one another.

14.7 The wording of claim 46 is awkward in the sense that a "polymer bearing pad" comprises a "plurality of polymer bearing pads", thereby raising doubt as to what should be understood with the notion of "polymer bearing pas". Likewise the link between this plurality of pads and the uniform bearing surface cannot be clearly established.

14.8 Due to its summarizing wording, claim 48 is redundant at least with claims 40-42, the latter indeed implicitly referring to claims 6-8.

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PATENT COOPERATION TREATY

ADVANCE E-MAIL

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION RELATING TO
DECLARATION MADE UNDER PCT RULE 4.17

(PCT Rules 26*ter* and 48.2(a)(x)
and Administrative Instructions, Section 419)

To:

SHELSTON IP
Shelston IP
Level 21, 60 Margaret Street
Sydney, New South Wales 2000
AUSTRALIE

Date of mailing *(day/month/year)* 21 October 2013 (21.10.2013)	
Applicant's or agent's file reference 74861WOP00	**IMPORTANT NOTIFICATION**
International application No. PCT/IB2013/055305	International filing date *(day/month/year)* 28 June 2013 (28.06.2013)
Applicant OUTOTEC OYJ et al	

1. The applicant is hereby **notified** of the following regarding the declaration indicated below in respect of OUTOTEC OYJ :

   (i) ☐ declaration as to the identity of the inventor (Rules 4.17(i) and 51*bis*.1(a)(i) and Section 211)

   (ii) ☒ declaration as to the applicant's entitlement, as at the international filing date, to apply for or be granted a patent (Rules 4.17(ii) and 51*bis*.1(a)(ii) and Section 212)

   (iii) ☐ declaration as to the applicant's entitlement, as at the international filing date, to claim priority of the earlier application (Rules 4.17(iii) and 51*bis*.1(a)(iii) and Section 213)

   (iv) ☐ declaration of inventorship (for the purposes of the designation of the United States of America) (Rules 4.17(iv) and 51*bis*.1(a)(iv) and Section 214)

   (v) ☐ declaration as to non-prejudicial disclosures or exceptions to lack of novelty (Rules 4.17(v) and 51*bis*.1(a)(v) and Section 215)

2. ☒ **Addition or correction of the declaration within the time limit under Rule 26*ter*.1.**

   The added or corrected declaration was received on 10 October 2013 (10.10.2013) , which was within the time limit under Rule 26*ter*.1.

   Any declaration referred to under items 1(i) to (v), whether or not the declaration complies with Rule 4.17, will be published as part of the international application pursuant to Rule 48.2(a)(x).

3. ☐ **Failure to add or correct the declaration within the time limit under Rule 26*ter*.1.**

   The declaration was received on which was **after** the expiration of the time limit under Rule 26*ter*.1; therefore, that declaration, as added or corrected, referred to under items 1(i) to (v) will **not** be published as part of the international application, and any signed declaration referred to under item 1(iv) is attached. **Such declaration should be submitted by the applicant directly to the designated Office(s) concerned.**

4. The applicant's attention is drawn to Rule 51*bis*.2 which provides that the designated Office shall not, unless it may reasonably doubt the veracity of the declaration concerned, require any document or evidence relating to the subject matter of any declaration complying with Rule 4.17(i) to (iv) which is contained in the request or submitted to the International Bureau or directly to the designated Office. Note, however, that Rule 51*bis*.2 may not apply in respect of certain States. For further information, see Notes to the request form, Box No. VIII.

5. A copy of this notification is being sent to the receiving Office and the International Searching Authority.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 910 06 10

Authorized officer
Diot Sylvie
e-mail ro.ib@wipo.int
Telephone No. +4122 338 9608

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NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92*bis*.1 and Administrative Instructions, Section 422)

To:

SHELSTON IP
Shelston IP
Level 21, 60 Margaret Street
Sydney, New South Wales 2000
AUSTRALIE

Date of mailing *(day/month/year)*
26 September 2013 (26.09.2013)

Applicant's or agent's file reference
74861WOP00

IMPORTANT NOTIFICATION

International application No.
PCT/IB2013/055305

International filing date *(day/month/year)*
28 June 2013 (28.06.2013)

1. The following indications appeared on record concerning:

☒ the applicant ☐ the inventor ☐ the agent ☐ the common representative

Name and Address
OUTOTEC OYJ
Puolikkotie 10
FIN-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address
OUTOTEC OYJ
Puolikkotie 10
FI-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:
☐ Notifications by e-mail authorized

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☐ the receiving Office
☒ the International Searching Authority
☐ the Authority(ies) specified for supplementary search
☐ the International Preliminary Examining Authority
☐ the designated Offices concerned
☐ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 910 06 10

Authorized officer
Martinez Sandrine
e-mail ro.ib@wipo.int
Telephone No. +4122 338 9741

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NOTIFICATION OF THE RECORDING OF A CHANGE

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SHELSTON IP
Shelston IP
Level 21, 60 Margaret Street
Sydney, New South Wales 2000
AUSTRALIE

Date of mailing *(day/month/year)*
10 September 2013 (10.09.2013)

Applicant's or agent's file reference
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International application No.
PCT/IB2013/055305

International filing date *(day/month/year)*
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1. The following indications appeared on record concerning:

☒ the applicant ☐ the inventor ☐ the agent ☐ the common representative

Name and Address
OUTOTEC OYJ
Riihitontuntie 7
FI-02200 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address
OUTOTEC OYJ
Puolikkotie 10
FIN-02230 Espoo
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: (358) 205 29211
Facsimile No.: (358) 205 292988
E-mail address:
☐ Notifications by e-mail authorized

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☐ the receiving Office
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☐ the Authority(ies) specified for supplementary search
☐ the International Preliminary Examining Authority
☐ the designated Offices concerned
☐ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 910 06 10

Authorized officer
Lambert Jean-Francois
e-mail ro.ib@wipo.int
Telephone No. +4122 338 8717

Abstract

The present invention provides improvements to a fluid bearing (11, 12) for a journal (4), one being a polymer bearing pad (17) comprising an outer surface (13), at least one recess (18) for receiving lubricating fluid from a base (14) of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means (8, 18A) for securely mounting said polymer bearing pad to said base. Other improvements include a fluid bearing (11, 12) comprising the polymer bearing pad (17), methods of making the polymer bearing pad and fluid bearing, a fluid bearing comprising a polymer bearing pad (17) having a chamfer (37) and a multidirectional fluid bearing (70).

Figure 6

Exhibit 1027
FLS v. Metso - IPR2025-00985

Claims

1. A polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and mounting means for securely mounting said polymer bearing pad to said base.

2. The polymer bearing pad of claim 1, wherein said mounting means comprises a mounting portion extending from said polymer bearing pad.

3. The polymer bearing pad of claim 2, wherein said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base.

4. The polymer bearing pad of any one of the preceding claims, wherein said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer pad to said base.

5. The polymer bearing pad of claim 4, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess.

6. The polymer bearing pad of any one of the preceding claims, wherein said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

7. The polymer bearing pad of any one of the preceding claims, further comprising a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

8. The polymer bearing pad of claim 7, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

9. The polymer bearing pad of any one of the preceding claims, wherein said outer surface is partially curved. .

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10. The polymer bearing pad of any one of claims 1 to 8, wherein said outer surface is substantially planar.

11. The polymer bearing pad of any one of the preceding claims, further comprising at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

12. A fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

the polymer bearing pad of any one of the preceding claims mountable to said base.

13. The fluid bearing of claim 12, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

14. The fluid bearing of claim 13, wherein said flange is located at an outer edge of said base.

15. The fluid bearing of any one of claims 10 to 14, said at least one recess of said polymer bearing pad comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage of said base.

16. The fluid bearing of any one of claims 10 to 15, further comprising at least one fastener for mounting said polymer bearing pad to said base, said at least one fastener comprising a bore for conveying lubricating fluid from said at least one passage to said at least one recess.

17. The fluid bearing of claim 16, wherein said at least one recess has a locking tab for retaining said head portion within said at least one recess.

18. The fluid bearing of claim 16, further comprising a plug for engagement with said head portion and said at least one recess.

19. The fluid bearing of claim 16 or 18, further comprising a locking element for retaining said at least one fastener within said at least one recess.

20. The fluid bearing of any one of claims 12 to 19, further comprising a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

21. The fluid bearing of claim 20, wherein each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

22. The fluid bearing of any one of claims 12 to 21, wherein said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface.

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

23. The fluid bearing of claim 22, wherein said first surface is orthogonal to said second surface.

24. The fluid bearing of claim 22 or 23, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

25. The fluid bearing of any one of claims 12 to 21, wherein said fluid bearing is at least one of a radial hydrostatic bearing, a self-aligning radial hydrostatic bearing, a

fixedly mounted radial hydrostatic bearing, a hydrostatic slipper bearing, an axial bearing, a self-aligning axial hydrostatic bearing and a fixedly mounted axial hydrostatic bearing.

26. A method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

27. The method of claim 26, wherein said mounting means forming step comprises machining said polymer pad to form a mounting portion extending from said polymer pad.

28. The method of claim 26, wherein said mounting means forming step comprises drilling, punching, cutting or machining an opening in said at least one recess to receive at least one fastener.

29. The method of claim 26 or 28, further comprising chamfering an outer edge of said polymer pad.

30. The method of any one of claims 26 to 29, wherein said at least one recess forming step comprises machining said at least one recess in said polymer pad and machining at least one interconnecting passage to interconnect said at least one recess to said base.

31. A method of making a fluid bearing for a journal, comprising:

providing a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port and at least one flange;

making a polymer bearing pad in accordance with the method of any one of claims 26 to 30, and

mounting said polymer bearing pad to said base.

32. The method of claim 31, wherein said mounting step comprising mechanically fastening said polymer bearing pad to said base.

33. The method of claim 31 or 32, wherein there are a plurality of said polymer pads, said method further comprising connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal.

34. The method of claim 33, further comprising forming at least one lateral connecting portion in each said polymer bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

35. The method of claim 33 or 34, wherein said further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

36. A fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

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37. The fluid bearing of claim 36, wherein said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

38. The fluid bearing of claim 36 or 37, wherein said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

39. A multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface, one or more lubricating fluid supply ports and a plurality of passages in fluid communication with said lubricating fluid supply ports, said first surface and said second surface,

a first polymer bearing pad mountable to said first surface, said polymer bearing pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer bearing pad mountable to said second surface, said second polymer bearing pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

40. The multidirectional fluid bearing of claim 39, said first polymer bearing pad substantially covers said first outer surface and said polymer bearing pad substantially covers said second outer surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

41. The multidirectional fluid bearing of claim 40, wherein at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal.

42. The multidirectional fluid bearing of claim 41, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

43. The multidirectional fluid bearing of any one of claims 39 to 42, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, wherein said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess, said head portion being tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

44. The multidirectional fluid bearing of any one of claims 39 to 43, wherein said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

45. The multidirectional fluid bearing of any one of claims 39 to 42, wherein at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base, and further comprising a locking element for retaining said at least one fastener within said at least one recess.

46. The multidirectional fluid bearing of any one of claims 39 to 45, wherein at least one of said first and second polymer bearing pads comprises a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

47. The fluid bearing of claim 46, wherein each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

48. The multidirectional fluid bearing of claim 39, wherein at least one of said first polymer bearing pad and said second polymer bearing pad comprises said polymer bearing pad of any one of claims 1 to 11.

49. The multidirectional fluid bearing of claim 48, wherein base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

50. The multidirectional fluid bearing of claim 49, wherein said flange is located at an outer edge of said base.

51. The multidirectional fluid bearing of any one of claims 39 to 50, wherein said first surface is orthogonal to said second surface.

52. The multidirectional fluid bearing of any one of claims 39 to 51, wherein said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing and said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing.

"Improvements in fluid bearings"

Field of the Invention

[0001] The present invention relates to a fluid bearing and in a particular a hydrostatic polymeric bearing for use in a mill. The invention has been developed primarily for use as a hydrostatic polymeric bearing in grinding mills and will be described hereinafter by reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use, but also extends to other types of fluid bearings such as hydrodynamic bearings and hybrid bearings (i.e. bearings that use a combination of hydrodynamic and continuous hydrostatic flow for lubrication).

Background of the Invention

[0002] The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its advantages to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an express or implied admission that such art is widely known or forms part of common general knowledge in the field.

[0003] A grinding mill has a mill chamber and two journal shafts, the journals being mounted upon supports for rotation. Typical bearings have two main components; a steel base for mounting to the support and a bearing pad or surface for contact with the mill journal. These mill bearings are installed between the mill journals and the supports so that the mill journals rotate on the bearing pads during operation of the grinding mill.

[0004] The applicant developed a hydrostatic pad bearing system for grinding mills that is currently in use. In this hydrostatic pad bearing system, an external oil supply system pumps high-pressure oil to recesses machined into the bearing so that the oil forms a thin film on the bearing pad surface. The resultant hydraulic pressure is sufficient to completely lift the mill journal off the hydrostatic pads and separate the sliding surfaces. Thus, mill actually “floats” on a film of oil between journal and bearing. As such the bearing will operate under both static and dynamic conditions. Since the surfaces are completely separated and the bearing is self aligning there is no metal-to-metal contact between the bearing surface and the mill journal due to the oil film, thus

resulting in only low friction. Consequently, maintaining the oil film between the surfaces means that there is virtually no wear in the bearing.

[0005] Despite the advantages conferred by this hydrostatic bearing system, a loss of oil pressure (and thus a reduction in the oil film thickness) can cause failure of the bearings, leading to damage to the bearing pad and/or the mill journal. For example, it can take a few seconds for a grinding mill to stop turning in the event of a power failure, and when this happens there is a high risk of damage to the mill bearing pads or journal surfaces due to a loss of oil reducing the oil film thickness, thereby bringing the journal and bearings into direct metal to metal contact. The consequential downtime for replacement of any damaged bearings and/or journals severely impairs operation of the mill, reducing its efficiency.

[0006] To prevent this type of damage, grinding mill lubrication systems usually have pressure accumulator systems that are typically used to store and deliver high pressure oil to the bearing in the event of a power failure and the oil supply system fails. These pressure accumulators are expensive, require frequent maintenance to ensure that they are at the appropriate pressure level and can interfere with control systems in the mill. Thus, there are increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and then the oil supply ports for delivering high pressure oil to the recesses are then drilled into the base. Bronze is spray welded or cast onto the relevant parts of the steel base to form the bearing pad or lining. Spray welding enables the bronze metal to form a seal with the base. White metal may be used instead of bronze, but is cast onto the base. Due to this manufacturing process, the repair and/or refurbishment of these bearings involves initially cleaning the damaged bearing surface, machining any parts of the steel base and either spray welding the bronze or re-casting the bronze/white metal. This repair process cannot be performed on-site but requires the bearing to be returned to the manufacturer. Consequently, mills must keep a sufficient stock of spare bearings to account for the absence of damaged bearings being repaired. This adds to the maintenance costs of the mill.

[0008] It is an object of the present invention to overcome or substantially ameliorate one or more of the disadvantages of prior art, or at least to provide a useful alternative.

[0009] It is an object of the invention in at least one preferred form to provide improved fluid bearings for mills that are more tolerant to the loss of oil film, distortions in the journal, require less strict manufacturing tolerances, can be easily repaired, minimise waste and reduce or eliminate the need for pressure accumulators, and a method for making such fluid bearings.

Summary of the Invention

[0010] According to a first aspect of the invention, there is provided a polymer bearing pad for a fluid bearing, comprising an outer surface, at least one recess for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface and a mounting means for securely mounting said polymer bearing pad to said base.

[0011] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0012] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0013] Preferably, said mounting means comprises a mounting portion extending from said polymer bearing pad. More preferably, said mounting portion comprises a protrusion from a mounting surface opposite to said outer surface for engaging a flange of said base. In one preferred form, said mounting surface comprises an inner surface of said polymer bearing pad. In another preferred form, said inner surface is the underside of said polymer bearing pad.

[0014] Alternatively or additionally, said mounting means comprises at least one opening for receiving at least one fastener for mounting said polymer bearing pad to

said base. More preferably, said at least one recess has a locking tab for retaining a head portion of said fastener within said at least one recess.

[0015] Preferably, said polymer bearing pad substantially covers an outer surface of said base to create a fluid seal between said polymer bearing pad and said base.

[0016] Preferably, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said base.

[0017] Preferably, said outer surface is partially curved. Alternatively, said outer surface is substantially planar.

[0018] Preferably, said polymer bearing pad comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said polymer bearing pad comprises two chamfers at opposing outer edges. In one preferred form, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In a particularly preferred form, said chamfer is inclined approximately 8° from said tangent.

[0019] Preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer bearing pad.

[0020] Preferably, said polymer bearing pad comprises at least one complementary connecting portion for connecting said polymer bearing pad to an adjacent polymer bearing pad. In a particularly preferred form, said polymer pad has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of said adjacent polymer bearing pad.

[0021] Preferably, said polymer bearing pad is made from any suitable polymer, including, but not limited to, polyetheretherketone (PEEK), PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the polymer pad is made of PEEK.

[0022] According to a second aspect of the invention, there is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port, and

the polymer bearing pad of the first aspect of the present invention mountable to said base.

[0023] Preferably, said polymer bearing pad has the preferred features of the abovementioned first aspect of the invention. In this second aspect, said at least one recess comprises at least one interconnecting passage for fluidly connecting said at least one recess to said at least one passage.

[0024] Preferably, said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base. More preferably, said at least one flange is located at an outer edge of said base. In one preferred form, said base comprises two of said flanges located at opposing outer edges of said base.

[0025] Preferably, said fluid bearing comprises at least one fastener for mounting said polymer bearing pad to said base. More preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said bore conveys lubricating fluid from said at least one passage to said interconnecting passage.

[0026] Preferably, said fluid bearing is a hydrostatic bearing. More preferably, said outer surface is partially curved such that said fluid bearing acts as a radial hydrostatic bearing. In one preferred form, said fluid bearing is a self-aligning radial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted radial hydrostatic bearing. In a further preferred form, said fluid bearing is a hydrostatic slipper bearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing acts as an axial bearing. In one preferred form, said fluid bearing is a self-aligning axial hydrostatic bearing. In another preferred form, said fluid bearing is a fixedly mounted axial hydrostatic bearing.

[0028] Preferably, said at least one fastener is partially received in said at least one passage. Preferably, said at least one fastener comprises a head portion for engagement with said at least one recess. More preferably, said at least one recess has a locking tab for retaining said head portion within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0029] Alternatively, said fluid bearing comprises a plug for engagement with said head portion and said at least one recess to retain said at least one fastener. In one preferred form, said at least one fastener is countersunk into said at least one recess.

[0030] Preferably, said at least one fastener is substantially retained within said at least one recess by a locking element. More preferably, said locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0031] Preferably, the fluid bearing comprises a plurality of said polymer pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

[0032] Preferably, said polymer pads are connected together. More preferably, each of said polymer pads has at least one complementary connecting portion for connecting said polymer pad to an adjacent polymer pad. In one preferred form, each of said polymer pads has at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0033] Preferably, said base further comprises a first surface, a second surface, a plurality of said at least one passages and a plurality of said at least one lubricating fluid supply ports, wherein said at least one passages are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

a first of said polymer bearing pads is mountable to said first surface and a second of said polymer bearing pads is mountable to said second surface,

wherein said first polymer bearing pad comprises a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

said second polymer bearing pad comprises a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0034] Preferably, said first outer surface is partially curved such that said first polymer bearing pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer bearing pad acts as a self-aligning radial hydrostatic bearing.

[0035] Preferably, said second outer surface is substantially planar such that said second polymer bearing pad acts as an axial bearing. In one preferred form, said second polymer bearing pad acts as a fixedly mounted axial hydrostatic bearing.

[0036] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0037] According to a third aspect of the invention, there is provided a method of making a polymer bearing pad for a fluid bearing, comprising forming a polymer pad having an outer surface, forming at least one recess in said polymer pad for receiving lubricating fluid from a base of said fluid bearing and distributing said lubricating fluid to said outer surface, and forming a mounting means on said polymer pad for securely mounting said polymer pad to said base.

[0038] Preferably, said mounting means forming step comprises forming a mounting portion to extend from said polymer pad. More preferably, said mounting portion forming step comprises machining said polymer pad to form said mounting portion. Alternatively, said mounting portion forming step comprises placing said polymer pad in a mould to form said mounting portion. Alternatively or additionally, said mounting means forming step comprises forming an opening in said at least one recess for receiving at least one fastener. More preferably, said opening is drilled, punched, cut or machined into said at least one recess.

[0039] Preferably, said at least one recess forming step comprises machining said at least one recess in said polymer pad. More preferably, said at least one recess forming

step comprises machining at least one interconnecting passage to interconnect said at least one recess to said base.

[0040] Preferably, said method further comprises chamfering an outer edge of said polymer pad. In one preferred form, said chamfering step comprises chamfering two opposing outer edges of said polymer pad.

[0041] According to a fourth aspect of the invention, there is provided a method of making a fluid bearing for a journal, comprising the steps of:

providing a base having at least one lubricating fluid supply port and at least one passage in fluid communication with said at least one lubricating fluid supply port;

forming a polymer pad having an outer surface and at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to said outer surface, and

mounting said polymer bearing pad to said base.

[0042] Preferably, said method comprises each of the preferred steps in the abovementioned third aspect of the invention. In this aspect, said forming step further comprises machining at least one interconnecting passage to interconnect said at least one recess to said passage.

[0043] Preferably, said mounting step comprising mechanically fastening said polymer bearing pad to said base. More preferably, the method further comprises the steps of using a fastener to mechanically fasten said polymer bearing pad to said base and forming a bore in said at least one fastener for conveying lubricating fluid from said at least one passage to said at least one recess. In one preferred form, said mounting step comprises bolting said polymer pads to said base.

[0044] Preferably, where there are a plurality of said polymer pads, said method further comprises the step of connecting said polymer bearing pads such that said outer surfaces of said polymer bearing pads form a substantially uniform bearing surface for said journal. More preferably, said forming step further comprises the step of forming at least one connecting portion in each said polymer bearing pad for connecting said polymer pad to an adjacent polymer bearing pad. In one preferred form, said forming step comprises forming at least one lateral connecting portion in each said polymer

bearing pad for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0045] Preferably, said method further comprises selecting one or more polymer bearing pads for mounting at the outer edges of said base and chamfering an outer edge of each selected polymer bearing pad.

[0046] Where said fluid bearing is a radial hydrostatic bearing, each of said polymer pads have curved outer surfaces such that said outer surfaces define a substantially curved uniform bearing surface.

[0047] According to a fifth aspect of the invention, there is provided a fluid bearing for a journal, comprising:

a base having at least one lubricating fluid supply port, at least one passage in fluid communication with said at least one lubricating fluid supply port, and

a polymer bearing pad having at least one recess for receiving lubricating fluid from said at least one passage and distributing said lubricating fluid to an outer surface of said bearing pad,

said polymer bearing pad being mountable to said base and further comprising a chamfer at an outer edge for retaining said lubricating fluid thereon and transferring said lubricating fluid to said journal.

[0048] Preferably, said chamfer is inclined approximately 0.01° to 89° from a tangent of an edge of said outer surface. In one preferred form, said chamfer is inclined approximately 8° from a tangent of an edge of said outer surface.

[0049] Preferably, said chamfer has an outer edge that is displaced from said journal when said journal engages said polymer bearing pad.

[0050] Preferably, the polymer bearing pad is composed of a polymer material that includes, but is not limited to, PEEK, PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. In one preferred form, the bearing pad is composed of polyetheretherketone (PEEK).

[0051] Preferably, said fluid bearing is a hydrostatic bearing.

[0052] According to a sixth aspect of the invention, there is provided a multidirectional fluid bearing for a journal, comprising:

a base having a first surface, a second surface, at least one lubricating fluid supply port and a plurality of passages in fluid communication with said at least one lubricating fluid supply port, said first surface and said second surface,

a first polymer pad mountable to said first surface, said polymer pad having a first outer surface and at least one recess for receiving lubricating fluid from at least one of said plurality of passages and distributing said lubricating fluid to said first outer surface, and

a second polymer pad mountable to said second surface, said polymer pad having a second outer surface and at least one recess for receiving lubricating fluid at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

[0053] Preferably, said first polymer bearing pad substantially covers said first outer surface and said polymer bearing pad substantially covers said second outer surface to respectively create fluid seals between said first and second polymer bearing pads and said base.

[0054] Preferably, at least one of said first and second polymer bearing pads comprises a chamfer at an outer edge for retaining lubricating fluid at said outer edge and transferring said lubricating fluid to a journal. More preferably, said chamfer has an outer edge that is displaced from a journal when said journal engages said at least one polymer bearing pad.

[0055] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. More preferably, said at least one recess comprises a locking tab for retaining a head portion of said fastener within said at least one recess. In one preferred form, said head portion is tapered to facilitate retention of said at least one fastener within said at least one recess by said locking tab.

[0056] Preferably, said at least one fastener comprises a bore for conveying lubricating fluid from said at least one passage to said at least one recess, said at least one fastener being partially received in said at least one passage.

[0057] Preferably, at least one of said first and second polymer bearing pads comprises at least one opening for receiving at least one fastener for mounting said at least one polymer bearing pad to said base. Preferably, said at least one polymer bearing pad comprises a locking element for retaining said at least one fastener within said at least one recess.

[0058] Preferably, least one of said first and second polymer bearing pads comprises a plurality of said polymer bearing pads, wherein said outer surfaces of said polymer pads form a substantially uniform bearing surface for said journal. More preferably, each of said polymer bearing pads comprises at least one lateral connecting portion for mutual engagement with a corresponding lateral connecting portion of an adjacent polymer bearing pad.

[0059] Preferably, said first outer surface is partially curved such that said first polymer pad acts as a radial hydrostatic bearing. In one preferred form, said first polymer pad acts as a self-aligning radial hydrostatic bearing.

[0060] Preferably, said second outer surface is substantially planar such that said second polymer pad acts as an axial bearing. In one preferred form, said second polymer pad acts as a fixedly mounted axial hydrostatic bearing.

[0061] Preferably, said first surface is orthogonal to said second surface. In one preferred form, said first surface is an upper or top surface of said base and said second surface is a side surface of said base.

[0062] Preferably, said first polymer bearing pad and said second polymer bearing pad have the preferred features of the abovementioned aspects of the invention.

[0063] Preferably, said lubricating fluid includes oil or water.

Brief Description of the Drawings

[0064] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

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[0065] Figure 1 is a cross-sectional side view of a grinding mill for receiving a hydrostatic bearing according to a first embodiment of the invention;

[0066] Figure 2 is a perspective view of a bearing assembly in the mill of Figure 1;

[0067] Figure 3 is a front view of the bearing assembly of Figure 2;

[0068] Figure 4 is a schematic plan view of a radial hydrostatic bearing for the bearing assembly of Figure 3;

[0069] Figure 5 is a cross-sectional view of the radial hydrostatic bearing along section A-A of Figure 4;

[0070] Figure 5A is a expanded partial cross-sectional view of the chamfer of the radial hydrostatic bearing of Figure 4;

[0071] Figure 6 is a cross-sectional view of the radial hydrostatic bearing taken along section B-B of Figure 4;

[0072] Figure 7 is a schematic plan view of the base of the radial hydrostatic bearing of Figure 4;

[0073] Figure 8 is a schematic cross-sectional view of the base of Figure 7;

[0074] Figure 9 is a schematic cross-sectional view of an axial hydrostatic bearing for the bearing assembly of Figure 3;

[0075] Figure 10 is a schematic plan view of the axial hydrostatic bearing of Figure 9;

[0076] Figures 11 and 11A are schematic partial views of a fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0077] Figure 12 and 12A are schematic partial views of an alternative fastener for use with the hydrostatic bearings of Figures 4 to 10;

[0078] Figure 13 is a schematic partial view of the chamfer of Figure 5A;

[0079] Figure 14 is a schematic cross-sectional view of a prior art hydrostatic bearing;

[0080] Figure 15 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with another embodiment of the invention;

[0081] Figures 16 and 16A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0082] Figures 17 and 17A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0083] Figures 18 and 18A are a schematic plan and cross-sectional views, respectively, of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0084] Figure 19 is a schematic cross-sectional view of a hydrostatic bearing manufactured in accordance with a further embodiment of the invention;

[0085] Figure 20 is a schematic partial cross-sectional view of an axial hydrostatic bearing according to a further embodiment of the invention;

[0086] Figure 21 is a schematic partial expanded view of the axial hydrostatic bearing of Figure 20;

[0087] Figure 22 is a schematic side view of the axial hydrostatic bearing of Figure 20;

[0088] Figure 23 is a schematic plan view of a hydrostatic bearing in accordance with a further embodiment of the invention;

[0089] Figure 24 is a schematic end view of the hydrostatic bearing of Figure 23;

[0090] Figure 25 is a schematic side view of the hydrostatic bearing of Figure 23, and

[0091] Figure 26 is a schematic perspective view of a hydrostatic bearing in accordance with a further embodiment of the invention.

Preferred Embodiments of the Invention

[0092] Referring to Figure 1, a typical grinding mill 1 comprises a milling chamber or body 2 rotatably mounted on supports 3 via journal shafts 4 and bearing assemblies 5. The mill body 2 has an inlet 6 for introducing a charge for grinding and a discharge outlet 7 for removing the processed charge from the mill 1.

[0093] As best shown in Figures 2 and 3, each bearing assembly 5 has a frame 10 and a plurality of fluid bearings in the form of radial hydrostatic bearings 11 and axial hydrostatic bearings 12, which are designed to transport a lubricating fluid in the form of a high pressure oil to an outer surface 13A, 13B of each bearing 11, 12.

[0094] Referring to Figures 4 to 8, where corresponding features have been given the same reference numerals, each radial hydrostatic bearing 11 comprise a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. The hydrostatic bearings 11, 12 are self-aligning in that the hydrostatic bearings self-adjust to any changes in the angular position of the journals 4 during operation of the mill 1. This is typically achieved by having the base 14 mounted on a spherical seat (not shown) to permit self-adjustment to any angular movement of the journals 4. The base 14 is composed of cast iron, but can be made of any other suitable metal or material.

[0095] A polymer pad 17 is mountable to the base 14 of each radial hydrostatic bearing 11 via a mounting portion 8 extending from the polymer pad. In this embodiment, the mounting portion 8 is a protrusion extending from a mounting surface opposite the outer surface 13A to engage flanges 9 located at respective outer edges or sides of the base 14. Generally, the mounting surface will be an inner surface or the underside of the polymer pad 17, but in other embodiments can be located elsewhere. Likewise, the flanges 9 need not be located at opposing outer edges of the base 14, but

can be arranged in any manner that would act to hold captive the bearing pad 17, such as the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting portions 8 are constrained.

[0096] The polymer bearing pad 17 has at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13A to act as a lubricating fluid between the radial hydrostatic bearing 11 and the journal shafts 4. In the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19. Also, the radial hydrostatic bearings 11 have a plurality of oil supply ports 15, oil galleries 16, recesses 18 and interconnecting passages 19.

[0097] The outer surface 13A of the polymer pad 17 of the radial hydrostatic bearings 11, 12 is curved to receive the curved bearing surface 20 of the journal 4, as best shown in Figures 1, 9, 11 and 11A. Thus, the outer surface 13A of the polymer pad 17 forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 11 when assembled with the base 14.

[0098] Referring to Figures 9 and 10, where corresponding features have been given the same reference numerals, each of the axial hydrostatic bearings 12 also comprises a base 14 having at least one lubricating fluid supply port in the form of an oil supply port 15 and at least one passage in the form of an oil gallery 16 in fluid communication with the oil supply port 15. A polymer pad 17 is mountable to the base 14 of each axial hydrostatic bearing 12, the polymer pad 17 having at least one recess 18 for receiving oil from the oil gallery 16 and distributing it to the outer surface 13B to act as a lubricating fluid between the axial hydrostatic bearings 12 and the journal shafts 4. Again, in the preferred embodiment, the recess 18 is fluidly connected to the oil gallery 16 via an interconnecting passage 19 in the polymer pad 17. In addition, the axial hydrostatic bearings 12 have a plurality of oil galleries 16 in the base 14, and recesses 18 and interconnecting passages 19 in the polymer pad 17.

[0099] Also, the outer surface 13B of the axial hydrostatic bearing 12 is substantially planar as it receives the substantially planar end surface 21 of the journal 4, as best shown in Figure 1. Similarly to outer surface 13A, the outer surface 13B of the polymer

pad 17 also forms a bearing surface, and hence the polymer pad is a bearing pad for the bearings 12 when assembled with the base 14.

[00100] In both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 substantially covers the entire outer surface 22 of the base 14 to form a substantially fluid impermeable seal between the base and the polymer pad. Also, the polymer pad 17 is mounted to the base 14 using at least one fastener in the form of bolts 23, as best shown in Figures 5 and 9. The fastening system for both the radial hydrostatic bearing 11 and the axial hydrostatic bearing 12 is described in more detail below.

[00101] The fastening system for mounting the polymer pad 17 to the bases 14 of the radial and axial hydrostatic bearings 11, 12 is illustrated in more detail in Figures 11 and 11A, where corresponding features have been given the same reference numerals. The fastening system comprises one of more bolts 23 that are inserted into corresponding openings 18A that are in fluid communication with the oil galleries 16. Each bolt 23 has a bore in the form of through bore 24 for conveying oil from the oil galleries 16 to the recesses 18 via a discharge port 25, as best shown in Figure 11. Thus, there is no need to provide separate oil passages between the oil galleries 16 in the base 14 and the recesses 18 in the polymer pad 17, unlike conventional bronze/white metal hydrostatic bearings. This reduces the complexity and cost in the manufacture of the hydrostatic polymer bearings. It will be appreciated that not all the bolts necessarily will have a bore as sometimes more fasteners are required to mount the polymer bearing pad 17 than the number of oil passages to connect the oil galleries 16 to the recesses 18.

[00102] The bolt 23 is inserted into the oil gallery 16 via the opening 18A and has a head portion 26 for engagement with a seat 27 of the recess 18, as best shown in Figure 11A. The bolt 23 engages the recess 18 to ensure that, in the event of the bolt becoming loose, it is held captive within the recess 18. This prevents any loose bolts 23 coming into contact with and damaging the journal 4. A locking tab 28 is also provided for retaining the head portion 26 within the recess 18. In addition, the head portion 26 has a tapered portion 29 to facilitate retention of the bolt 23 within the recess 18 by the locking tab 28.

[00103] Also, the mounting portion 8 of the polymer pad 17 engages the flanges 9 of the base 14 to help lock the polymer pad in place. This ensures that frictional loads

generated during the rotation of the journal 4 do not forcibly remove or "wipe" the polymer pad 17 from the base 14, even where the bolts 23 become loose, such that the mounting portion 8 and flanges 9 in effect replace the restraint of the bolts 23 against frictional related lateral loads. This makes for a very simple but reliable arrangement, with a level of redundancy to ensure correct operation even if the bolts 23 become loose.

[00104] Moreover, hydrostatic pressure acts between the journal 4 and the polymer bearing pad 17, while there is atmospheric pressure between the polymer bearing pad and the base 14. This pressure difference during operation of the fluid bearing 11, 12, together with the engagement of the mounting portion 8 and the flange or shoulder 9, acts to hold the polymer bearing pad 17 in place. In practice, the fastening system primarily assists in the initial installation of the polymer bearing pad 17 since there is no pressure between polymer bearing pad and the journal 4. This means that in the event bolts 23 are loose the polymer bearing pad 17 would be free to move or "float" until the hydrostatic pressure at the journal 4 is greater than the atmospheric pressure between polymer bearing pad and the base 14.

[00105] An alternative fastening arrangement is illustrated in Figure 12, where corresponding features have been given the same reference numerals. The fastener takes the form of a countersunk screw 30 having a tapered head portion 31 for engagement with a seat 27 recessed in the polymer pad 17. Due to the screw 30 being countersunk into the base 14 and the polymer pad 17, the head portion 31 is tapered in the reverse direction to the taper of the head portion 26 of the bolt 23. To prevent any screw 30 becoming loose and coming into contact with the journal 4, a plug 32 is used to engage the head portion 31 and a locking tab 28 is used to retain the plug 32, and thus the screw 30, within the seat 27. Oil is delivered to the outer surface 13 through a separate recess in the form of a hole 33 that is connected to a bore 34 located over the same position as the oil gallery 16 in the base 14 below, as best shown in Figure 12A.

[00106] In either fastening arrangement, separate O-rings 36 are fitted to the base 14 to provide a fluid seal preventing oil leaking in between the polymer pad 17 and the base, as best shown in Figures 9, 11, 11A and 12A. The thread into which the bolts 23 also assists in forming a fluid seal between the polymer bearing pad 17 and the base 14.

The threads 35 act as plugs to close off holes that are required for machining the oil galleries 16 that direct lubricating fluid into the corner pockets from the central pocket.

[00107] In operation, the radial and axial hydrostatic bearings 11, 12 are installed in the bearing assembly 5 in the positions generally shown in Figure 3 in a manner readily understood by a person skilled in the art. The mill body 2 is then mounted on the bearing assembly 5 via the journals 4. An oil supply system is fluidly connected to the oil supply ports 15 in the base 14 of each radial and axial hydrostatic bearing 11, 12. Typically, the oil is positively pumped to the oil supply ports 15. However, in some variants, the oil need not be supplied by positive displacement pump. In either case, high pressure oil is conveyed from the oil supply ports 15 through the passages 16, bores 23 and interconnecting passages 19 to the recesses 18 and discharge ports 25 and up to the outer surfaces 13A, 13B, as best shown by arrow 39 in Figure 11. The oil collects on the outer surfaces 13A, 13B to create an oil film and lubricate the bearing surfaces 20, 21 of the journals 4.

[00108] Where there is a loss of oil due to a failure in the oil supply system, the polymer pad 17 absorbs most, if not all, of the detrimental effects so any damage is limited to the polymer pad 17 rather than the bearing surfaces 20, 21 of the journal 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and any damage is suffered by the polymer pad 17. Thus, by having the polymer pad 17 provided with recesses 18 for distributing oil to the outer surface 13, rather than the base 14, the polymer pad can be easily replaced in the event of damage without having to repair the entire bearing. In addition, this advantage is further facilitated by using mechanical fasteners described above to mount the polymer pad 17. Thus, a damaged polymer pad 17 can be removed simply by removing the fasteners 23, 30, enabling easy replacement of the polymer pads 17. Thus, maintenance and operational costs of the mill 1 are reduced, increasing the efficiency of the mill.

[00109] It has also been discovered that providing a polymer pad for the hydrostatic bearings 11, 12 confer numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads, as follows:

(1) It has been discovered that the polymer pad 17 behaves similar to white metal/bronze pads, but is able to self-mould to the journal 4. That is, the polymer pad 17 is able to modify its outer surface 13A, 13B to accommodate circumferential surface imperfections on the bearing surfaces 20, 21 of the journal 4. This reduces or eliminates the need for tight machining tolerances required for bronze bearings, and can subsequently reduce the associated machining costs. Hence, there is a reduced manufacturing cost for the hydrostatic bearings by using a polymer pad.

(2) The polymer bearing pads 17 enable reduced lubrication rates to be used over traditional bronze bearing pads due to the running in characteristics of polymer material, thus conserving lubricating fluid. However, where necessary or desirable, the polymer pads 17 operate equally well at the same lubrication rates used for conventional bronze/white metal bearing pads.

(3) The hydrostatic polymer bearing pads 17 have a lower modulus of elasticity, and thus are able to create a “hovercraft” type cushion around the perimeter of the polymer pad. This acts to accommodate journal imperfections whilst maintaining pressure, much like the cushioning effect produced when a hovercraft moves over bumpy ground.

(4) The hydrostatic polymer bearing pads 17 are much more tolerant than traditional materials to a loss of oil to the bearing 11,12, to contact between journal 4 and outer surface 13A, 13B, and to deformations in the journal bearing surfaces 20, 21. Thus, a loss of oil film due to oil viscosity being too low (from such causes as a high temperature or oil degradation) can be more tolerably managed by the polymer pad 17.

(5) The polymer is elastic, unlike bronze, and is significantly softer than bronze. Thus, the elastic nature of the polymer pads 17 dampen excessive forces that are applied to the hydrostatic bearings 11, 12. For example, where there is a loss of oil through a shock load placed on the hydrostatic bearing 11, 12 there is little or no risk of damage to the metal journal 4 because the polymer pad 17 dampens the shock to some extent and any damage sustained is suffered by the polymer pad rather than the journal. By way of contrast, with white metal/bronze bearings there

is a significant risk of damage to metal journals, resulting in on-site machining and costly stoppages. This advantage of the elasticity of the polymer bearing pads also extends to white metal bearing pads, which are brittle and so are more easily damaged when subjected to typical shock loads.

(6) Any contaminants in the oil that would normally damage the bearing surfaces of the journal 4 or a standard bearing pad tend to be embedded into the polymer pad 17 without adversely affecting operation of the hydrostatic bearing 11, 12.

(7) The self-moulding property of the polymer pads 17 means that the outer surfaces 13A, 13B of the polymer pads tend to conform to the profile of the bearing surface 21 of the journal 4 that it is running against. As a consequence, the polymer pads 17 (and hence bearing 11) do not necessarily require a self-alignment mechanism (such as a spherical seat) within certain limits, unlike conventional bearings. It is also contemplated that the self-moulding property also permits the design and installation of hydrostatic bearings that ordinarily would be outside of the capacity of conventional bearings, since the polymer pad 17 can provide some degree of self-alignment in addition to a conventional self-alignment mechanism.

[00110] These advantages of the polymer pad 17 means that the hydrostatic bearings can be operated at lower oil film thicknesses. This has a flow on effect, permitting the use of smaller and cheaper lubrication systems, reducing power consumption and conserving the use of oil. Also, in the event of operational problems damage to the journals 4 and polymer bearing pads 17 is significantly reduced, increasing product life and reducing the frequency of maintenance and repair. Furthermore, any damage is limited to the polymer bearing pads 17 and does not adversely affect operation of the journal 4. Finally, the complex and expensive accumulator systems can be removed, saving installation costs and eliminating their associated maintenance costs.

[00111] Referring now to Figures 5A, 9 and 13, another aspect of the invention is described, where corresponding features have been given the same reference numerals. In this aspect of the invention, a chamfer is provided at an outer edge of a bearing pad for retaining lubricating fluid on the chamfer, thus enabling recycling of lubricating fluid in the bearing. In applying this aspect of the invention to both the radial and axial hydrostatic bearings 11, 12, the polymer pad 17 has a chamfer 37 at both

outer edges 38 for retaining oil on the chamfer, as best shown in Figures 5A, 9 and 13. The chamfer 37 creates a lead-in and lead-out for the oil, especially when residual oil on the outer surfaces 13A, 13B must be relied upon for lubrication in the event of an unexpected loss of normal oil supply to the bearings 11, 12. The chamfer 37 inhibits or prevents oil being wiped off the journal 4, as would occur with a bearing having a sharp straight edge. Thus, the chamfer 37 helps to ensure that there is a residual amount of oil between the polymer pad 17 and the metal journal 4.

[00112] In a conventional bearing, the straight edge would wipe off oil from the journal and thus increase the loss of oil from the bearing. By way of contrast, in this aspect of the invention, the chamfer 37 provides a capture point for the oil that may be lost during operation. As the journal 4 rotates on the hydrostatic bearing 11, 12 the "lead-in" chamfer 37 enables the bearing surface 20 of the journal 4 to capture oil from the chamfer 37 and thus is lubricated before coming into contact with the outer surface 13A, 13B of the hydrostatic bearing. The inventors believe that the oil held by the "lead-in" chamfer 37 is recaptured by the journal 4 due to a hydrodynamic effect produced by its rotation. When the bearing surface 20 of the journal 4 leaves the outer surface 13A, 13B of the hydrostatic bearing, the "lead-out" chamfer 37 on the other side of the hydrostatic bearing 11, 12 feeds any discharging oil from the outer surface 13A, 13B onto the journal to provide a consistent oil thickness over the journal, thus maintaining its lubrication. The provision of chamfers 37 at each outer edge 38 enables the mill journal 4 to be operated in either rotational direction. As a consequence, the use of the chamfers 37 minimises the loss of oil and effectively removes the need to provide oil pressure accumulators with their associated high maintenance and installation costs. Therefore, the chamfers 37 provide the radial and axial hydrostatic bearings 11, 12 provide a cost effective solution and safety measure for the hydrostatic bearings.

[0100] The chamfer 37 is inclined approximately at an angle α to the outer surface 13A, 13B. In the case of the radial hydrostatic bearing 11, the angle α is defined relative to a tangent 39 from the curved outer surface 13A, as best shown in Figure 13. In the case of the axial hydrostatic bearing 12, the angle α is defined relative to the horizontal plane of the planar outer surface 13B. In either case, the angle α is in the range of 0.01° to 89°, and is preferably 8°.

[0101] In addition, the chamfer 37 has an outer edge 40 that is displaced from the journal 4 when the journal engages the polymer pad 17. In both the radial and axial hydrostatic bearings 11, 12 the outer edge 40 of the chamfer 27 is displaced approximately 0.5mm to 1.5 mm from the journal 4. The displacement β is preferably displaced by approximately 0.85 mm from the journal 4.

[0102] It will be appreciated by a person skilled in the art that the chamfer 37 could also be applied to existing bronze/white metal hydrostatic bearings and is not limited to hydrostatic bearings having a polymer pad.

[0103] Referring now to Figures 14 to 19, various methods of making the polymer pads 17 and the hydrostatic bearings 11, 12 of Figures 4 to 10 are illustrated, where corresponding features have been given the same reference numerals. As best shown in Figure 14, manufacturing the curved surface for a radial hydrostatic bearing involves removing the hatched area 41 from the material. This waste material can be a significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[0104] With the hydrostatic bearings of Figures 4 to 10, polymer material can be purchased “off the shelf” in sheet form and subsequently formed to produce the polymer pads 17. One method involves heating the polymer material to a holding temperature which does not melt the material, but the polymer retains some structural integrity while having some malleability or pliability to be able to be formed. There are various procedures that can be used to heat and form the polymer readily understood by the person skilled in the art.

[0105] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated to an intermediate temperature, removed from oven, fully clamped and returned to the oven. After heating to a holding temperature, the former is held for a set period of time, removed from oven and allowed to cool.

[0106] In another example, the polymer is placed in a shaped former and clamped using springs or a dead weight. The former is heated to the holding temperature and

kept at this temperature for a set period of time. After being allowed to cool, the polymer is removed from the former.

[0107] In a further example, the polymer sheet is heated to the holding temperature for set period of time to ensure uniform heating of material. The polymer is then removed from the heat, immediately placed in cold former and pressed to profile. In the case of a radial hydrostatic bearing 11, the former also creates the curved outer surface 13A. After being allowed to cool, the polymer pad 17 is removed from the former.

[0108] After assuming the required shape for the hydrostatic bearing 11, 12, the recesses 18 and interconnecting passages 19 are machined into the outer surface 13A, 13B of the polymer pad 17. Also, the chamfer 37 is machined at the same time. The mounting portion 8 is machined, either before or after machining of the recesses 18, interconnecting passages 19 and the chamfer 37. Alternatively, the mounting portion 8 is formed during the initial moulding of the polymer sheet. The openings 18A can also be formed either during the initial moulding or by drilling, punching, cutting or machining the polymer pad 17. The machined polymer pad 17 is then mechanically mounted to the base 14 using the fastener systems described above to complete assembly of the hydrostatic bearing 11, 12.

[0109] Referring now to Figures 15 to 16, another method of making the hydrostatic bearings is illustrated, where corresponding features have been given the same reference numerals. This method involves making a plurality of polymer pads in the form of slats 50 each having outer surfaces 51 that form a substantially uniform bearing surface 52 for the journal 4, as best shown in Figure 15. The slats 50 are produced using the same heating and forming method described above, and then fastened to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. As best shown in Figure 15, the resultant amount of removed material indicated by hatched area 53 is considerably less than the amount of material removed in a conventional bearing indicated by hatched area 41.

[0110] Also, the polymer pad 17 can be divided into any number of smaller polymer pads or slats 50 of any shape and/or size, as required. For example, there could be six polymeric slats 50 that are rectangular and uniform in shape but have differently shaped

recesses, as best shown in Figures 16, 16A, 17 and 17A. Similarly, the polymeric slats 50 could be larger in size, as best shown in Figures 18 and 18A.

[0111] In a further variation to this method, the polymeric slats 55 each have complementary connecting portions 56 to connect with an adjacent polymer pad 55, as best shown in Figure 19. The complementary connecting portions in this variation take the form of teeth 56 that are splayed together so that the slats 55 form a complete polymer pad 17. The polymer pads 55 are then mounted to the base 14 using either of the fastener systems as described in relation to Figures 4 to 10. Once in position, glue may be applied at adjacent surfaces of the polymer slats and their teeth 56 to enhance sealing. Then, the polymer slats 55 are clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of mill journal 4 on the polymeric slats 55 works to ensure the joint is always in compression. It has been found by testing such bearings that they are strong enough as a bearing surface for the journal 4. It will be appreciated that other profiles for the connecting portions 56 can be used, such as tabs and detents of any polygonal shape.

[0112] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50reduces the amount of wastage involved with machining standard bearings, as indicated in area 41 of Figure 14, and provides a suitable supplementary option to heating and forming the entire polymer pad 17 as described above.

[0113] While the hydrostatic bearings 11, 12 have been described in the context of self-aligning hydrostatic bearings, it will be appreciated that the various aspects of the invention are also equally applicable to fixedly mounted hydrostatic bearings. Referring now to Figures 20 to 22, one example of a fixedly mounted hydrostatic bearing 60 is illustrated, where corresponding features have been given the same reference numerals. In this embodiment, the fixedly mounted hydrostatic bearing is an axial hydrostatic bearing 60 comprises a polymer pad 17 mounted on a base 14, which is fixedly mounted to mounting plate 61 via fasteners 62. Due to the polymeric nature of the polymer bearing pad 17, the outer surface 13B of the polymer pad will conform to the profile of the bearing surface 21 of the journal 4 that it is running against. This means that the axial hydrostatic bearing can provide some degree of self-alignment, if necessary, which is not possible in a conventional axial hydrostatic bearing. Aside from

the manner of its mounting, the axial hydrostatic bearing 60 operates in substantially same manner as the self-aligning axial hydrostatic bearing 12 described above. Furthermore, while this embodiment concerns as axial hydrostatic bearing, it is also applicable to a fixedly mounted radial hydrostatic bearing.

[0114] Referring now to Figures 23 to 25, a fluid bearing 70 according to another aspect of the invention is illustrated, where corresponding features have been given the same reference numerals. The fluid bearing 70 is a hydrostatic bearing that is a combination of the radial and axial hydrostatic bearings 11, 12, 60 described above. The base 71 has been adapted to receive both a polymer pad 17A having a radial or curved outer surface 13A mounted on its outer surface 72 and two polymer pads 17B having a substantially planar outer surface 13B mounted on opposing side surfaces 73 that are orthogonal to the outer surface 72. Thus, the combination hydrostatic bearing 70 acts as a self-aligning radial hydrostatic bearing 11 in one direction and as two fixedly mounted axial hydrostatic bearings 60 in two other directions, as best shown in Figure 25. Again, due to the polymer's characteristics the outer surfaces 13B of the polymer pads 17B with conform to the profile of the bearing surface 21 of the journal 4 that it is running against. Thus, there is no need for a separate base for the axial hydrostatic bearings. The inventors contemplate that this combination hydrostatic bearing 70 avoids the need to install three separate hydrostatic bearings and thus allows for ease of installation in the mill 1. Due to the easy replacement of the polymer pads 17A, 17B, there is no need to remove the base 71 in the event one or more of the polymer pads 17A, 17B are damaged during operation of the mill 1. Thus, the combination hydrostatic bearing 70 creates cost savings in installation and repair.

[0115] The inventors also contemplate that the combination bearing 70 can be modified so as to minimise or eliminate the "axial float". Axial float is the difference between the distance between axial bearing pads and the distance between axial journal faces. Axial float is generally required so that the axial hydrostatic bearings are not tightly fitted with the mill journal 4. Typically, this axial float is set to around 0.5 to 1mm, meaning that the mill journal is able to freely float in the axial direction by this 0.5 to 1mm. A potential advantage of this combination bearing 70 is that the amount of axial float can be reduced or eliminated, since one of the axial bearings on the combination bearing 70 can be configured to move axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

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[0116] In other embodiments, the hydrostatic bearing takes the form of a slipper bearing 80, as best shown in Figure 26. Due to the larger size of the bearing pad for a slipper bearing and its 120° curvature, it could be difficult to mould a single polymer pad 17. Thus, segmenting the bearing pad surface into multiple polymer pads or slats 81 having curved outer surfaces and laterally connected together enables the invention to be used for a slipper bearing. The lateral connections can be formed as described in relation to Figure 19. Thus, the advantages of the polymer pad 17 can be extended to a slipper bearing.

[0117] In the preferred embodiments of the invention, the polymer pad 17 is made of polyetheretherketone (PEEK). However, it will be appreciated that other polymer materials are also suitable for the hydrostatic bearings 11, 12, such as PEEK composites, polyamide, polyamide composites, polyamide-imide and polyamide-imide composites. Also, while the preferred embodiments of the invention have been described as employing oil as the lubricating fluid, other lubricating fluids can be used such as water.

[0118] It will be appreciated by a person skilled in the art that the hydrostatic bearings of the preferred embodiments of the invention can be readily retrofitted into existing bearing assemblies, and thus do not require the replacement of each bearing in a milling apparatus.

[0119] While the preferred embodiments of the invention have been described using one of two possible fastener arrangements as illustrated in Figures 11, 11A, 12 and 12A, it will be appreciated that other fastener type arrangements may be used to implement the invention. For example, in one preferred form the fasteners are substantially retained within the recesses 18 by a locking element. The locking element comprises, but is not limited to, a liquid thread locker, a Scotch key, a non-loosening thread, a non-loosening washer or similar locking device.

[0120] In another embodiment, the outer (bearing) surface of the polymer bearing pad comprises two co-planar surfaces at 45° to each other. In this embodiment, the polymer bearing pad acts as both a linear and axial bearing pad simultaneously, similar to a lathe bed bearing.

[0121] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the chamfer 37 could be readily applied to the outermost polymer slats 81 in the slipper bearing to provide the advantages of reducing oil loss and elimination of oil pressure accumulators.

[0122] Also, while the preferred embodiment of the invention have been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the invention and the corresponding preferred features are also applicable to other types of fluid bearings, such as hydrodynamic bearings and hybrid bearings that use a combination of hydrodynamic and a continuous hydrostatic flow for lubrication.

[0123] By providing a polymer bearing pad for a hydrostatic bearing, the invention confers numerous advantages over existing hydrostatic bearings with white metal/bronze bearing pads. The polymer bearing pads 17 reduces or eliminates damage to the journal and the base of the hydrostatic bearing, thus increasing product life and reducing the frequency of maintenance and repair. Moreover, the polymer pads 17 are easily replaceable, enabling easy installation and removal for repair. This advantage is facilitated by the use of the mounting portion 8, flange 9 and a mechanical fastening system to mount the polymer pad 17 to the base 14.

[0124] Also, the polymer pads 17 do not require tight machining tolerances, can conform to the profile of the journal, have reduced lubrication rates enabling the use of less oil, resistant to damage caused by the loss of oil or contaminants, and dampen any excessive shock forces, protecting the journal bearing surface. These advantages permits the operation of the hydrostatic bearings of the preferred embodiments of the invention at lower oil film thicknesses, thus reducing oil consumption, permitting the use of smaller and cheaper lubrication systems and more efficient power consumption and conserving the use of oil.

[0125] Also, the use of chamfer in hydrostatic bearings in general obviates the need for expensive accumulator systems that are difficult to operate and maintain. Furthermore, the chamfer conserves the use of oil and thus reduces oil consumption. Furthermore, since the base is of a standard design, the hydrostatic bearings of the

invention can be readily retrofitted to existing mills. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0126] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

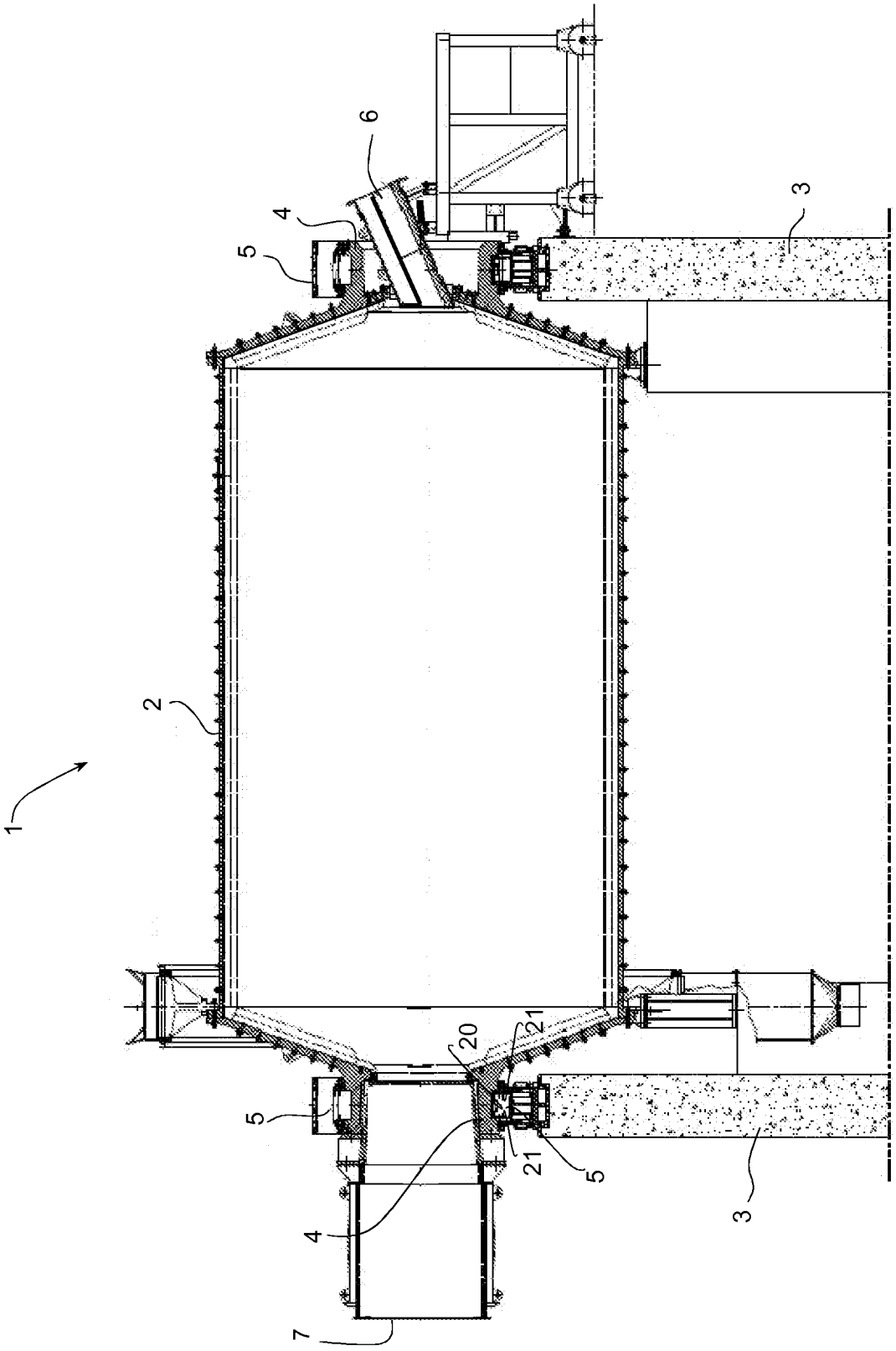


Fig. 1

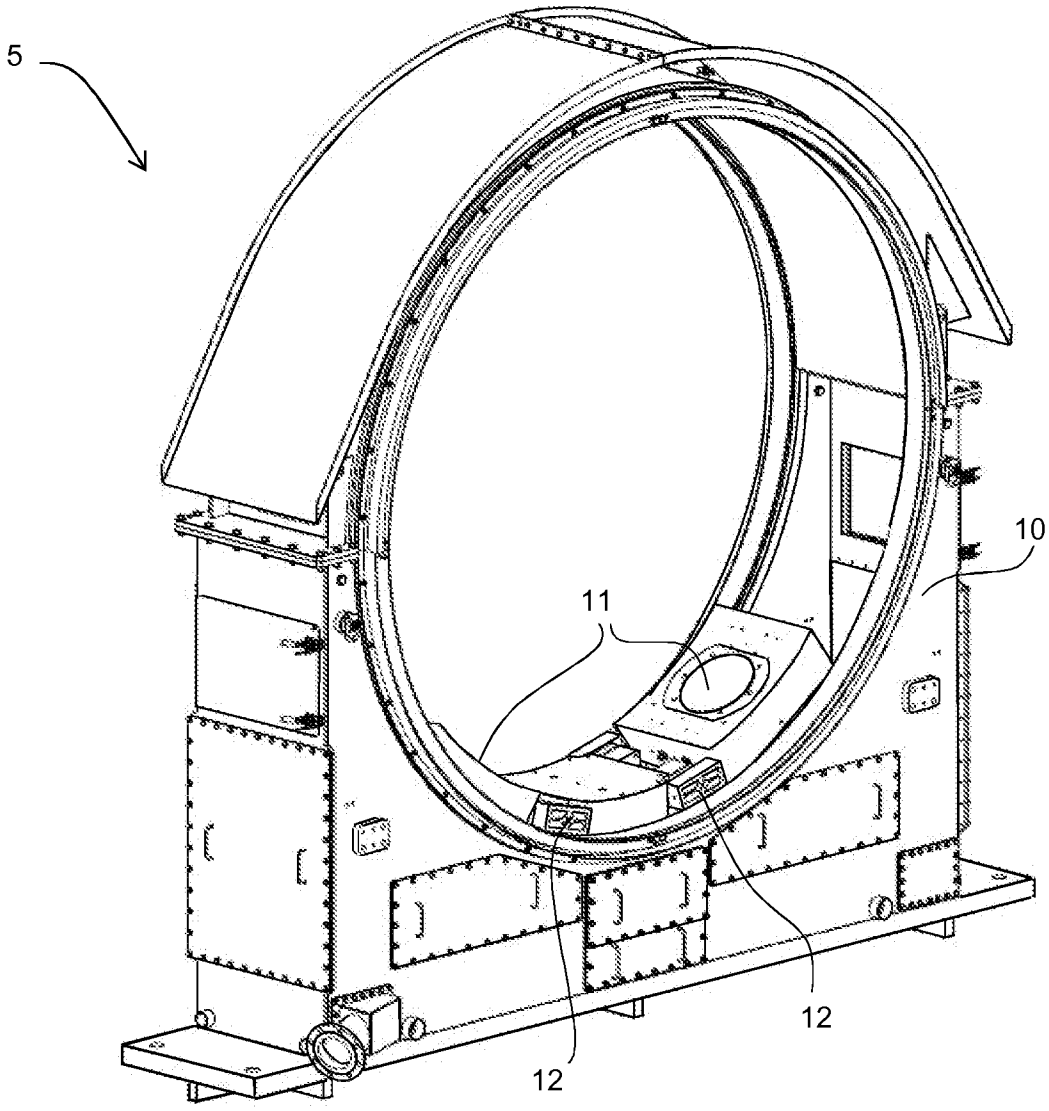


Fig. 2

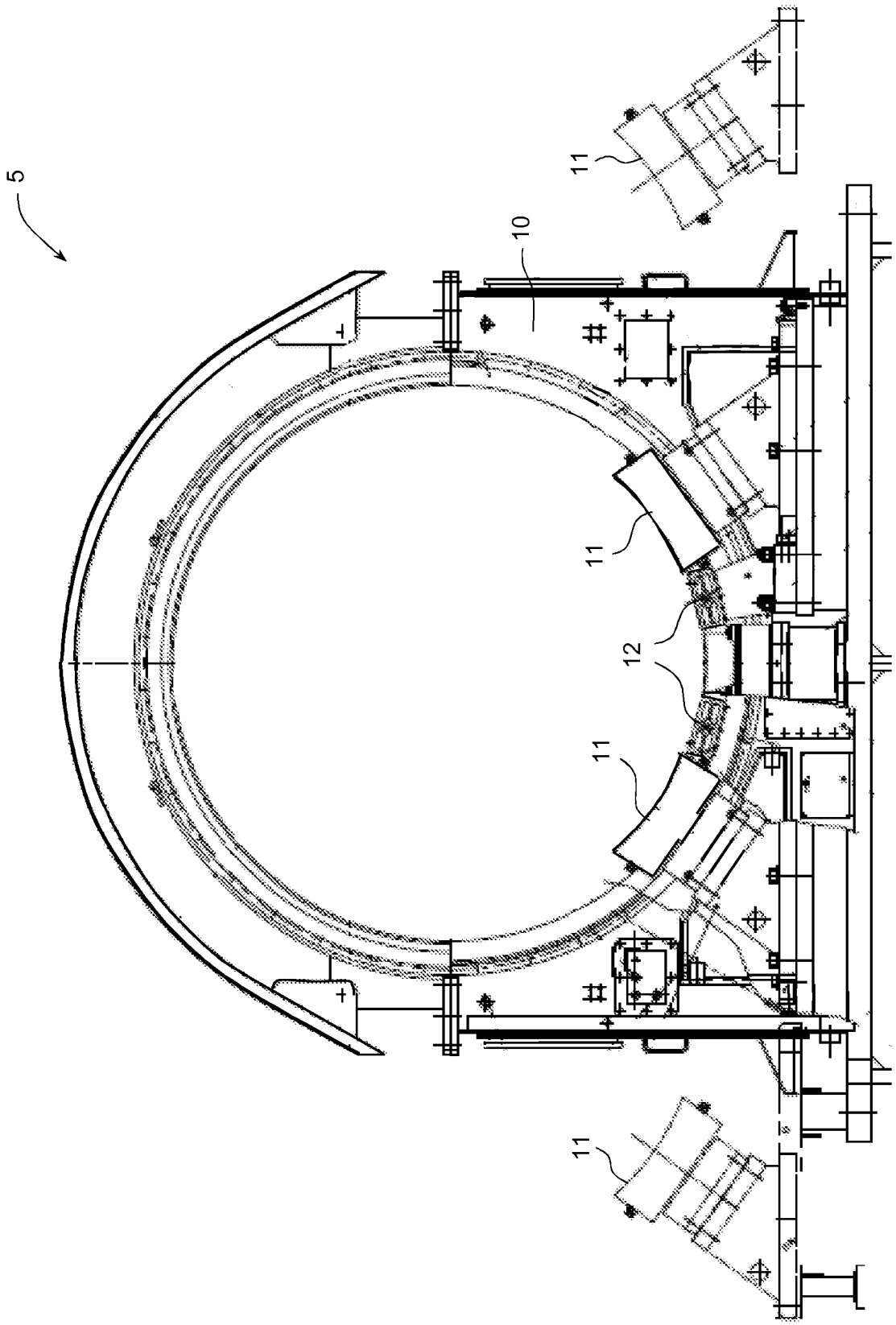


Fig. 3

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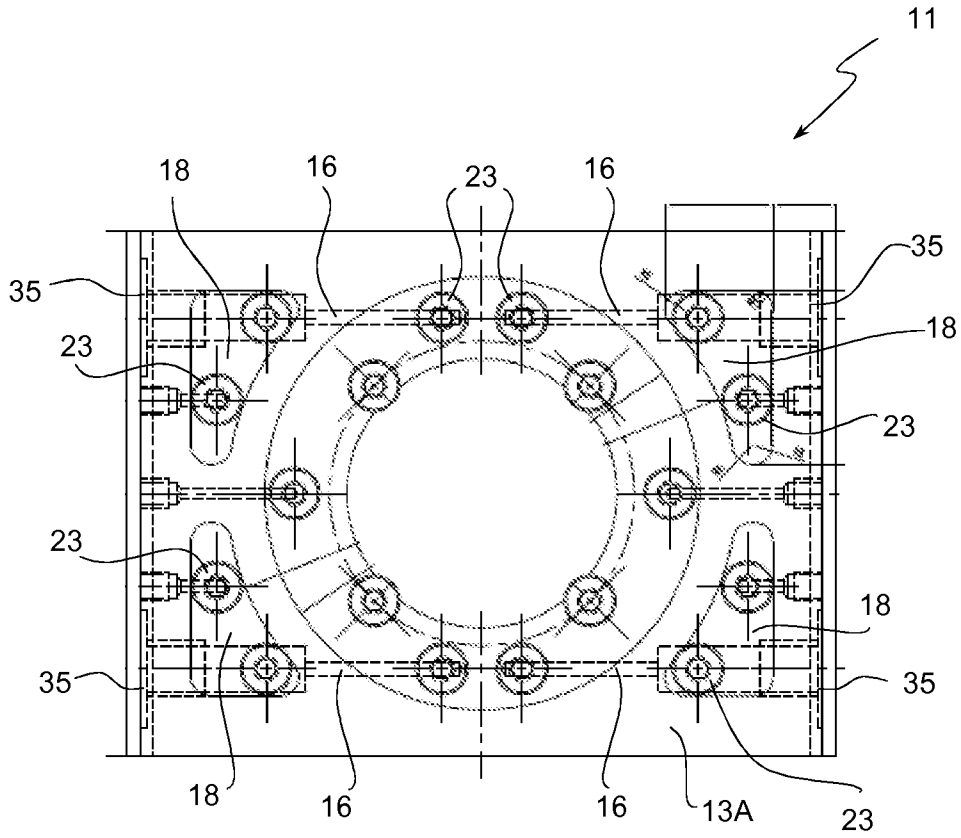


Fig. 4

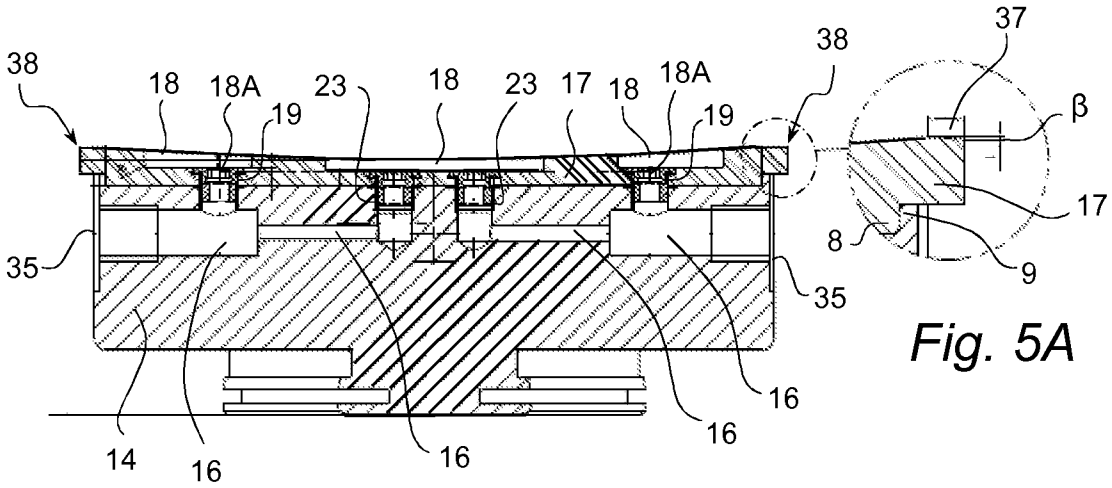


Fig. 5A

Fig. 5

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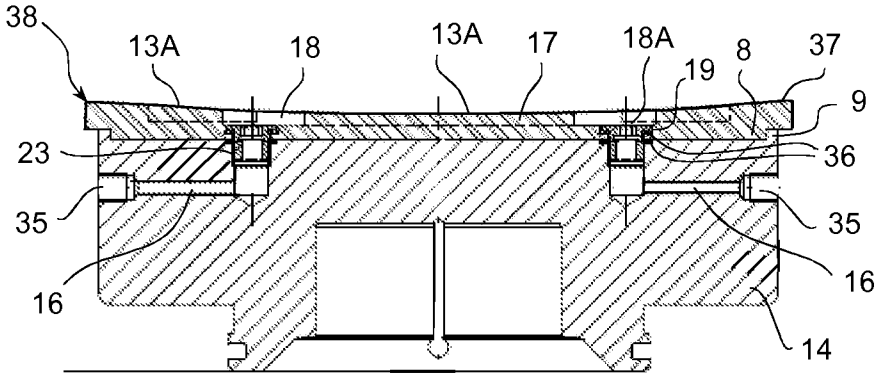


Fig. 6

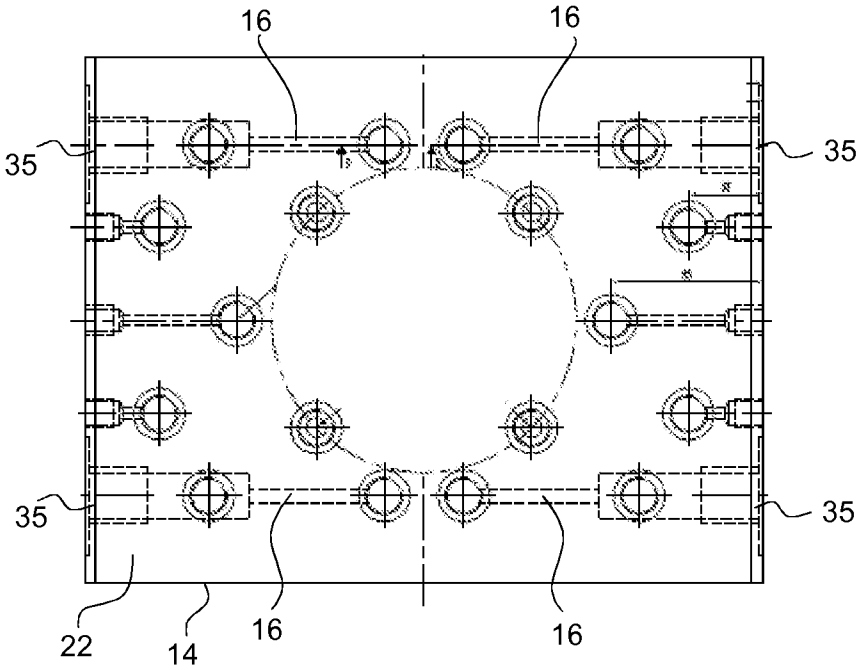


Fig. 7

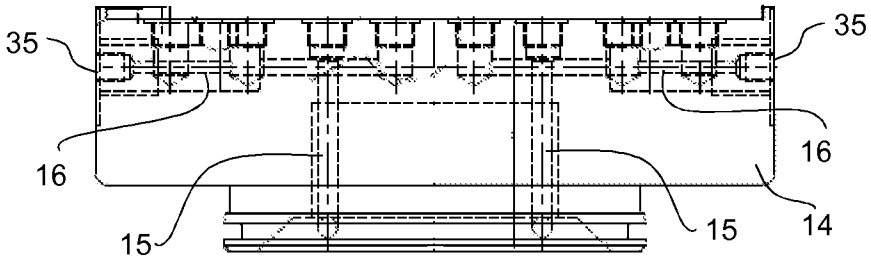


Fig. 8

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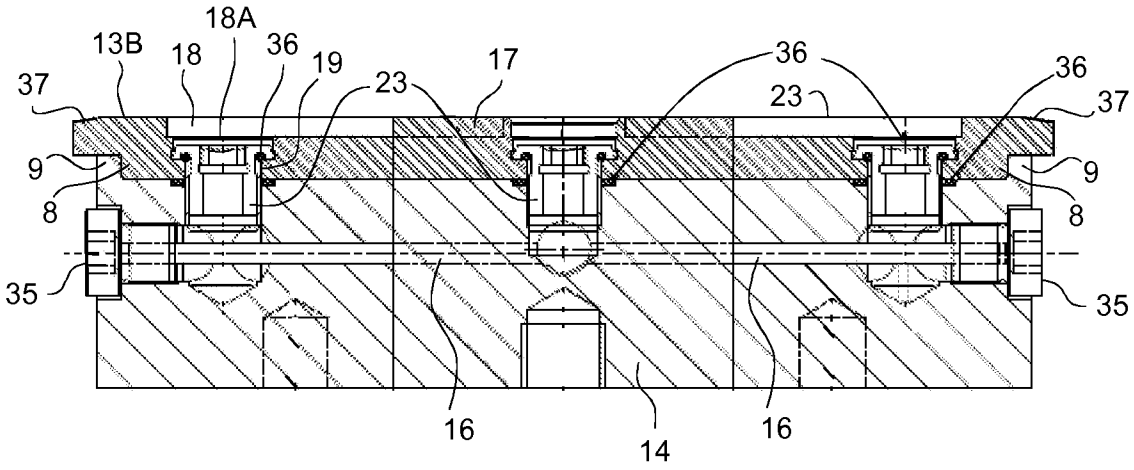


Fig. 9

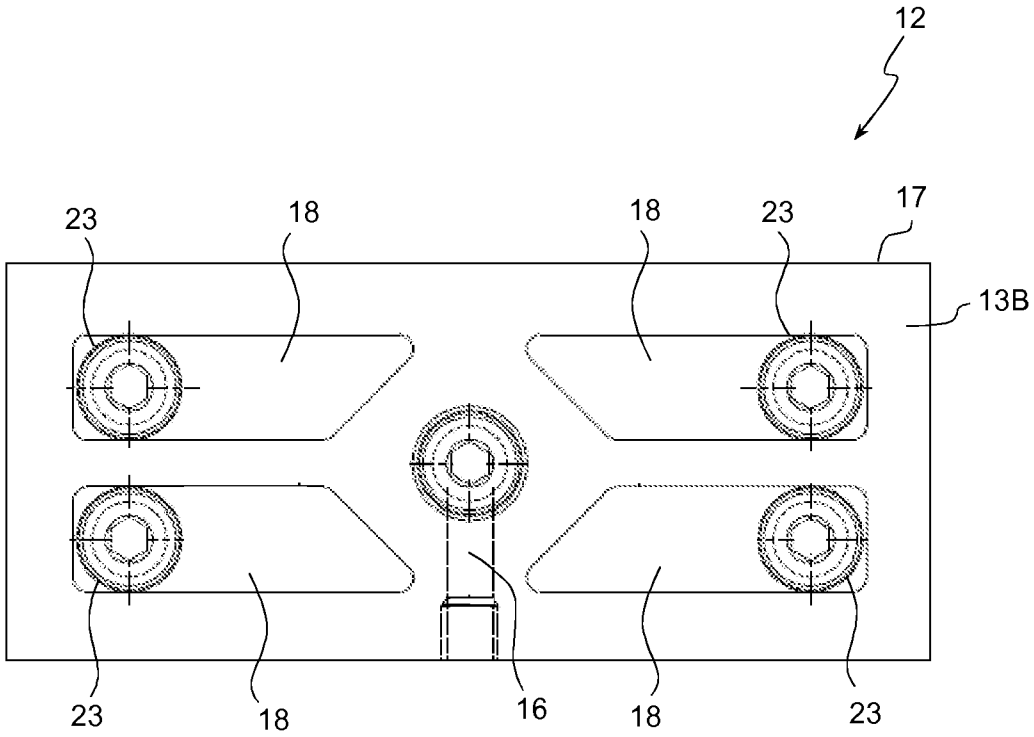


Fig. 10

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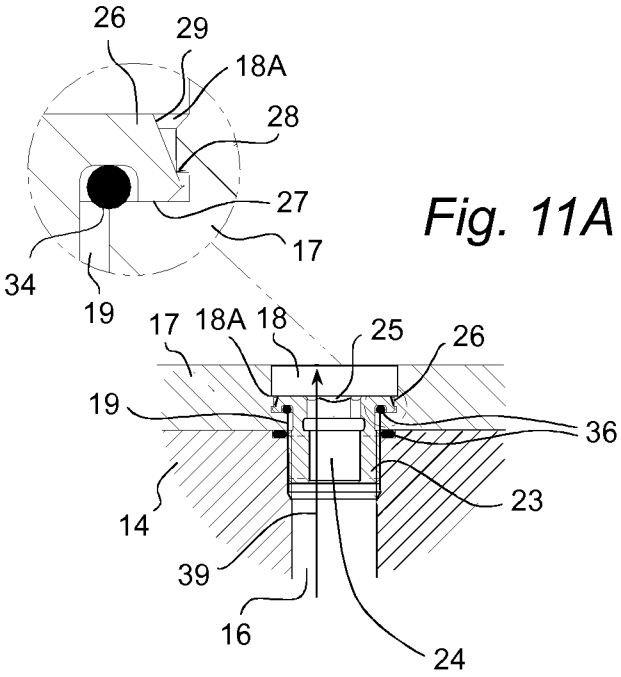


Fig. 11A

Fig. 11

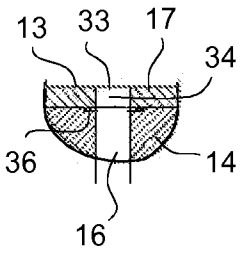


Fig. 12A

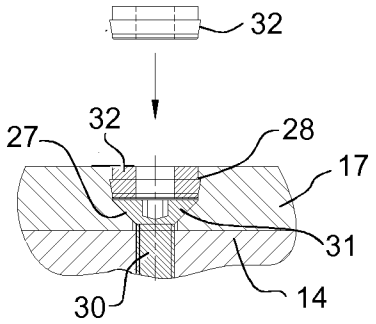


Fig. 12

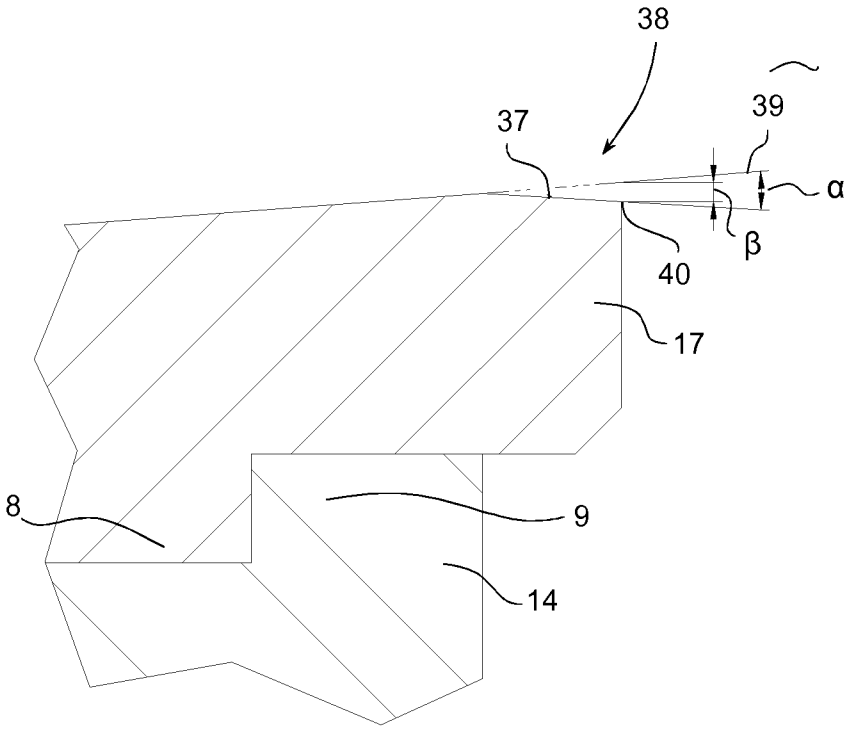


Fig. 13

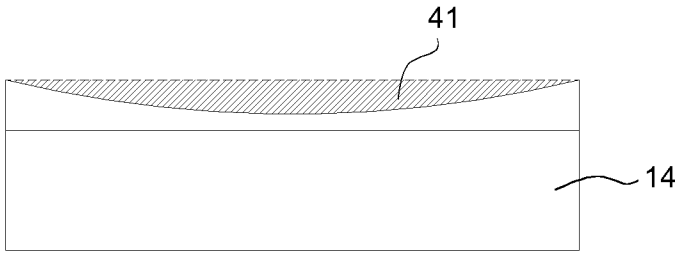


Fig. 14

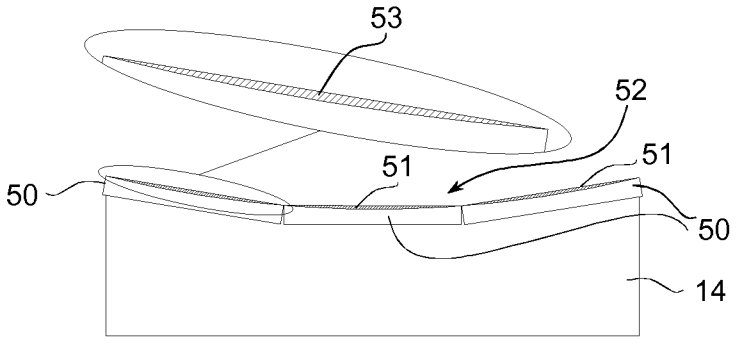


Fig. 15

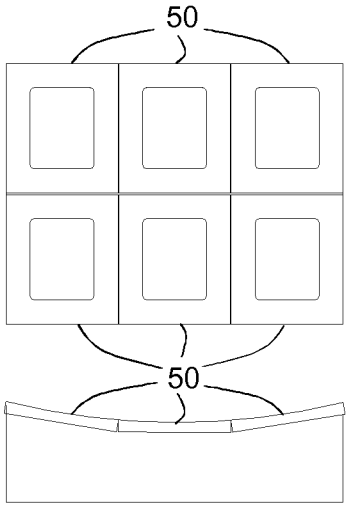


Fig.16

Fig.16A

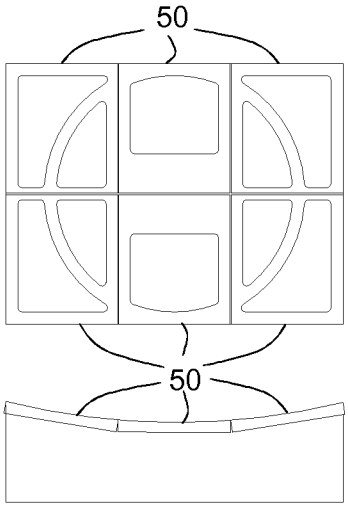


Fig.17

Fig.17A

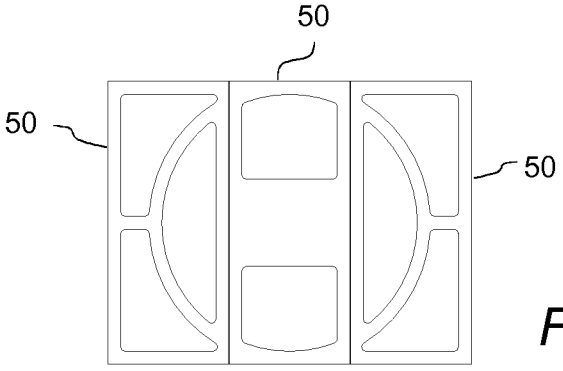


Fig. 18

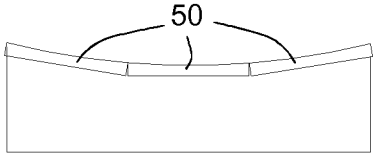


Fig. 18A

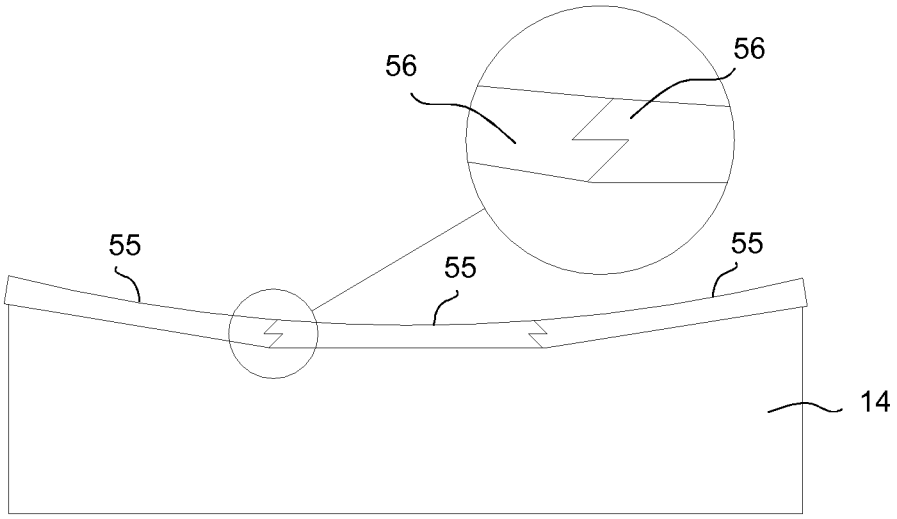


Fig. 19

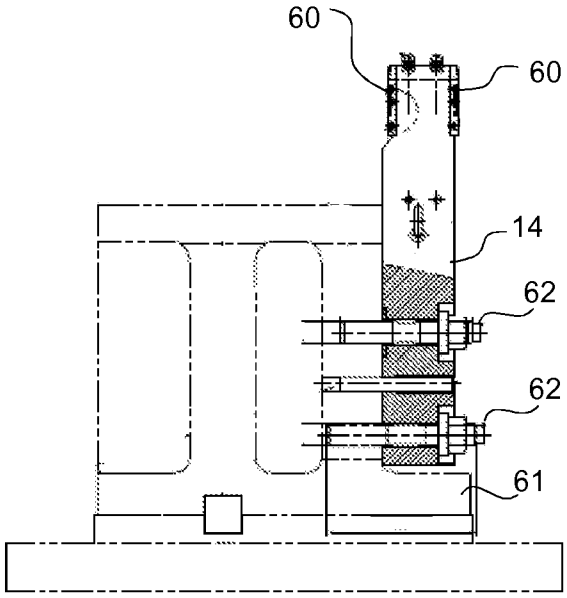


Fig. 22

Fig. 21

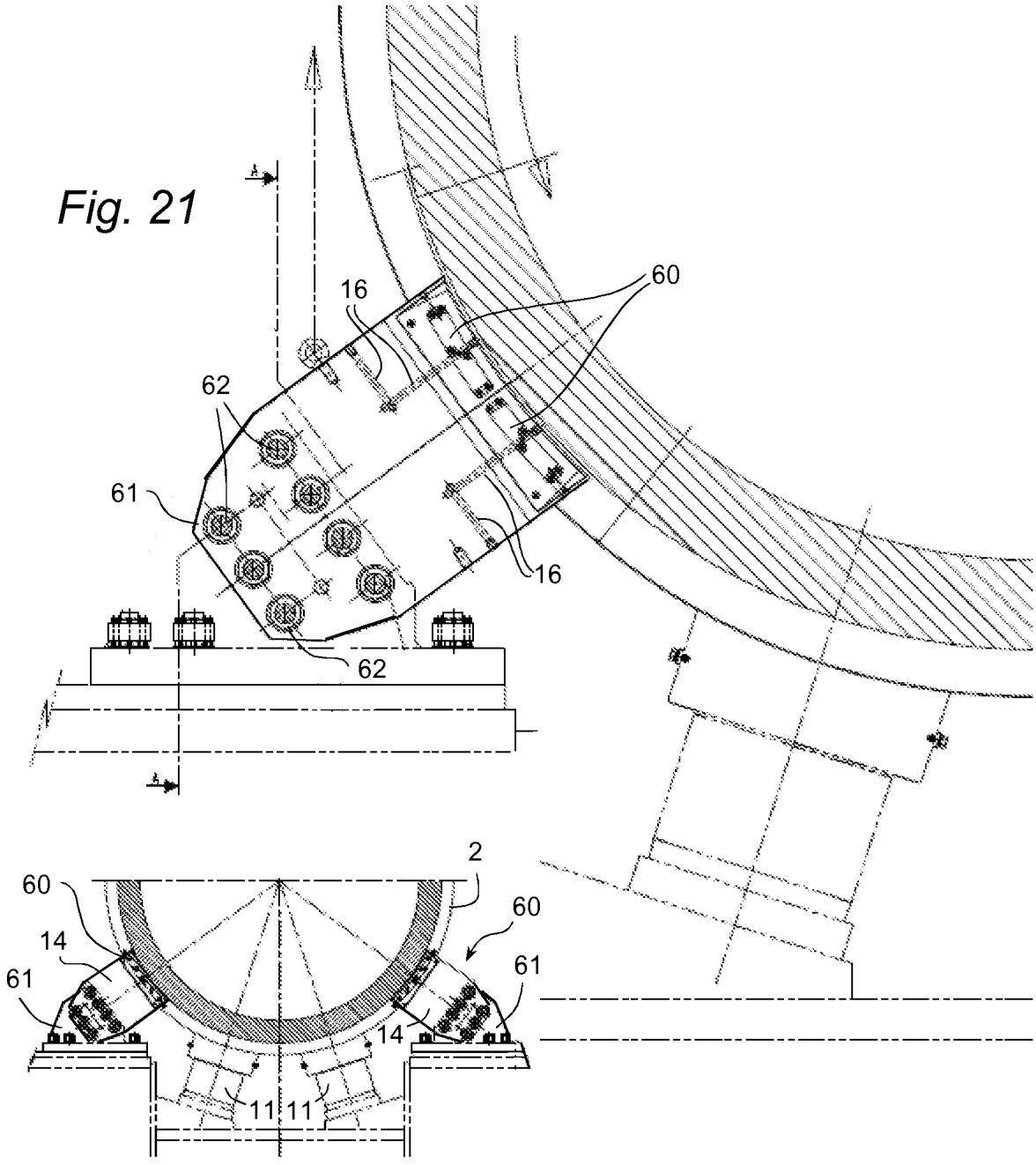


Fig. 20

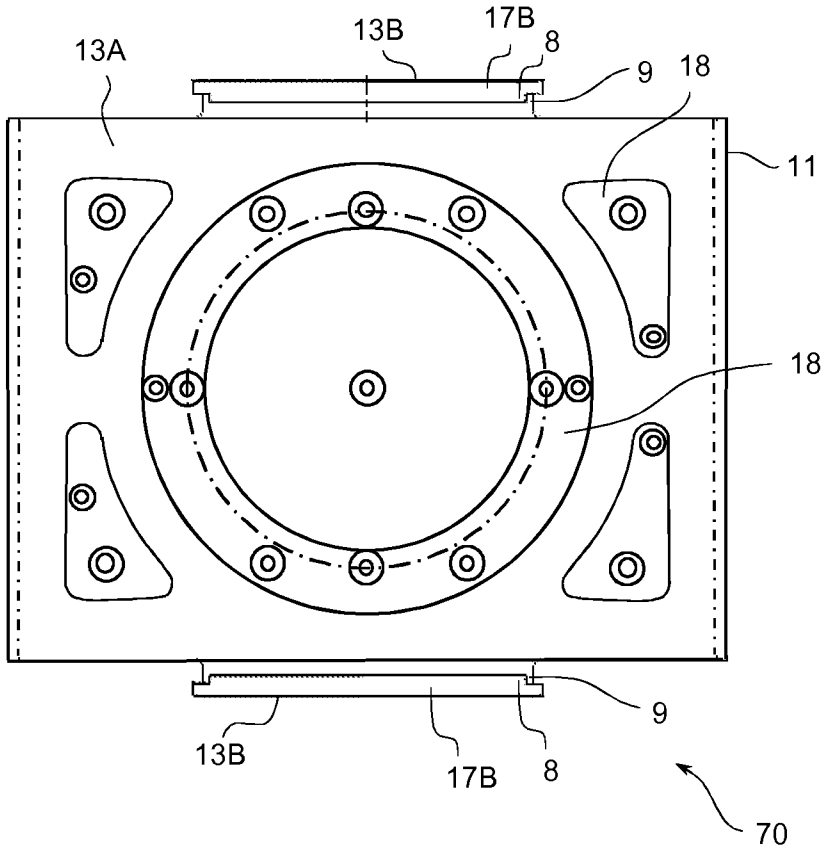


Fig. 23

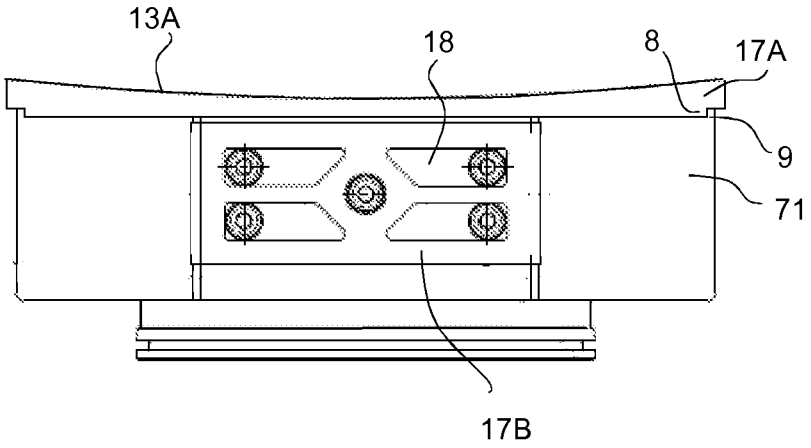


Fig. 24

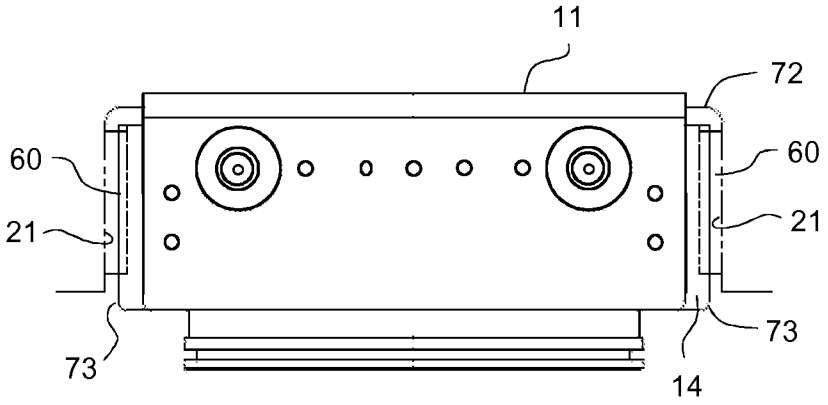


Fig. 25

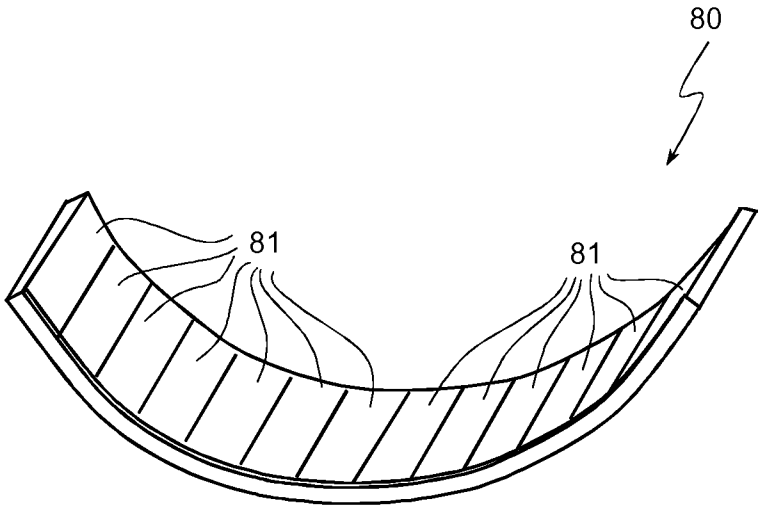


Fig. 26

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