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Patent number	2013282771
Patentee name	Metso Finland Oy
Your reference	-5894574/2583631/13/Y

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Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	-5894574/2583631/12/Y

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Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	-5894574/2583631/11/Y

Dear Patentee,

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Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	-5894574/2583631/10/Y

Dear Patentee,

Thank you for your fee payment, received on 3 May 2022, for your patent.

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15 March 2022

Request for amendment has been allowed

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PO Box 1321
SPRINGWOOD QLD 4127
Australia

Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	P10598AUw1-OUT-WAS:lh

Dear Patentee,

Thank you for your request, received on 19 November 2021, to make amendments to your patent under the provisions of *section 104 of the Patents Act 1990.*

Your request has been allowed and the amendments have been incorporated into your patent.

What will happen next

- **Details of the allowance will be advertised** - in the Australian Official Journal of Patents dated 24 March 2022.

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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, the mill actually “floats” on a film of oil between the 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, which results in low friction. Consequently, maintaining the

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oil film between the surfacesmeans that there is virtually no wear of the bearing in use.

[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 impacts 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 causing the oil supply system to fail. 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, they lead to increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and 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, a mill operator must keep a sufficient stock of spare bearings to allow for an absence of damaged bearings that are beingrepaired. This also adds to the maintenance costs of the mill.

Summary of the Invention

[0008] At least one embodiment of the present invention at least partly ameliorates one or more of the disadvantages of prior art, or at least provides a useful alternative.

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[0009] At least one embodiment of the invention provides improved fluid bearings for mills that are more tolerant to a loss of oil film, distortions in the journal, and require less strict manufacturing tolerances. They can be easily repaired, minimize waste and also reduce or eliminate the need for pressure accumulators. A method for making such fluid bearings may also be provided.

[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

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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

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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 edgesof 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 slipperbearing.

[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

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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] 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.

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[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 any of the other aspects 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 ofan 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

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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 in this application 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,

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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.

[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

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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] Some 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;

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

[0070] Figure 5A is an 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

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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.

Detailed Description

[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

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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 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. 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 suitablemetal 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 for example, the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or instead 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

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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.

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[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 a 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 journals 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and

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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 usinga 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

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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.

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[00111] [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] [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.

[00113] [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

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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°.

[00114] 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.

[00115] 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.

[00116] 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 significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[00117] 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 enable it to be formed. There are various procedures that can be used to heat and form the polymer, that would be readily understood by the person skilled in the art.

[00118] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated in an oven to an intermediate temperature, removed from the 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 the oven and allowed to cool.

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[00119] 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.

[00120] 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 a cold former and pressed to a 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.

[00121] 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.

[00122] Referring now to Figures 15 and 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.

[00123] 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

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could be larger in size, as best shown in Figures 18 and 18A.

[00124] 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. The polymer slats 55 are then clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of the 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.

[00125] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50 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.

[00126] 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.

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[00127] 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 will 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.

[00128] 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.

[00129] 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

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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.

[00130] 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.

[00131] 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 millingapparatus.

[00132] 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.

[00133] 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.

[00134] 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.

[00135] Also, while the preferred embodiment of the invention has been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the

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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.

[00136] 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 base14.

[00137] 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.

[00138] 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.

[00139] 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 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 of 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 claim 2, wherein said polymer bearing pad is removably mounted to said base.

4. The bearing assembly of any one of the preceding claims, wherein said mounting portion comprises a protrusion extending 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 at least one of a locking element and said at least one recess comprising a locking tab is used for retaining a head portion of said fastener within said at least one recess.

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8. The bearing assembly of claim 7, 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.

9. The bearing assembly of claim 7 or claim 8, further comprising a plug for engagement with said head portion and said at least one recess.

10. 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.

11. 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.

12. The bearing assembly of claim 11, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

13. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved.

14. The bearing assembly of any one of claims 1 to 12, wherein said outer surface is substantially planar.

15. The bearing assembly of any one of the preceding claims, wherein 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 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.

17. The bearing assembly of claim 16, 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.

18. The bearing assembly of any one of claims 1 to 15, 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

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are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

the bearing assembly further includes 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 from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

19. The bearing assembly of claim 18, wherein said first surface is orthogonal to said second surface.

20. The fluid bearing of claim 18 or claim 19, 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.

21. 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 from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

22. The multidirectional fluid bearing of claim 21, wherein said first polymer bearing pad is removably mounted to said first surface and said second polymer bearing pad is removably mounted to said second surface.

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23. The multidirectional fluid bearing of claim 21 or claim 22, wherein 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 21 or claim 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 21, including 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 21 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 21 to 29, wherein said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

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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 21 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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Cover Sheet: General - Administration

Requested by	IP Gateway Patent & Trade Mark Attorneys Pty Ltd
Request date	10-Mar-2022
Customer's service request reference	P10598AUw1-OUT-WAS:aj
Application numbers	**Customer's IP Right Reference**
2013282771	P10598AUw1-OUT-WAS:aj
Request supported by physical media?	No
Fee Unit Count	1
Fee Total Amount	**$0.00**

Payment Instructions

Attachment(s)

20220310 - P10598AUw1 - AU 2013282771 - APO - Response to Request for Advice under S112.pdf

This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

The Commissioner of Patents IP Australia PO Box 200 Woden ACT 2606	IP Gateway Patent & Trade Mark Attorneys Pty Ltd PO Box 1321 Springwood QLD 4127 Phone: +61 7 3808 3566 Fax: +61 7 3808 7466 Attorney Code: 1388004

Submitted via eServices

10 March 2022

Dear Commissioner

Australian Patent No. 2013282771
in the name of Outotec (Finland) Oy
entitled IMPROVEMENTS IN FLUID BEARINGS
Our Ref: P10598AUw1-OUT-WAS:aj

We refer to the *Amendment to the Specification – Request for Advice under S112* dated 21 February 2022 in relation to the above matter.

As requested, patentee advises that, to the best of their knowledge, there are no relevant court proceedings specified under Section 112 of the Patents Act pending.

We look forward to your report on the amendment request in due course.

Yours respectfully
IP GATEWAY



Wayne Slater
Registered Patent Attorney
Email: wslater@ipgateway.com.au

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21 February 2022

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ABN: 38 113 072 755

Amendment to the Specification - Request for Advice under S112

IP GATEWAY PATENT & TRADE MARK ATTORNEYS PTY LTD
PO Box 1321
SPRINGWOOD QLD 4127
Australia

Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	P10598AUw1-OUT-WAS:lh

Dear Sir/Madam,

I refer to your request, received on 19 November 2021, to make amendments to the specification of the above patent under the provisions of Section 104 of the Patents Act 1990.

Before the Commissioner allows the amendment, the Commissioner requires your advice as to whether any action specified in Section 112 of the Patents Act 1990 is pending. Please provide this advice within 1 month of the date of this letter (Regulation 10.6(5)), even if you have previously provided this advice to us at an earlier stage.

Please note that the Commissioner will not allow the Section 104 request until you have responded with this advice.

Need help?

Talk to Alex, our virtual assistant



For further information on this topic, visit our website.

Make an enquiry or provide feedback on our website.

Contact details

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Details of your patent can be viewed on AusPat, our Australian patent search database.

Yours sincerely,

IP Australia

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30 November 2021

Request for amendment will be advertised

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IP GATEWAY PATENT & TRADE MARK ATTORNEYS PTY LTD
PO Box 1321
SPRINGWOOD QLD 4127
Australia

Your reference	P10598AUw1-OUT-WAS:lh
Patent number	2013282771
Patentee name	Outotec (Finland) Oy

Dear IP GATEWAY PATENT & TRADE MARK ATTORNEYS PTY LTD,

Thank you for your request, received on 19 November 2021, to amend this patent.

We are pleased to advise that the Delegate of the Commissioner considers that your request for leave to amend is valid.

Your request will be advertised for opposition purposes in the Australian Official Journal of Patents dated 9 December 2021 for a period of two months.

If no opposition is filed, the amendment will be allowed and incorporated into the patent once this period has elapsed.

If the specification has been accepted and the proposed amendment results in the number of claims exceeding 20, a fee is payable for each additional claim. An Invitation to Pay will be issued to you at the time of advertising the proposed amendment.

Contact details

Name:	Steve Richards
Organisational unit:	CUSTOMER EXPERIENCE GROUP
Personal phone:	+61 2 6283 2237

Details of your patent can be viewed on AusPat, our Australian patent search database.

Yours sincerely,

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ABN: 38 113 072 755

Request for amendment has been filed

IP GATEWAY PATENT & TRADE MARK ATTORNEYS PTY LTD
PO Box 1321
SPRINGWOOD QLD 4127
Australia

Your reference	P10598AUw1-OUT-WAS:lh
Patent number	2013282771
Patentee name	Outotec (Finland) Oy

Dear IP GATEWAY PATENT & TRADE MARK ATTORNEYS PTY LTD,

Thank you for your request for voluntary amendment to this patent filed on 19 November 2021. Your request will be processed shortly.

If a fee is payable in relation to the filing of this request, an Invitation to Pay has been issued to you and no further action will take place until payment is received.

If the specification has been accepted and the proposed amendment results in the number of claims exceeding 20, a fee is payable for each additional claim. An Invitation to Pay will be issued to you at the time of advertising the proposed amendment.

Contact details

Name:	Steve Richards
Organisational unit:	CUSTOMER EXPERIENCE GROUP
Personal phone:	+61 2 6283 2237

Details of your patent can be viewed on AusPat, our Australian patent search database.

Yours sincerely,

IP Australia

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IP Australia

Cover Sheet: Voluntary amendments Sec 104 to a Specification (not under exam)

Requested by	IP Gateway Patent & Trade Mark Attorneys Pty Ltd
Request date	19-Nov-2021
Customer's service request reference	P10598AUw1-OUT-WAS:lh
Application numbers	**Customer's IP Right Reference**
2013282771	P10598AUw1-OUT-WAS:lh
Request supported by physical media?	No
Fee Unit Count	1
Fee Total Amount	**$250.00**
Attachment(s)	
20211119 - AU2013282771 - APO - Post Grant Voluntary Amendment.pdf	
20211119 - AU2013282771 - CLEAN AMENDED CLAIMS.pdf	
20211119 - AU2013282771 - MARKED UP CLAIMS.pdf	
20211119 - AU2013282771 - CLEAN AMENDED DESCRIPTION.pdf	
20211119 - AU2013282771 - MARKED UP DESCRIPTION.pdf	

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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, the mill actually "floats" on a film of oil between the 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~~ which at result~~ings~~ in ~~only~~ low friction. Consequently,

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maintaining the oil film between the surfaces means that there is virtually no wear of~~in~~ the bearing in use.

[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~~ impacts 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~~ causing the oil supply system to fail~~s~~. 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~~they lead to 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, a mill~~s~~ operator must keep a sufficient stock of spare bearings to~~-~~ allow~~ccount~~ for an ~~the~~ absence of damaged bearings that are being repaired. This also adds to the maintenance costs of the mill.

Summary of the Invention

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[0008] ~~It is an object~~ At least one embodiment of the present invention ~~to overcome or substantially~~ at least partly ameliorates one or more of the disadvantages of prior art, or at least ~~to~~ provides a useful alternative.

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

~~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

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“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~~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 edgesof 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 slipperbearing.

[0027] Alternatively, said outer surface is substantially planar such that said fluid bearing

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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

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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~~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~~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~~any of the other aspects 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

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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 ofan 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 in this application 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.

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[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

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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~~ Some 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;

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[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 an 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;

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[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

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[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~~Detailed Description

[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 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. 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 suitablemetal 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 for example, the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or instead the flanges 9 being opposed herringbone flanges positioned on the base 14 between which the mounting

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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~~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

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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

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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 a 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

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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~~journals 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 usinga 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

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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

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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] [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] [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

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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.

[00113] [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°.

[00114] 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.

[00115] 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.

[00116] 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.

[00117] 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~~ enable it to be formed. There are various procedures that can be used to heat and form the polymer, that would be readily understood by the person skilled in

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the art.

[00118] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated in an oven to an intermediate temperature, removed from the 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 the oven and allowed to cool.

[00119] 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.

[00120] 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 a cold former and pressed to a 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.

[00121] 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.

[00122] Referring now to Figures 15 ~~to~~and 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

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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.

[00123] 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.

[00124] 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, t~~The polymer slats 55 are then clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of the 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.

[00125] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50 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.

[00126] 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

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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.

[00127] 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~~ will 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 hydrostaticbearing 70 creates cost savings in installation and repair.

[00128] 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

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axially on a piston which is supplied by pressurised oil. This effectively ensures that axial float is minimised or removed.

[00129] 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.

[00130] 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.

[00131] 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 millingapparatus.

[00132] 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.

[00133] 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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[00134] 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.

[00135] Also, while the preferred embodiment of the invention ~~have~~has 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.

[00136] 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 base14.

[00137] 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.

[00138] 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.

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[00139] 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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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, the mill actually “floats” on a film of oil between the 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, which results in low friction. Consequently, maintaining the

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oil film between the surfacesmeans that there is virtually no wear of the bearing in use.

[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 impacts 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 causing the oil supply system to fail. 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, they lead to increased operational and maintenance costs of the mill.

[0007] Typically, to manufacture hydrostatic bearings, the recesses are machined into the steel base and 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, a mill operator must keep a sufficient stock of spare bearings to allow for an absence of damaged bearings that are beingrepaired. This also adds to the maintenance costs of the mill.

Summary of the Invention

[0008] At least one embodiment of the present invention at least partly ameliorates one or more of the disadvantages of prior art, or at least provides a useful alternative.

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[0009] At least one embodiment of the invention provides improved fluid bearings for mills that are more tolerant to a loss of oil film, distortions in the journal, and require less strict manufacturing tolerances. They can be easily repaired, minimize waste and also reduce or eliminate the need for pressure accumulators. A method for making such fluid bearings may also be provided.

[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

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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

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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 edgesof 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 slipperbearing.

[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

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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] 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.

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[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 any of the other aspects 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 ofan 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

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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 in this application 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,

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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.

[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

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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] Some 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;

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

[0070] Figure 5A is an 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

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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.

Detailed Description

[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

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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 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. 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 suitablemetal 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 for example, the flanges 9 being located closer to the centre of the base 14 rather than at the outer edges or instead 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

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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.

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[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 a 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 journals 4 or the base 14. Thus, the base 14 (and its oil galleries 16 and oil supply ports 15) are protected from damage and

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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 usinga 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

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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.

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[00111] [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] [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.

[00113] [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

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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°.

[00114] 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.

[00115] 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.

[00116] 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 significant, especially on larger bearings, and contributes to unnecessary additional manufacturing costs. Furthermore, the manufacturing process is not environmentally sustainable.

[00117] 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 enable it to be formed. There are various procedures that can be used to heat and form the polymer, that would be readily understood by the person skilled in the art.

[00118] In one example, the polymer can be placed in a shaped former or mould and lightly clamped. The former or mould is then heated in an oven to an intermediate temperature, removed from the 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 the oven and allowed to cool.

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[00119] 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.

[00120] 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 a cold former and pressed to a 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.

[00121] 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.

[00122] Referring now to Figures 15 and 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.

[00123] 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

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could be larger in size, as best shown in Figures 18 and 18A.

[00124] 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. The polymer slats 55 are then clamped and heated to cure the adhesive joint. The joint formed by the connecting teeth 56 is such that the weight of the 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.

[00125] The inventors believe that segmenting the surface area of the polymer pad 17 into individual polymer pads or slats 50 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.

[00126] 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.

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[00127] 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 will 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.

[00128] 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.

[00129] 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

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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.

[00130] 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.

[00131] 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 millingapparatus.

[00132] 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.

[00133] 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.

[00134] 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.

[00135] Also, while the preferred embodiment of the invention has been described in relation to hydrostatic bearings in general, it will be appreciated that each of the aspects of the

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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.

[00136] 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 base14.

[00137] 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.

[00138] 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.

[00139] 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 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 of 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 claim 2, wherein said polymer bearing pad is removably mounted to said base.

4. The bearing assembly of any one of the preceding claims, wherein said mounting portion comprises a protrusion extending 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 at least one of a locking element and said at least one recess comprising a locking tab is used for retaining a head portion of said fastener within said at least one recess.

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8. The bearing assembly of claim ~~6 or~~ 7, wherein said at least one fastener comprisinges 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 or claim 8, further comprising a plug for engagement with said head portion and said at least one recess.

10. 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.

11. 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.

12. The bearing assembly of claim 11, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

13. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved.~~.~~

14. The bearing assembly of any one of claims 1 to 12, wherein said outer surface is substantially planar.

15. The bearing assembly of any one of the preceding claims, wherein 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 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~~ journal.

17. The bearing assembly of claim 16, 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.

18. The bearing assembly of any one of claims 1 to 15, 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

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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~~the bearing assembly further includes 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 from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

19. The bearing assembly of claim 18, wherein said first surface is orthogonal to said second surface.

20. The fluid bearing of claim 18 or claim 19, 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.

21. 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 from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

22. The multidirectional fluid bearing of claim 21, wherein said first polymer bearing pad is removably mounted to said first surface and said second polymer bearing pad is removably mounted to said second surface.

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23. The multidirectional fluid bearing of claim 21 or claim 22, wherein 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 21 or claim 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 21, ~~wherein there is a~~including 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 21 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 21 to 29, wherein said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

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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 21 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 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 of 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 claim 2, wherein said polymer bearing pad is removably mounted to said base.

4. The bearing assembly of any one of the preceding claims, wherein said mounting portion comprises a protrusion extending 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 at least one of a locking element and said at least one recess comprising a locking tab is used for retaining a head portion of said fastener within said at least one recess.

This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

19 Nov 2021 2013282771

8. The bearing assembly of claim 7, 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.

9. The bearing assembly of claim 7 or claim 8, further comprising a plug for engagement with said head portion and said at least one recess.

10. 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.

11. 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.

12. The bearing assembly of claim 11, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

13. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved.

14. The bearing assembly of any one of claims 1 to 12, wherein said outer surface is substantially planar.

15. The bearing assembly of any one of the preceding claims, wherein 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 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.

17. The bearing assembly of claim 16, 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.

18. The bearing assembly of any one of claims 1 to 15, 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

2013282771 19 Nov 2021

are in fluid communication with said at least one lubricating fluid supply ports, said first surface and said second surface, and

the bearing assembly further includes 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 from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

19. The bearing assembly of claim 18, wherein said first surface is orthogonal to said second surface.

20. The fluid bearing of claim 18 or claim 19, 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.

21. 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 from at least one of said plurality of passages and distributing said lubricating fluid to said second outer surface.

22. The multidirectional fluid bearing of claim 21, wherein said first polymer bearing pad is removably mounted to said first surface and said second polymer bearing pad is removably mounted to said second surface.

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23. The multidirectional fluid bearing of claim 21 or claim 22, wherein 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 21 or claim 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 21, including 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 21 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 21 to 29, wherein said base comprises at least one flange for engagement with said mounting portion to securely mount said polymer bearing pad to said base.

2013282771 19 Nov 2021

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 21 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.

2013282771 19 Nov 2021

The Commissioner of Patents
IP Australia
PO Box 200
Woden ACT 2606

IP Gateway Patent & Trade Mark Attorneys Pty Ltd
PO Box 1321
Springwood QLD 4127
Phone: +61 7 3808 3566
Fax: +61 7 3808 7466
Attorney Code: IG

Submitted via eServices

19 November 2021

Dear Commissioner

Australian Patent No. 2013282771
in the name of Outotec (Finland) Oy
entitled IMPROVEMENTS IN FLUID BEARINGS
Our Ref: P10598AUw1-OUT-WAS:lh

The Patentee would like to request some amendments to the current patent specification. In support of our request, we **enclose** the following:

1. Second Statement of Proposed Amendments;
2. Substitute description pages 1 to 26, together with a marked up copy; and
3. Substitute claims pages 27 to 31, together with a marked up copy.

The Patentee requests that the proposed amendments be incorporated into the specification of the granted patent. None of the amendments add any subject matter into the specification nor do they broaden the scope of the claims. Most of the proposed amendments are of an editorial nature and help to make the patent specification clearer.

We also submit the official fee for a voluntary amendment together with this amendment request.

We look forward to receiving your report on the amendment request in due course.

Yours respectfully
IP GATEWAY



Wayne Slater
Registered Patent Attorney

Email: wslater@ipgateway.com.au

This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

2013282771 19 Nov 2021

AUSTRALIA
Patents Act 1990

P/00/0028
Section 104
Regulation 10.1

IN THE MATTER of Patent No. 2013282771 by Outotec (Finland) Oy

- and -

IN THE MATTER of Proposed Amendments under Section 104

Second Statement of Proposed Amendments

The following amendments are respectfully submitted:

DESCRIPTION

1. Delete all description pages currently on file and substitute therefore new description pages 1 to 26 herewith.

CLAIMS

2. Delete all claims pages currently on file and substitute therefore new claims pages 27 to 31 herewith.

DATED THIS 19th day of November 2021

IP GATEWAY PATENT AND TRADE MARK ATTORNEYS



…….....
Wayne Slater
Registered Patent Attorney

TO: The Commissioner of Patents
IP Australia
PO Box 200
Woden ACT 2606

Australian Government
IP Australia

17 June 2021

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International: +61 2 6283 2999

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ABN: 38 113 072 755

Notification of change of agent

Shelston IP Pty Ltd.
L 9
60 Margaret St
Sydney NSW 2000
Australia

Your reference	74861AUP00
Application/Patent number	2013282771
Applicant/Patentee name	Outotec (Finland) Oy

Dear Shelston IP Pty Ltd.,

We have processed a request, received on 16 June 2021, to change the agent for this application/patent.

You are no longer recorded as the agent for this application/patent.

The agent for this application/patent is now recorded as:

Agent name:	IP GATEWAY PATENT & TRADE MARK ATTORNEYS PTY LTD
Address for correspondence:	PO Box 1321 SPRINGWOOD QLD 4127 Australia
Address for legal service:	PO Box 1321 SPRINGWOOD QLD 4127 Australia

Details of this application/patent can be viewed on AusPat, our Australian patent search database.

Yours sincerely,

IP Australia

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Change of agent has been processed

IP GATEWAY PATENT & TRADE MARK ATTORNEYS PTY LTD
PO Box 1321
SPRINGWOOD QLD 4127
Australia

Application/Patent number	2013282771
Applicant/Patentee name	Outotec (Finland) Oy
Your reference	P10598AUw1-OUT-WAS:lc

Dear Sir/Madam,

Thank you for your request received on 16 June 2021 to change the agent for this application/patent.

The agent for this application/patent is now:

Agent name:	IP GATEWAY PATENT & TRADE MARK ATTORNEYS PTY LTD
Address for correspondence:	PO Box 1321 SPRINGWOOD QLD 4127 Australia
Address for legal service:	PO Box 1321 SPRINGWOOD QLD 4127 Australia

What you need to do now

- **Check the agent details** – please review the agent details to ensure they are correct.

Details of this application/patent can be viewed on AusPat, our Australian patent search database.

Yours sincerely,

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Cover Sheet: Request for Change Agent

Requested by	IP Gateway Patent & Trade Mark Attorneys Pty Ltd
Request date	16-Jun-2021
Customer's service request reference	P10598AUw1-OUT-WAS:lc
Application numbers	**Customer's IP Right Reference**
2013282771	P10598AUw1-OUT-WAS:lc
Request supported by physical media?	No
Fee Unit Count	1
Fee Total Amount	**$0.00**
Attachment(s)	

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25 May 2021

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COMPUTER PATENT ANNUITIES
PO BOX Q263
QVB Post Shop
SYDNEY NSW 1230
Australia

Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	-5894574/2583631/09/Y

Dear Patentee,

Thank you for your fee payment, received on 25 May 2021, for your patent.

What this means

- Your patent has now been renewed to 28 June 2022. The next renewal fee will be due at this date.

Things to be aware of

- Payment may be made using online services and you can pay your renewal fee up to 6 months after 28 June 2022. However, if you pay in the 6-month period after this date, your payment must be accompanied by the appropriate additional fee(s). If payment is not received by the end of the 6 months your patent will cease.

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22 June 2020

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Dennemeyer & Co (Luxembourg)
P.O. Box 1502
Luxembourg L-1015
Luxembourg

Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	4054821;13813839

Dear Patentee,

Thank you for your fee payment, received on 22 June 2020, for your patent.

What this means

- Your patent has now been renewed to 28 June 2021. The next renewal fee will be due at this date.

Things to be aware of

- Payment may be made using online services and you can pay your renewal fee up to 6 months after 28 June 2021. However, if you pay in the 6-month period after this date, your payment must be accompanied by the appropriate additional fee(s). If payment is not received by the end of the 6 months your patent will cease.

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Yours sincerely,

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Your progress

- **Filed** — Application is filed
- **Examination** — Application is being examined
- **Acceptance** — Application is accepted (enters an opposition period lasting 3 months)
- **Grant** — Patent is granted (patent is now enforceable)
- **Continuation/Renewal** — Fees required to maintain application/patent (fees are due annually – please refer to the 'paid to' date in AusPat for your next due date)

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25 June 2019

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Dennemeyer & Co (Luxembourg)
P.O. Box 1502
Luxembourg L-1015
Luxembourg

Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	4054821;12698782

Dear Patentee,

Thank you for your fee payment, received on 24 June 2019, for your patent.

What this means

- Your patent has now been renewed to 28 June 2020. The next renewal fee will be due at this date.

Things to be aware of

- Payment may be made using online services and you can pay your renewal fee up to 6 months after 28 June 2020. However, if you pay in the 6-month period after this date, your payment must be accompanied by the appropriate additional fee(s). If payment is not received by the end of the 6 months your patent will cease.

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27 June 2018

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Dennemeyer & Co (Luxembourg)
P.O. Box 1502
Luxembourg L-1015
Luxembourg

Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	PO190828

Dear Patentee,

Thank you for your fee payment, received on 27 June 2018, for your patent.

What this means

- Your patent has now been renewed to 28 June 2019. The next renewal fee will be due at this date.

Things to be aware of

- Payment may be made using online services and you can pay your renewal fee up to 6 months after 28 June 2019. However, if you pay in the 6-month period after this date, your payment must be accompanied by the appropriate additional fee(s). If payment is not received by the end of the 6 months your patent will cease.

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Yours sincerely,

IP Australia

Your progress

- **Filed** — Application is filed
- **Examination** — Application is being examined
- **Acceptance** — Application is accepted (enters an opposition period lasting 3 months)
- **Grant** — Patent is granted (patent is now enforceable)
- **Continuation/Renewal** — Fees required to maintain application/patent (fees are due annually – please refer to the 'paid to' date in AusPat for your next due date)

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19 June 2017

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Dennemeyer & Co (Luxembourg)
P.O. Box 1502
Luxembourg L-1015
Luxembourg

Patent number	2013282771
Patentee name	Outotec (Finland) Oy
Your reference	4054821;10479301

Dear Patentee,

Thank you for your fee payment, received on 19 June 2017, for your patent.

What this means

- Your patent has now been renewed to 28 June 2018. The next renewal fee will be due at this date.

Things to be aware of

- Payment may be made using online services and you can pay your renewal fee up to 6 months after 28 June 2018. However, if you pay in the 6-month period after this date, your payment must be accompanied by the appropriate additional fee(s). If payment is not received by the end of the 6 months your patent will cease.

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CERTIFICATE OF GRANT

STANDARD PATENT

2013282771

The Commissioner of Patents has granted the above patent on 9 June 2016, and certifies that the following are the particulars of this patent appearing in the Register of Patents:

Name and Address of Patentee(s):

Outotec (Finland) Oy

Rauhalanpuisto 9 FI-02230 Espoo Finland

Name of Actual Inventor(s):

Braithwaite, Daniel; Belke, Jeffrey, Victor; Green, Nicholas John; Tate, Chris; Harrison, Oscar and Vaage, Knut

Title of Invention:
Improvements in fluid bearings

Term of Patent:
Twenty years from 28 June 2013

Priority Details

Number	*Date*	*Filed with*
2012902770	28 June 2012	AU

Dated this 9th day of June 2016

Commissioner of Patents

PATENTS ACT 1990

The Australian Patents Register is the official record and should be referred to for the full details pertaining to this IP Right.

This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

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9 June 2016

Shelston IP Pty Ltd.
L 21 60 Margaret St
Sydney NSW 2000
Australia

Notice of Grant

Patent Number: 2013282771

Patentee Name(s): Outotec (Finland) Oy

Your Ref: 74861AUP00

IP Australia is pleased to advise that a Patent has been granted in respect of this application. The patent was granted on 9 June 2016 and the Certificate of Grant is enclosed.

Please note the provisions of Section 67 of the Patents Act 1990, which states that the term of a standard patent is 20 years from the date of the patent.

To maintain this standard patent, Section 143(a) of the Patents Act 1990 requires you to pay the prescribed renewal fee annually, within the set time. If renewal fees are not paid the patent will cease.

Please Note:

1. Your first renewal fee payment, being for the 4th year anniversary is due on 28 June 2017.

2. The fee can be paid up to 6 months after the anniversary provided it is accompanied by the relevant late payment fee(s).

If you need any further information please contact 1300 651 010. Alternatively, please visit us at www.ipaustralia.gov.au.

Yours faithfully

Patent and Plant Breeder's Rights Administration

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12 February 2016

Shelston IP Pty Ltd.
L 21 60 Margaret St
Sydney NSW 2000
Australia

Notice of Acceptance

Application Number: 2013282771

Applicant Name(s): Outotec (Finland) Oy

Your Ref: 74861AUP00

I am pleased to advise that there are no objections to the application. The Examiner has incorporated into the complete specification amendments made under PCT Article 34 Section 104 based on the following:

PCT: WO2014/002060
S104 amendments up to and including item number: 2

The application and complete specification were accepted on 28 January 2016 and a notice of the acceptance will appear in the Supplement to the Australian Official Journal of Patents on 25 February 2016.

A fee for acceptance of an application applies. This fee includes a component determined by the number of claims in excess of 20. If the acceptance has not been paid, an Invitation to Pay (ITP) will issue. If the amount is paid by the due date, your patent will be granted as soon as practicable after the 3 month period for opposition has expired.

The total number of claims at acceptance has been reported as: 32

The attached sheet provides bibliographic details of this application at acceptance and may be displayed on the Certificate of Grant. If you wish to amend any details prior to grant please do so within 3 months of the accepted advertised date.

If you need any further information please contact 1300 651 010. Alternatively, please visit us at www.ipaustralia.gov.au.

Yours faithfully

Patent and Plant Breeder's Rights Administration

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Bibliographic Details at Acceptance

Details for Patent Application: 2013282771

Your Reference: 74861AUP00

Acceptance Date: 28 January 2016

Acceptance to be Advertised: 25 February 2016

Complete Filing Date: 28 June 2013

OPI Date: 3 January 2014

National Phase Entry Date: 5 December 2014

Applicant Name and Address *(as it will appear on certificate/s)*:
Outotec (Finland) Oy
Rauhalanpuisto 9, FI-02230 Espoo, Finland

Title: Improvements in fluid bearings

Inventor Name(s):
Braithwaite, Daniel
Belke, Jeffrey, Victor
Green, Nicholas John
Tate, Chris
Harrison, Oscar
Vaage, Knut

Agent Name: Shelston IP Pty Ltd.

Address for Correspondence:
L 21 60 Margaret St
Sydney NSW 2000
Australia

Address for Legal Service:
Level 21, 60 Margaret Street
Sydney NSW 2000
Australia

Prior Art Documents:
GB 1508384

Priority Details:

Date	Application Number	Country
28 June 2012	2012902770	AU

International Classification:
F16C 32/06 (2006.01)

Continuation Fee Due Date: **28 June 2017**

Date of Patent: 28 June 2013

Expiry Date: 28 June 2033

2013282771 31 Dec 2015

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.

4. The bearing assembly of any one of the preceding claims, wherein said mounting portion comprises a protrusion extending 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.

This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

2013282771 31 Dec 2015

7. The bearing assembly of claim 6, wherein at least one of a locking element and said at least one recess comprising a locking tab is used 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 or 8, further comprising a plug for engagement with said head portion and said at least one recess.

10. 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.

11. 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.

12. The bearing assembly of claim 11, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

13. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

14. The bearing assembly of any one of claims 1 to 12, wherein said outer surface is substantially planar.

15. 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.

16. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer

2013282771 31 Dec 2015

surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

17. The bearing assembly of claim 16, 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.

18. The bearing assembly of any one of claims 1 to 15, 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.

19. The bearing assembly of claim 18, wherein said first surface is orthogonal to said second surface.

20. The fluid bearing of claim 18 or 19, 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.

21. 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,

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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.

22. The multidirectional fluid bearing of claim 21, wherein said first polymer bearing pad is removably mounted to said first surface and said second polymer bearing pad is removably mounted to said second surface.

23. The multidirectional fluid bearing of claim 21 or 22, said first polymbearing 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 21 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 21, 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

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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 21 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 21 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 21 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 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.

4. The bearing assembly of any one of the preceding claims, wherein said mounting portion comprises a protrusion extending 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.

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7. The bearing assembly of claim 6, wherein at least one of a locking element and said at least one recess comprising a locking tab is used 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 or 8, further comprising a plug for engagement with said head portion and said at least one recess.

10. 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.

11. 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.

12. The bearing assembly of claim 11, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

13. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

14. The bearing assembly of any one of claims 1 to 12, wherein said outer surface is substantially planar.

15. 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.

16. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer

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surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

17. The bearing assembly of claim 16, 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.

18. The bearing assembly of any one of claims 1 to 15, 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.

19. The bearing assembly of claim 18, wherein said first surface is orthogonal to said second surface.

20. The fluid bearing of claim 18 or 19, 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.

21. 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,

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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.

22. The multidirectional fluid bearing of claim 21, wherein said first polymer bearing pad is removably mounted to said first surface and said second polymer bearing pad is removably mounted to said second surface.

23. The multidirectional fluid bearing of claim 21 or 22, said first polymbearing 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 21 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 21, 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

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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 21 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 21 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 21 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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"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 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

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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.

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[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-

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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,

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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] 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

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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

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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.

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[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.

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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, 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:

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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;

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[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

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[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

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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.

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[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,

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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

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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.

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(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.

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(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

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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

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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,

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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

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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

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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

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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

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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.

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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 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

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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.

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[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-

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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,

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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] 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

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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

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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.

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[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.

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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, 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:

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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;

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[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

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[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

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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.

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[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,

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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

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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.

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(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.

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(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

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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

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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,

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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

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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

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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

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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

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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.

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Description of Request

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31 December 2015

Our Ref: 74861AUP00

Attention: Ranganath Subbarayan
A4 – Mechanical, Patent Examination B

Contact: Andrew Lowe

Dear Commissioner

Australian Patent Application No. 2013282771
Applicant: Outotec (Finland) Oy
Title: Improvements in fluid bearings

In response to the examination report dated 27 August 2015, we lodge herewith a statement of proposed amendments, substitute pages and a copy of pages indicating the nature and location of the amendments.

Amendments

The proposed amendments have revised the claims to merge claims 3 and 4, and claims 7 and 10. New claims 3 and 22 have been added. Consequential amendments have been made to the specification.

It is submitted that the proposed amendments are supported by the specification as originally filed.

Inventive step

The Applicant acknowledges that the Examiner has considered originally pending claims 6 to 10, 12, 13 and 19 to 32 (now claims 6 to 9, 11, 12, 18 to 21 and 23 to 32) to be novel and have an inventive step over the prior art.

In reply to item 1, it is submitted that claims 1 to 5, 11 and 14 to 18 (now claims 1, 3 to 5, 10 and 13 to 17) have an inventive step over the cited prior art, being D1: GB 1,508,384 (Chielens).

The Examiner has referred to the reasoning in the IPRP that issued on the corresponding international application in support of his inventive step objection. The reasoning in the IPRP concedes that D1 does not describe a polymer bearing pad but asserts that it would have been obvious to substitute the bearing pads in D1 with polymer bearing pads.

The Examiner has also asserted that feature of a fixedly mounted bearing in claim 2 is a workshop improvement of the self-adjusting fluid bearing defined in claim 1.

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It is submitted that it would not have been obvious for a skilled person to simply substitute the lining 16 in D1 for a polymer bearing pad. There is no disclosure or teaching in D1 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 D1 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 for bearing pads is part of the common general knowledge in the art. 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 part of the common general knowledge in the art, 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 D1. Consequently, to modify the bearing pads in D1 with polymer bearing pads would in fact frustrate the purpose of the bearings in D1 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, D1 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 D1, as discussed in 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 D1 or the common general knowledge in the art.

It is therefore submitted that the person skilled in the art, reading D1 in light of the common general knowledge in the art teaching bronze/white metal linings, would not be led **directly**, as a matter of course to the claimed invention. Accordingly, it is submitted that the claims have an inventive step and it is requested that this objection be withdrawn.

Postponement of acceptance

The Applicant also requests withdrawal of the current postponement of acceptance in respect of this application.

Closing comments

In conclusion, it is submitted that this application is now in order for acceptance and favourable reconsideration is requested.

Yours respectfully
Shelston IP



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Encl. First Statement of Proposed Amendments

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31 December 2015

Our Ref: 74861AUP00

Contact: Andrew Lowe

Dear Commissioner

Australian Patent Application No. 2013282771
Applicant: Outotec (Finland) Oy
Title: Improvements in fluid bearings

FIRST STATEMENT OF PROPOSED AMENDMENTS - SECTION 104(1)

Complete Specification

Description

1. Cancel pages 1 to 28 now on file and replace with new pages 1 to 27.

Claims

2. Cancel pages 29 to 33 now on file and replace with new pages 28 to 32.

DATED this 31st day of December 2015
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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 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

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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.

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[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-

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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,

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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] 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

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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

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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.

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[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.

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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, 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:

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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;

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[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

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[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

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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.

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[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,

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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

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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.

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(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.

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(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

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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

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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,

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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

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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

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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

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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

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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.

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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.

4. The bearing assembly of any one of the preceding claims, wherein said mounting portion comprises a protrusion extending 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.

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7. The bearing assembly of claim 6, wherein at least one of a locking element and said at least one recess comprising a locking tab is used 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 or 8, further comprising a plug for engagement with said head portion and said at least one recess.

10. 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.

11. 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.

12. The bearing assembly of claim 11, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

13. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

14. The bearing assembly of any one of claims 1 to 12, wherein said outer surface is substantially planar.

15. 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.

16. The bearing assembly of any one of the preceding claims, further comprising a plurality of said polymer bearing pads, wherein said respective outer

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surfaces of said polymer pads form a substantially uniform bearing surface for said journal.

17. The bearing assembly of claim 16, 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.

18. The bearing assembly of any one of claims 1 to 15, 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.

19. The bearing assembly of claim 18, wherein said first surface is orthogonal to said second surface.

20. The fluid bearing of claim 18 or 19, 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.

21. 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,

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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.

22. The multidirectional fluid bearing of claim 21, wherein said first polymer bearing pad is removably mounted to said first surface and said second polymer bearing pad is removably mounted to said second surface.

23. The multidirectional fluid bearing of claim 21 or 22, said first polymbearing 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 21 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 21, 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

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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 21 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 21 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 21 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.

MARKED UP

~~(AMENDED)~~

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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-

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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.

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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] 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

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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°

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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

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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.

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[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

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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.

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[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.

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[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

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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.

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[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.

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[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

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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

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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

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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

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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.

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(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

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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.

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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

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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

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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 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

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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

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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,

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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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~~(AMENDED)~~

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~~ing means comprises a mounting portion extending from said polymer bearing pad~~.

4. The bearing assembly of any one of the preceding claims ~~3~~, wherein said mounting portion comprises a protrusion extending from a mounting surface opposite to said outer surface for engaging a flange of said base.

5. The bearing assembly of claim 4~~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~~6, wherein at least one of a locking element and said at least one recess comprising~~es~~ a locking tab is used for retaining a head portion of said fastener within said at least one recess.

8. The bearing assembly of claim ~~6~~6 or ~~7~~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~~7 or 8, 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.~~10. 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.~~11. 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.~~12. The bearing assembly of claim 11~~11~~12, wherein said chamfer has an outer edge that is displaced from a journal when said journal engages said polymer pad.

~~14.~~13. The bearing assembly of any one of the preceding claims, wherein said outer surface is partially curved. .

~~15.~~14. The bearing assembly of any one of claims 1 to 12~~12~~13, wherein said outer surface is substantially planar.

~~16.~~15. 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.~~16. 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.~~17. The bearing assembly of claim 161~~6~~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.~~18. The bearing assembly of any one of claims 1~~1~~ to 151~~5~~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.~~19. The bearing assembly of claim 181~~8~~19, wherein said first surface is orthogonal to said second surface.

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~~21.~~20. The fluid bearing of claim 18~~18~~19 or 19~~19~~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.~~21. 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.

22. The multidirectional fluid bearing of claim 21, wherein said first polymer bearing pad is removably mounted to said first surface and said second polymer bearing pad is removably mounted to said second surface.

23. The multidirectional fluid bearing of claim 21~~21~~22 or 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 21~~21~~22 or ~~23~~ 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.

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25. The multidirectional fluid bearing of claim 24~~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 21~~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~~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 21~~22~~ to 27~~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~~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 21~~22~~ to 29~~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~~30~~, wherein said flange is located at an outer edge of said base.

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~~(AMENDED)~~

32. The multidirectional fluid bearing of any one of claims 212~~2122~~ to 313~~3131~~, 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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Patent Examination Report No. 1

Application Details

Patent Application No.:	2013282771
Applicant/s:	Outotec (Finland) Oy
Your reference:	74861AUP00
Earliest Priority Date:	28 June 2012
Examination Request Date:	02 January 2015

Your application has been examined under Section 45 of the *Patents Act 1990*. I consider that the application does not meet the requirements of the Act for the reasons indicated below.

Actions you can take

NOTE: There is a current postponement of acceptance in place. If you overcome all other objections before the expiration of that postponement, the Commissioner will only accept the application at that time if you have filed a clear and unambiguous statement requesting the withdrawal of that postponement. Otherwise, a further adverse report will be issued.

You have **12 months** from the date of this report to overcome all my objection(s) otherwise your application will lapse.

You will also need to pay any annual continuation fees that apply. Information about fees may be obtained by phoning 1300 651 010 or by visiting www.ipaustralia.gov.au.

Basis of the report

In examining your application I have considered:

- the PCT pamphlet and amendments already made under the PCT Articles

Statement of Novelty, Inventive Step and Patentable Subject Matter

Novelty/Inventive Step	Claim No. 6-10, 12, 13, 19-32 Claim No. 1-5, 11, 14-18	**Yes** **No**
Patentable Subject Matter	Claim No. 1-32 Claim No. NONE	**Yes** **No**

Documents Cited or Considered Relevant

D1 : GB 1508384 A (FIVES-CAIL BABCOCK) 26 April 1978 #
Category: **X** Claims: 1-5, 11, 14-18

Cited in the IPRPII

Special categories of cited documents:

X: The claimed invention cannot be considered novel under subsection 7(1) in light of the document and/or cannot be considered to involve an inventive step under subsection 7(2) of the Act in light of the common general knowledge considered together with the document.

Novelty and Inventive Step

1 **Claim 1** lacks inventive step in light of the prior art document D1 discussed in item V of the IPRPII.

While the objection regarding this document was not made under Australian law, I agree with the reasons given in that report and consider that they support a corresponding objection against the Australian claims.

In relation to independent **claim 2**, I consider that mounting the base fixedly on the frame rather than through self-adjusting mounts is no more than a mere workshop improvement. It is an arrangement that any competent worker in the art would be expected to make directly and without difficulty and by routine steps alone.

Furthermore, appended **claims 3-5, 11, 14-18** add only features that are either disclosed in D1 or are matters of design choice and which therefore cannot contribute to providing a patentable invention.

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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

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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)).

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

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.

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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
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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
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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.

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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.

IP Australia Our Ref: 74861WOP00

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
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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.

[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

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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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.

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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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Examination Request Acknowledgement

Application Number: 2013282771

Applicant Name(s): Outotec (Finland) Oy

Your Ref: 74861AUP00

Thank you for your request, received on 2 January 2015, for full examination of the above patent application.

If the fees payable for this service request have not been paid in full, an Invitation to Pay will be issued and examination will not commence until full payment is received.

Your request has been allowed and acceptance of the application has been postponed. Please note that the Commissioner will not be able to accept this patent application unless a clear and unambiguous statement is received, requesting withdrawal of postponement. If no such statement is received by the final date for acceptance, the application will lapse.

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Postponement of Acceptance Acknowledgement

Application Number: 2013282771

Applicant Name(s): Outotec (Finland) Oy

Your Ref: 74861AUP00

Thank you for your request, received on 2 January 2015, for postponement of acceptance of the above patent application.

Your request has been allowed and acceptance of the application has been postponed. Please note that the Commissioner will not be able to accept this patent application unless a clear and unambiguous statement is received, requesting withdrawal of postponement. If no such statement is received by the final date for acceptance, the application will lapse.

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Patents Act 1990

Statement of Entitlement

Filed by	Shelston IP
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We state:

That the applicant (or each joint applicant):

- is an actual inventor; or
- derives title to the invention from an actual inventor(s); or
- would, on the grant of the patent, be entitled to have the patent assigned to them.

The applicant (or each joint applicant):

- is an applicant of the application(s) (if any) listed in the patent request, or in an applicable declaration under Article 8 of the PCT; or
- has entitlement from an applicant of the listed application(s), including entitlement to make a request under Section 113 in relation to any original or associated provisional application.

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Cover Sheet: Request for Patents Examination Full

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Applicant Name(s): Outotec (Finland) Oy

Your Ref: 74861AUP00

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The specification on file contains the following documents:

- Description
- Claim(s)
- Drawing(s)

This application currently has an abstract on file.

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(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

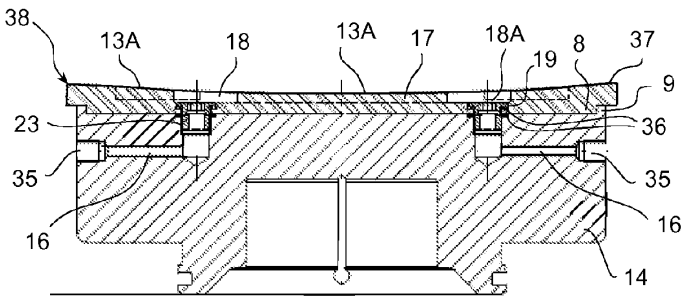


Fig. 6

(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).

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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).

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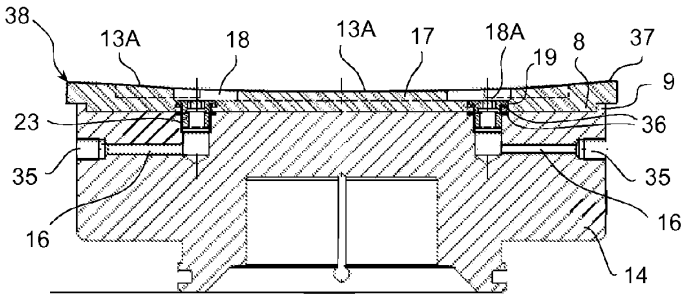


Fig. 6

(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).

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This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

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

Form PCT/ISA/210 (second sheet) (April 2005)

This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/055305

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

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

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.

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.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2013/055305

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

Form PCT/ISA/210 (patent family annex) (April 2005)

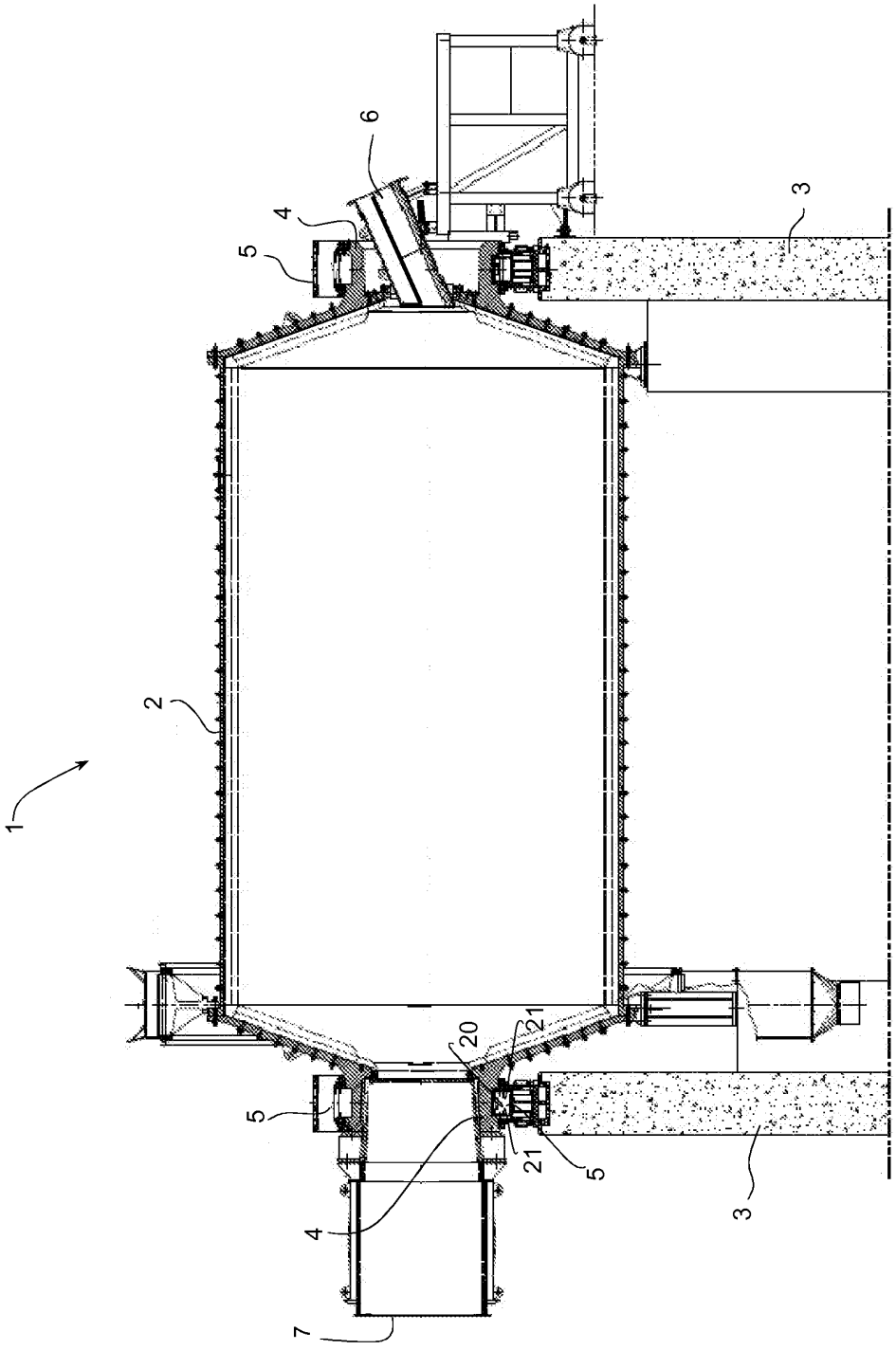


Fig. 1

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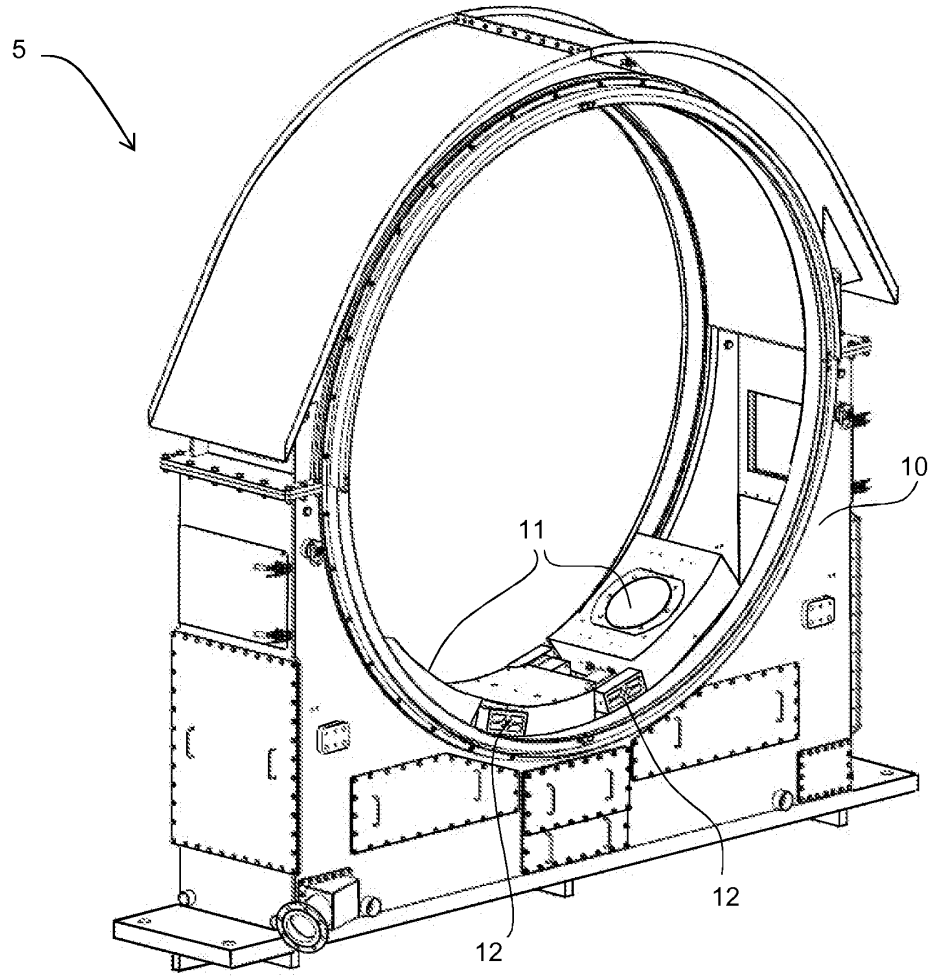


Fig. 2

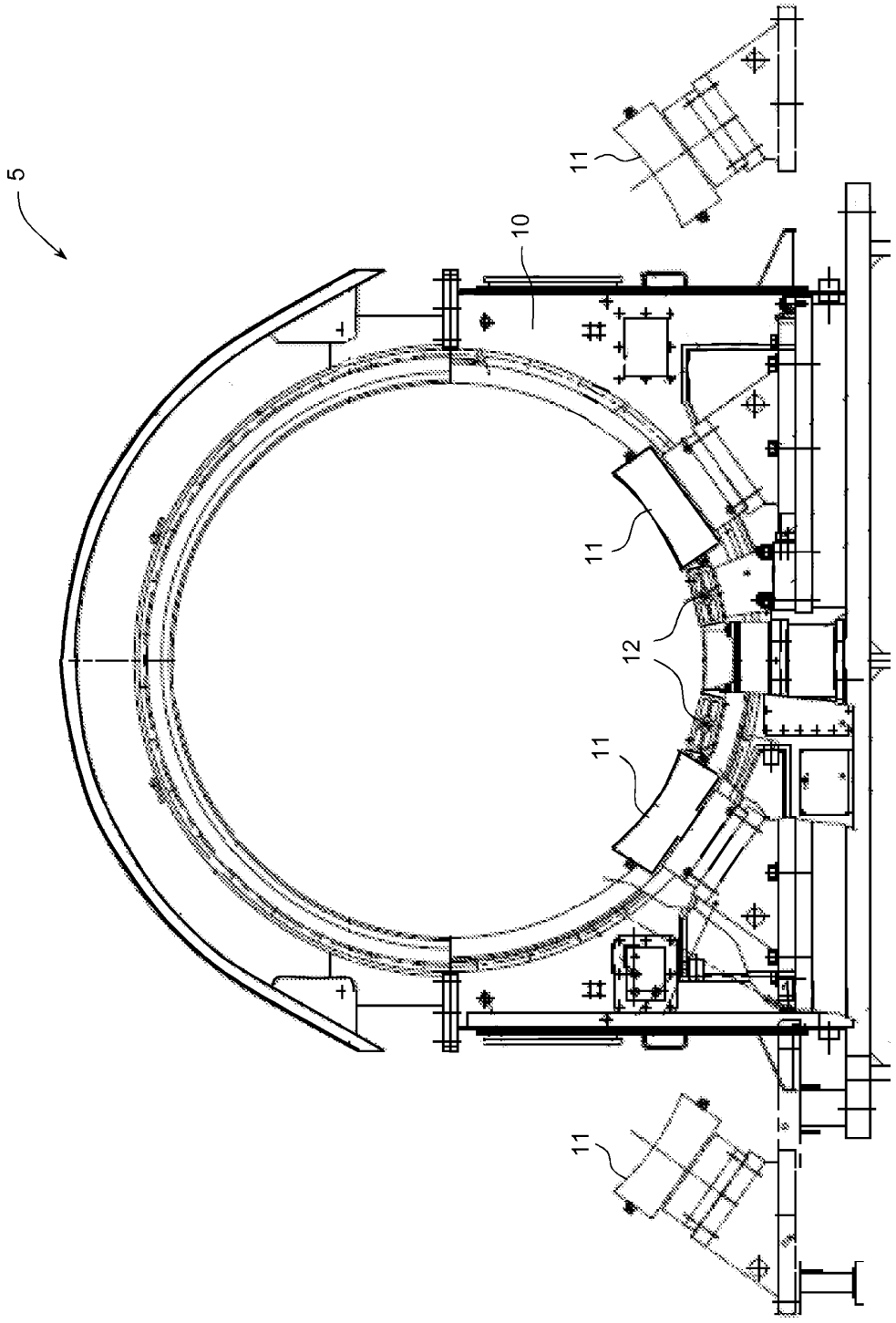


Fig. 3

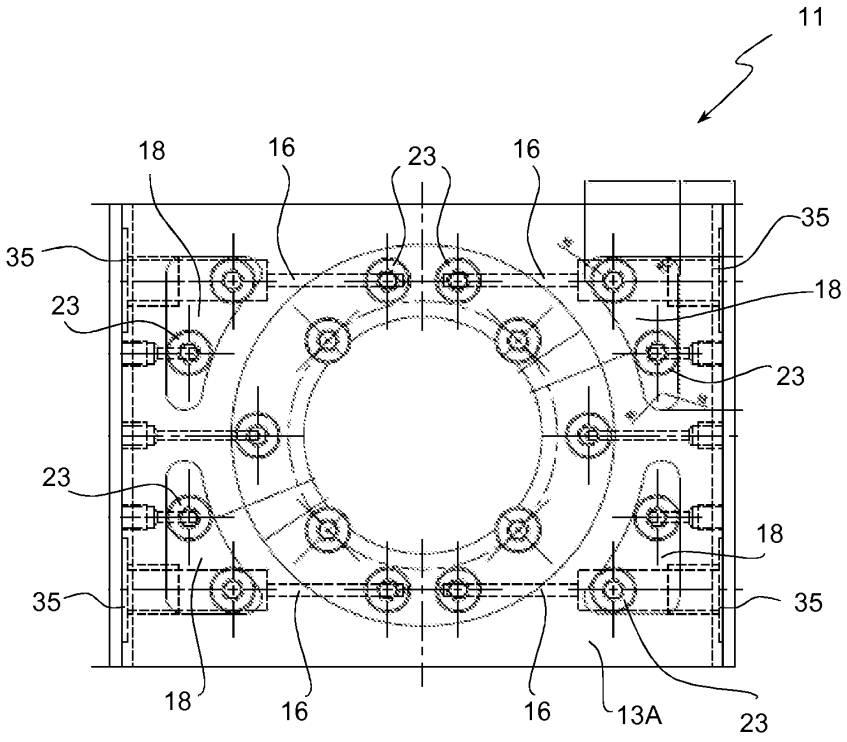


Fig. 4

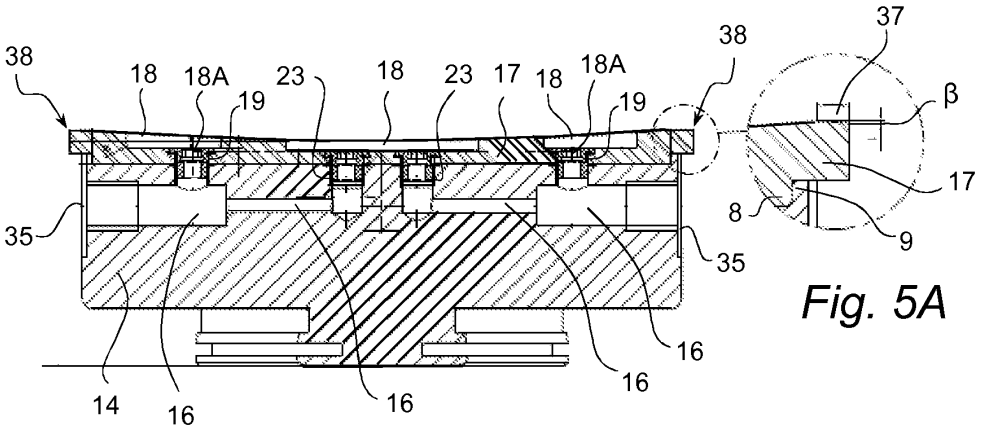


Fig. 5A

Fig. 5

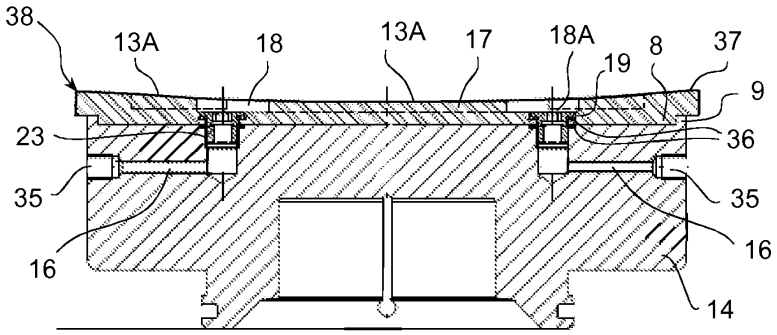


Fig. 6

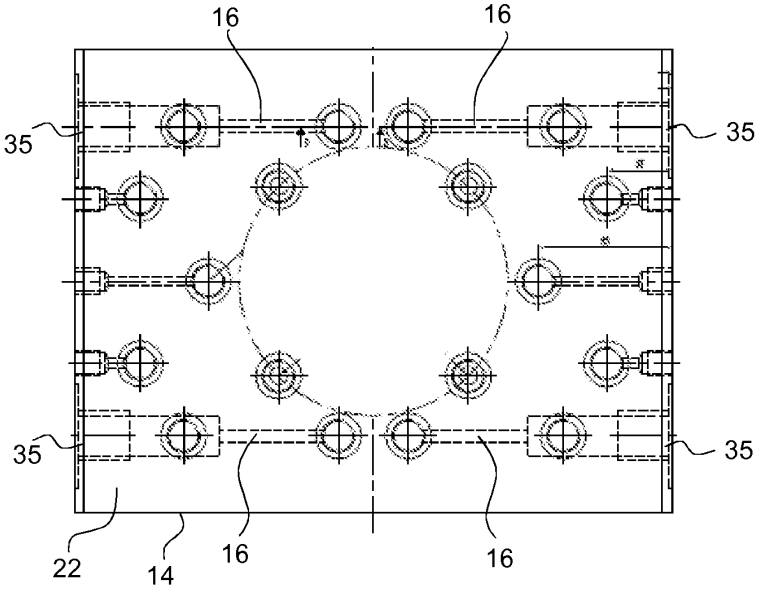


Fig. 7

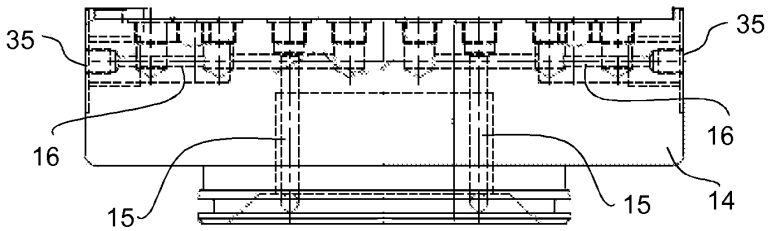


Fig. 8

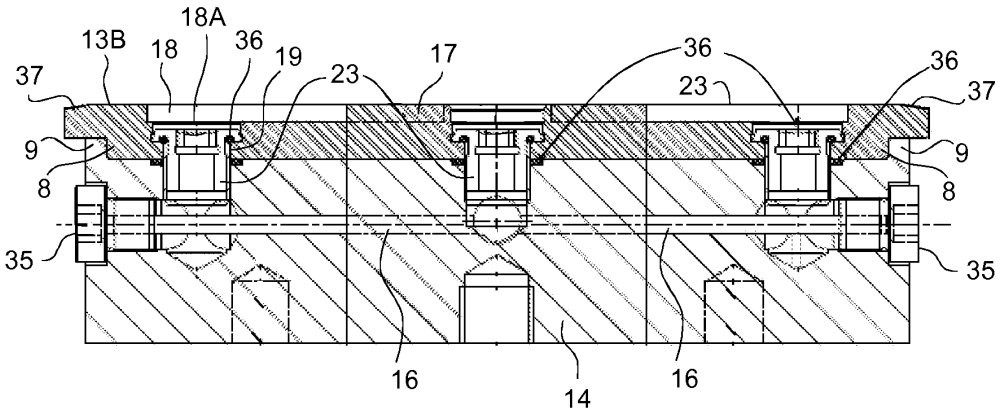

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Fig. 9

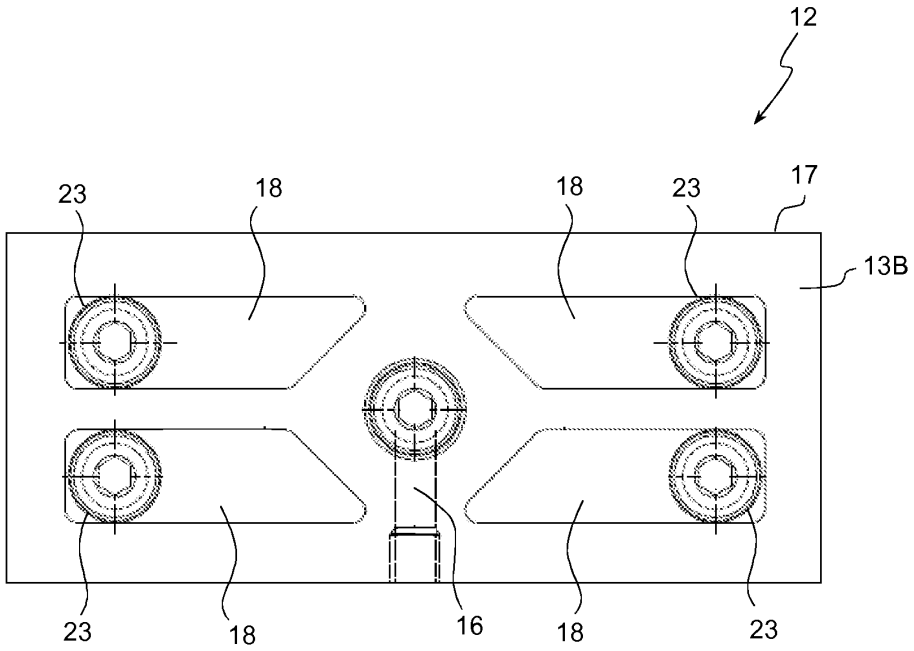

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Fig. 10

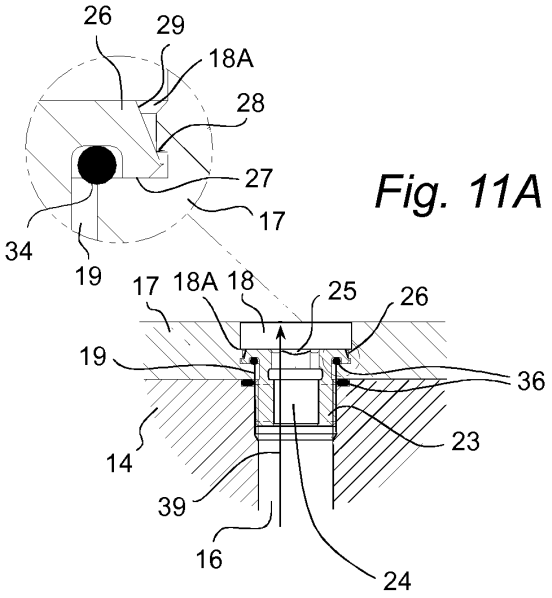


Fig. 11A

Fig. 11

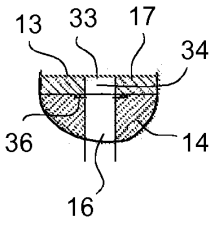


Fig. 12A

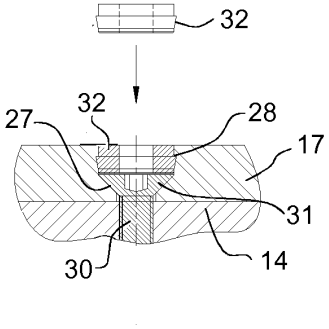


Fig. 12

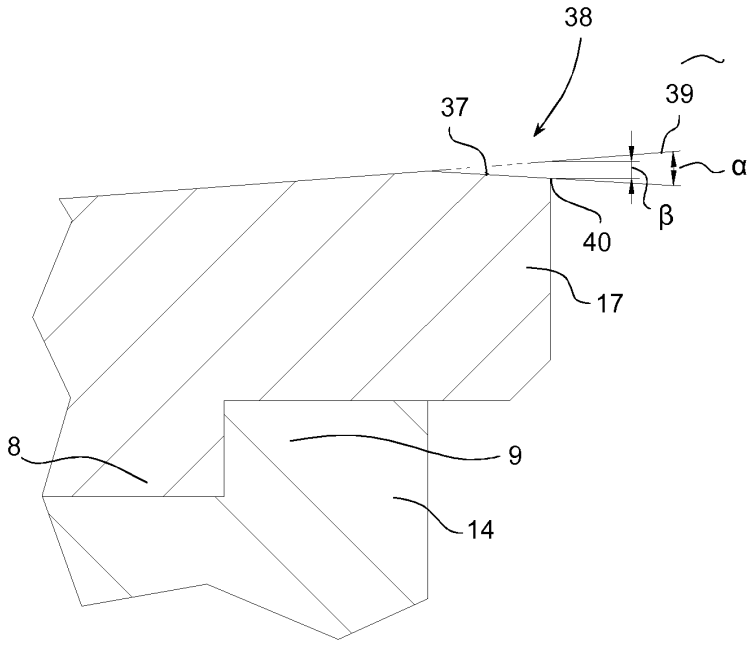


Fig. 13

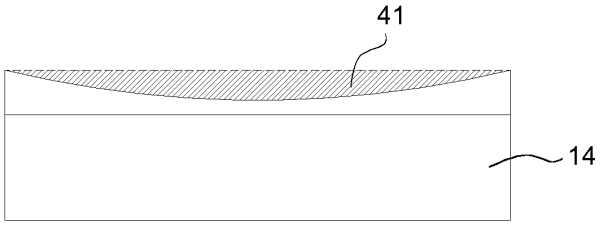


Fig. 14

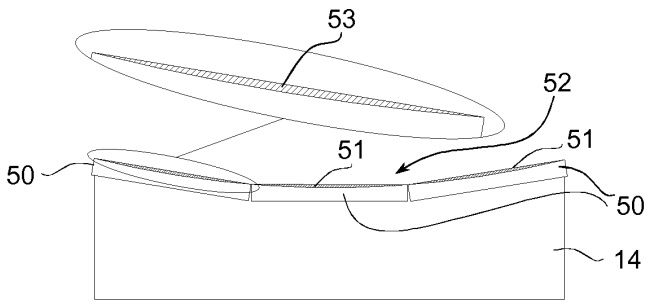


Fig. 15

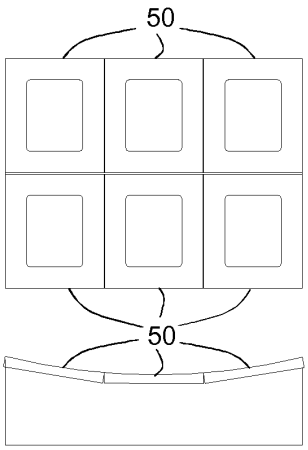


Fig.16

Fig.16A

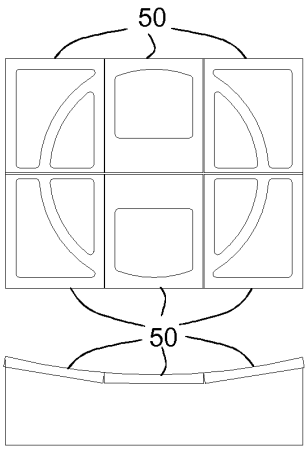


Fig.17

Fig.17A

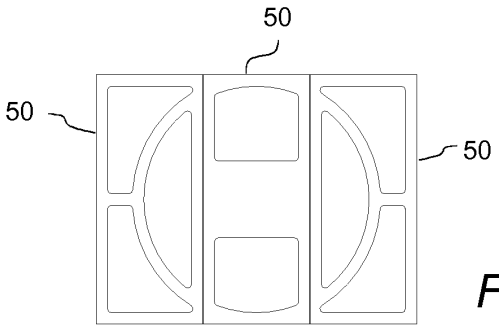


Fig. 18

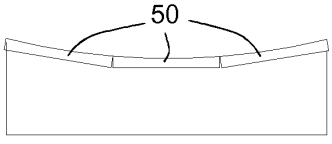


Fig. 18A

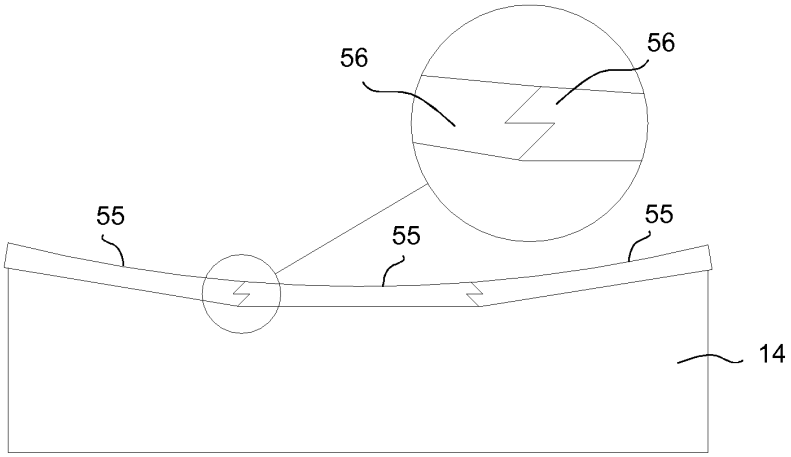


Fig. 19

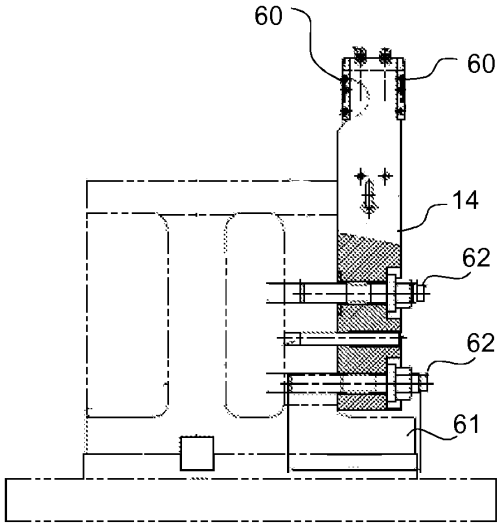
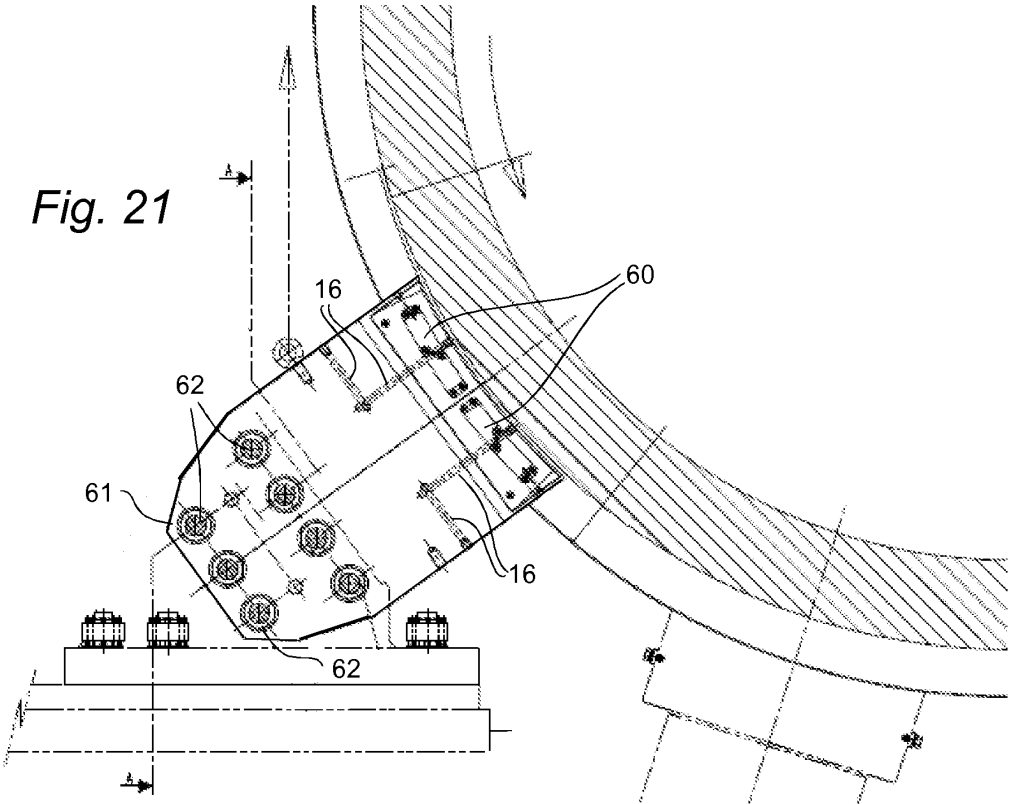


Fig. 22

Fig. 21



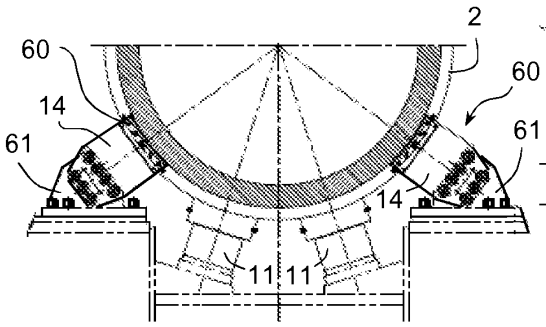


Fig. 20

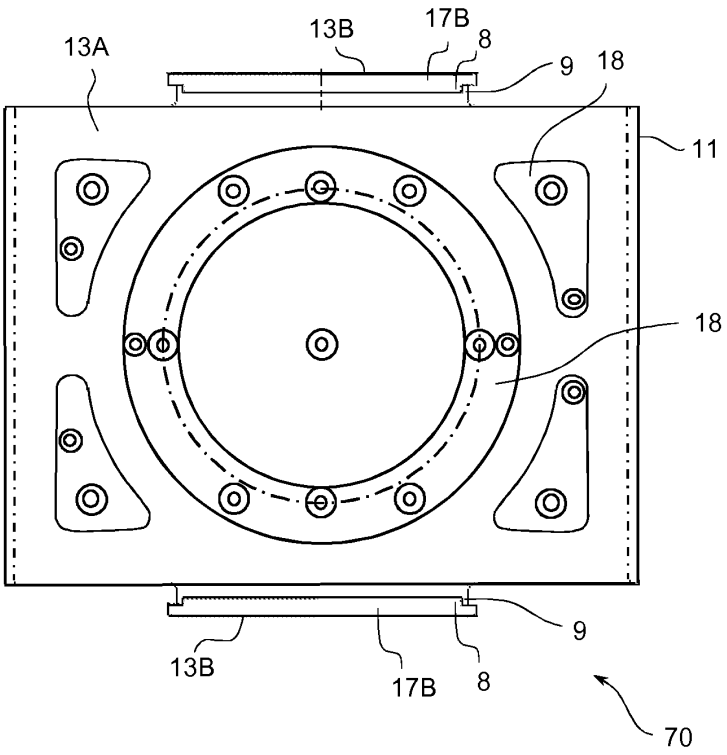


Fig. 23

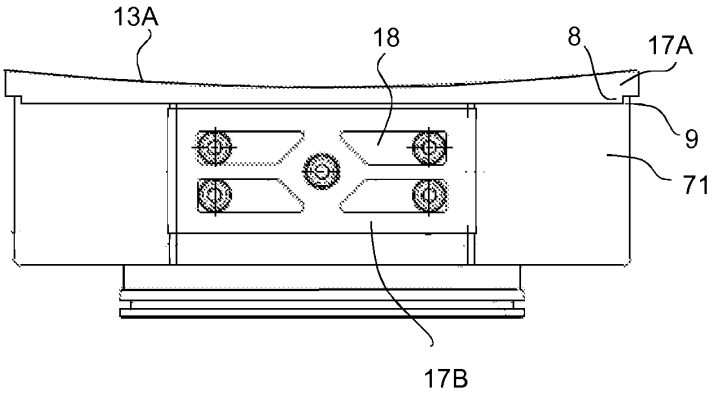


Fig. 24

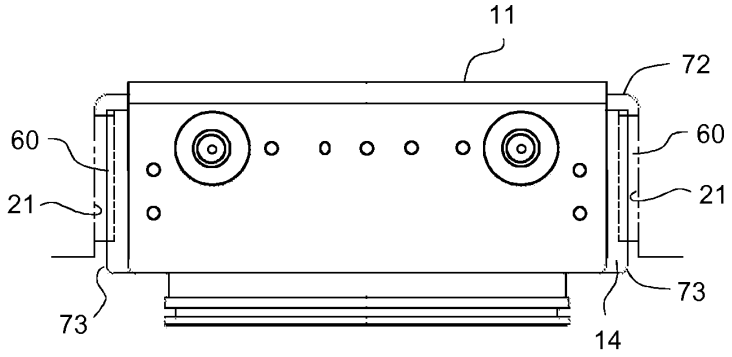


Fig. 25

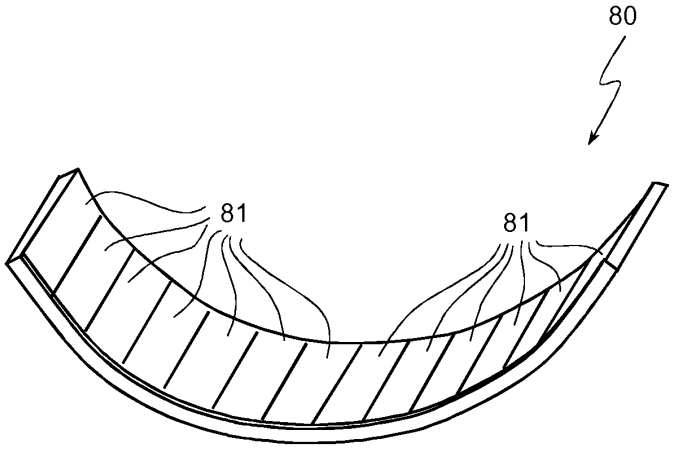


Fig. 26

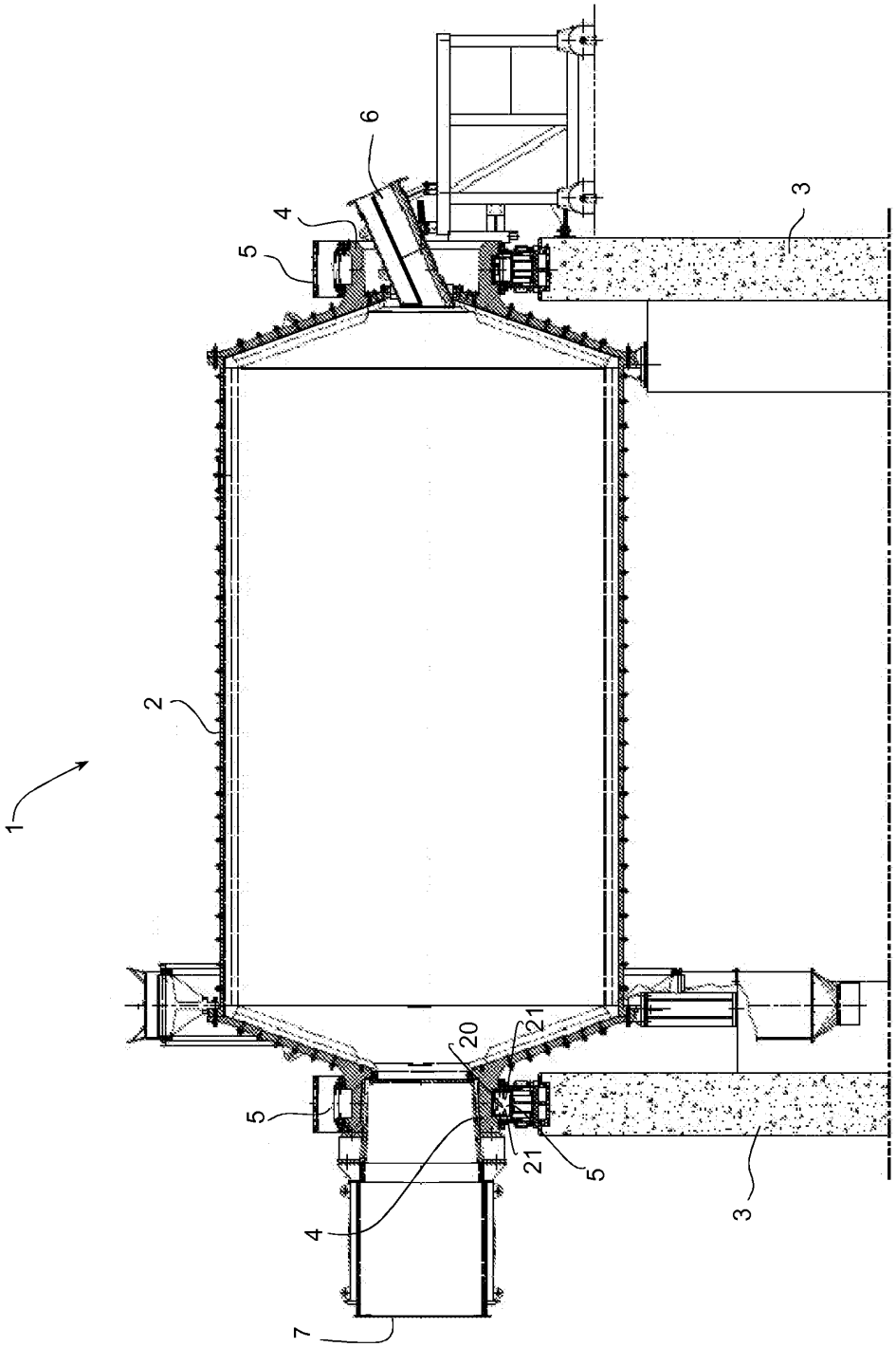


Fig. 1

This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

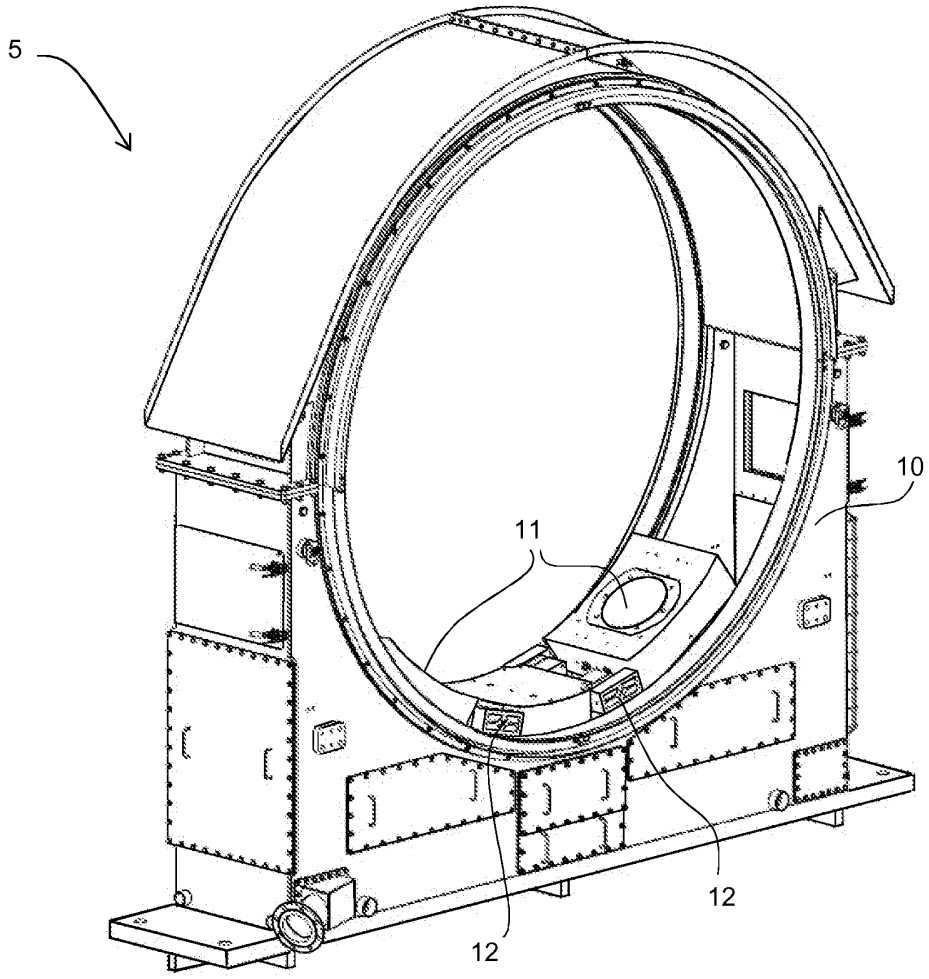


Fig. 2

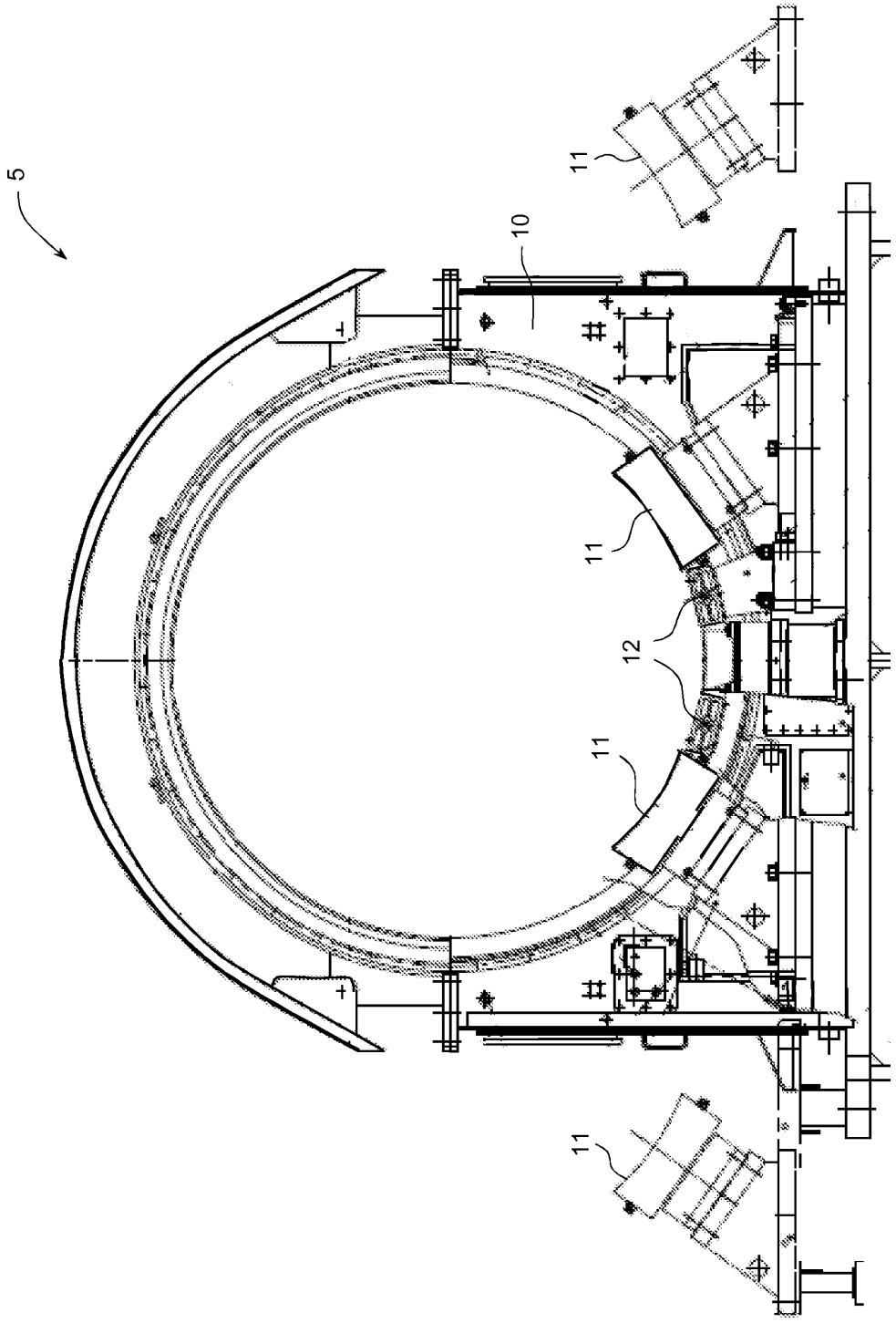


Fig. 3

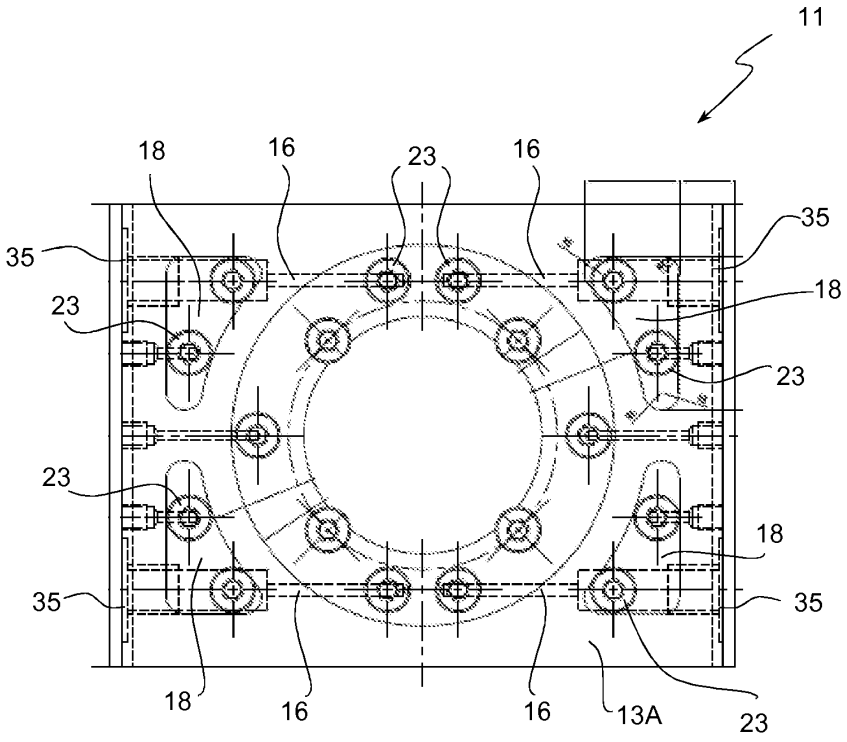


Fig. 4

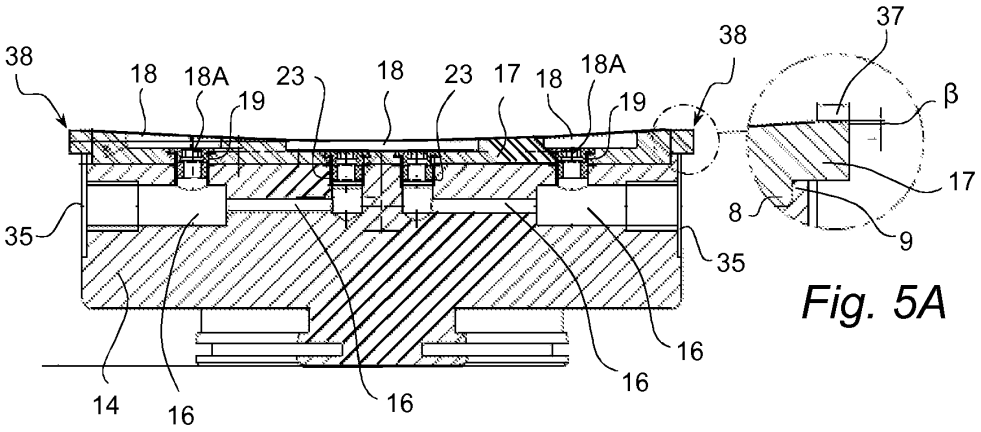


Fig. 5A

Fig. 5

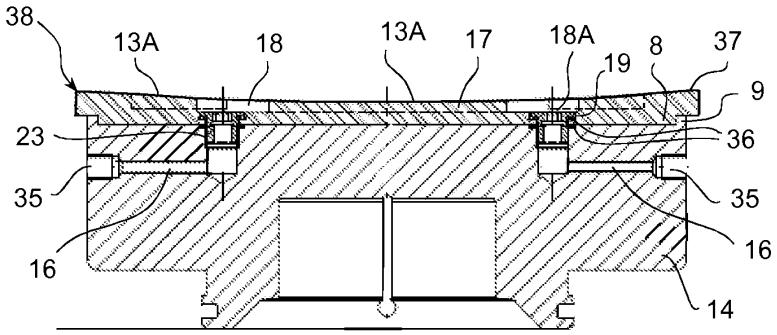


Fig. 6

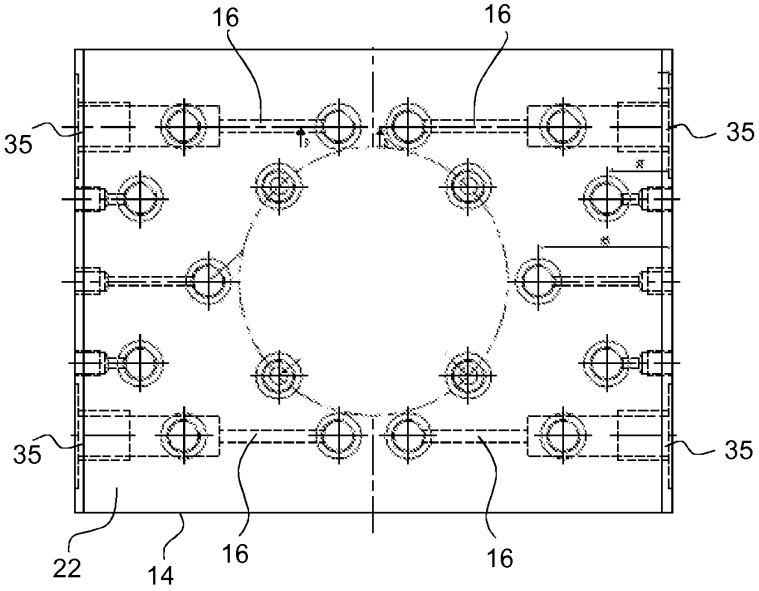


Fig. 7

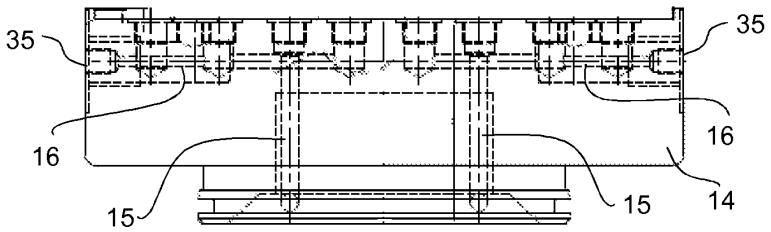


Fig. 8

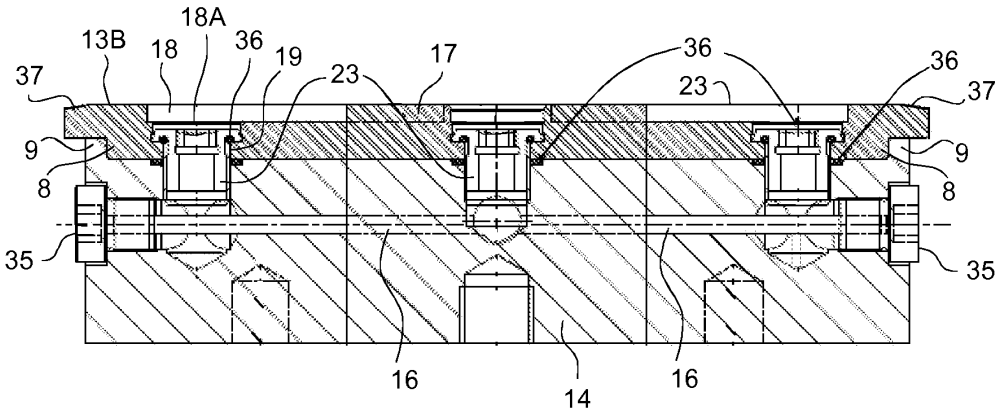

18A
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Fig. 9

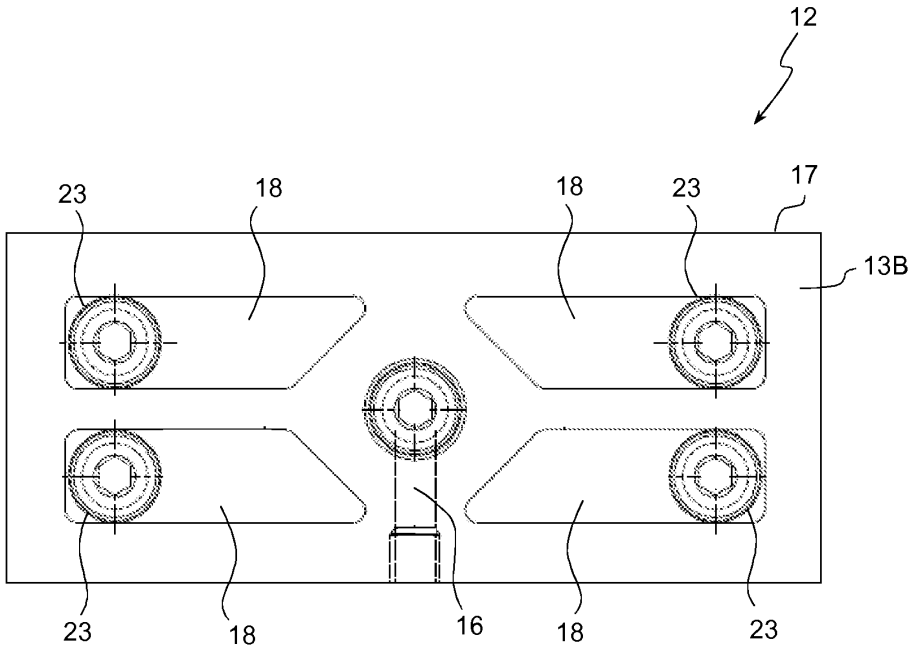

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13B
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Fig. 10

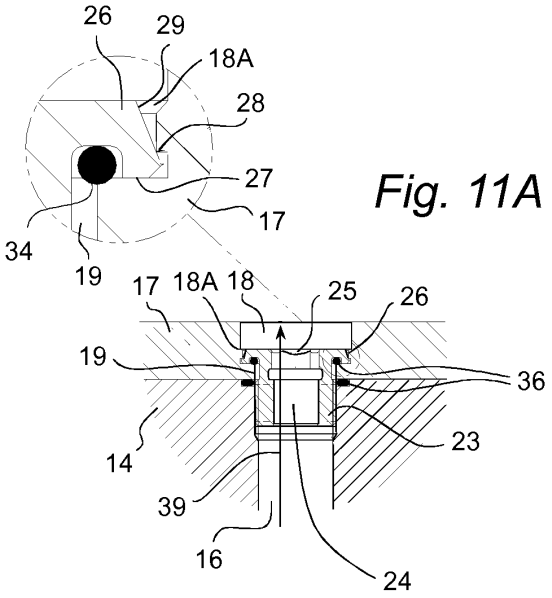


Fig. 11A

Fig. 11

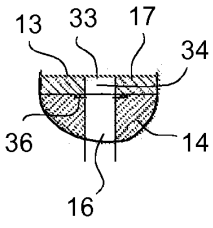


Fig. 12A

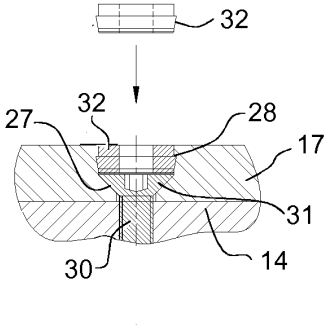


Fig. 12

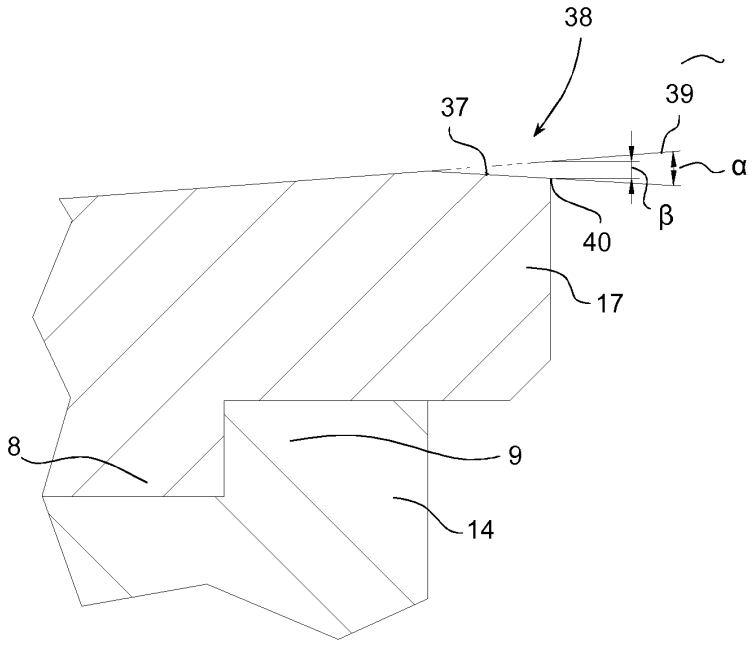


Fig. 13

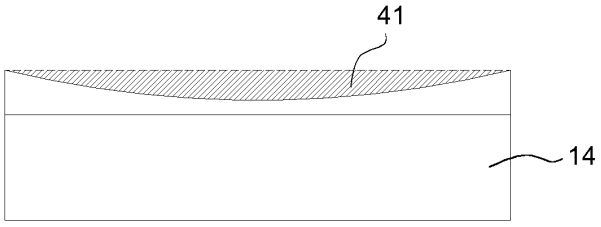


Fig. 14

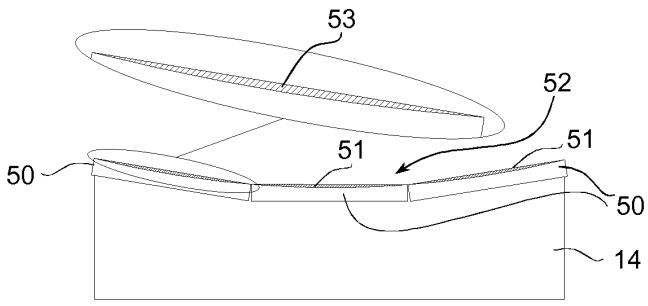


Fig. 15

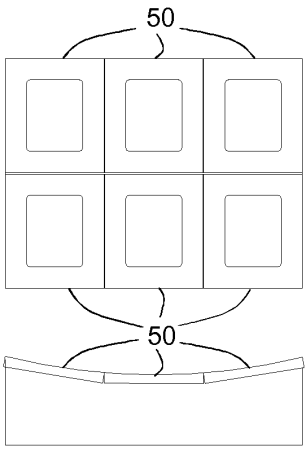


Fig.16

Fig.16A

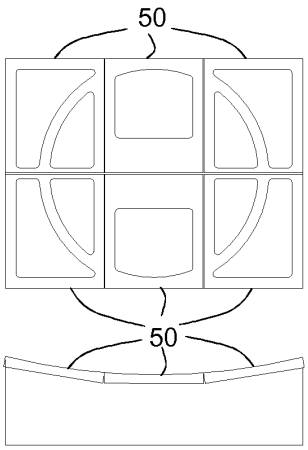


Fig.17

Fig.17A

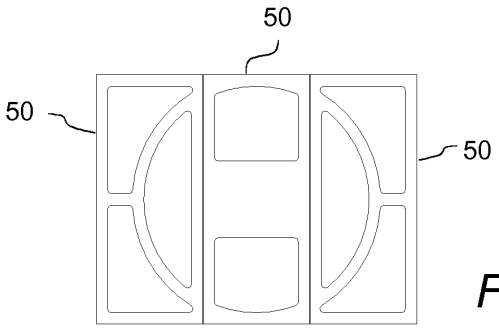


Fig. 18

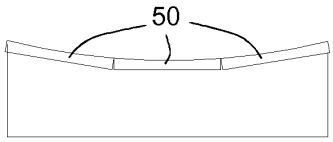


Fig. 18A

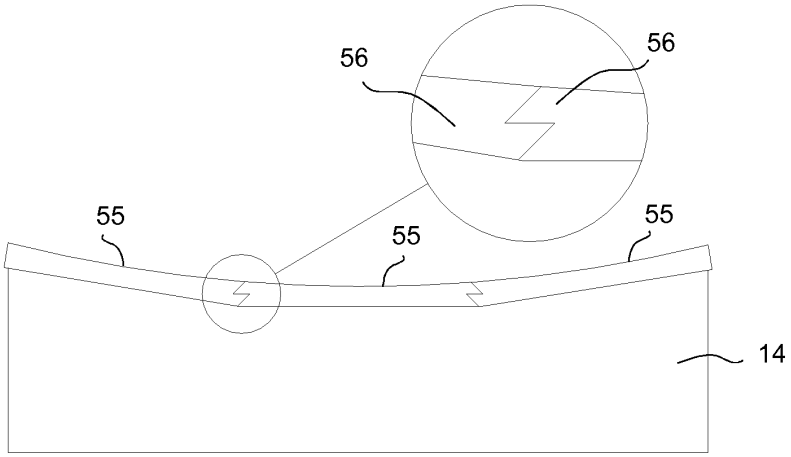


Fig. 19

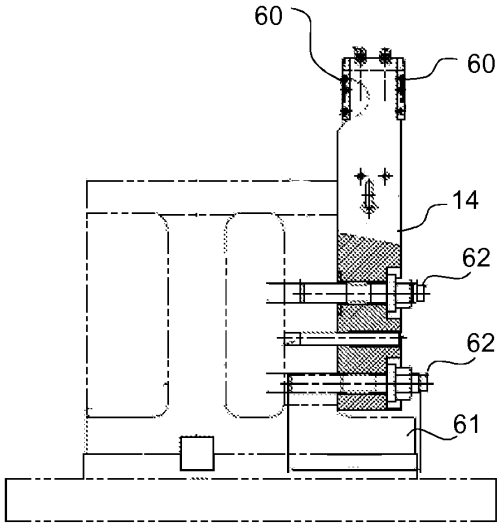
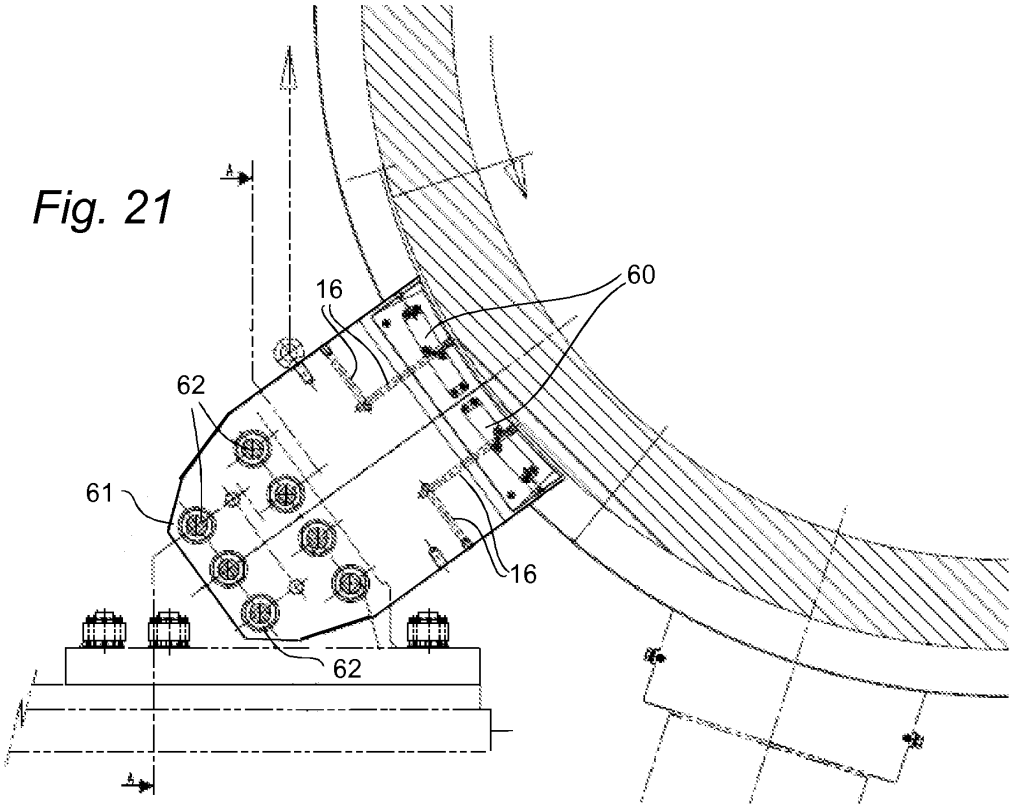


Fig. 22

Fig. 21



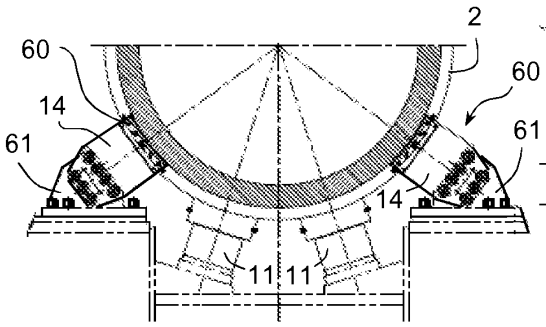


Fig. 20

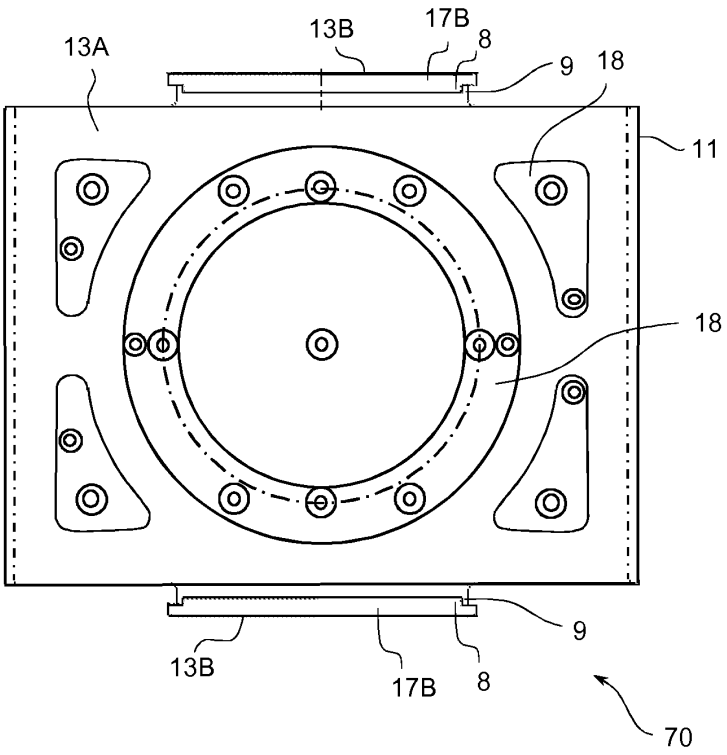


Fig. 23

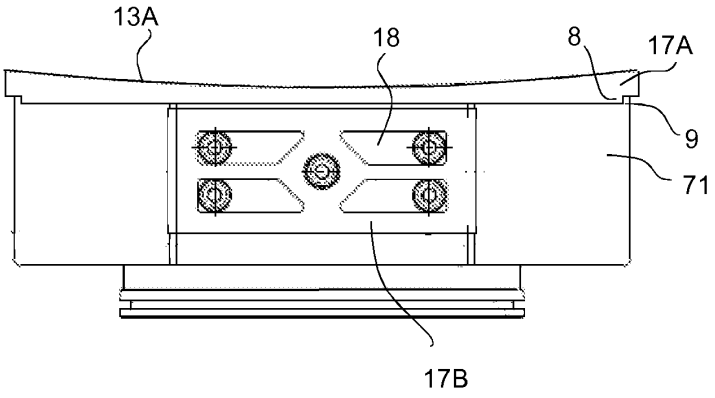


Fig. 24

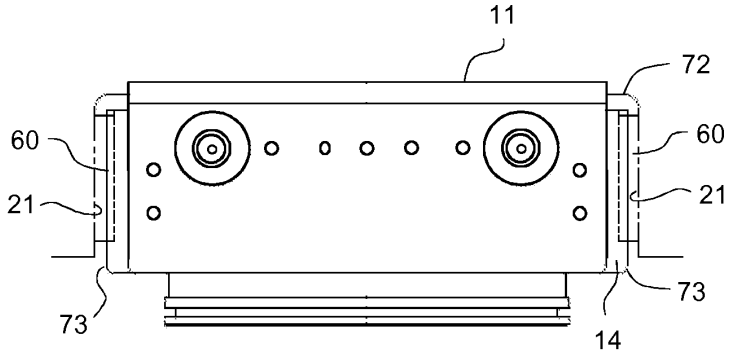


Fig. 25

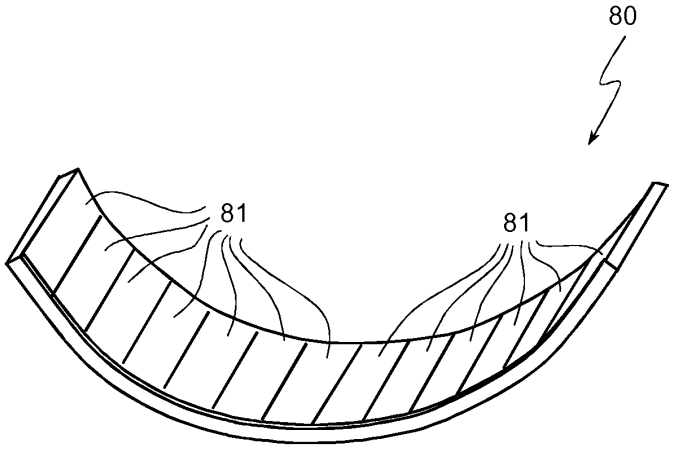


Fig. 26

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.

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

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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, 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:

[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, 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.

IP Australia

Cover Sheet: Patent Application National Phase Entry

Requested by	Shelston IP
Filing date	05-December-2014
Australian application number	2013282771
PCT application number	PCT/IB2013/055305
WIPO publication number	WO2014/002060
User submitted PCT application number	PCT/IB2013/055305
Invention title	Improvements in fluid bearings
Customer's reference	74861AUP00
Address for legal service	Shelston IP
	Level 21, 60 Margaret Street Sydney NSW, 2000 AU
I intend to enter the National Phase in Australia	Yes
Fee total amount	**$370.00**

This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

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	FOR FURTHER ACTION	See Form PCT/IPEA/416
74861WOP00		

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 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:

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This data, for application number 2013282771, is current as of 2025-09-30 00:07 AEST

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)).

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

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

Attention: Christophe Martin

22 April 2014

Our Ref: 74861WOP00

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

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CONFIRMATION BY MAIL

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Attention: Christophe Martin

CONFIRMATION

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.

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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.

IP Australia Our Ref: 74861WOP00

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.

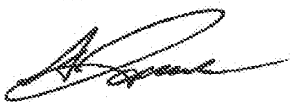
In reply to item 14.7, claim 46 (now claim 26) has clarified that there is a plurality of at least one of the first and second polymer bearing pads. Accordingly, it is submitted that this objection has now been overcome.

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



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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;

[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

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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.

[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 138 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.

[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.

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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.

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

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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