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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/577,797	03/27/2007	Ruediger Pfaff	095309.57635US

CONFIRMATION NO. 5226

POA ACCEPTANCE LETTER

35690
MEYERTONS, HOOD, KIVLIN, KOWERT & GOETZEL, P.C.
P.O. BOX 398
AUSTIN, TX 78767-0398



OC00000053210148

Date Mailed: 03/21/2012

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/13/2012.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/snguyen/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/577,797	03/27/2007	Ruediger Pfaff	095309.57635US

CONFIRMATION NO. 5226

POWER OF ATTORNEY NOTICE

23911
CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC 20044-4300



OC000000053210125

Date Mailed: 03/21/2012

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/13/2012.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/snguyen/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

☒ Practitioners associated with the Customer Number.

35690

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used).

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

☒ The address associated with Customer Number.

35690

OR

☐ Firm or Individual Name			
Address			
City	State	Zip	
Country			
Telephone		Email	

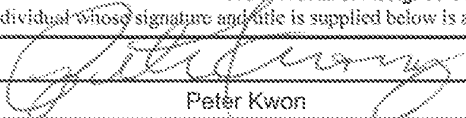
Assignee Name and Address.

Burani Consulting Limited Liability Company
2711 Centerville Rd, Suite 400
Wilmington, Delaware U.S.A. 19808

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

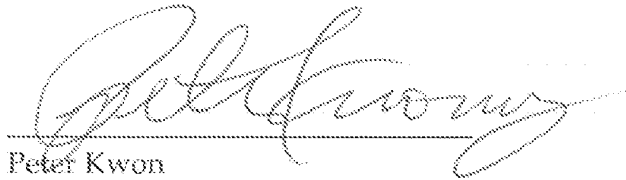
Signature		Date	1/3/2012
Name	Peter Kwon	Telephone	
Title	Authorized Person for Burani Consulting Limited Liability Company		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

DECLARATION REGARDING AUTHORITY TO SIGN
ON BEHALF OF A LEGAL ENTITY
37 C.F.R. 3.73(b)(2)(i)

I, Peter Kwon (whose title is supplied below), hereby declare that I am authorized to sign documents on behalf of Burani Consulting Limited Liability Company.



Peter Kwon

Authorized Person for Burani Consulting Limited Liability Company

1/3/2012
Date

Electronic Acknowledgement Receipt	
EFS ID:	12297530
Application Number:	10577797
International Application Number:	
Confirmation Number:	5226
Title of Invention:	DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE
First Named Inventor/Applicant Name:	Ruediger Pfaff
Customer Number:	23911
Filer:	Dean M. Munyon/Dawn DeLuca
Filer Authorized By:	Dean M. Munyon
Attorney Docket Number:	095309.57635US
Receipt Date:	13-MAR-2012
Filing Date:	27-MAR-2007
Time Stamp:	21:14:15
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Assignee showing of ownership per 37 CFR 3.73(b).	373b.pdf	485574 7b2273c98496981ce7348f958df195302b2049b	no	2

Warnings:

Information:

2	Power of Attorney	POA_Drats.pdf	1077663	no	2
			e9a6133225b81133a831365d7bb5e3aaeb74e5c5		
Warnings:					
Information:					
			Total Files Size (in bytes):	1563237	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: BURANI CONSULTING LIMITED LIABILITY COMPANY

Application No./Patent No.: 7513238 Filed/Issue Date: 04/07/2009

Titled: DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE

BURANI CONSULTING LIMITED LIABILITY COM, a Limited Liability Company

(Name of Assignee)

(Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest in;
2. ☐ an assignee of less than the entire right, title, and interest in
(The extent (by percentage) of its ownership interest is _____ %); or
3. ☐ the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made)

the patent application/patent identified above, by virtue of either:

- A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy therefore is attached.

OR

- B. ☒ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: Ruediger Pfaff; Martin Schnabel; Joachim Sue To: Daimlerchrysler AG

The document was recorded in the United States Patent and Trademark Office at
Reel 019124, Frame 0896, or for which a copy thereof is attached.

2. From: Daimlerchrysler AG To: Daimler AG

The document was recorded in the United States Patent and Trademark Office at
Reel 020976, Frame 0889, or for which a copy thereof is attached.

3. From: Daimler AG To: Burani Consulting Limited Liability Company

The document was recorded in the United States Patent and Trademark Office at
Reel 027624, Frame 0585, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

- ☒ As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Dean M. Munyon/

March 13, 2012

Signature

Date

Dean M. Munyon

Attorney (Reg. No. 42,914)

Printed or Typed Name

Title

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.



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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/577,797	04/07/2009	7513238	095309.57635US	5226

23911 7590 03/18/2009
CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC 20044-4300

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment is 115 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

Ruediger Pfaff, Stuttgart, GERMANY;
Martin Schnabel, Aalen, GERMANY;
Joachim Suess, Ludwigsburg, GERMANY;

PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

23911 7590 01/13/2009

**CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC 20044-4300**

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/577,797	03/27/2007	Ruediger Pfaff	095309.57635US	5226

TITLE OF INVENTION: DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1510	\$300	\$0	\$1810	04/13/2009

EXAMINER	ART UNIT	CLASS-SUBCLASS
WOLFE JR, WILLIS RAY	3747	123-276000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Crowell & Moring LLP

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

Daimler AG

(B) RESIDENCE: (CITY AND STATE OR COUNTRY)

Stuttgart, Germany

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☒ Issue Fee

☒ Publication Fee (No small entity discount permitted)

☒ Advance Order - # of Copies - 5 -

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

☐ A check is enclosed.

☒ Payment by credit card. Form PTO-2038 is attached.

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 05-1323 (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____

Date February 23, 2009

Typed or printed name James F. McKeown

Registration No. 25,406

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Electronic Patent Application Fee Transmittal				
Application Number:		10577797		
Filing Date:		27-Mar-2007		
Title of Invention:		DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE		
First Named Inventor/Applicant Name:		Ruediger Pfaff		
Filer:		James Mckeown/Alison Field		
Attorney Docket Number:		095309.57635US		
Filed as Large Entity				
U.S. National Stage under 35 USC 371 Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	1501	1	1510	1510
Publ. Fee- early, voluntary, or normal	1504	1	300	300

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Printed copy of patent - no color	8001	5	3	15
Total in USD (\$)				1825

Electronic Acknowledgement Receipt	
EFS ID:	4838533
Application Number:	10577797
International Application Number:	
Confirmation Number:	5226
Title of Invention:	DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE
First Named Inventor/Applicant Name:	Ruediger Pfaff
Customer Number:	23911
Filer:	James Mckeown/Alison Field
Filer Authorized By:	James Mckeown
Attorney Docket Number:	095309.57635US
Receipt Date:	23-FEB-2009
Filing Date:	27-MAR-2007
Time Stamp:	14:58:09
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$1825
RAM confirmation Number	321
Deposit Account	051323
Authorized User	MC KEOWN,JAMES F.
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees) Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	10577797if.pdf	92859 dc03b911829f39141b2786abc23e696ac76de498	no	1

Warnings:

Information:

2	Fee Worksheet (PTO-06)	fee-info.pdf	33893 9f873dd0e4e17d8581675bf4c80edda5033b555d	no	2
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Warnings:

Information:

Total Files Size (in bytes):	126752
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This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

23911 7590 01/13/2009

CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC 20044-4300

EXAMINER

WOLFE JR, WILLIS RAY

ART UNIT

PAPER NUMBER

3747

DATE MAILED: 01/13/2009

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/577,797	03/27/2007	Ruediger Pfaff	095309.57635US	5226

TITLE OF INVENTION: DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1510	\$300	\$0	\$1810	04/13/2009

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

23911 7590 01/13/2009

**CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC 20044-4300**

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/577,797	03/27/2007	Ruediger Pfaff	095309.57635US	5226

TITLE OF INVENTION: DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1510	\$300	\$0	\$1810	04/13/2009

EXAMINER	ART UNIT	CLASS-SUBCLASS
WOLFE JR, WILLIS RAY	3747	123-276000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

- (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, 1 _____
- (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 _____
- 3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☐ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____

Date _____

Typed or printed name _____

Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/577,797	03/27/2007	Ruediger Pfaff	095309.57635US	5226
23911	7590	01/13/2009	EXAMINER	
CROWELL & MORING LLP INTELLECTUAL PROPERTY GROUP P.O. BOX 14300 WASHINGTON, DC 20044-4300			WOLFE JR, WILLIS RAY	
			ART UNIT	PAPER NUMBER
			3747	
DATE MAILED: 01/13/2009				

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 115 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 115 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

Notice of Allowability	Application No.	Applicant(s)	
	10/577,797	PFAFF ET AL.	
	Examiner	Art Unit	
	Willis R. Wolfe, Jr.	3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to amendment filed December 19, 2008.

2. ☒ The allowed claim(s) is/are 11-18 and 22-27.

3. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) ☒ All b) ☐ Some* c) ☐ None of the:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. _____.
3. ☒ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
(a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
(b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892) 2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948) 3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date <u>4/28/06</u> 4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material	5. ☐ Notice of Informal Patent Application 6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____. 7. ☐ Examiner's Amendment/Comment 8. ☐ Examiner's Statement of Reasons for Allowance 9. ☐ Other _____.
--	--

/ Willis R. Wolfe, Jr. / Primary Examiner Art Unit: 3747	
--	--

Index of Claims 	Application/Control No. 10577797	Applicant(s)/Patent Under Reexamination PFAFF ET AL.
	Examiner Willis R Wolfe, Jr.	Art Unit 3747

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant				☐ CPA		☐ T.D.		☐ R.1.47	
CLAIM		DATE							
Final	Original	09/15/2008	01/05/2009						
	1	-	-						
	2	-	-						
	3	-	-						
	4	-	-						
	5	-	-						
	6	-	-						
	7	-	-						
	8	-	-						
	9	-	-						
	10	-	-						
1	11	✓	=						
2	12	✓	=						
3	13	✓	=						
5	14	✓	=						
6	15	✓	=						
7	16	✓	=						
8	17	✓	=						
4	18	✓	=						
	19	✓	-						
	20	✓	-						
	21	✓	-						
9	22	✓	=						
10	23	✓	=						
11	24	✓	=						
12	25	✓	=						
13	26	✓	=						
14	27	✓	=						
	28	✓	-						
	29	✓	-						
	30	✓	-						



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BIB DATA SHEET

CONFIRMATION NO. 5226

SERIAL NUMBER 10/577,797	FILING or 371(c) DATE 03/27/2007 RULE	CLASS 123	GROUP ART UNIT 3747	ATTORNEY DOCKET NO. 095309.57635US	
APPLICANTS Ruediger Pfaff, Stuttgart, GERMANY; Martin Schnabel, Aalen, GERMANY; Joachim Suess, Ludwigsburg, GERMANY; ** CONTINUING DATA ***** YES /WRW/ This application is a 371 of PCT/EP04/11637 10/15/2004 ** FOREIGN APPLICATIONS ***** YES /WRW/ GERMANY 103 50 795.7 10/29/2003 ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 05/11/2007					
Foreign Priority claimed ☒ Yes ☐ No 35 USC 119(a-d) conditions met ☒ Yes ☐ No Verified and /WILLIS RAY WOLFE Acknowledged JR/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY GERMANY	SHEETS DRAWINGS 4	TOTAL CLAIMS 20	INDEPENDENT CLAIMS 1
ADDRESS CROWELL & MORING LLP INTELLECTUAL PROPERTY GROUP P.O. BOX 14300 WASHINGTON, DC 20044-4300 UNITED STATES					
TITLE Directly injecting internal combustion engine					
FILING FEE RECEIVED 1030	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

IAP17 Rec'd PCT/PTO 28 APR 2006

PTO/SB/08a (08-03)

Approved for use through 07/31/2006. OMB 0651-0031

U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(use as many sheets as necessary)</i>		Complete if Known	
		Application Number	Not Yet Assigned 10/577797
		Filing Date	Herewith
		First Named Inventor	Ruediger PFAFF
		Art Unit	Not Yet Assigned
Examiner Name	Not Yet Assigned		
Attorney Docket Number	095309.57635US		
Sheet	1	of	1

U.S. PATENT DOCUMENTS					
Examiner Initials ¹	Cite No. ¹	Document Number Number-Kind Code ² (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
/WRW/	A1	US - 2002/0117146 A1	08-29-2002	Gatellier et al.	
	A2	US-			
		US-			
		US-			
		US-			

FOREIGN PATENT DOCUMENTS						
Examiner Initials ¹	Cite No. ¹	Foreign Patent Document Country Code ³ -Number ⁴ -Kind Code ⁵ (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T ⁶
/WRW/	B1	EP 1 291 516 A2	03-12-2003	Shimazaki et al.		
/WRW/	B2	DE 1 219 283	06-16-1966	Boettger		
/WRW/	B3	DE 196 49 052 A1	05-28-1998	Velji et al.		

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials ¹	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ²
/WRW/	C1	International Search Report January 28, 2005.	

Examiner Signature	/Willis Wolfe, Jr/	Date Considered	01/08/2009
--------------------	--------------------	-----------------	------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. 3 Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). 4 For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. 5 Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. 6 Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L18	17	engine and cylinder with piston with recess with inject\$3 with surface	US-PGPUB	OR	ON	2009/01/05 09:08
L19	0	engine and cylinder with piston with recess with inject\$3 with surface with ascend\$3	US-PGPUB	OR	ON	2009/01/05 09:08
L20	8	engine and cylinder with piston with recess with inject\$3 with surface with (jet or nozzle)	US-PGPUB	OR	ON	2009/01/05 09:08
L21	4	engine and cylinder with piston with recess with inject\$3 with surface with (jet or nozzle) with cent\$4	US-PGPUB	OR	ON	2009/01/05 09:09
L22	56	(123/276). CCLS.	US-PGPUB	OR	OFF	2009/01/05 09:09
L23	1	engine and cylinder with piston with recess with inject\$3 with surface with (jet or nozzle) with cent\$4 with eleva\$4	US-PGPUB	OR	ON	2009/01/05 09:09

L24	2	engine and cylinder with piston with (bowl or recess) with inject\$3 with (ris\$3 or elevat \$3)	US-PGPUB	OR	ON	2009/01/05 09:10
L25	1	engine and cylinder with piston with ((bowl or recess) near3 edge) with inject\$3 with (ris\$3 or elevat \$3)	US-PGPUB	OR	ON	2009/01/05 09:10

1/5/09 9:13:24 AM

C:\Documents and Settings\wwolfe\My Documents\EAST\workspaces
\10577797 Piston with recess with elevated portion.wsp

Search Notes 	Application/Control No. 10577797	Applicant(s)/Patent Under Reexamination PFAFF ET AL.
	Examiner Willis R Wolfe, Jr.	Art Unit 3747

SEARCHED			
Class	Subclass	Date	Examiner
123	263, 276, 278, 298-300, 304, 305	9/15/2008	/WRW/
ABOVE	UPDATED	1/5/2009	/WRW/
123	266, 267, 275, 279	1/5/2009	/WRW/

SEARCH NOTES		
Search Notes	Date	Examiner
INVENTOR NAME/EAST WORD SEARCH - see printout	9/15/2008	/WRW/
INVENTOR NAME/EAST WORD SEARCH UPDATE - see printout	1/5/2009	/WRW/
Interference Search History Printout	1/5/2009	/WRW/

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
	SEARCHED ALL OF THE ABOVE	1/5/2009	/WRW/
	PGPUB TEXT SEARCH - see printout	1/5/2009	/WRW/

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EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	8	((RUEDIGER) near2 (PFAFF)).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2009/01/05 08:57
L2	32	((RUEDIGER) near2 (PFAFF)).INV.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 08:57
L3	13	((MARTIN) near2 (SCHNABEL)).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2009/01/05 08:57
L4	23	((MARTIN) near2 (SCHNABEL)).INV.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 08:57
L5	5	((JOACHIM) near2 (SUESS)).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2009/01/05 08:58
L6	28	((JOACHIM) near2 (SUESS)).INV.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 08:58
L7	148	engine and cylinder with piston with recess with inject\$3 with surface	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 08:59
L8	0	engine and cylinder with piston with recess with inject\$3 with surface with ascend\$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 08:59
L9	53	engine and cylinder with piston with recess with inject\$3 with surface with (jet or nozzle)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 09:00

L10	16	engine and cylinder with piston with recess with inject\$3 with surface with jet	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 09:01
L11	27	engine and cylinder with piston with recess with inject\$3 with surface with (jet or nozzle) with cent\$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 09:02
L12	1	engine and cylinder with piston with recess with inject\$3 with surface with (jet or nozzle) with cent\$4 with eleva\$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 09:03
L13	1	engine and cylinder with piston with recess with inject\$3 with surface with (jet or nozzle) with eleva\$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 09:03
L14	1	engine and cylinder with piston with recess with inject\$3 with surface with eleva\$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 09:04
L15	15	engine and cylinder with piston with (bowl or recess) with inject\$3 with (ris\$3 or elevat\$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 09:04
L16	673	(123/276).OCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2009/01/05 09:05
L17	2	engine and cylinder with piston with ((bowl or recess) near3 edge) with inject\$3 with (ris\$3 or elevat\$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/01/05 09:06

1/ 5/ 09 9:12:43 AM

C:\ Documents and Settings\ wwolfe\ My Documents\ EAST\ workspaces\ 10577797

Piston with recess with elevated portion.wsp

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No. : 10/577,797 Confirmation No. : 5226
First Named Inventor : Ruediger PFAFF
Filed : March 27, 2007
TC/A.U. : 3747
Examiner : WOLFE JR, WILLIS RAY

Docket No. : 095309.57635US
Customer No. : 23911

Title : Directly Injecting Internal Combustion Engine

AMENDMENT AND REPLY UNDER 37 CFR § 1.111

Mail Stop AMENDMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The following amendments and remarks are respectfully submitted in response to the Office Action dated September 19, 2008.

Amendments to the Claims are reflected in the listing of claims which begins on page 2 of this paper. *No additional claims fees are due.*

Remarks begin on page 5 of this paper.

Amendments to the Claims:

The listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claims 1-10 (canceled).

Claim 11 (Currently Amended): A directly injecting internal combustion engine, comprising at least one cylinder which has a combustion space in which a piston executes an oscillating movement, and an injection nozzle for injection of fuel into the combustion space, wherein the piston ~~has~~ has a piston recess, which, in a central region thereof, has an elevation extending in a cylinder head direction, and a surface of the piston recess adjoining the elevation in a recess edge direction is connected to the elevation via a radius so that an injection jet impinging ~~in this region~~ the surface and injected as early as possible is distributed both in a elevation direction and in the recess edge direction, and the surface is substantially planar and has an extent-ascending gradient in the recess edge direction such that an injection jet injected as late as possible impinges onto the surface, the last-mentioned injection jet being distributed both in the elevation direction and in the recess edge direction.

Claim 12 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 11, wherein a surface connected to the recess edge adjoins the surface of the piston recess.

Claim 13 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 12 ,wherein the surface connected to the recess edge is connected via a radius to the surface of the piston recess.

Claim 14 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 12, wherein the surface connected to the recess edge forms an acute angle with an upper surface of the piston.

Claim 15 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 14, wherein the surface connected to the recess edge is connected via a radius to the surface of the piston recess.

Claim 16 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 12, wherein the surface connected to the recess edge forms an obtuse angle with an upper surface of the piston.

Claim 17 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 16, wherein the surface connected to the recess edge is connected via a radius to the surface of the piston recess.

Claim 18 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 12, wherein the surface connected to the recess edge merges in a radius into an upper surface of the piston.

Claims 19-21 (Canceled)

Claim 22 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 11, wherein an injection angle of the injection nozzle is between 50° and 120°.

Claim 23 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 22, wherein a surface connected to the recess edge adjoins the surface of the piston recess.

Claim 24 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 23, wherein the surface connected to the recess edge is connected via a radius to the surface of the piston recess.

Claim 25 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 23, wherein the surface connected to the recess edge forms an acute angle with an upper surface of the piston.

Claim 26 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 23, wherein the surface connected to the recess edge forms an obtuse angle with an upper surface of the piston.

Claim 27 (Previously Presented): The directly injecting internal combustion engine as claimed in claim 23, wherein the surface connected to the recess edge merges in a radius into an upper surface of the piston.

Claims 28-30 (Canceled)

REMARKS

The rejections of Claims 11, 12, 16-24 and 26-30 as being anticipated by Nakakita et al under 35 U.S.C. §102(b), of Claims 11-15, 18-25 and 27-30 as being anticipated by Kataoka et al under 35 U.S.C. §102(e), and of Claims 11, 12, 16-24 and 26-30 as being anticipated by Quigley et al under 35 U.S.C. §102(e) are each respectfully traversed. Reconsideration is requested in view of the foregoing amendments and following comments.

The amendments to Claim 11 are based upon the features disclosed in paragraphs [0026] and [0028] of the Specification, two of which were found in now canceled Claims 19 and 20. The claimed geometry allows the directly injecting engine to operate with both a homogenous operator and a conventional combustion operation by ensuring that the injection jet impinges at the piston recess for optimal intermixing of fuel and air independently of the injection time point as described at paragraph [0009] of the Specification. The three cited references do not show or suggest the claimed geometry in amended Claim 11.

Nakakita et al's piston does not have a surface with an ascending gradient. The Kataoka et al piston does not have a substantially planar surface anywhere in the recess. The Quigley et al piston does not have the claimed surface adjoining the elevation in terms of an ascending gradient. Nothing in the teachings of the cited documents would have led to the present invention.

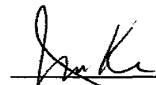
Accordingly, early and favorable action is earnestly solicited.

If there are any questions regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #095309.57635US).

Respectfully submitted,

December 19, 2008



James F. McKeown
Registration No. 25,406

CROWELL & MORING LLP
Intellectual Property Group
P.O. Box 14300
Washington, DC 20044-4300
Telephone No.: (202) 624-2500
Facsimile No.: (202) 628-8844
JFM/cee

Electronic Acknowledgement Receipt

EFS ID:	4490482
Application Number:	10577797
International Application Number:	
Confirmation Number:	5226
Title of Invention:	Directly injecting internal combustion engine
First Named Inventor/Applicant Name:	Ruediger Pfaff
Customer Number:	23911
Filer:	James Mckeown/Cindy Edwards
Filer Authorized By:	James Mckeown
Attorney Docket Number:	095309.57635US
Receipt Date:	19-DEC-2008
Filing Date:	27-MAR-2007
Time Stamp:	12:01:41
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		57635US-AMENDMENT.PDF	203576 2a91328a68cc14934ddb8794c24329ce9270b7f5	yes	6

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	4
	Applicant Arguments/Remarks Made in an Amendment	5	6
Warnings:			
Information:			
Total Files Size (in bytes):			203576
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 10/577,797		Filing Date 03/27/2007		☐ To be Mailed	
APPLICATION AS FILED – PART I										
(Column 1)		(Column 2)		SMALL ENTITY ☐ OR		OTHER THAN SMALL ENTITY				
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	OR	RATE (\$)	FEE (\$)			
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A				
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A				
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A				
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$ =		OR	X \$ =				
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$ =			X \$ =				
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL				
APPLICATION AS AMENDED – PART II										
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT	12/19/2008	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	* 14	Minus	** 20	= 0	X \$ =		OR	X \$52=	0
	Independent (37 CFR 1.16(h))	* 1	Minus	*** 3	= 0	X \$ =		OR	X \$220=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =		OR	X \$ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =		OR	X \$ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

Legal Instrument Examiner:
/BRENDA HARRISON/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/577,797	03/27/2007	Ruediger Pfaff	095309.57635US	5226

23911 7590 09/19/2008
CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC 20044-4300

EXAMINER

WOLFE JR, WILLIS RAY

ART UNIT	PAPER NUMBER
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3747

MAIL DATE	DELIVERY MODE
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09/19/2008

PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 10/577,797	Applicant(s) PFAFF ET AL.	
	Examiner Willis R. Wolfe, Jr.	Art Unit 3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 28 April 2006.
- 2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 11-30 is/are pending in the application.
- 4a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 5) ☐ Claim(s) _____ is/are allowed.
- 6) ☒ Claim(s) 11-30 is/are rejected.
- 7) ☐ Claim(s) _____ is/are objected to.
- 8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

- 12) ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☒ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☒ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).
- * See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

- | | |
|--|---|
| 1) ☒ Notice of References Cited (PTO-892) | 4) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. _____ |
| 2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) | 5) ☐ Notice of Informal Patent Application |
| 3) ☒ Information Disclosure Statement(s) (PTO/SB/08)
Paper No(s)/Mail Date <u>4/28/06</u> . | 6) ☐ Other: _____ |

DETAILED ACTION

Claim Rejections - 35 USC § 102

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

(e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent.

The changes made to 35 U.S.C. 102(e) by the American Inventors Protection Act of 1999 (AIPA) and the Intellectual Property and High Technology Technical Amendments Act of 2002 do not apply when the reference is a U.S. patent resulting directly or indirectly from an international application filed before November 29, 2000.

Therefore, the prior art date of the reference is determined under 35 U.S.C. 102(e) prior to the amendment by the AIPA (pre-AIPA 35 U.S.C. 102(e)).

Claims 11, 12, 16-24 and 26-30 are rejected under 35 U.S.C. 102(b) as being anticipated by Nakakita et al. Note Figures 1, 4 and 7 and column 9, line 28 through column 10, line 39.

Claims 11-15, 18-25 and 27-30 are rejected under 35 U.S.C. 102 (e) as being anticipated by Kataoka et al. Note Figure 3.

Claims 11, 12, 16-24 and 26-30 are rejected under 35 U.S.C. 102(e) as being anticipated by Quigley et al. Note Figures 2 and 4 and paragraphs 0016-0019.

Conclusion

The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. The references of Onc et al and Chmela et al are cited to show direct injection engines with pistons having recesses with raised portions.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Willis R. Wolfe, Jr. whose telephone number is (571)

272-4855. The examiner can normally be reached on Monday through Thursday (6:00 AM-4:30 PM).

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stephen K. Cronin can be reached on (571) 272-4536. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/ Willis R. Wolfe, Jr. /
Willis R. Wolfe, Jr.
Primary Examiner
Art Unit 3747

WRW
September 19, 2008

Notice of References Cited	Application/Control No. 10/577,797	Applicant(s)/Patent Under Reexamination PFAFF ET AL.	
	Examiner Willis R. Wolfe, Jr.	Art Unit 3747	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,161,518 A	12-2000	Nakakita et al.	123/298
*	B	US-2003/0217732 A1	11-2003	Kataoka et al.	123/276
*	C	US-2004/0123832 A1	07-2004	Quigley et al.	123/276
*	D	US-7,156,069 B2	01-2007	Ono et al.	123/276
*	E	US-7,415,963 B2	08-2008	Chmela et al.	123/299
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Receipt date: 04/28/2006

10577797 - GAU: 3747

IAP17 Rec'd PCT/PTO 28 APR 2006

PTO/SB/08a (08-03)

Approved for use through 07/31/2006. OMB 0651-0031

U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary)		Complete if Known	
		Application Number	Not Yet Assigned 10/577797
		Filing Date	Herewith
		First Named Inventor	Ruediger PFAFF
		Art Unit	Not Yet Assigned
		Examiner Name	Not Yet Assigned
		Attorney Docket Number	095309.57635US
Sheet	1	of	1

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Document Number Number-Kind Code ² (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
/WRW/	A1	US - 2002/0117146 A1	08-29-2002	Gatellier et al.	
	A2	US-			
		US-			
		US-			
		US-			

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	Cite No. ¹	Foreign Patent Document Country Code ³ -Number ⁴ -Kind Code ⁵ (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T ⁶
/WRW/	B1	EP 1 291 516 A2	03-12-2003	Shimazaki et al.		
/WRW/	B2	DE 1 219 283	06-16-1966	Boettger		
/WRW/	B3	DE 196 49 052 A1	05-28-1998	Velji et al.		

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ²
/WRW/	C1	International Search Report	

Examiner Signature	/Willis Wolfe, Jr/	Date Considered	09/10/2008
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. 3 Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). 4 For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. 5 Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. 6 Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	8	((RUEDIGER) near2 (PFAFF)).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2008/09/11 09:36
L2	32	((RUEDIGER) near2 (PFAFF)).INV.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2008/09/11 09:36
L3	13	((MARTIN) near2 (SCHNABEL)).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2008/09/11 09:36
L4	23	((MARTIN) near2 (SCHNABEL)).INV.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2008/09/11 09:36
L5	5	((JOACHIM) near2 (SUESS)).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2008/09/11 09:36
L6	28	((JOACHIM) near2 (SUESS)).INV.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2008/09/11 09:37
L7	4	engine and cylinder with piston with recess with inject\$3 with elevat\$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2008/09/11 09:37
L8	8	engine and cylinder with piston with (bowl or recess) with inject\$3 with (rise or elevat\$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2008/09/11 09:37
L9	672	(123/276).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/09/11 09:37

9/11/08 10:18:05 AM

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Piston with recess with elevated portion.wsp



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BIB DATA SHEET

CONFIRMATION NO. 5226

SERIAL NUMBER 10/577,797	FILING or 371(c) DATE 03/27/2007 RULE	CLASS 123	GROUP ART UNIT 3747	ATTORNEY DOCKET NO. 095309.57635US		
APPLICANTS Ruediger Pfaff, Stuttgart, GERMANY; Martin Schnabel, Aalen, GERMANY; Joachim Suess, Ludwigsburg, GERMANY; ** CONTINUING DATA ***** YES /WRW/ This application is a 371 of PCT/EP04/11637 10/15/2004 ** FOREIGN APPLICATIONS ***** TES /WRW/ GERMANY 103 50 795.7 10/29/2003 ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 05/11/2007						
Foreign Priority claimed ☒ Yes ☐ No 35 USC 119(a-d) conditions met ☒ Yes ☐ No Verified and /WILLIS RAY WOLFE JR/ Acknowledged Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY GERMANY	SHEETS DRAWINGS 4	TOTAL CLAIMS 20	INDEPENDENT CLAIMS 1
ADDRESS CROWELL & MORING LLP INTELLECTUAL PROPERTY GROUP P.O. BOX 14300 WASHINGTON, DC 20044-4300 UNITED STATES						
TITLE Directly injecting internal combustion engine						
FILING FEE RECEIVED 1030	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:			☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

Search Notes 	Application/Control No. 10577797	Applicant(s)/Patent Under Reexamination PFAFF ET AL.
	Examiner Willis R Wolfe, Jr.	Art Unit 3747

SEARCHED			
Class	Subclass	Date	Examiner
123	263, 276, 278, 298-300, 304, 305	9/15/2008	/WRW/

SEARCH NOTES		
Search Notes	Date	Examiner
INVENTOR NAME/EAST WORD SEARCH - see printout	9/15/2008	/WRW/

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

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Index of Claims 	Application/Control No. 10577797	Applicant(s)/Patent Under Reexamination PFAFF ET AL.
	Examiner Willis R Wolfe, Jr.	Art Unit 3747

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47										
CLAIM		DATE								
Final	Original	09/15/2008								
	1	-								
	2	-								
	3	-								
	4	-								
	5	-								
	6	-								
	7	-								
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	9	-								
	10	-								
	11	✓								
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	27	✓								
	28	✓								
	29	✓								
	30	✓								



UNITED STATES PATENT AND TRADEMARK OFFICE

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www.uspto.gov

APPLICATION NUMBER	FILING OR 371(c) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/577,797	03/27/2007	Ruediger Pfaff	095309.57635US

CONFIRMATION NO. 5226

23911
CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC20044-4300

Title: Directly injecting internal combustion engine

Publication No. US-2007-0193556-A1

Publication Date: 08/23/2007

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publicly available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently <http://www.uspto.gov/patft/>.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently <http://pair.uspto.gov/>. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Pre-Grant Publication Division, 703-605-4283



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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
10/577,797	03/27/2007	3747	1030	095309.57635US	20	1

CONFIRMATION NO. 5226

23911
CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC 20044-4300

FILING RECEIPT

Date Mailed: 05/15/2007

Receipt is acknowledged of this regular Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please mail to the Commissioner for Patents P.O. Box 1450 Alexandria Va 22313-1450. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections (if appropriate).**

Applicant(s)

Ruediger Pfaff, Stuttgart, GERMANY;
Martin Schnabel, Aalen, GERMANY;
Joachim Suess, Ludwigsburg, GERMANY;

Assignment For Published Patent Application

DAIMLERCHRYSLER AG, STUTTGART, GERMANY

Power of Attorney: The patent practitioners associated with Customer Number 23911

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/EP04/11637 10/15/2004

Foreign Applications

GERMANY 103 50 795.7 10/29/2003

If Required, Foreign Filing License Granted: 05/11/2007

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is
US10/577,797

Projected Publication Date: 08/23/2007

Non-Publication Request: No

Early Publication Request: No

Title

Directly injecting internal combustion engine

Preliminary Class

123

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

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The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

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NOT GRANTED

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U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
10/577,797	Ruediger Pfaff	095309.57635US

INTERNATIONAL APPLICATION NO.

PCT/EP04/11637

I.A. FILING DATE	PRIORITY DATE
------------------	---------------

10/15/2004

10/29/2003

23911
 CROWELL & MORING LLP
 INTELLECTUAL PROPERTY GROUP
 P.O. BOX 14300
 WASHINGTON, DC 20044-4300

CONFIRMATION NO. 5226

371 ACCEPTANCE LETTER



OC000000023839363

Date Mailed: 05/15/2007

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office in its capacity as a Designated / Elected Office (37 CFR 1.495), has determined that the above identified international application has met the requirements of 35 U.S.C. 371, and is ACCEPTED for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above and the relevant dates are:

<u>03/27/2007</u>	<u>03/27/2007</u>
DATE OF RECEIPT OF 35 U.S.C. 371(c)(1), (c)(2) and (c)(4) REQUIREMENTS	DATE OF COMPLETION OF ALL 35 U.S.C. 371 REQUIREMENTS

A Filing Receipt (PTO-103X) will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE " FILING DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 (c)(1), (c)(2) and (c)(4) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN ABOVE.** The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363). Once the Filing Receipt has been received, send all correspondence to the Group Art Unit designated thereon.

The following items have been received:

- Copy of the International Application filed on 04/28/2006
- English Translation of the IA filed on 04/28/2006
- Copy of the International Search Report filed on 04/28/2006
- Preliminary Amendments filed on 04/28/2006
- Information Disclosure Statements filed on 04/28/2006
- Oath or Declaration filed on 03/27/2007
- Request for Immediate Examination filed on 04/28/2006
- U.S. Basic National Fees filed on 04/28/2006
- Substitute Specification filed on 04/28/2006
- Priority Documents filed on 04/28/2006

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

TERRY M JOHNSON VESSELS
Telephone: (703) 308-9140 EXT 221

PART 3 - OFFICE COPY

FORM PCT/DO/EO/903 (371 Acceptance Notice)

IAP12 Rec'd PCT/PTO 27 MAR 2007

PTO-1390 (Rev. 07-2005)

Approved for use through 3/31/2007. OMB 0651-0021

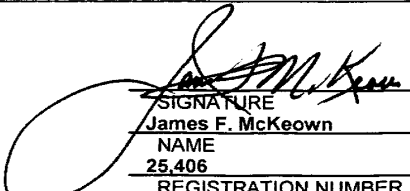
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NUMBER	
		095309.57635US	
		U.S. APPLICATION NO. (If known, see 37 CFR 1.5)	
		10/577,797	
INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED	
PCT/EP2004/011637	October 15, 2004	October 29, 2003	
TITLE OF INVENTION			
DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE			
APPLICANT(S) FOR DO/EO/US			
Ruediger PFAFF, et al.			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
1.	☐	This is a FIRST submission of items concerning a submission under 35 U.S.C. 371.	
2.	☒	This is a SECOND or SUBSEQUENT submission of items concerning a submission under 35 U.S.C. 371.	
3.	☒	This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.	
4.	☒	The US has been elected (Article 31).	
5.	☐	A copy of the International Application as filed (35 U.S.C. 371(c)(2))	
	a. ☐	is attached hereto (required only if not communicated by the International Bureau).	
	b. ☐	has been communicated by the International Bureau.	
	c. ☐	Is not required, as the application was filed in the United States Receiving Office (RO/US).	
6.	☐	An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).	
	a. ☐	is attached hereto.	
	b. ☐	has been previously submitted under 35 U.S.C. 154(d)(4).	
7.	☐	Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))	
	a. ☐	are attached hereto (required only if not communicated by the International Bureau).	
	b. ☐	have been communicated by the International Bureau.	
	c. ☐	have not been made; however, the time limit for making such amendments has NOT expired.	
	d. ☐	have not been made and will not be made.	
8.	☐	An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).	
9.	☒	An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (One (1) page).	
10.	☐	An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).	
Items 11 to 20 below concern document(s) or information included:			
11.	☐	An Information Disclosure Statement under 37 CFR 1.97 and 1.98.	
12.	☐	An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.	
13.	☐	A preliminary amendment.	
14.	☐	An Application Data Sheet under 37 CFR 1.76.	
15.	☐	A substitute specification.	
16.	☐	A power of attorney and/or change of address letter.	
17.	☐	A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 37 CFR 1.821- 1.825.	
18.	☐	A second copy of the published International Application under 35 U.S.C. 154(d)(4).	
19.	☐	A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).	
20.	☒	Other items or information: A copy of Notification of Missing Requirements dated March 6, 2007.	

This collection of information is required by 37 CFR 1.414 and 1.491-1.492. The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 15 minutes to complete, including gathering information, preparing, and submitting the completed form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 10/577,797		INTERNATIONAL APPLICATION NO. PCT/EP2004/011637		ATTORNEY'S DOCKET NUMBER 095309.57635US	
The following fees have been submitted				CALCULATIONS	
21. ☐ Basic national fee (37 C.F.R. §1.492(a))				\$	
22. ☐ Examination fee (37 C.F.R. §1.492(c))					
If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4)				\$	
All other situations				\$	
23. ☐ Search fee (37 C.F.R. §1.492(b))					
If the written opinion of the ISA/US or the International preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4)				\$	
Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority				\$100	
International Search Report prepared by an ISA other than the US and provided to the Office or previously communicated to the US by the IB				\$400	
All other situations				\$500	
TOTAL OF 21, 22 AND 23 =				\$	
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is \$250 for each additional 50 sheets of paper or fraction thereof.					
Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof (round up to a whole number)	RATE		
- 100	/ 50 =		x 250	\$	
Surcharge of \$130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(h)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	- 20		x 50	\$	
Independent claims	- 3		x 200	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+ 360	
TOTAL OF ABOVE CALCULATIONS =				\$	
☐ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.					
SUBTOTAL =				\$	
Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)).				+	
TOTAL NATIONAL FEE =				\$	
Fee for recording the enclosed assignment (37 CFR 1.21 (h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				+	
TOTAL FEES ENCLOSED =				\$	
				Amount to be refunded: \$	
				Amount to be charged: \$	
a. ☐ A check in the amount of \$ to cover the above fees is enclosed.					
b. ☐ Please charge my Deposit Account No. 05-1323 (Attorney Docket No. 095309.57635US) in the amount of \$ to cover the above fees. A duplicate copy of this sheet is enclosed.					
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 05-1323 (Attorney Docket No. 095309.57635US). A duplicate copy of this sheet is enclosed.					
d. ☐ Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.					
NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.					
SEND ALL CORRESPONDENCE TO: Crowell & Moring, LLP Intellectual Property Group P.O. Box 14300 Washington, D.C. 20044-4300 Tel. No. (202) 624-2500 Fax No. (202) 628-8844					
				SIGNATURE  James F. McKeown NAME 25,406 REGISTRATION NUMBER March 27, 2007 DATE	

JFM/mc

FORM PTO-1390 (REV. 02-2005)

Page 2 of 2



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U.S. APPLICATION NUMBER NO. 10/577,797	FIRST NAMED APPLICANT Ruediger Pfaff	ATTY. DOCKET NO. 095309.57635US
INTERNATIONAL APPLICATION NO. PCT/EP04/11637		
LA. FILING DATE 10/15/2004	PRIORITY DATE 10/29/2003	

23911
 CROWELL & MORING LLP
 INTELLECTUAL PROPERTY GROUP
 P.O. BOX 14300
 WASHINGTON, DC 20044-4300

CONFIRMATION NO. 5226

371 FORMALITIES LETTER



OC000000022750070

Date Mailed: 03/06/2007

NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

The following items have been submitted by the applicant or the IB to the United States Patent and Trademark Office as a Designated / Elected Office (37 CFR 1.495).

- Copy of the International Application filed on 04/28/2006
- English Translation of the IA filed on 04/28/2006
- Copy of the International Search Report filed on 04/28/2006
- Preliminary Amendments filed on 04/28/2006
- Information Disclosure Statements filed on 04/28/2006
- Request for Immediate Examination filed on 04/28/2006
- U.S. Basic National Fees filed on 04/28/2006
- Substitute Specification filed on 04/28/2006
- Priority Documents filed on 04/28/2006

Action MISS. REQ.
 Due Date 5-6-07
 Docket # 57635US
 Attorney JFM
 Docketing sp 2/9 Q

The following items **MUST** be furnished within the period set forth below in order to complete the requirements for acceptance under 35 U.S.C. 371:

- Oath or declaration of the inventors, in compliance with 37 CFR 1.497(a) and (b), identifying the application by the International application number and international filing date.

ALL OF THE ITEMS SET FORTH ABOVE MUST BE SUBMITTED WITHIN TWO (2) MONTHS FROM THE DATE OF THIS NOTICE OR BY 32 MONTHS FROM THE PRIORITY DATE FOR THE APPLICATION, WHICHEVER IS LATER. FAILURE TO PROPERLY RESPOND WILL RESULT IN ABANDONMENT.

The time period set above may be extended by filing a petition and fee for extension of time under the provisions of 37 CFR 1.136(a).

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

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If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

VIRGINIA L IRBY

Telephone: (703) 308-9140 EXT 229

PART 1 - ATTORNEY/APPLICANT COPY

U.S. APPLICATION NUMBER NO.	INTERNATIONAL APPLICATION NO.	ATTY. DOCKET NO.
10/577,797	PCT/EP04/11637	095309.57635US

FORM PCT/DO/EO/905 (371 Formalities Notice)

P 803662/US 11

DECLARATION AND POWER OF ATTORNEY

(For Use with Application Data Sheet)

Title Of Invention	Directly Injecting Internal Combustion Engine
--------------------	---

As the below named inventor(s), I/we declare that:

This declaration is directed to:

- ☐ The attached application, or
☒ PCT international application Number PCT/EP2004/011637, filed October 15, 2004
☐ Application No. _____, filed _____
as amended on _____ (if applicable);

I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought.

I/we have reviewed and understand the contents of the above-identified application, including the claims, as amended by any amendment specifically referred to above;

I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56, including material information which became available between the filing date of the prior application and the National or PCT International filing date of the continuation-in-part application, if applicable;

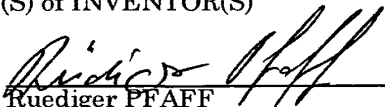
I/we hereby appoint the practitioners at **CROWELL & MORING L.L.P.**, whose Customer Number is:

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as my/our attorneys to prosecute the application identified above, and to transact all business in the United States Patent and Trademark Office connected therewith; and

All statements made herein of my/our own knowledge are true; all statements made herein on information and belief are believed to be true, and further these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and may jeopardize the validity of the application or any patent issuing thereon.

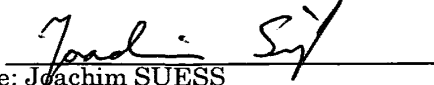
FULL NAME(S) of INVENTOR(S)

Signature: 
Inventor one: Ruediger PFAFF
Citizen of: German

Date: 28.06.06

Signature: 
Inventor two: Martin SCHNABEL
Citizen of: German

Date: 07.07.06

Signature: 
Inventor three: Joachim SUESS
Citizen of: German

Date: 3.7.06

Additional Inventors on Attached sheet if checked
DN#2755934_1

DO/ EO WORKSHEET

Virginia Irby, Patent Application Specialist/ National Stage Division

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INTERNATIONAL APPLICATION PAPERS IN THE APPLICATION FILE :

- ☒ International Application (RECORD COPY)
- ☐ Article 19 Amendments
- ☐ PCT/IPEA/409 IPER : ☐ EP ☐ JP ☐ SE ☐ AU
☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ _____
- ☐ Annexes to 409
- ☐ PCT/ISA/237 : ☐ EP ☐ JP ☐ SE ☐ AU
☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ _____
☐ PCT/IPEA/409 or PCT/ISA/237 was NOT AVAILABLE at the time of paralegal review

- ☐ PCT/IB/306
- ☐ Request form PCT/RO/101
- ☒ PCT/ISA/210 - Search Report : ☒ EP ☐ JP ☐ SE ☐ AU
☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ _____ ☐ NONE
- ☐ Search Report References
- ☒ Priority Document (s) No. 1
☐ N/A
☐ Priority Document was NOT AVAILABLE at the time of paralegal review
- ☐ Other : _____

RECEIPTS FROM THE APPLICANT (other than checked above) :

- ☒ Basic National Fee (or authorization to charge) 1
- ☒ Description 8 ☒ Claims 3 ☒ Abstract
- ☒ Drawing Figure(s) - (# of drwgs. 4)
- ☐ Translation of Article 19 Amendments
☐ entered ☐ not entered :
☐ not a page for page substitution
☐ replaced by Article 34 Amendment
- ☐ Annexes to 409
☐ entered ☐ not entered :
☐ not a page for page substitution
☐ no translation ☐ other : _____
- ☒ Application Data Sheet
- ☐ Power of Attorney
- ☐ Change of Address

- ☒ Preliminary Amendment(s) Filed on :
1. ☒ same as 371 request date 2. _____ 3. _____
- ☒ Information Disclosure Statement(s) Filed on :
1. ☒ same as 371 request date 2. _____ 3. _____
- ☐ Assignment Document (forwarded to Assignment Branch)
- ☐ Assignee Statement Under 37 CFR 3.73(b)
- ☐ Assignee PG Publication Notice
- ☒ Substitute Specification Filed on :
1. ☒ same as 371 request date 2. _____ 3. _____
- ☐ Verified Small Status Statement
- ☐ Oath/ Declaration (executed)
- ☐ Oath/ Declaration ☐ unsigned ☐ no citizenship ☐ other
- ☐ DNA Diskette ☐ Sequence Listing
- ☐ Other : _____

NOTES : ☐ I.A. used as Specification ☐ Other :

35 U.S.C. 371 - Receipt of Request (PTO-1390)

28 April 2006

Date Acceptable Oath/ Declaration Received

Date of Completion of requirements under 35 U.S.C. 371

Date of Completion of DO/ EO 903 - Notification of Acceptance

Date of Completion of DO/ EO 905 - Notification of Missing Requirements

05 March 2007

Date of Completion of DO/ EO 909 - Notification of Abandonment

Date of Completion of DO/ EO 916 - Notification of Defective Response

Date of Completion of DO/ EO 922 - Notification to Comply w/ Requirements for Patent Applications Containing Nucleotide and/or Amino Acid Sequence Disclosures

Date of Completion of DO/ EO 923



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U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
10/577,797	Ruediger Pfaff	095309.57635US

INTERNATIONAL APPLICATION NO.
PCT/EP04/11637

23911
 CROWELL & MORING LLP
 INTELLECTUAL PROPERTY GROUP
 P.O. BOX 14300
 WASHINGTON, DC 20044-4300

I.A. FILING DATE	PRIORITY DATE
10/15/2004	10/29/2003

CONFIRMATION NO. 5226

371 FORMALITIES LETTER



OC000000022750070

Date Mailed: 03/06/2007

NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

The following items have been submitted by the applicant or the IB to the United States Patent and Trademark Office as a Designated / Elected Office (37 CFR 1.495).

- Copy of the International Application filed on 04/28/2006
- English Translation of the IA filed on 04/28/2006
- Copy of the International Search Report filed on 04/28/2006
- Preliminary Amendments filed on 04/28/2006
- Information Disclosure Statements filed on 04/28/2006
- Request for Immediate Examination filed on 04/28/2006
- U.S. Basic National Fees filed on 04/28/2006
- Substitute Specification filed on 04/28/2006
- Priority Documents filed on 04/28/2006

The following items **MUST** be furnished within the period set forth below in order to complete the requirements for acceptance under 35 U.S.C. 371:

- Oath or declaration of the inventors, in compliance with 37 CFR 1.497(a) and (b), identifying the application by the International application number and international filing date.

ALL OF THE ITEMS SET FORTH ABOVE MUST BE SUBMITTED WITHIN TWO (2) MONTHS FROM THE DATE OF THIS NOTICE OR BY 32 MONTHS FROM THE PRIORITY DATE FOR THE APPLICATION, WHICHEVER IS LATER. FAILURE TO PROPERLY RESPOND WILL RESULT IN ABANDONMENT.

The time period set above may be extended by filing a petition and fee for extension of time under the provisions of 37 CFR 1.136(a).

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
<https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html>

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If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

VIRGINIA L IRBY

Telephone: (703) 308-9140 EXT 229

PART 2 - OFFICE COPY

U.S. APPLICATION NUMBER NO.	INTERNATIONAL APPLICATION NO.	ATTY. DOCKET NO.
10/577,797	PCT/EP04/11637	095309.57635US

FORM PCT/DO/EO/905 (371 Formalities Notice)

IAP6 Rec'd PCT/PTO 28 APR 2006

PTO-1390 (Rev. 07-2005)

Approved for use through 3/31/2007. OMB 0651-0021

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NUMBER 095309.57635US	
INTERNATIONAL APPLICATION NO. PCT/EP2004/011637	INTERNATIONAL FILING DATE October 15, 2004	U.S. APPLICATION NO. (if known, see 37 CFR 1.55) 10/577797	
		PRIORITY DATE CLAIMED October 29, 2003	
TITLE OF INVENTION DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE			
APPLICANT(S) FOR DO/EO/US Ruediger PFAFF, et al.			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
1. ☒ This is a FIRST submission of items concerning a submission under 35 U.S.C. 371. 2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a submission under 35 U.S.C. 371. 3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below. 4. ☐ The US has been elected (Article 31). 5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)) a. ☐ is attached hereto (required only if not communicated by the International Bureau). b. ☒ has been communicated by the International Bureau. c. ☐ Is not required, as the application was filed in the United States Receiving Office (RO/US). 6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)). a. ☒ is attached hereto. b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4). 7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) a. ☐ are attached hereto (required only if not communicated by the International Bureau). b. ☐ have been communicated by the International Bureau. c. ☐ have not been made; however, the time limit for making such amendments has NOT expired. d. ☐ have not been made and will not be made. 8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)). Items 11 to 20 below concern document(s) or information included: 11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98 (Int'l. Search Report; refs.) 12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. ☒ A preliminary amendment. 14. ☒ An Application Data Sheet under 37 CFR 1.76. 15. ☒ A substitute specification (clean/marked-up versions) 16. ☐ A power of attorney and/or change of address letter. 17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 37 CFR 1.821- 1.825. 18. ☐ A second copy of the published International Application under 35 U.S.C. 154(d)(4). 19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4). 20. ☒ Other items or information: PCT/IB/308; Credit Card Payment Form; four (4) sheets of drawings consisting of Figs. 1-10.			

This collection of information is required by 37 CFR 1.414 and 1.491-1.492. The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 15 minutes to complete, including gathering information, preparing, and submitting the completed form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Page 1 of 2

IAP17 Rec'd PCT/PTO 28 APR 2006

PTO-1390 (Rev. 02-2005)

Approved for use through 3/31/2007. OMB 0651-0021

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U.S. APPLICATION NO. (if known, see 37 CFR 1.53)		INTERNATIONAL APPLICATION NO.		ATTORNEY'S DOCKET NUMBER	
107577797		PCT/EP2004/011637		095309.57635US	
The following fees have been submitted				CALCULATIONS	
21. ☒ Basic national fee (37 C.F.R. §1.492(a))				\$ 300.00	
22. ☒ Examination fee (37 C.F.R. §1.492(c))					
If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4)				\$ 0.00	
All other situations				\$ 200.00	
23. ☒ Search fee (37 C.F.R. §1.492(b))					
If the written opinion of the ISA/US or the International preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4)				\$ 0	
Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority				\$ 100	
International Search Report prepared by an ISA other than the US and provided to the Office or previously communicated to the US by the IB				\$ 400	
All other situations				\$ 500	
TOTAL OF 21, 22 AND 23 =				\$ 900.00	
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is \$250 for each additional 50 sheets of paper or fraction thereof.					
Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof (round up to a whole number)	RATE		
- 100	/ 50 =		x 250	\$	
Surcharge of \$130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(h)).				\$ 130.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	18	0	x 50	\$ 0.00	
Independent claims	1	0	x 200	\$ 0.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ 360	\$ 0.00	
TOTAL OF ABOVE CALCULATIONS =				\$ 1030.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.					
SUBTOTAL =				\$ 1030.00	
Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)).				\$	
TOTAL NATIONAL FEE =				\$ 1030.00	
Fee for recording the enclosed assignment (37 CFR 1.21 (h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				\$	
TOTAL FEES ENCLOSED =				\$ 1030.00	
				Amount to be refunded:	\$
				Amount to be charged:	\$
a. ☐ A check in the amount of \$ to cover the above fees is enclosed.					
b. ☐ Please charge my Deposit Account No. 05-1323 (Attorney Docket No. 095309.57635US) in the amount of \$ to cover the above fees. A duplicate copy of this sheet is enclosed.					
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 05-1323 (Attorney Docket No. 095309.57635US). A duplicate copy of this sheet is enclosed.					
d. ☒ Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.					
NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.					
SEND ALL CORRESPONDENCE TO:					
Crowell & Moring, LLP					
Intellectual Property Group					
P.O. Box 14300					
Washington, D.C. 20044-4300					
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/xxx (doc no.)					
SIGNATURE					
James F. McKeown					
NAME					
25.406					
REGISTRATION NUMBER					
April 28, 2006					
DATE					

FORM PTO-1390 (REV. 02-2005)

Page 2 of 2

2760229

DaimlerChrysler AG

Directly injecting internal combustion engine

5

The invention relates to a directly injecting internal combustion engine with at least one cylinder which has a combustion space and in which a piston executes an oscillating movement, according to the type defined in more detail in the preamble of claim 1.

A generic internal combustion engine is known from US 2002/0117146 A1. In this case, the fuel is injected at a relatively steep injection angle into the combustion space, and the piston recess is adapted at least partially to the injection angle.

In an internal combustion engine described in DE 196 49 052 A1, a special shape of the piston recess is likewise provided, in order to achieve an additional reduction in the pollutants emitted by the internal combustion engine.

When early homogenization is to be achieved within the combustion space when an internal combustion engine, in particular a diesel internal combustion engine, is in operation, then injection time points of approximately 130 to 30° before the top dead center of the piston must be selected, since, at this time point, the combustion space pressure is still relatively low, so that the injected fuel can penetrate very deeply into the combustion space. In order to prevent the injection jet from impinging onto the cylinder wall or the liner, as steep an injection angle as possible at the injection nozzle should be selected, in order to ensure as long a free jet length as possible. This also requires the shape of the piston recess to be adapted to this injection, as is the case, for example, in

US 2002/0117146 A1.

Since, however, it is not possible to operate the internal combustion engine with a homogeneous
5 combustion process over its entire characteristic map, the piston recess must be designed both for homogeneous and for conventional mixture formation. This is not easily possible in known solutions.

10 The object of the present invention, therefore, is to provide a directly injecting internal combustion engine, in which the shape of the piston recess is designed such that the internal combustion engine can be operated by means of both a homogeneous and a
15 conventional combustion process.

This object is achieved, according to the invention, by means of the features mentioned in claim 1.

20 The solution according to the invention ensures that the injection jet always impinges on the piston recess such that the injected fuel can be intermixed optimally with the air located in the combustion space, specifically independently of the time point of
25 injection. Particularly the fact that an injection jet injected at the latest possible time point always impinges onto the surface adjoining the elevation ensures that the momentum of the impinging injection jet is not nullified, with the result that it could no
30 longer be used optimally for mixture formation, which, in turn, would entail an increased formation of black smoke.

An internal combustion engine is thus afforded which
35 can easily be operated by means of both a homogeneous and a conventional combustion process.

Advantageous refinements of the invention may be

gathered from the subclaims. An exemplary embodiment of the invention is illustrated below, in principle, by means of the drawing in which:

- 5 fig. 1 shows an internal combustion engine according to the invention with a piston oscillating in a combustion space of the latter and with an injection jet impinging on the piston recess of the piston;
- 10 fig. 2 shows the configuration of the piston recess of the piston from fig. 1 in a first region;
- 15 fig. 3 shows the configuration of the piston recess of the piston from fig. 1 in a second region;
- 20 fig. 4 shows the configuration of the piston recess of the piston from fig. 1 in a third region;
- 25 fig. 5 shows the deflection of the injected fuel jet into that region of the piston recess which is illustrated in fig. 4;
- 30 fig. 6 shows the configuration of the piston recess of the piston from fig. 1 in a fourth region;
- 35 fig. 7 shows the air capture in a sixth region of the piston recess;
- 30 fig. 8 shows a first embodiment of a fifth region of a piston from fig. 1;
- 35 fig. 9 shows a second embodiment of a fifth region of a piston from fig. 1; and
- 35 fig. 10 shows a third embodiment of a fifth region of a piston from fig. 1.

Fig. 1 shows an internal combustion engine 1 which has a crankcase 2 and a cylinder head 3. Within the crankcase 2 of the internal combustion engine 1 is located at least one cylinder 4 which has a combustion space 5 and in which a piston 6 executes an oscillating movement in a way known per se. In the cylinder head 3 is arranged an injection nozzle 7 having a plurality of injection orifices 8 from which an injection jet 9 emerges. In the present case, the opening angle α of the injection jet 9 is relatively steep and lies in a range of between 50° and 120° . Thus, fuel is thereby injected directly into the combustion space 5, so that this is a directly injecting internal combustion engine 1.

Fig. 1 depicts two different injection jets, to be precise an injection jet 9a, which is obtained when the piston 6 is at a top dead center, and an injection jet 9b, which is obtained in the case of fuel injection at the latest possible injection time point. The injection jets 9a and 9b are in each case illustrated merely as axes of an injection cone being distributed within the combustion space 5.

The piston 6 has a piston recess 10 in its side facing the cylinder head 3. In the following figures, the contour of the piston recess 10 and its adaptation to the injection jets 9 are explained in more detail, for the sake of clarity the individual figures in each case indicating only those reference symbols which are relevant for describing the respective figure. The piston recess 10 is identical in all the figures.

As can be seen in fig. 2, the piston recess 10 has in its central region an elevation 11 extending in the direction of the cylinder head 3. The elevation 11 in this case has an angle β with respect of the axis of the piston which is smaller than half the injection

angle α , so that the outermost edge of the injection jet 9a, illustrated here as a mid-axis, does not come into contact with the elevation 11.

5 As can be seen in fig. 2 and fig. 3, the elevation 11 has adjoining it in the direction of a recess edge 12, that is to say the end of the piston recess 10, a surface 13 which is connected to the elevation 11 via a radius 14 in such a way that the injection jet 9a
10 injected at the earliest possible time point impinges onto the surface 13 at an impingement point 15 and is distributed both in the direction of the elevation 11 and in the direction of the recess edge 12. This distribution of the injection jet 9a is important in
15 order to intermix the fuel as effectively as possible with the air located in the combustion space 5. Owing to the above-described steeper angle β of the elevation 11, as compared with the injection angle α , there is still sufficient free space in the region from the
20 impingement point 15 of the injection jet 9a on the surface 13 to the elevation 11 to ensure that the fuel quantity deflected in the direction of the elevation 11 can be effectively distributed. The fuel deflected in the direction of the elevation 11 is designated by the
25 arrow 16, whereas the fuel deflected in the direction of the recess edge 12 is designated by the arrow 17. It can be seen here that the fuel quantity deflected or distributed in the direction of the recess edge 12 is greater than the fuel quantity deflected in the
30 direction of the elevation 11. The radius 14 should be selected, in this respect, such that an accumulation of the fuel flowing back is avoided.

It can be seen in fig. 4 that the surface 13 adjoining
35 the elevation 11 in the direction of the recess edge 12 is of essentially planar design and has an ascending gradient in the direction of the recess edge 12. In other words, the surface 13 forms a plane which is at a

constant angle γ to the injection jet 9 over the entire maximum injection duration. The angle γ may be varied as a function of the required momentum deflection of an injection jet 9c in this case impinging in the middle region of the surface 13, the main momentum taking place in the direction of the recess edge 12, as already mentioned above. If appropriate, it may also be expedient for the surface 13 adjoining the elevation 11 in the direction of the recess edge 12 to have a curved design.

Fig. 5 illustrates by means of arrows 18 and 19 that, during the entire fuel injection, a smaller fraction of the injection jet 9 is thereby conducted in the direction of the elevation 11 and a larger fraction is thereby conducted in the direction of the recess edge 12. The arrow 18 in this case shows the fuel quantity conducted in the direction of the elevation 11, whereas the arrow 19 shows the fuel quantity conducted in the direction of the recess edge 12.

The distance of the surface 13 from the injection nozzle 7 should be selected such that the injection jet 9 can achieve a sufficiently free jet length and therefore an optimum jet velocity and the optimum momentum. Depending on the number of injection orifices 8 of the injection nozzle 7, an interaction of the fuel deflected on the piston recess 10 between two injection jets 9 is possible, thus additionally contributing to the capture of air in the combustion space 5. In addition, the division of the fuel may also be assisted by swirl.

Fig. 6 illustrates the injection jet 9b injected at the latest possible time point. In this case, it can be seen that the surface 13 has an extent in the direction of the recess edge 12 such that the injection jet 9b injected at the latest possible time point impinges

onto the surface 13. In this region, too, the surface 13 is designed in such a way that the injection jet 9b is distributed both in the direction of the elevation 11 and in the direction of the recess edge 12. The fuel quantity distributed in the direction of the elevation 11 is designated by an arrow 20 and the fuel quantity distributed in the direction of the recess edge 12 is designated by an arrow 21. Thus, a vertical impingement of the injection jet 9 on the piston recess 10 is prevented, and it is ensured that the momentum of the injection jet 9b is maintained.

It is apparent from fig. 7 that the surface 13 has adjoining it a surface 23 connected to the recess edge 12 via a radius 22. At the recess edge 12, a pinch gap region 24, as it may be referred to, at or above an upper surface 25 of the piston 6 occurs, which pinches the fuel/air mixture in the edge region in the direction of the piston recess 10 and thereby reduces the emission of hydrocarbons and carbon monoxide. The pinch gap region 24 selected should not be too large, since, even in this region, an air capture is required. The surface 23 contributes to the fact that the fuel jet following the arrow 21 is deflected such that an increased introduction of fuel into the pinch gap region 24 is prevented.

Figs 8, 9 and 10 illustrate various tie-ups of the surface 23 to the upper surface 25 of the piston 6.

In the embodiment according to fig. 8, the surface 23 connected to the recess edge 12 forms an acute angle with the upper surface 25 of the piston 6. The supply of fuel to a glow plug or spark plug, not illustrated, can thereby be improved.

In the version according to fig. 9, the surface 23 merges at a radius 26 into the upper surface 25 of the

P803662/WO/1

- 8 -

piston 6.

Fig. 10 illustrates a version in which the surface 23
connected to the recess edge 12 forms an obtuse angle
5 with the upper surface 25 of the piston 6.

DaimlerChrysler AG

Patent claims

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1. A directly injecting internal combustion engine, with at least one cylinder which has a combustion space and in which a piston executes an oscillating movement, and with an injection nozzle for the injection of fuel
10 into the combustion space, the piston having a piston recess which has in its central region an elevation extending in the direction of a cylinder head, characterized in that a surface (13) of the piston recess (10) which adjoins the elevation (11) in the
15 direction of the recess edge (12) is connected to the elevation (11) via a radius (14) in such a way that an injection jet (9a) impinging in this region and injected at the earliest possible time point is distributed both in the direction of the elevation (11)
20 and in the direction of the recess edge (12), and in that the surface (13) adjoining the elevation (11) in the direction of the recess edge (12) has an extent in the direction of the recess edge (12) such that an injection jet (9b) injected at the latest possible time
25 point impinges onto the surface (13), the injection jet (9b) injected at the latest possible time point being distributed both in the direction of the elevation (11) and in the direction of the recess edge (12).

30 2. The directly injecting internal combustion engine as claimed in claim 1, characterized in that a surface (23) connected to the recess edge (12) adjoins the surface (13) adjoining the elevation (11) in the direction of the recess edge (12).

35

3. The directly injecting internal combustion engine as claimed in claim 2, characterized in that the surface (23) connected to the recess edge (12) is

connected via a radius (22) to the surface (13) adjoining the elevation (11) in the direction of the recess edge (12).

5 4. The directly injecting internal combustion engine as claimed in claim 2 or 3, characterized in that the surface (23) connected to the recess edge (12) forms an acute angle with the upper surface (25) of the piston (6).

10

5. The directly injecting internal combustion engine as claimed in claim 2 or 3, characterized in that the surface (23) connected to the recess edge (12) forms an obtuse angle with the upper surface (25) of the piston (6).

15

6. The directly injecting internal combustion engine as claimed in one of claims 2 to 5, characterized in that the surface (23) connected to the recess edge (12) merges in a radius (26) into the upper surface (25) of the piston (6).

20

7. The directly injecting internal combustion engine as claimed in one of claims 1 to 6, characterized in that the surface (13) adjoining the elevation (11) in the direction of the recess edge (12) has an ascending gradient in the direction of the recess edge (12).

25

8. The directly injecting internal combustion engine as claimed in claim 7, characterized in that the surface (13) adjoining the elevation (11) in the direction of the recess edge (12) is of essentially planar design.

30

9. The directly injecting internal combustion engine as claimed in claim 7, characterized in that the surface (13) adjoining the elevation (11) in the direction of the recess edge (12) is of curved design.

35

10. The directly injecting internal combustion engine as claimed in one of claims 1 to 9, characterized in that the injection angle (α) of the injection nozzle
- 5 (7) is between 50° and 120°.

DaimlerChrysler AG

Abstract

A directly injecting internal combustion engine (1) has at least one cylinder (4) which has a combustion space (5) and in which a piston (6) executes an oscillating movement, and an injection nozzle (7) for the injection of fuel into the combustion space (5). A piston (6) has a piston recess (10) which has in its central region an elevation extending in the direction of a cylinder head (3). A surface (13) of the piston recess (10) which adjoins the elevation (11) in the direction of the recess edge (12) is connected to the elevation (11) via a radius (14) in such a way that an injection jet (9a) impinging in this region and injected at the earliest possible time point is distributed both in the direction of the elevation (11) and in the direction of the recess edge (12). The surface (13) adjoining the elevation (11) in the direction of the recess edge (12) has an extent in the direction of the recess edge (12) such that an injection jet (9b) injected at the latest possible time point impinges onto the surface (13). The injection jet (9b) injected at the latest possible time point is distributed both in the direction of the elevation (11) and in the direction of the recess edge (12).

(Fig. 1)

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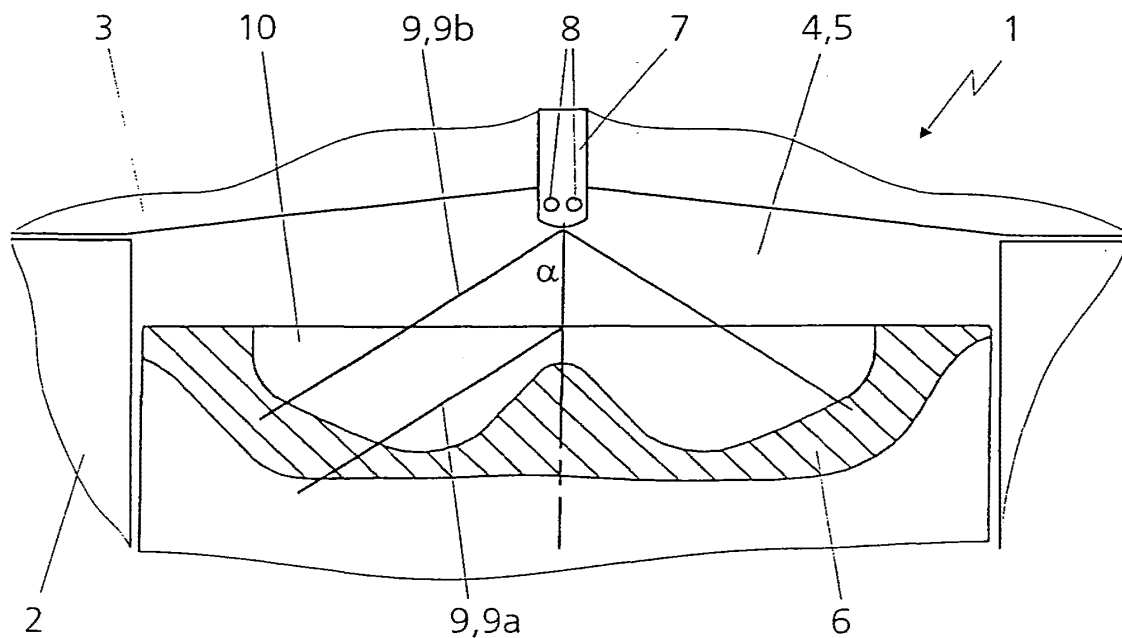


Fig. 1

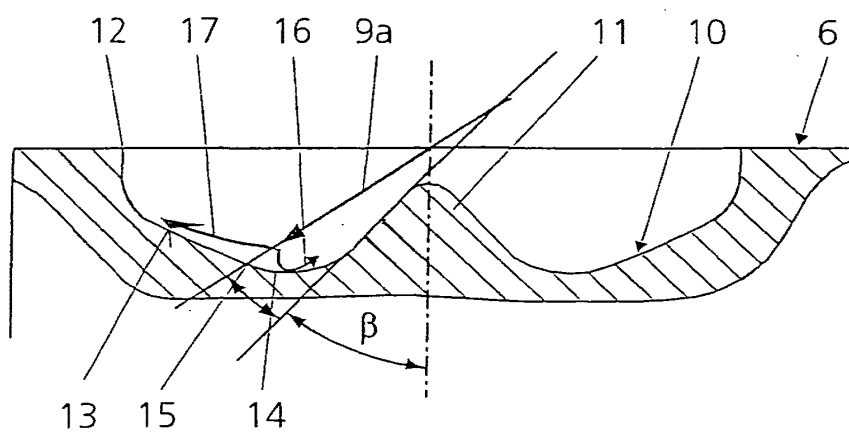
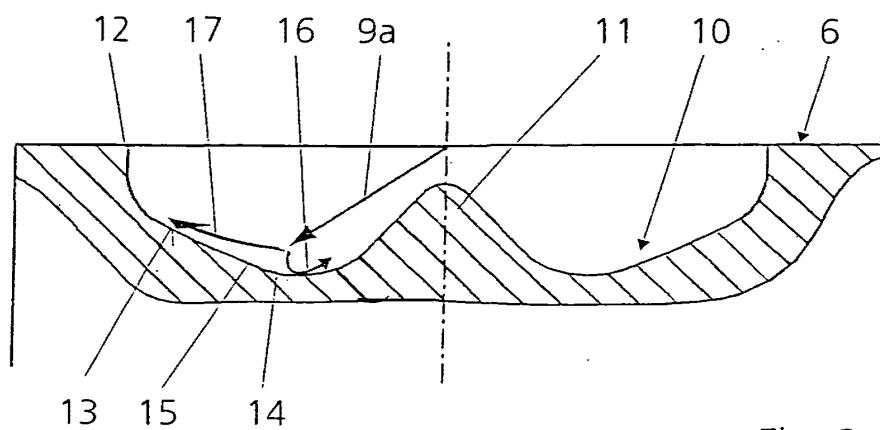
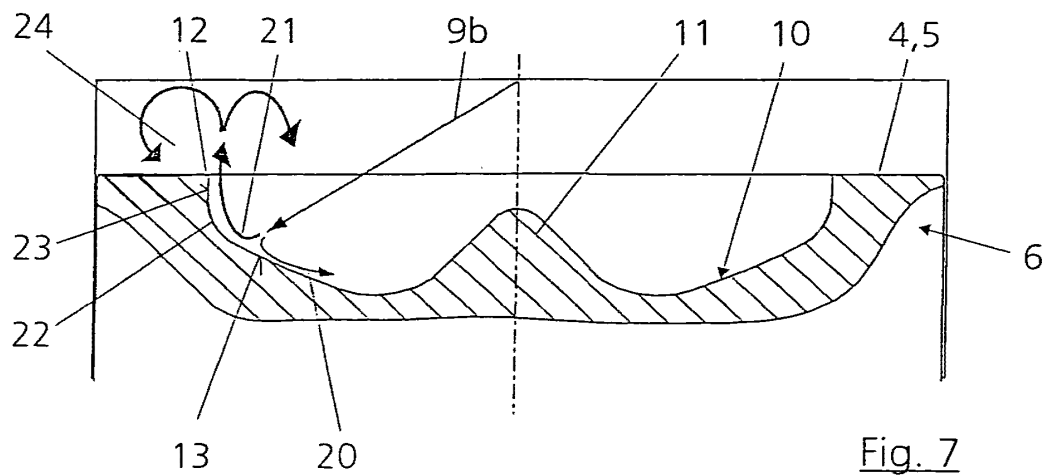
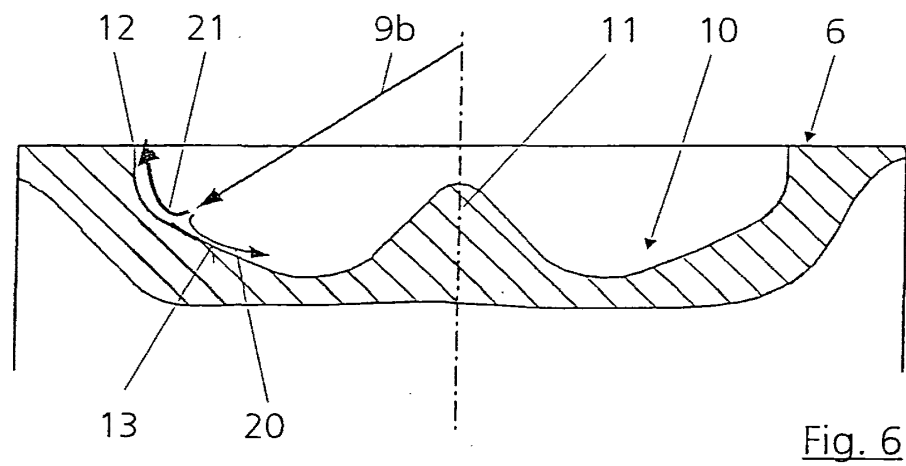
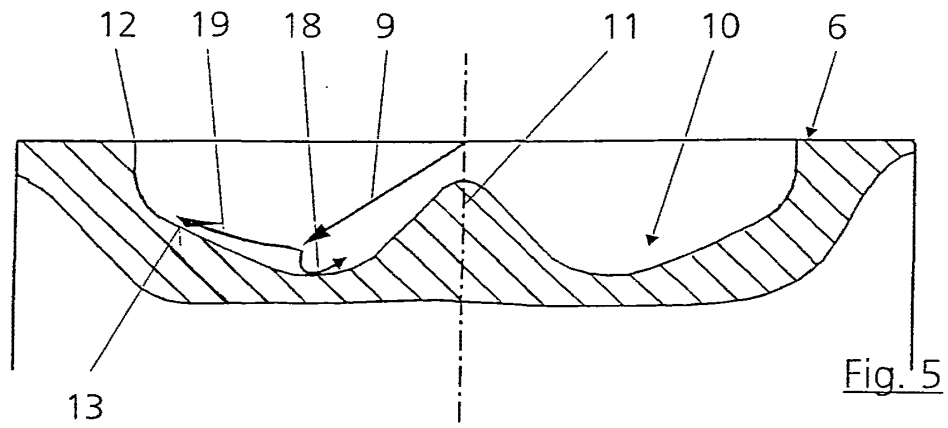
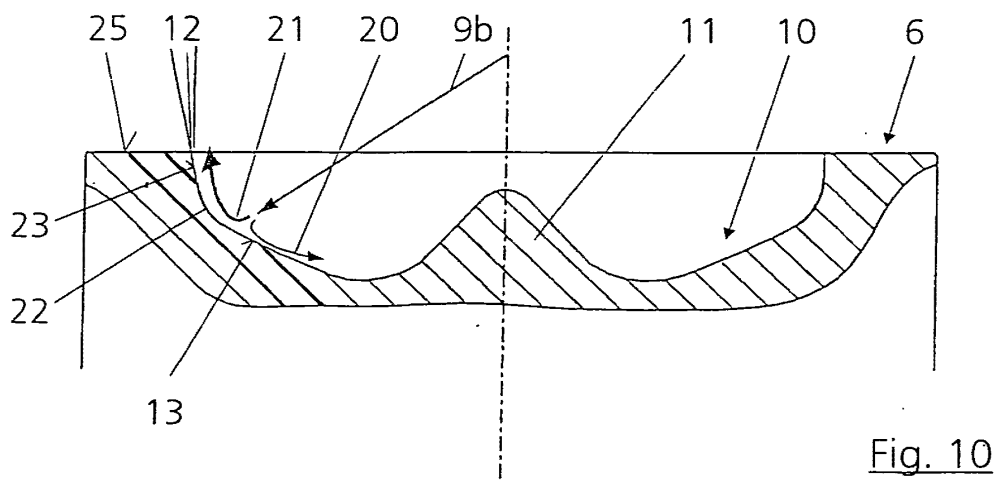
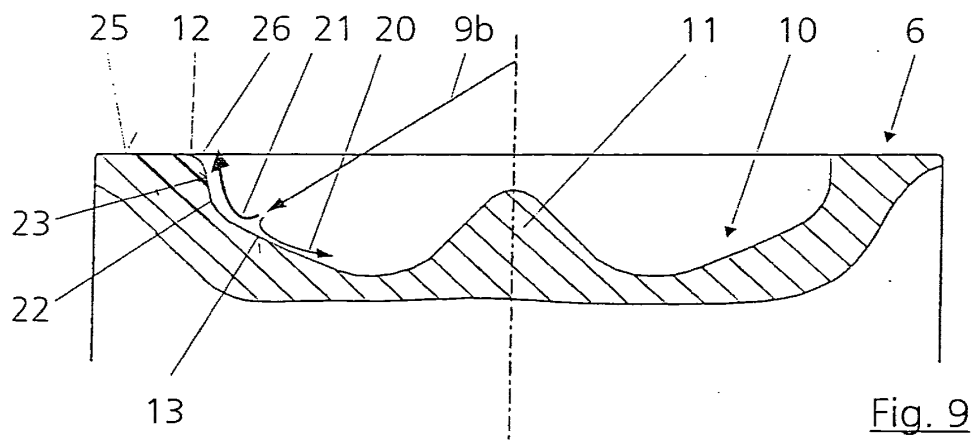
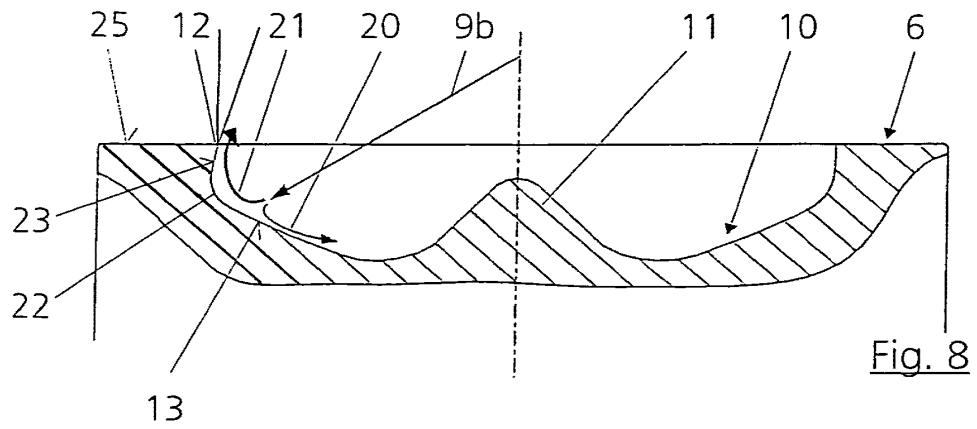


Fig. 2







PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

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01 FC:1631	300.00	OP
02 FC:1633	200.00	OP
03 FC:1642	400.00	OP
04 FC:1617	130.00	OP

PTO-1556
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No. : Not Yet Assigned
First Named Inventor : Ruediger PFAFF
Filed : Herewith (National Phase of PCT/EP2004/011637
TC/A.U. : Not Yet Assigned
Examiner : Not Yet Assigned

Docket No. : 095309.57635US
Customer No. : 23911

Title : Directly Injecting Internal Combustion Engine

PRELIMINARY AMENDMENT

Mail Stop PCT
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Please enter the following amendments to the specification, claims and abstract prior to the examination of the application.

Amendments to the Specification begin on page 2 of this paper. (*A Substitute Specification with marked up version is submitted concurrently herewith*).

Amendments to the Claims are reflected in the listing of claims which begins on page 3 of this paper.

Amendments to the Abstract are noted on page 7 and attached hereto as a separate unnumbered page.

Remarks begin on page 8 of this paper.

Amendments to the Specification:

Submitted concurrently herewith is a substitute specification and marked up version thereof. No new matter has been added.

10/577797

Preliminary Amendment

Atty. Dkt. No.: 095309.57635US

IAP17 Rec'd PCT/PTO 28 APR 2006

Amendments to the Claims:

The listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claims 1-10 (canceled).

Claim 11 (new): A directly injecting internal combustion engine, comprising at least one cylinder which has a combustion space in which a piston executes an oscillating movement, and an injection nozzle for injection of fuel into the combustion space, wherein the piston has a piston recess, which, in a central region thereof, has an elevation extending in a cylinder head direction, and a surface of the piston recess adjoining the elevation in a recess edge direction is connected to the elevation via a radius so that an injection jet impinging in this region and injected as early as possible is distributed both in a elevation direction and in the recess edge direction, and the surface has an extent in the recess edge direction such that an injection jet injected as late as possible impinges onto the surface, the last-mentioned injection jet being distributed both in the elevation direction and in the recess edge direction.

Claim 12 (new): The directly injecting internal combustion engine as claimed in claim 11, wherein a surface connected to the recess edge adjoins the surface of the piston recess.

Claim 13 (new): The directly injecting internal combustion engine as claimed in claim 12 ,wherein the surface connected to the recess edge is connected via a radius to the surface of the piston recess.

Claim 14 (new): The directly injecting internal combustion engine as claimed in claim 12, wherein the surface connected to the recess edge forms an acute angle with an upper surface of the piston.

Claim 15 (new): The directly injecting internal combustion engine as claimed in claim 14, wherein the surface connected to the recess edge is connected via a radius to the surface of the piston recess.

Claim 16 (new): The directly injecting internal combustion engine as claimed in claim 12, wherein the surface connected to the recess edge forms an obtuse angle with an upper surface of the piston.

Claim 17 (new): The directly injecting internal combustion engine as claimed in claim 16, wherein the surface connected to the recess edge is connected via a radius to the surface of the piston recess.

Claim 18 (new): The directly injecting internal combustion engine as claimed in claim 12, wherein the surface connected to the recess edge merges in a radius into an upper surface of the piston.

Claim 19 (new): The directly injecting internal combustion engine as claimed in claim 11, wherein the surface of the piston recess has an ascending gradient in the recess edge direction.

Claim 20 (new): The directly injecting internal combustion engine as claimed in claim 19, wherein the surface of the piston recess in the recess edge direction is substantially planar.

Claim 21 (new): The directly injecting internal combustion engine as claimed in claim 19, wherein the surface of the piston recess in the recess edge direction is curved.

Claim 22 (new): The directly injecting internal combustion engine as claimed in claim 11, wherein an injection angle of the injection nozzle is between 50° and 120°.

Claim 23 (new): The directly injecting internal combustion engine as claimed in claim 22, wherein a surface connected to the recess edge adjoins the surface of the piston recess.

Claim 24 (new): The directly injecting internal combustion engine as claimed in claim 23, wherein the surface connected to the recess edge is connected via a radius to the surface of the piston recess.

Claim 25 (new): The directly injecting internal combustion engine as claimed in claim 23, wherein the surface connected to the recess edge forms an acute angle with an upper surface of the piston.

Claim 26 (new): The directly injecting internal combustion engine as claimed in claim 23, wherein the surface connected to the recess edge forms an obtuse angle with an upper surface of the piston.

Claim 27 (new): The directly injecting internal combustion engine as claimed in claim 23, wherein the surface connected to the recess edge merges in a radius into an upper surface of the piston.

Claim 28 (new): The directly injecting internal combustion engine as claimed in claim 22, wherein the surface of the piston recess has an ascending gradient in the recess edge direction.

Claim 29 (new): The directly injecting internal combustion engine as claimed in claim 28, wherein the surface of the piston recess in the recess edge direction is substantially planar.

Claim 30 (new): The directly injecting internal combustion engine as claimed in claim 28, wherein an injection angle of the injection nozzle is between 50° and 120°.

Amendments to the Abstract:

Please substitute the new Abstract of the Disclosure submitted herewith on a separate page for the original Abstract presently in the application.

REMARKS

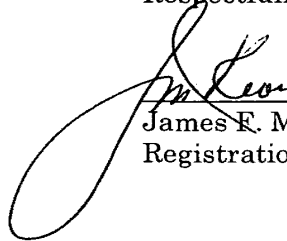
Entry of the amendments to the specification, claims and abstract before examination of the application is respectfully requested. These claims have been amended to remove multiple dependencies.

If there are any questions regarding this Preliminary Amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket # 095309.57635US).

Respectfully submitted,

April 28, 2006



James E. McKeown
Registration No. 25,406

CROWELL & MORING LLP
Intellectual Property Group
P.O. Box 14300
Washington, DC 20044-4300
Telephone No.: (202) 624-2500
Facsimile No.: (202) 628-8844
JFM:aw

2760230

ABSTRACT OF THE DISCLOSURE

A directly injecting internal combustion engine has at least one cylinder which has a combustion space and in which a piston executes an oscillating movement, and an injection nozzle for the injection of fuel into the combustion space. The piston has a piston recess which has in its central region an elevation extending in the direction of a cylinder head. A surface of the piston recess which adjoins the elevation in the direction of the recess edge is connected to the elevation via a radius so an injection jet impinging in this region and injected at the earliest possible time point is distributed both in the elevation direction and in the recess edge direction. The surface adjoining the elevation in that direction has an extent in that direction such that an injection jet injected at the latest possible time point impinges onto the surface and is distributed both in the elevation direction and in the recess edge direction.

DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE

BACKGROUND AND SUMMARY OF THE INVENTION

[0001] This application is a National Phase of PCT/EP2004/011637, filed October 15, 2004, and claims the priority of German patent document DE 103 50 795.7, filed October 29, 2003, the disclosure of which is expressly incorporated by reference herein.

[0002] The present invention relates to a directly injecting internal combustion engine with at least one cylinder which has a combustion space and in which a piston executes an oscillating movement.

[0003] A known internal combustion engine is described in U.S. patent publication No. 2002/0117146 A1. In this case, the fuel is injected at a relatively steep injection angle into the combustion space, and the piston recess is adapted at least partially to the injection angle.

[0004] In an internal combustion engine described in DE 196 49 052 A1, a special shape of the piston recess is likewise provided, in order to achieve an additional reduction in the pollutants emitted by the internal combustion engine.

[0005] When early homogenization is to be achieved within the combustion space of an operating internal combustion engine, in

particular a diesel internal combustion engine, then injection time points of approximately 130 to 30° before the top dead center of the piston must be selected, since, at this time point, the combustion space pressure is still relatively low, so that the injected fuel can penetrate very deeply into the combustion space. In order to prevent the injection jet from impinging onto the cylinder wall or the liner, as steep an injection angle as possible at the injection nozzle should be selected, in order to ensure as long a free jet length as possible. This also requires the shape of the piston recess to be adapted to this injection, as is the case, for example, in US 2002/0117146 A1.

[0006] Since, however, it is not possible to operate the internal combustion engine with a homogeneous combustion process over its entire characteristic map, the piston recess must be designed both for homogeneous and for conventional mixture formation. This is not easily possible in known solutions.

[0007] An object of the present invention, therefore, is to provide a directly injecting internal combustion engine, in which the shape of the piston recess is configured such that the internal combustion engine can be operated by both a homogeneous and a conventional combustion process.

[0008] This object has been achieved, according to the invention providing that a surface of the piston recess which adjoins the elevation in the direction of the recess edge is connected to the elevation vi a radius in such a way that an injection jet impinging in this region and injected at the earliest possible time point is distributed both in the direction of the elevation and in the direction of the recess edge, and in that the surface adjoining the elevation in the direction of the recess edge has an extent in the direction of the recess edge such that an injection jet injected at the latest possible time point impinges onto the surface, the injection jet injected at the latest possible time point being distributed both in the direction of the elevation and in the direction of the recess edge.

[0009] The solution according to the invention ensures that the injection jet always impinges on the piston recess such that the injected fuel can be intermixed optimally with the air located in the combustion space, specifically independently of the time point of injection. Particularly the fact that an injection jet injected at the latest possible time point always impinges onto the surface adjoining the elevation ensures that the momentum of the impinging injection jet is not nullified, i.e., with the result from nullification that it could no longer be used optimally for mixture formation, which, in turn, would entail an increased formation of black smoke.

[0010] An internal combustion engine is thus afforded which can easily be operated by both a homogeneous and a conventional combustion process.

[0011] Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Fig. 1 is a partial, cross-sectional view of an internal combustion engine according to the invention with a piston oscillating in a combustion space of the latter and with an injection jet impinging on the piston recess of the piston;

[0013] Fig. 2 is a cross-sectional view of the configuration of the piston recess of the piston shown in Fig. 1 in a first region;

[0014] Fig. 3 is a cross-sectional view of the configuration of the piston recess of the piston shown in Fig. 1 in a second region;

[0015] Fig. 4 is a cross-sectional view of the configuration of the piston recess of the piston shown in Fig. 1 in a third region;

[0016] Fig. 5 is a cross-sectional view showing the deflection of the injected fuel jet into that region of the piston recess which is illustrated in Fig. 4;

[0017] Fig. 6 is a cross-sectional view of the configuration of the piston recess of the piston shown in Fig. 1 in a fourth region;

[0018] Fig. 7 is a cross-sectional view showing the air capture in a sixth region of the piston recess;

[0019] Fig. 8 is a cross-sectional view of a first embodiment of a fifth region of a piston shown in Fig. 1;

[0020] Fig. 9 is a cross-sectional view of a second embodiment of a fifth region of the piston shown in Fig. 1; and

[0021] Fig. 10 is a cross-sectional view of a third embodiment of a fifth region of a piston shown in Fig. 1.

DETAILED DESCRIPTION OF THE DRAWINGS

[0022] Fig. 1 shows an internal combustion engine 1 which has a crankcase 2 and a cylinder head 3. Within the crankcase 2 of the internal combustion engine 1 is located at least one cylinder 4 which has a combustion space 5 and in which a piston 6 executes an oscillating movement in a way known per se. Arranged in the cylinder

head 3 is an injection nozzle 7 having a plurality of injection orifices 8 from which an injection jet 9 emerges. In the present embodiment, the opening angle α of the injection jet 9 is relatively steep and lies in a range of between 50° and 120° . Thus, fuel is thereby injected directly into the combustion space 5, so that this is a directly injecting internal combustion engine 1.

[0023] Fig. 1 depicts two different injection jets, to be precise an injection jet 9a, which is obtained when the piston 6 is at a top dead center, and an injection jet 9b, which is obtained in the case of fuel injection at the latest possible injection time point. The injection jets 9a and 9b are in each case illustrated merely as axes of an injection cone being distributed within the combustion space 5.

[0024] The piston 6 has a piston recess 10 in its side facing the cylinder head 3. In the following, the contour of the piston recess 10 and its adaptation to the injection jets 9 are explained in more detail, and, for the sake of clarity, the individual figures in each case indicate only those reference symbols which are relevant for describing the respective figure. The piston recess 10 is identical in all the drawing figures.

[0025] As can be seen in Fig. 2, the piston recess 10 has in its central region an elevation 11 extending in the direction of the cylinder head 3. The elevation 11 in this case has an angle β with respect of the pistons axis which is smaller than half the injection angle α , so that the

outermost edge of the injection jet 9a, illustrated here as a mid-axis, does not come into contact with the elevation 11.

[0026] As can be seen in Fig. 2 and Fig. 3, the elevation 11 has adjoining it in the direction of a recess edge 12, that is to say the end of the piston recess 10, a surface 13 which is connected to the elevation 11 via a radius 14 so that the injection jet 9a injected at the earliest possible time point impinges onto the surface 13 at an impingement point 15 and is distributed both in the direction of the elevation 11 and in the direction of the recess edge 12. This distribution of the injection jet 9a is important in order to intermix the fuel as effectively as possible with the air located in the combustion space 5.

[0027] Owing to the above-described steeper angle β of the elevation 11, as compared with the injection angle α , there is still sufficient free space in the region from the impingement point 15 of the injection jet 9a on the surface 13 to the elevation 11 to ensure that the fuel quantity deflected in the direction of the elevation 11 can be effectively distributed. The fuel deflected in the direction of the elevation 11 is designated by the arrow 16, whereas the fuel deflected in the direction of the recess edge 12 is designated by the arrow 17. It can be seen here, by the length of the arrows, that the fuel quantity deflected or distributed in the direction of the recess edge 12 is greater than the fuel quantity deflected in the direction of the elevation 11. The radius 14

should be selected, in this respect, such that an accumulation of the fuel flowing back is avoided.

[0028] Fig. 4 shows that the surface 13 adjoining the elevation 11 in the direction of the recess edge 12 is of essentially planar design and has an ascending gradient in the direction of the recess edge 12. In other words, the surface 13 forms a plane which is at a constant angle γ to the injection jet 9 over the entire maximum injection duration. The angle γ may be varied as a function of the required momentum deflection of an injection jet 9c in this case impinging in the middle region of the surface 13, with the main momentum taking place in the direction of the recess edge 12, as mentioned above. If appropriate, the surface 13 adjoining the elevation 11 in the direction of the recess edge 12 may have a curved configuration.

[0029] Fig. 5 illustrates with the length of arrows 18 and 19 that, during the entire fuel injection, a smaller fraction of the injection jet 9 is thereby conducted in the direction of the elevation 11 and a larger fraction is thereby conducted in the direction of the recess edge 12. The arrow 18 in this case shows the fuel quantity conducted in the direction of the elevation 11, whereas the arrow 19 shows the fuel quantity conducted in the direction of the recess edge 12.

[0030] The distance of the surface 13 from the injection nozzle 7 should be selected such that the injection jet 9 can achieve a sufficiently

free jet length and therefore an optimum jet velocity and the optimum momentum. Depending on the number of injection orifices 8 of the injection nozzle 7, an interaction of the fuel deflected on the piston recess 10 between two injection jets 9 is possible, thus additionally contributing to the capture of air in the combustion space 5. In addition, the division of the fuel may also be assisted by swirl.

[0031] Fig. 6 illustrates the injection jet 9b injected at the latest possible time point. In this case, the surface 13 has an extent in the direction of the recess edge 12 such that the injection jet 9b injected at the latest possible time point impinges onto the surface 13. In this region, too, the surface 13 is configured in such a way that the injection jet 9b is distributed both in the direction of the elevation 11 and in the direction of the recess edge 12. The fuel quantity distributed in the direction of the elevation 11 is designated by an arrow 20 and the fuel quantity distributed in the direction of the recess edge 12 is designated by an arrow 21. Thus, a vertical impingement of the injection jet 9 on the piston recess 10 is prevented, and it is ensured that the momentum of the injection jet 9b is maintained.

[0032] It is apparent from Fig. 7 that the surface 13 has adjoining it a surface 23 connected to the recess edge 12 via a radius 22. At the recess edge 12, a pinch gap region 24, as it may be referred to, at or above an upper surface 25 of the piston 6 occurs, which pinches the

fuel/air mixture in the edge region in the direction of the piston recess 10 and thereby reduces the emission of hydrocarbons and carbon monoxide. The pinch gap region 24 selected should not be too large, since, even in this region, an air capture is required. The surface 23 contributes to the fact that the fuel jet following the arrow 21 is deflected such that an increased introduction of fuel into the pinch gap region 24 is prevented.

[0033] Figs 8, 9 and 10 illustrate various tie-ups of the surface 23 to the upper surface 25 of the piston 6.

[0034] In the embodiment according to Fig. 8, the surface 23 connected to the recess edge 12 forms an acute angle with the upper surface 25 of the piston 6. The supply of fuel to a glow plug or spark plug, not illustrated, can thereby be improved.

[0035] In the embodiment according to Fig. 9, the surface 23 merges at a radius 26 into the upper surface 25 of the piston 6.

[0036] Fig. 10 illustrates an embodiment in which the surface 23 connected to the recess edge 12 forms an obtuse angle with the upper surface 25 of the piston 6.

[0037] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and

substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.

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Marked-Up Version
IAP17 Rec'd PCT/PTO 28 APR 2006

~~DaimlerChrysler AG~~

Directly injecting internal combustion engine

5 DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE

BACKGROUND AND SUMMARY OF THE INVENTION

This application is a National Phase of
PCT/EP2004/011637, filed October 15, 2004, and claims
10 the priority of German patent document DE 103 50 795.7,
filed October 29, 2003, the disclosure of which is
expressly incorporated by reference herein.

The present invention relates to a directly injecting
internal combustion engine with at least one cylinder
15 which has a combustion space and in which a piston
executes an oscillating movement, ~~according to the type~~
~~defined in more detail in the preamble of claim 1.~~

A generic known internal combustion engine is ~~known~~
~~from~~ US described in U.S. patent publication No.
20 2002/0117146 A1. In this case, the fuel is injected at
a relatively steep injection angle into the combustion
space, and the piston recess is adapted at least
partially to the injection angle.

In an internal combustion engine described in
25 DE 196 49 052 A1, a special shape of the piston recess
is likewise provided, in order to achieve an additional
reduction in the pollutants emitted by the internal
combustion engine.

When early homogenization is to be achieved within the combustion space ~~[[when]]~~ of an operating internal combustion engine, in particular a diesel internal combustion engine, ~~is in operation~~, then injection time
5 points of approximately 130 to 30° before the top dead center of the piston must be selected, since, at this time point, the combustion space pressure is still relatively low, so that the injected fuel can penetrate very deeply into the combustion space. In order to
10 prevent the injection jet from impinging onto the cylinder wall or the liner, as steep an injection angle as possible at the injection nozzle should be selected, in order to ensure as long a free jet length as possible. This also requires the shape of the piston
15 recess to be adapted to this injection, as is the case, for example, in US 2002/0117146 A1.

Since, however, it is not possible to operate the internal combustion engine with a homogeneous combustion process over its entire characteristic map,
20 the piston recess must be designed both for homogeneous and for conventional mixture formation. This is not easily possible in known solutions.

~~[[The]]~~ An object of the present invention, therefore, is to provide a directly injecting internal combustion
25 engine, in which the shape of the piston recess is ~~designed~~ configured such that the internal combustion engine can be operated by ~~means of~~ both a homogeneous and a conventional combustion process.

This object ~~[[is]]~~ has been achieved, according to the
30 invention, ~~by means of the features mentioned in claim 1~~ providing that a surface of the piston recess

which adjoins the elevation in the direction of the recess edge is connected to the elevation vi a radius in such a way that an injection jet impinging in this region and injected at the earliest possible time point
5 is distributed both in the direction of the elevation and in the direction of the recess edge, and in that the surface adjoining the elevation in the direction of the recess edge has an extent in the direction of the recess edge such that an injection jet injected at the
10 latest possible time point impinges onto the surface, the injection jet injected at the latest possible time point being distributed both in the direction of the elevation and in the direction of the recess edge.

The solution according to the invention ensures that
15 the injection jet always impinges on the piston recess such that the injected fuel can be intermixed optimally with the air located in the combustion space, specifically independently of the time point of injection. Particularly the fact that an injection jet
20 injected at the latest possible time point always impinges onto the surface adjoining the elevation ensures that the momentum of the impinging injection jet is not nullified, i.e., with the result from nullification that it could no longer be used optimally
25 for mixture formation, which, in turn, would entail an increased formation of black smoke.

An internal combustion engine is thus afforded which can easily be operated by ~~means of~~ both a homogeneous and a conventional combustion process.

30 ~~Advantageous refinements of the invention may be gathered from the subclaims. An exemplary embodiment of~~

~~the invention is illustrated below, in principle, by means of the drawing in which.~~

Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

10 [[fig.]] Fig. 1 [[shows]] is a partial, cross-sectional view of an internal combustion engine according to the invention with a piston oscillating in a combustion space of the latter and with an injection jet impinging on the piston recess of the piston;

15 [[fig.]] Fig. 2 [[shows]] is a cross-sectional view of the configuration of the piston recess of the piston ~~from fig. shown in Fig. 1~~ in a first region;

[[fig.]] Fig. 3 [[shows]] is a cross-sectional view of the configuration of the piston recess of the piston ~~from fig. shown in Fig. 1~~ in a second region;

[[fig.]] Fig. 4 [[shows]] is a cross-sectional view of the configuration of the piston recess of the piston ~~from fig. shown in Fig. 1~~ in a third region;

25 [[fig.]] Fig. 5 [[shows]] is a cross-sectional view showing the deflection of the injected fuel jet into that region of the piston recess which is illustrated in [[fig.]] Fig. 4;

[[fig.]] Fig. 6 [[shows]] is a cross-sectional view of the configuration of the piston recess of the piston from fig. shown in Fig. 1 in a fourth region;

5 [[fig.]] Fig. 7 [[shows]] is a cross-sectional view showing the air capture in a sixth region of the piston recess;

[[fig.]] Fig. 8 [[shows]] is a cross-sectional view of a first embodiment of a fifth region of a piston from fig. shown in Fig. 1;

10 [[fig.]] Fig. 9 [[shows]] is a cross-sectional view of a second embodiment of a fifth region of [[a]] the piston from fig. shown in Fig. 1; and

15 [[fig.]] Fig. 10 [[shows]] is a cross-sectional view of a third embodiment of a fifth region of a piston from fig. shown in Fig. 1.

DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an internal combustion engine 1 which has a crankcase 2 and a cylinder head 3. Within the
 20 crankcase 2 of the internal combustion engine 1 is located at least one cylinder 4 which has a combustion space 5 and in which a piston 6 executes an oscillating movement in a way known per se. [[In]] Arranged in the cylinder head 3 is ~~arranged~~ an injection nozzle 7
 25 having a plurality of injection orifices 8 from which an injection jet 9 emerges. In the present [[case]] embodiment, the opening angle α of the injection jet 9 is relatively steep and lies in a range of between 50°

and 120° . Thus, fuel is thereby injected directly into the combustion space 5, so that this is a directly injecting internal combustion engine 1.

Fig. 1 depicts two different injection jets, to be precise an injection jet 9a, which is obtained when the piston 6 is at a top dead center, and an injection jet 9b, which is obtained in the case of fuel injection at the latest possible injection time point. The injection jets 9a and 9b are in each case illustrated merely as axes of an injection cone being distributed within the combustion space 5.

The piston 6 has a piston recess 10 in its side facing the cylinder head 3. In the following figures, the contour of the piston recess 10 and its adaptation to the injection jets 9 are explained in more detail, and, for the sake of clarity, the individual figures in each case ~~indicating~~ indicate only those reference symbols which are relevant for describing the respective figure. The piston recess 10 is identical in all the drawing figures.

As can be seen in ~~[[fig.]]~~ Fig. 2, the piston recess 10 has in its central region an elevation 11 extending in the direction of the cylinder head 3. The elevation 11 in this case has an angle β with respect of the pistons axis ~~of the piston~~ which is smaller than half the injection angle α , so that the outermost edge of the injection jet 9a, illustrated here as a mid-axis, does not come into contact with the elevation 11.

As can be seen in ~~[[fig.]]~~ Fig. 2 and ~~[[fig.]]~~ Fig. 3, the elevation 11 has adjoining it in the direction of a

recess edge 12, that is to say the end of the piston recess 10, a surface 13 which is connected to the elevation 11 via a radius 14 ~~in such a way~~ so that the injection jet 9a injected at the earliest possible time point impinges onto the surface 13 at an impingement point 15 and is distributed both in the direction of the elevation 11 and in the direction of the recess edge 12. This distribution of the injection jet 9a is important in order to intermix the fuel as effectively as possible with the air located in the combustion space 5.

Owing to the above-described steeper angle β of the elevation 11, as compared with the injection angle α , there is still sufficient free space in the region from the impingement point 15 of the injection jet 9a on the surface 13 to the elevation 11 to ensure that the fuel quantity deflected in the direction of the elevation 11 can be effectively distributed. The fuel deflected in the direction of the elevation 11 is designated by the arrow 16, whereas the fuel deflected in the direction of the recess edge 12 is designated by the arrow 17. It can be seen here, by the length of the arrows, that the fuel quantity deflected or distributed in the direction of the recess edge 12 is greater than the fuel quantity deflected in the direction of the elevation 11. The radius 14 should be selected, in this respect, such that an accumulation of the fuel flowing back is avoided.

~~It can be seen in fig.~~ Fig. 4 shows that the surface 13 adjoining the elevation 11 in the direction of the recess edge 12 is of essentially planar design and has

an ascending gradient in the direction of the recess edge 12. In other words, the surface 13 forms a plane which is at a constant angle γ to the injection jet 9 over the entire maximum injection duration. The angle γ may be varied as a function of the required momentum deflection of an injection jet 9c in this case impinging in the middle region of the surface 13, with the main momentum taking place in the direction of the recess edge 12, as ~~already~~ mentioned above. If appropriate, ~~it may also be expedient for~~ the surface 13 adjoining the elevation 11 in the direction of the recess edge 12 ~~[[to]]~~ may have a curved ~~design~~ configuration.

Fig. 5 illustrates ~~by means of~~ with the length of arrows 18 and 19 that, during the entire fuel injection, a smaller fraction of the injection jet 9 is thereby conducted in the direction of the elevation 11 and a larger fraction is thereby conducted in the direction of the recess edge 12. The arrow 18 in this case shows the fuel quantity conducted in the direction of the elevation 11, whereas the arrow 19 shows the fuel quantity conducted in the direction of the recess edge 12.

The distance of the surface 13 from the injection nozzle 7 should be selected such that the injection jet 9 can achieve a sufficiently free jet length and therefore an optimum jet velocity and the optimum momentum. Depending on the number of injection orifices 8 of the injection nozzle 7, an interaction of the fuel deflected on the piston recess 10 between two injection jets 9 is possible, thus additionally contributing to

the capture of air in the combustion space 5. In addition, the division of the fuel may also be assisted by swirl.

Fig. 6 illustrates the injection jet 9b injected at the latest possible time point. In this case, ~~it can be seen that~~ the surface 13 has an extent in the direction of the recess edge 12 such that the injection jet 9b injected at the latest possible time point impinges onto the surface 13. In this region, too, the surface 13 is ~~designed~~ configured in such a way that the injection jet 9b is distributed both in the direction of the elevation 11 and in the direction of the recess edge 12. The fuel quantity distributed in the direction of the elevation 11 is designated by an arrow 20 and the fuel quantity distributed in the direction of the recess edge 12 is designated by an arrow 21. Thus, a vertical impingement of the injection jet 9 on the piston recess 10 is prevented, and it is ensured that the momentum of the injection jet 9b is maintained.

It is apparent from ~~[[fig.]]~~ Fig. 7 that the surface 13 has adjoining it a surface 23 connected to the recess edge 12 via a radius 22. At the recess edge 12, a pinch gap region 24, as it may be referred to, at or above an upper surface 25 of the piston 6 occurs, which pinches the fuel/air mixture in the edge region in the direction of the piston recess 10 and thereby reduces the emission of hydrocarbons and carbon monoxide. The pinch gap region 24 selected should not be too large, since, even in this region, an air capture is required. The surface 23 contributes to the fact that the fuel jet following the arrow 21 is deflected such that an

increased introduction of fuel into the pinch gap region 24 is prevented.

Figs 8, 9 and 10 illustrate various tie-ups of the surface 23 to the upper surface 25 of the piston 6.

- 5 In the embodiment according to ~~[[fig.]]~~ Fig. 8, the surface 23 connected to the recess edge 12 forms an acute angle with the upper surface 25 of the piston 6. The supply of fuel to a glow plug or spark plug, not illustrated, can thereby be improved.
- 10 In the ~~version~~ embodiment according to ~~[[fig.]]~~ Fig. 9, the surface 23 merges at a radius 26 into the upper surface 25 of the piston 6.

- Fig. 10 illustrates ~~a version~~ an embodiment in which the surface 23 connected to the recess edge 12 forms an
- 15 obtuse angle with the upper surface 25 of the piston 6.

- The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of
- 20 the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Docket No. : 095309.57635US
Customer No. : 23911

Title : Directly Injecting Internal Combustion Engine

**INFORMATION DISCLOSURE STATEMENT
UNDER 37 C.F.R. §§ 1.97 AND 1.98**

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Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In accordance with the duty of disclosure under 37 C.F.R. § 1.56, the attached Form PTO-1449 lists documents which the Examiner may deem relevant to patentability of the claims of the above-identified application.

I. Time Period of Submission

This Information Disclosure Statement is submitted:

☒ 1) no later than three months from the application's filing date or 2) before the mailing date of the first Office Action on the merits (whichever is later) or 3) before a first Office Action after the filing of a Request for Continued Examination, and therefore no statement under 37 C.F.R. § 1.97(e) or fee under 37 C.F.R. § 1.17(p) is required.

☐ 2) after the later of three months from the application's filing date and the mailing date of the first Office Action on the merits, but before a Final Office Action, a Notice of Allowance, or an action closing prosecution (*Ex parte Quayle*), (whichever is earlier), and therefore Applicant is filing concurrently herewith:

☐ a Statement under 37 C.F.R. § 1.97(e); or

☐ a fee in the amount of \$180.00 under 37 C.F.R. § 1.17(p).

10/577797

Information Disclosure Statement

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☐ 3) after either a Final Office Action or a Notice of Allowance, but before payment of the Issue Fee, and therefore Applicant is submitting herewith:

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a fee in the amount of \$180.00 under 37 C.F.R. § 1.17(p).

II. Statement Under 37 C.F.R. § 1.97(e)

☐ I hereby state that each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; or

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III. Statement under 37 C.F.R. § 1.704(d)

☐ I hereby state that each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart application and that this communication was not received by any individual designated in 37 C.F.R. § 1.56(c) more than thirty days prior to the filing of this Information Disclosure Statement.

IV. Submission of Non-English Language Documents

☒ The following is a concise explanation of relevance of the non-English language documents listed in the attached Form PTO-1449:

☒ The relevance of documents A1 and B3 to the subject matter of the present invention is/are provided in the specification of the above-identified application.

☒ Corresponding foreign or international report(s) citing documents A1 and B1-B3, together with an English-language version(s) (if not already in English) of that portion of the report(s) indicating the degree of relevance found by the foreign office(s) is/are submitted.

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Information Disclosure Statement
Atty. Dkt. No.: 095309.57635US

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☐ English language family member publication(s) of document(s) _____ is/are noted on Form PTO-1449.

☐ English language abstract(s) is/are submitted for document(s) _____.

☐ English translation(s) of the foreign language document(s) _____ is/are submitted herewith.

☐ Applicant submits the following explanations: _____.

V. Continuations/Divisionals

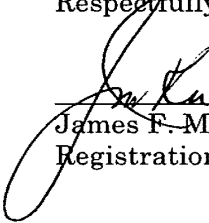
☐ Documents _____ were of record in parent application Serial No. _____, filed _____, from which this application claims benefit. As provided in 37 C.F.R. §1.98(d), copies of the documents are not being provided since they were previously submitted to or cited by the United States Patent and Trademark Office in the afore-mentioned parent application.

The submission of the listed documents is not intended as an admission that any such document constitutes prior art against the claims of the present application. Applicant does not waive any right to take any action that would be appropriate to antedate or otherwise remove any listed document as a competent reference against the claims of the present application.

If necessary, this paper should be considered as an authorization to charge Deposit Account 05-1323, Attorney Docket No.: 095309.57635US, for the fee set forth in 37 C.F.R. § 1.17(p).

Respectfully submitted,

April 28, 2006



James F. McKeown
Registration No. 25,406

CROWELL & MORING LLP
Intellectual Property Group
P.O. Box 14300
Washington, DC 20044-4300
Telephone No.: (202) 624-2500
Facsimile No.: (202) 628-8844
JFM:aw

2760251

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		Art Unit	Not Yet Assigned
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Sheet	1	of	1

U.S. PATENT DOCUMENTS					
Examiner Initials ¹	Cite No. ¹	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Number-Kind Code ² (if known)			
	A1	US - 2002/0117146 A1	08-29-2002	Gatellier et al.	
	A2	US-			
		US-			
		US-			
		US-			

FOREIGN PATENT DOCUMENTS						
Examiner Initials ¹	Cite No. ¹	Foreign Patent Document	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T ⁶
		Country Code ³ -Number ⁴ -Kind Code ⁵ (if known)				
	B1	EP 1 291 516 A2	03-12-2003	Shimazaki et al.		
	B2	DE 1 219 283	06-16-1966	Boettger		
	B3	DE 196 49 052 A1	05-28-1998	Velji et al.		

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials ¹	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ²
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This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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(71) Applicant: **ISUZU MOTORS LIMITED**
Shinagawa-ku, Tokyo (JP)

(72) Inventor: **Shimazaki, Naoki**
Fujisawa-shi, Kanagawa (JP)

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(74) Representative: **Schaumburg, Thoenes & Thurn**
Postfach 86 07 48
81634 München (DE)

(54) **Direct injection diesel engine**

(57) Cleaning of exhaust gas and reduction of fuel costs are aimed at while realizing homogenous charge (or pre-mixing) compression ignition combustion and performing fuel injection in a suitable manner in all regions of engine operation. In a direct injection diesel engine there are provided an conventional injection mode in which fuel is injected with a timing (I) in the vicinity of the compression top dead center of piston (1) and a homogenous charge compression injection mode in which fuel is injected with a timing (II to V) which is earlier than that in the conventional injection mode, and such that

fuel ignition does not occur at least until injection has been completed, fuel injection being performed by the conventional injection mode during full load operation of the engine and fuel injection being performed by the homogenous charge compression injection mode during part (low/medium) load operation of the engine. Ordinary diffusion combustion is realized when operating the engine under full load yet while receiving the benefit of amelioration of exhaust gas etc due to homogenous charge compression ignition combustion; thus, suitable fuel injection can be implemented over the entire operating range.

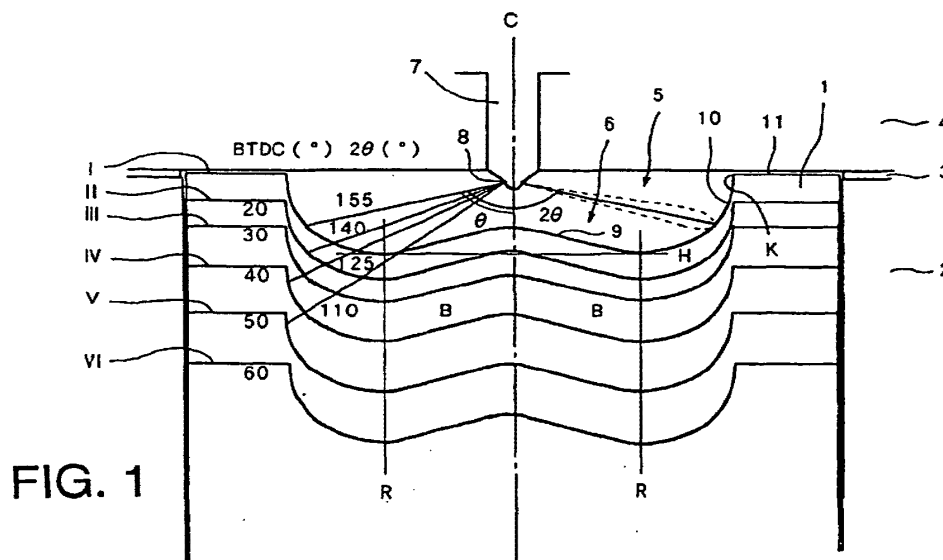


FIG. 1

Description

[0001] The present invention relates to a direct injection diesel engine and in particular relates to a direct injection diesel engine wherein the cleaning of exhaust gas and improvement in fuel consumption are effected by performing homogenous charge compression ignition combustion.

[0002] In recent years, demands for environmental measures relating to internal combustion engines, in particular diesel engines, have become increasingly strong and various means such as diesel particulate filters (DPF) that capture soot such as black smoke or NOx catalysts that effect cleaning by reducing NOx are being provided. In addition, various combustion systems are being studied in order to respond to demands for lowering fuel consumption with the aim of basically eliminating black smoke or NOx and, in addition, lowering CO₂.

[0003] However, DPF or NOx catalysts of the continuous regeneration type, which have recently been attracting attention, are restricted in regard to the temperature at which they function effectively; in particular, they have problems such as not functioning effectively in the region of low/medium engine load, where the temperature of the engine exhaust gas is low. Also, in the case of the above DPF or catalysts, when the reducing agent HC is added from the fuel, this is accompanied by a deterioration of fuel consumption.

[0004] In view of the above, it is preferable from the technical standpoint to improve combustion itself.

[0005] One way of doing this which has recently attracted attention is homogenous charge (or pre-mixing) combustion, in which ignition is effected after pre-mixing the fuel within the combustion chamber by altering the fuel injection timing from the normal timing to make use of the time from the start of fuel injection up to ignition. It is known that low NOx and low smoke can be achieved by such homogenous charge combustion.

[0006] Known ways of achieving homogenous charge combustion include early injection of fuel relative to the fuel injection timing in the case where ordinary diffusion combustion is performed (typically, BTDC 10° to ATDC 10°) and the achievement of homogenous charge combustion by prolonging the ignition lag period by retarding the timing.

[0007] However, retarding the fuel injection timing always results in a timing wherein the combustion period departs from the top dead center such that deterioration of thermal efficiency is difficult to avoid, and it is therefore undesirable since this is accompanied by deterioration of fuel consumption. Early fuel injection is therefore considered preferable, since the combustion period can be set in the vicinity of the top dead center so as not to be accompanied by deterioration of fuel consumption.

[0008] However, homogenous charge combustion in which fuel is injected earlier than usual (this is called homogenous charge (or pre-mixing) compression igni-

tion combustion) is subject to the following problems.

[0009] First of all, homogenous charge compression ignition combustion cannot be performed in all operating regions of the engine. This is because higher rates of fuel injection under full load result in ignition starting before the engine reaches the vicinity of the top dead center, resulting in severe knocking, which damages the engine. Another reason is that even if ignition starts in the vicinity of the top dead center, subsequent combustion proceeds all at once, resulting in a rise in combustion temperature and increased NOx.

[0010] Next, in homogenous charge compression ignition combustion, since the fuel is injected when the piston is lower than normal, if the injection angle is not correctly set, the fuel that is injected sticks to the inside wall of the cylinder, tending to cause an increase in unburnt HC and/or oil dilution, which tends to result in a deterioration in fuel consumption.

[0011] The present invention was made in view of the above problems, its object being the implementation of suitable fuel injection in all engine operating regions, cleaning of exhaust gas and reduction in fuel consumption, while implementing homogenous charge compression ignition combustion.

[0012] According to the present invention, in a direct injection diesel engine comprising a combustion chamber defined by a cylinder, cylinder head and piston, a cavity formed as a recess in the piston defining and forming part of the combustion chamber, and a fuel-injection nozzle that injects fuel into the combustion chamber, and in which there are provided a conventional injection mode in which fuel is injected from the fuel injection nozzle with a timing in the vicinity of the compression top dead center of the piston, and a homogenous charge compression injection mode in which fuel is injected from the fuel injection nozzle with a timing that is earlier than that in the conventional injection mode and such that fuel ignition does not occur at least until injection has been completed, fuel injection is performed by the conventional injection mode during full load operation of the engine and fuel injection is performed by the homogenous charge compression injection mode during part (low/medium) load operation of the engine.

[0013] In this way, during part load operation of the engine, fuel injection is performed with the homogenous charge compression injection mode, achieving homogenous charge compression ignition combustion and making it possible to obtain benefits such as an amelioration of [the amount of] exhaust gas and, in addition, during operation of the engine under a full load, fuel injection is performed with the conventional fuel injection mode, so conventional diffusion combustion is achieved; as a result appropriate fuel injection can be performed over the entire range of engine operation regions.

[0014] Preferably, an excess air ratio λ of less than 2.5 is identified as full load operation, and fuel injection is performed in the conventional injection mode in this

case, and an excess air ratio λ of at least 2.5 is identified as part load operation, and fuel injection is performed in the homogenous charge compression injection mode in this case.

[0015] Also preferably the injection angle of the fuel injection nozzle with respect to the nozzle axis is a fixed angle such that in the conventional injection mode fuel reaches the inside wall of the cavity on the outside in the radial direction from the lowermost position of the cavity, and in the homogenous charge compression injection mode fuel reaches at least the inside wall of the cavity.

[0016] In this way, since the fuel is injected in the radially outer direction from the lowermost position of the cavity in the conventional injection mode, fuel can be injected into the interior of the cavity both in the conventional injection mode and in the homogenous charge compression injection mode, making it possible to prevent fuel from adhering to the side wall within the cylinder in the homogenous charge compression injection mode and also preventing fuel accumulation in the vicinity of this lowermost position. Thereby, discharge of unburnt HC can be prevented.

[0017] Preferably the injection angle is less than 67.5° .

[0018] Also preferably the timing of commencement of fuel injection in the homogenous charge compression injection mode is subsequent to 50° before compression top dead center and prior to 20° .

[0019] Preferably a protrusion is formed in the middle of the bottom wall of the cavity, the sidewall of the cavity being constituted with a face such that throttling is not formed at the cavity inlet.

[0020] Figure 1 is a cross sectional view illustrating the interior of an engine according to an embodiment of the present invention.

[0021] A preferred embodiment of the present invention is described below with reference to the accompanying drawings.

[0022] Figure 1 is a cross sectional view showing the interior of a direct injection diesel engine according to this embodiment. As shown in the Figure, a cylinder head 4 is mounted with the aid of a gasket 3 at the top of a cylinder 2, piston 1 being provided so as to be free to reciprocate vertically within cylinder 2. A combustion chamber 5 is defined by this piston 1, cylinder 2 and cylinder head 4. A cavity 6 is provided at the top of piston 1; cavity 6 defines part of combustion chamber 5. A fuel-injection nozzle 7 for injecting fuel into combustion chamber 5 is provided in cylinder head 4. The tip of fuel-injection nozzle 7 projects into the interior of the combustion chamber 5 and a plurality of jets 8 are provided at its tip.

[0023] The axes of piston 1, cylinder 2, fuel-injection nozzle 7 and cavity 6 are arranged on the same axis C. These are therefore all arranged coaxially. The jets 8 of fuel injection nozzle 7 are arranged at equal intervals in the circumferential direction in positions at the same

height on this axis C, being directed so as to inject fuel with a prescribed injection angle θ with respect to axis C, respectively. In the Figure, the angle (opening angle) which is made by corresponding injection axes represented symmetrically about axis C is shown as 2θ ; the half value θ thereof is the injection angle of fuel injection. Cavity 6 has a symmetric shape with respect to axis C.

[0024] In this case, the engine could be a diesel engine of the injection pump type comprising an electronic governor, in which the fuel-injection rate and injection period etc of the engine are electronically controlled in accordance with the engine operating condition, but is preferably a common rail type diesel engine, since this offers a greater degree of freedom in respect of the injection period. In the case of the common rail type, fuel-injection nozzle 7 can be an injector comprising an electronic actuator (electromagnetic solenoid etc). Engine operating condition detection means are provided for detecting engine operating condition such as engine speed and engine load; this includes at least intake rate detection means (airflow sensor etc) for detecting the rate of engine air intake. In addition, an electronic control unit is provided that calculates and determines the target fuel injection rate and injection period etc from these detected engine operating conditions and effects fuel injection corresponding to this target value.

[0025] Cavity 6 constitutes a so-called toroidal combustion chamber shaped as a shallow dish, having a shape with a surface area that is as small as possible. A gently rising protrusion 9 is formed in the middle of the bottom wall in the combustion chamber, where the air utilization rate is low. Also, the sidewall 10 of cavity 6 is constituted solely by surfaces such that no throttling of the cavity inlet is formed. That is, all surfaces of the side wall 10 either diverge from the axis C in the upwards direction or are parallel with axis C, so that no surface exists that approaches axis C in the upwards direction. In other words, only surfaces that open upwards or run vertically are present; there are no surfaces that open downwardly. Thus, cavity 6 does not constitute a so-called re-entrant combustion chamber having a lip.

[0026] A plurality of piston positions are shown in the Figure. The highest one of these (I) that is shown is a position in the vicinity of the compression top dead center; this is a position contained between 10° before the compression top dead center (BTDC) and 10° after the compression top dead center (ATDC). The positions following this, moving downwards, are BTDC 20° (II), 30° (III), 40° (IV), 50° (V) and 60° (VI).

[0027] Also, a plurality of injection angles are shown in the Figure; taken in order respectively from the top, these are $\theta=77.5^\circ$, 70° , 62.5° , and 55° . Expressed in terms of 2θ , these are $2\theta=155^\circ$, 140° , 125° and 110° .

[0028] Next, the engine of this embodiment is provided with two fuel-injection modes, namely, a conventional injection mode and a homogenous charge compression injection mode.

[0029] The conventional injection mode is a mode in

which fuel is injected from fuel-injection nozzle 7 with a timing in the vicinity of the compression top dead center of the piston and is a mode in which fuel injection is performed with the same timing as in the case of an ordinary engine. Specifically, injection of fuel is commenced at some time between BTDC 10° and ATDC 10°. As well as a single injection in which all of the injection amount is injected at a single injection, this conventional injection mode may include double injection, in which a pilot injection of small quantity is performed before the main injection, in which the remaining amount is injected. In the case of double injection, the starting time of the later i.e. the main injection is between BTDC 10° and ATDC 10°. Thus, for example in the case of single injection, the combustion mode adopted is a diffusion combustion mode, in which the fuel that was injected in the initial period of fuel-injection ignites after an ignition lag time and by continued injection of fuel into the flame which is thereby produced, this fuel is burnt.

[0030] However, in the case of diffusion combustion, since fuel newly injected into the flame is burnt, the fuel must be burnt by supplying it into a region where there is originally little oxygen, and therefore smoke tends to be produced. This may therefore be combined with a homogenous charge compression injection mode, as follows.

[0031] The homogenous charge compression injection mode is a mode in which fuel is injected from fuel-injection nozzle 7 with a timing earlier than the conventional injection mode and in which fuel ignition will not occur at least until injection has terminated. More specifically, fuel injection is commenced at a timing between BTDC 50° and 20°. This timing is a timing such that fuel ignition commences after completion of fuel injection. In the same way as described above, the homogenous charge compression injection mode includes double injection, in which a pilot injection is performed, in addition to single injection. In the case of double injection, the starting time of the main injection is between BTDC 50° and 20°. For example, the combustion mode which is adopted in the case of single injection is a homogenous charge compression injection mode, in which fuel is injected in a condition in which the temperature and pressure within the cylinder are not yet sufficiently high, so that the ignition lag period is increased and premixed vapor is formed by thorough stirring and mixing of the fuel and the air within combustion chamber 5 and, after completion of fuel injection, the premixed vapor that has been diffused substantially throughout all the regions within combustion chamber 5 with the rise in pressure and temperature within the cylinder is ignited, producing combustion. Since combustion occurs after all of the fuel has mixed with air and has been uniformly diluted within the combustion chamber, the combustion takes place with the fuel being surrounded by a generous amount of oxygen, so smoke can be prevented, the rate of combustion is comparatively gentle, and the combustion temperature does not rise abruptly so that production of

NOx can be prevented.

[0032] However, as described above, in the case of operation of the engine under full load, the problem of knocking etc occurs, making it impossible to implement the homogenous charge compression injection mode (homogenous charge compression ignition combustion).

[0033] Accordingly, in this embodiment, fuel injection is performed in the same way as ordinarily by the normal injection mode when operating under full load but when operating under part (low/medium) load i.e. at lower load than this, fuel injection is performed by the homogenous charge compression injection mode. In this way, homogenous charge compression ignition combustion, which is advantageous for cleansing exhaust gas, can be utilized while appropriate fuel injection is performed in all operating regions.

[0034] It is possible to make the decision regarding the mode changeover timing or which mode is to be employed by reference to the magnitude of the rate of fuel injection but, in this embodiment, the decision is made by reference to the magnitude of the rate of excess air. It has been found by experiment that the occurrence of diesel knocking in homogenous charge combustion is largely dependent on the ratio of excess air λ ; it has been confirmed that severe diesel knocking occurs at a ratio of excess air λ less than 2.5. The case where the excess air rate λ is less than a prescribed value, in this embodiment, 2.5, is therefore identified as full load operation and fuel injection is then performed in the conventional injection mode. In contrast, the case where the excess air ratio λ is 2.5 or more is identified as part (low/medium) load operation, and fuel injection is performed in the homogenous charge compression injection mode.

[0035] More specifically, the electronic control unit calculates the excess air ratio λ from the actual air intake rate detected by intake rate detection means and the target fuel injection rate, and if $\lambda < 2.5$, performs fuel injection in accordance with the conventional injection mode, and if $\lambda \geq 2.5$ performs fuel injection in accordance with the homogenous charge compression injection mode.

[0036] In this embodiment, two modes are implemented using a single fuel injection nozzle 7 having fixed jets 8. If therefore the injection angle θ of the fuel injection nozzle 7 is made too large with respect to the conventional injection mode (i.e. the opening angle 2θ is widened), as the piston is lower in the homogenous charge compression injection mode, the fuel mist does not enter the cavity 6 but collides with the inside wall of cylinder 2, tending to increase unburnt HC and/or dilute the oil. Also, if the injection angle θ is made too small with respect to the homogenous charge compression injection mode (i.e. the opening angle 2θ is narrowed), when in the conventional injection mode, the fuel mist collides with the bottom of cavity 6 and accumulates in cavity 6, tending to increase unburnt HC etc. For this reason, in

order for the two modes to co-exist, the injection angle θ of the fuel-injection nozzle 7 is set as below.

[0037] Specifically, the injection angle θ is set at a fixed angle such that in the conventional injection mode the fuel reaches the inside wall of the cavity on the radially outer side from the lowermost position of cavity 6 and, in the homogenous charge compression injection mode, the fuel reaches at least the inside wall of the cavity.

[0038] The lowermost position of cavity 6 is the position or point where cavity 6 is deepest and is the position B where the position of height H and the radial position R intersect in the drawing. This lowermost position B appears as a circle that makes one circuit around axis C. The limit on the small side of θ in the conventional injection mode is lowermost position B and the limit on the large side of θ is the position of intersection K where the side wall 10 of cavity 6 and piston crown 11 intersect. The injection angle θ is set such that, in the conventional injection mode, fuel cannot arrive at or collide with the cavity inside wall between this lowermost position B and intersection position K.

[0039] Also, in the homogenous charge compression injection mode, the fuel may reach the inside wall of the cavity, the essential point being that the fuel should be capable of entering cavity 6. The only limit of θ is therefore intersection position K on the large side, but there is no limit of θ on the small side. The reason why this is possible is that, in this mode, fuel is injected earlier than normal, so the ignition lag time is increased, with the result that meanwhile all of the fuel can mix with air, so the problem of unburnt HC does not arise.

[0040] The relationship between injection angle θ (or angle of opening 2θ) and the injection timing will next be described using the Figure. First of all, let us assume that fuel injection is performed in the conventional injection mode when piston 2 is in the uppermost position shown. Also, in the homogenous charge compression injection mode, let us assume that fuel injection is performed when piston 2 is in an illustrated position BTDC 20°, 30°, 40° or 50°. Position BTDC 60° is also shown, but this is depicted only for reference.

[0041] Injection angle $\theta=77.5^\circ$ ($2\theta=155^\circ$) which is the uppermost position shown is a typical value that can be adopted for an ordinary engine. In this case, the above condition is of course satisfied in the case of the conventional injection mode and the above condition is satisfied even in the homogenous charge compression injection mode if the injection commencement timing is BTDC 20° or 30°. However, in the case of BTDC 40° and 50°, this condition is not satisfied; therefore, in the case where the injection commencement timing of the homogenous charge compression injection mode is BTDC 20° or 30°, an injection angle $\theta=77.5^\circ$ ($2\theta=155^\circ$) may be adopted.

[0042] $\theta=70^\circ$ ($2\theta=140^\circ$) also satisfies the above condition of the conventional injection mode. If, in the homogenous charge compression injection mode, the in-

jection commencement timing is BTDC 20° or 30°, the above condition is satisfied, but in the case of BTDC 40° and 50°, the above condition is not satisfied. Consequently, if the injection commencement timing of the homogenous charge compression injection mode is BTDC 20° or 30°, injection angle $\theta=70^\circ$ ($2\theta=140^\circ$) may be adopted.

[0043] If $\theta=62.5^\circ$ ($2\theta=125^\circ$), the above condition of the conventional injection mode is also satisfied. If, in the homogenous charge compression injection mode, the injection commencement timing is BTDC 20°, 30° or 40°, the above condition is satisfied, but when the timing is BTDC 50°, the above condition is not satisfied. Consequently, if the injection commencement timing in the homogenous charge compression injection mode is BTDC 20°, 30° or 40°, an injection angle $\theta=62.5^\circ$ ($2\theta=125^\circ$) may be adopted.

[0044] $\theta=55^\circ$ ($2\theta=110^\circ$) does not satisfy the above condition of the conventional injection mode. In this case, the above condition is satisfied for any injection commencement timing (BTDC 20°, 30°, 40° or 50°) of the homogenous charge compression injection mode. However, the above condition is not satisfied in the conventional injection mode. An injection angle $\theta=55^\circ$ ($2\theta=110^\circ$) can therefore not be adopted.

[0045] Thus, in the determination of injection angle θ , the diameter and/or depth of cavity 6 are related to the injection commencement timing of the homogenous charge compression injection mode in particular, but, whatever the case, by selecting an angle such as to satisfy the above condition, discharge of unburnt HC in the conventional injection mode and/or collision etc of fuel mist with the side wall within cylinder 2 in the homogenous charge compression injection mode can be prevented. In the case of the conventional injection mode, by injecting fuel such that the fuel arrives at the inside wall of the cavity on the outside in the radial direction with respect to the lowermost position of cavity 6, the fuel after colliding with the inside wall of the cavity can be made to flow in the radially outward direction along the inner wall of the cavity, thereby becoming diffused and so making it possible to utilize air over a wider range; thus desirable combustion can be achieved.

[0046] However, it is desirable for combustion to occur in a position as remote as possible from the undersurface of cylinder head 4. The reason for this is that a water jacket is formed in the interior of cylinder head 4 so that cylinder head 4 is cooled by cooling water; consequently, if combustion occurs in the vicinity of the undersurface of the cylinder head, heat is abstracted by cylinder head 4, causing thermal efficiency to be lowered, which is disadvantageous in regard to fuel consumption and causes black smoke to be generated.

[0047] From this standpoint it is therefore desirable that the injection angle θ be as small as possible. It has been discovered by experiment that if the injection angle θ is equal to or less than 67.5° ($2\theta=135^\circ$), fuel consumption is improved and black smoke is suppressed. It is

therefore preferable that the injection angle θ be equal to or less than 67.5° .

[0048] Furthermore, in this embodiment, thermal efficiency and the fuel consumption are improved by making it more difficult for heat to be abstracted by piston 2, by employing a cavity shape with a surface area which is as small as possible. Also, since combustion in cavity 6 occurs chiefly on the outside, so that the rate of utilization of air in the middle of the cavity is low, protrusion 9 is formed so as to fill up this wasted portion: thus cavity 6 presents a toroidal combustion chamber configuration.

[0049] Also, in the case of the homogenous charge compression ignition combustion, it was found that suppressing air flow within combustion chamber 5 as far as possible lowers the combustion temperature and makes it possible to decrease NOx and furthermore makes it possible to improve fuel consumption by suppressing heat loss. Consequently, for cavity 6 in this embodiment, a shape is adopted that has no lip projecting inwards in the radial direction at the cavity inlet i.e. which is not of the so-called re-entrant type. Specifically, it is known that, in the case of a re-entrant type, in general the swirl-retaining capability within the cavity is high, thereby also conferring swirl on the air outside the cavity during the expansion stroke and promoting movement of air within the entire combustion chamber; this makes possible more vigorous combustion and so is desirable in the ordinary combustion mode. However, in the case of homogenous charge compression ignition combustion, premixed vapor is formed from the beginning, facilitating combustion, so, if combustion becomes too vigorous, the combustion temperature becomes elevated, increasing NOx. Also, to the extent that the combustion temperature is elevated, heat loss also increases, adversely affecting fuel consumption. Therefore, in this embodiment, in which homogenous charge compression ignition combustion is performed, a re-entrant type cavity is not adopted. For this reason, a low-swirl shape may also be adopted for the air intake port.

[0050] Various other embodiments of the present invention may also be adopted.

[0051] To summarize the above, with the present invention, the excellent benefits are exhibited that fuel injection is performed in a suitable manner in all regions of engine operation while also realizing homogenous charge compression ignition combustion and achieving cleaning of the exhaust gas and reduction of fuel costs.

Claims

1. A direct injection diesel engine comprising a combustion chamber defined by a cylinder, cylinder head and piston, a cavity formed as a recess in said piston defining and forming part of said combustion chamber, and a fuel-injection nozzle that injects fuel into said combustion chamber, in which there are

provided an conventional injection mode in which fuel is injected from said fuel injection nozzle with a timing in the vicinity of the compression top dead center of said piston and a homogenous charge compression injection mode in which fuel is injected from said fuel injection nozzle with a timing that is earlier than that in the conventional injection mode and such that fuel ignition does not occur at least until injection has been completed, fuel injection being performed by said conventional injection mode during full load operation of the engine and fuel injection being performed by said homogenous charge compression injection mode during part load operation of the engine.

2. The direct injection diesel engine according to claim 1, **characterized in that** a case in which the excess air ratio λ is less than 2.5 is identified as full load operation whereby fuel injection is performed in said conventional injection mode, and a case in which the excess air ratio λ is at least 2.5 is identified as part load operation whereby fuel injection is performed in said homogenous charge compression injection mode.
3. The direct injection diesel engine according to claim 1 or claim 2, **characterized in that** the injection angle of said fuel injection nozzle with respect to the nozzle axis is a fixed angle such that in said conventional injection mode fuel reaches the inside wall of the cavity on the outside in the radial direction from the lowermost position of said cavity and in said homogenous charge compression injection mode fuel reaches at least the inside wall of the cavity.
4. The direct injection diesel engine according to claim 3 **characterized in that** said injection angle is equal to or less than 67.5° .
5. The direct injection diesel engine according to any of claims 1 through 4, **characterized in that** the timing of commencement of fuel injection in said homogenous charge compression injection mode is subsequent to 50° before compression top dead center and prior to 20° .
6. The direct injection diesel engine according to any of claims 1 through 5, **characterized in that** a protrusion is formed in the middle of the bottom wall of said cavity, the sidewall of said cavity being constituted with a face such that throttling is not formed at the cavity inlet.



(19)



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(71) Applicant: ISUZU MOTORS LIMITED
Shinagawa-ku, Tokyo (JP)

(72) Inventor: Shimazaki, Naoki
Fujisawa-shi, Kanagawa (JP)

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(74) Representative: Schaumburg, Thoenes & Thurn
Postfach 86 07 48
81634 München (DE)

(54) Direct injection diesel engine

(57) Cleaning of exhaust gas and reduction of fuel costs are aimed at while realizing homogenous charge (or pre-mixing) compression ignition combustion and performing fuel injection in a suitable manner in all regions of engine operation. In a direct injection diesel engine there are provided an conventional injection mode in which fuel is injected with a timing (I) in the vicinity of the compression top dead center of piston (1) and a homogenous charge compression injection mode in which fuel is injected with a timing (II to V) which is earlier than that in the conventional injection mode, and such that

fuel ignition does not occur at least until injection has been completed, fuel injection being performed by the conventional injection mode during full load operation of the engine and fuel injection being performed by the homogenous charge compression injection mode during part (low/medium) load operation of the engine. Ordinary diffusion combustion is realized when operating the engine under full load yet while receiving the benefit of amelioration of exhaust gas etc due to homogenous charge compression ignition combustion; thus, suitable fuel injection can be implemented over the entire operating range.

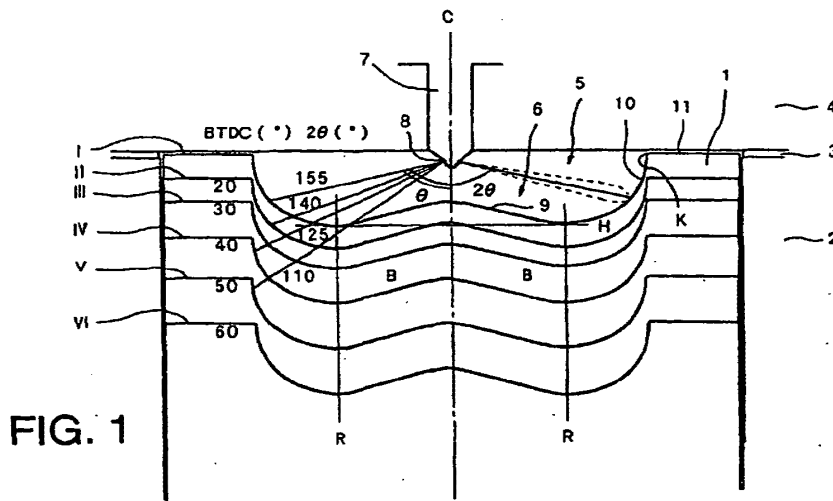


FIG. 1

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EUROPEAN SEARCH REPORT

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Place of search MUNICH		Date of completion of the search 22 September 2003	Examiner Wettemann, M
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AUSLEGESCHRIFT

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1

Die Erfindung bezieht sich auf eine Brennkraftmaschine mit direkter Kraftstoffeinspritzung und Verdichtungszündung, mit einem im Kolbenboden symmetrisch oder beinahe symmetrisch zur Zylinderachse angeordneten und im wesentlichen rotationskörperförmigen Brennraum, in welchem sich gegen Ende des Verdichtungshubes nahezu das gesamte angesaugte Luftvolumen befindet, das vorher in eine heftige Drehbewegung um die Brennraumachse versetzt wurde, und mit einer zu diesem Brennraum aussermittig angeordneten Einspritzdüse, die den Kraftstoff in mindestens zwei Kraftstoffstrahlen von verschiedener freier Länge im wesentlichen in Richtung der in den Brennraum einströmenden Verbrennungsluft an verschiedenen heißen Wandstellen des Brennraumes spritzt, von denen der kürzeste Kraftstoffstrahl mit einem kleinen Anteil über den Rand der Brennraumwand gegen den Boden des Kolbens gespritzt wird, während der übrige, weitaus größere Teil dieses »Zündstrahles« noch gegen den unmittelbar neben dem Rand befindlichen Teil der Brennraumwand gerichtet ist, nach Patent 1 175 486.

Bei der oben kurz geschilderten Brennkraftmaschine nach dem Hauptpatent bildet der oben erwähnte kürzeste Kraftstoffstrahl den »Zündstrahl«, und während des Normalbetriebes des Motors erfolgt die Zündung stets mit geringem Zündverzug und an derselben Stelle des Brennraumes, nämlich an dem von dem Zündstrahl etwas überspritzten Brennraumrand, an dem der mechanisch abgespaltene Kraftstoffanteil eine der Einströmungsrichtung der Verbrennungsluft entgegengerichtete Ausbreitungskomponente erhält und auf eine Fläche sowohl hoher Temperatur als vor allem auch anderer Neigung auftrifft, als sie die Brennraumwand an der Stelle des Auftreffens des Strahlkernes aufweist. Dadurch kommt es an der Stelle des Überspritzens des Brennraumrandes nicht nur zu einer entsprechend schnellen Aufheizung des Kraftstoffes, sondern — unter dem Einfluß der Radialkomponente der Lufteinströmung in den Brennraum — auch zu einem Aufstauen dieses kleinen Kraftstoffanteils, d. h. zu einer Übersättigung der dort befindlichen Luft mit Kraftstoff, was zur erwünschten raschen Zündung an dieser ganz bestimmten gleichbleibenden Stelle führt.

Der Hauptanteil des Kraftstoffes des Zündstrahls sowie der Kraftstoff aus dem oder den weiteren Kraftstoffstrahlen ist ausschließlich gegen unterhalb des Brennraumrandes gelegene und im Betrieb kühlere Teile der Brennraumwand gerichtet; da die Einspritzrichtung im wesentlichen mit der Einströmungsrichtung der Verbrennungsluft zusammenfällt, wodurch

Brennkraftmaschine mit direkter Kraftstoffeinspritzung und Verdichtungszündung

Zusatz zum Patent: 1 175 486

Anmelder:

Tatra, národní podnik,
Kopřivnice (Tschechoslowakei)

Vertreter:

Dipl.-Ing. R. Beetz und Dipl.-Ing. K. Lamprecht,
Patentanwälte, München 22, Steinsdorfstr. 10

Als Erfinder benannt:

Dipl.-Ing. Josef Böttger, Prag

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2

die Kraftstoffaufbereitung zur anschließenden Verbrennung etwas verzögert wird, und da der in den Strahlen enthaltene Kraftstoff im Falle seines Auftreffens auf die Brennraumwand diese lediglich an kühleren Stellen berührt als der die Zündung auslösende Teil des Zündstrahls, kann die Selbstzündung des Kraftstoffes allein von dem kleinen Anteil des Zündstrahls ausgehen, der über den Rand der Brennraumwand gespritzt und dabei sehr fein zerstäubt wird. Von dieser örtlich festgelegten Zündstelle geht dann die Zündung mit einer durch die heftige Drehbewegung der Luft gesteigerten Flammenausbreitungsgeschwindigkeit auch auf den weiteren in den Brennraum eingespritzten und in die Luft verdampfenden Kraftstoff über, ohne daß ein störendes Klopfen auftritt.

Bei dem in der Zeichnung des Hauptpatents veranschaulichten Ausführungsbeispiel hat die im wesentlichen kreisförmige, eingezogene Brennraumöffnung einen einseitigen, an seinem einen Ende vom eingezogenen Brennraumrand nach außen vorspringenden Ausschnitt, dessen dem Brennrauminneren zugewandte Fläche zum anderen Ende des Ausschnitts hin im Sinne der schnellen Drehbewegung der beim Verdichtungshub in den Brennraum verdrängten Luft

mit stetiger Wölbung etwa tangential in die seitliche Brennraumwand übergeht. Dieser Ausschnitt wirkt als Führung für einen erheblichen Anteil der Verbrennungsluft. Die Einspritzdüse ist derart angeordnet, daß sie sich in der oberen Totpunktstellung des Kolbens im Bereich des nach außen vorspringenden Luftenströmendes des Ausschnitts befindet; sie spritzt den Kraftstoff aus dem Kern des Zündstrahls auf die obere Randzone der Ausschnittsfläche auf und den Kraftstoff aus dem oder den weiteren Kraftstoffstrahlen größere Strahllänge etwa im Sinne der Luftströmung in Richtung auf weiter vom Brennraumrand entfernte Brennraumwandzonen, an denen die einströmende Luft entlangleitet. Der dabei auf die Brennraumwand gelangte Kraftstoff breitet sich in tiefer unterhalb des Brennraumrandes liegende, kühlere Wandbereiche aus, womit das Verdampfen des Kraftstoffs in die über ihn hinwegstreichende Luft verzögert wird und seine Fähigkeit zum raschen Zünden abnimmt.

Beim Vollastbetrieb mit höheren Drehzahlen des Motors, bei dem größere Kraftstoffmengen auf die Brennraumwand gelangen, kann durch das Ausbreiten des Kraftstoffs in immer kühlere Brennraumwandzonen das Verdampfen des aufgespritzten Kraftstoffs und sein genügendes Durchmischen mit der Verbrennungsluft zu stark verzögert werden, was den Verbrennungswirkungsgrad verringert und die Rauchgrenze des Motors herabsetzt.

Der Erfindung liegt die Aufgabe zugrunde, die Brennkraftmaschine mit direkter Kraftstoffeinspritzung und Verdichtungszündung nach dem Hauptpatent, bei der die örtlich festgelegte, frühzeitige Zündung einen kloppfreien Betrieb gewährleistet, derart zu verbessern, daß auch die Verbrennung bei hohen Drehzahlen und großer Leistung mit gutem Wirkungsgrad und praktisch rauchfrei erfolgt.

Man hat bereits erkannt, daß bei einem Aufspritzen größerer Kraftstoffmengen auf die Brennraumwand eine weitgehend rauchfreie Verbrennung des Kraftstoffs in wenig bewegter Verbrennungsluft nur dann einwandfrei zu erreichen ist, wenn der auf der Brennraumwand gelangte Kraftstoff sich von der Auftreffstelle nicht in kühlere, sondern im Gegenteil in wärmere Brennraumwandzonen ausbreitet, an denen das Abdampfen des Kraftstoffs und damit seine Vorbereitung für die Verbrennung beschleunigt wird. Eine derartige Verbesserung der Verbrennung wird auch bei der Brennkraftmaschine nach dem Hauptpatent angestrebt.

Nun ist die Temperatur der Brennraumwand im wesentlichen von der Richtung und Geschwindigkeit sowie von der Temperatur der an ihr vorbeiströmenden heißen Verbrennungsgase sowie der wesentlich kühleren Verbrennungsluft abhängig, die in den Brennraum einströmt; weiterhin spielt die Wärmeableitung von der Brennraumwand in das den Brennraum umgebende Material des Kolbens eine Rolle. Sowohl die Richtung und die Geschwindigkeit der Strömung der Verbrennungsluft sowie der Verbrennungsgase als auch die Wärmeableitung von den Brennraumwandungen lassen sich in gewissem Umfang durch die Formgebung des Brennraumes beeinflussen.

Die stärkste Kühlwirkung der in den Brennraum einströmenden Verbrennungsluft ergibt sich Erfahrungsgemäß dort, wo diese Luft mit hoher Geschwindigkeit an der Brennraumwand entlangströmt, wo-

gegen die Kühlwirkung an Stellen einer abgelösten Luftströmung wesentlich geringer ist. Ein durch bekannte Mittel, beispielsweise Schirme an den Ansaugventilen, tangentiale Einströmkanäle und dergleichen erzeugtes heftiges Kreisen der in den Zylinderraum einströmenden Verbrennungsluft begünstigt das »Anlegen« der Luftströmung an die Seitenwandung des Brennraumes und damit die Kühlung dieser Wand, insbesondere dort, wo für das Einspritzen des Kraftstoffs eine Ausnehmung am Brennraumrand vorgesehen ist, die stetig im Sinne der Luftströmung in die seitliche Brennraumwand übergeht und eine Führung für einen verhältnismäßig großen Anteil der in den Brennraum einströmenden Luft bildet. Diese Kühlwirkung der einströmenden Verbrennungsluft wird bei der Brennkraftmaschine nach dem Hauptpatent bereits ausgenutzt, indem der Kraftstoff im wesentlichen an solchen Stellen auf die Brennraumwand gespritzt wird, an denen durch die Eintrittsströmung der Verbrennungsluft eine Kühlung der Brennraumwand erfolgt; der dort aufgespritzte Kraftstoff breitet sich aber auch zunehmend in die Tiefe des Brennraumes aus, wo im allgemeinen die Wandtemperatur stark abnimmt.

Die zu lösende Aufgabe besteht also darin, bei einer Brennkraftmaschine nach dem Hauptpatent durch eine neuartige Gestaltung des Brennraumes, insbesondere seines oberen Teils und entsprechende Wahl der Auftreffstellen der Kraftstoffstrahlen zu erreichen, daß insbesondere beim Aufspritzen größerer Kraftstoffmengen auf die Brennraumwand der aufgespritzte Kraftstoff sich in Brennraumwandbereiche ausbreitet, deren Temperatur höher ist als die Temperatur an der Auftreffstelle des Kraftstoffes.

Die erfindungsgemäße Brennkraftmaschine mit direkter Kraftstoffeinspritzung und Verdichtungszündung, mit einem im Kolbenboden symmetrisch oder beinahe symmetrisch zur Zylinderachse angeordneten und im wesentlichen rotationskörperförmigen Brennraum, in welchem sich gegen Ende des Verdichtungshubes nahezu das gesamte angesaugte Luftvolumen befindet, das vorher in eine heftige Drehbewegung um die Brennraumachse versetzt wurde, und mit einer zu diesem Brennraum außermittig angeordneten Einspritzdüse, die den Kraftstoff in mindestens zwei Kraftstoffstrahlen von verschiedener freier Länge im wesentlichen in Richtung der in den Brennraum einströmenden Verbrennungsluft an verschiedenen heißen Wandstellen des Brennraumes spritzt, von denen der kürzeste Kraftstoffstrahl mit einem kleinen Anteil über den Rand der Brennraumwand gegen den Boden des Kolbens gespritzt wird, während der übrige, weitaus größere Teil dieses »Zündstrahles« noch gegen den unmittelbar neben dem Rand befindlichen Teil der Brennraumwand gerichtet ist, nach dem Hauptpatent 1.175.486, ist im wesentlichen dadurch gekennzeichnet, daß die Verbindungsöffnung vom Brennraum zum Zylinderraum am Kolbenboden von zwei gegenseitig symmetrisch zur Brennraumachse versetzten Halbkreisbogen begrenzt ist, wobei die von den beiden Halbkreisbogen in den nach dem Brennraumboden zu gelegenen Brennraumunterteil führenden Seitenwände des Brennraumes mit dem benachbarten Kolbenboden je einen Winkel einschließen, der sich von einem Wert größer als 90° an den gegenüber dem Brennraum außen liegenden Enden der Halbkreisbogen im Drehsinn der kreisenden einströmen-

den Verbrennungsluft stetig bis zu einem Wert kleiner als 90° an den in bezug auf den Brennraum innenliegenden Enden der Halbkreisbogen verkleinert, und daß der Mantelanteil des Zündstrahls den Brennraumrand in dem im Sinne der Luftströmung noch etwas vor der Mitte liegenden Abschnitt eines der Halbkreisbogen überspritzt, während der Kraftstoff des bzw. der weiteren Kraftstoffstrahlen etwa unterhalb des mittleren Bereiches des Halbkreisbogens auf den oberen Teil der Brennraum-Seitenwand auftrifft.

Durch die erfindungsgemäße Ausbildung der Brennraumöffnung ergibt sich eine Einströmung der Verbrennungsluft in den Brennraum, die entlang dem außenliegenden vorderen Teil der beiden Halbkreisbogen annähernd parallel zu diesen Bogen verläuft und dort infolgedessen in an sich bekannter Weise eine Kühlung der Brennraumwand bewirkt, während die Luft zum weiter innenliegenden Ende jedes der Halbkreisbogen hin eine zunehmend größere radiale Einströmungskomponente erhält, schließlich an den inneren Enden der Halbkreisbogen etwa radial nach innen in den Brennraum hineinströmt und sich dabei dort sowie an der etwa radial nach außen gerichteten Verbindungskante zum folgenden Halbkreisbogen unter Wirbelbildung von der oberen Kante der Brennraumwand ablöst, so daß an dieser gegenüber dem anschließenden zweiten Halbkreisbogen zum Brennrauminneren vorspringenden Stelle eine wesentlich geringere Kühlung der Brennraumwand erfolgt.

Andererseits strömen aber die heißen Verbrennungsgase, die beim Expansionshub in spiralig kreisender, turbulenter Bewegung aus dem Brennraum austreten, an der in das Brennrauminnere hineinragenden Verschneidungskante zwischen dem oberen Teil der eingezogenen Brennraumwand und dem anschließenden zweiten Halbkreisbogenschnitt mit hoher Geschwindigkeit vorbei, so daß sie diesen Bereich der Brennraumwand stark erhitzen, in dem die Wärmeableitung von der Verschneidungskante in das Material des Kolbens geringer ist als an der Brennraumwand mit gleichmäßiger stetiger Krümmung. Infolgedessen ergeben sich an der Brennraumwand unterhalb des in Strömungsrichtung der Luft hinteren Teiles jedes der beiden Ausschnitte die angestrebten höheren Brennraumwandtemperaturen. Der unterhalb des oberen Brennraumrandes etwa im mittleren Bereich eines der beiden halbkreisförmigen Ausschnitte auf die Brennraumwand gelangende Kraftstoff kann sich infolgedessen nur in zunehmend wärmere Brennraumwandbereiche ausbreiten; seine Verdampfung wird dadurch beschleunigt und die Verbrennung erfolgt unter günstigen Verbrennungsbedingungen.

Bei bekannten Brennkraftmaschinen mit direkter Krafteinspritzung und Verdichtungszündung, bei denen der Kraftstoff ebenfalls durch eine von einem Ausschnitt des Brennraumrandes gebildete seitliche Ausnehmung unterhalb des oberen Brennraumrandes auf die Brennraumwand aufgespritzt wird, ist die Einspritzrichtung des Kraftstoffs derart flach zur Brennraumwand, daß der Kraftstoff erst im hinteren Bereich des Ausschnittes unterhalb des Einspritzungsbereiches des Brennraumrandes auf die Brennraumwand gelangt, wo die seitliche Brennraumwand etwa die höchste Temperatur hat; die an die Einspritzstellen anschließenden Brennraumwandbereiche haben keine höheren Temperaturen als die Aufspritzstellen. Selbst durch Anordnung eines sich an die

»Einspritzausnehmung« in Umfangsrichtung anschließenden Brennraumrandausschnittes für das Ausströmen der Verbrennungsgase wird die Temperaturverteilung an der seitlichen Brennraumwand nicht wesentlich beeinflusst. Eine Temperaturzunahme der Brennraumwand in demjenigen Bereich, in den sich der aufgespritzte Kraftstoff ausbreiten kann und die bei der erfindungsgemäßen Brennkraftmaschine in der Größenordnung von etwa 50° liegt, läßt sich mit den bekannten Anordnungen von Ein- und Ausströmungsausschnitten am Brennraumrand keinesfalls erzielen.

Es kommt noch hinzu, daß bei allen Brennkraftmaschinen mit einseitigen Lufterströmungsausschnitten am oberen Brennraumrand infolge der starken einseitigen Einströmung die Achse des sich in dem Brennraum ausbildenden starken Strömungswirbels nach der dem Ausschnitt etwa gegenüberliegenden Brennraumwand verschoben und damit die Wirbelströmung unsymmetrisch wird, was eine Abnahme der Wirbelintensität zur Folge hat. Wenn noch ein »Ausströmungsausschnitt« für die Verbrennungsgase vorgesehen ist, wird die Wirbelströmung zusätzlich gestört.

Bei der erfindungsgemäßen Brennraumbildung bleibt die Wirbelachse in der Brennraummitte; dadurch wird die bereits in der Beschreibung des Hauptpatents erwähnte Zündung beim Kaltstart durch einen feinerstäubten Randanteil des längsten Kraftstoffstrahls in der zentralen »toten« Wirbelzone hoher Verdichtungs-temperatur begünstigt, die stets dann — natürlich mit entsprechender zeitlicher Verzögerung — auftritt, wenn wegen der niedrigen Temperatur des Kolbens an der Überspritzstelle des Zündstrahls sich dort noch keine Zündung einstellt.

Mit der bereits erwähnten Anordnung der Einspritzdüse, die in der oberen Totpunktstellung des Kolbens im Bereich des radial nach außen vorspringenden Endes eines Halbkreisbogens liegt, läßt sich beim Einspritzen des Kraftstoffes für den Zündstrahl eine für die Erzielung einer ausreichenden Randablösung genügend große Strahllänge erzielen, was für die Abspaltung des die Zündung auslösenden Randanteils an der oberen Ausschnittkante und das Auftreffen des Zündstrahlkerns auf einen kühleren, dicht unterhalb der Ausschnittkante gelegenen Wandteil des Brennraumes vorteilhaft ist. Die Auftreffstellen des oder der längeren Kraftstoffstrahlen auf die Brennraumwand können in an sich bekannter Weise durch Ölkühlung, insbesondere Spritzölkühlung, von der Unterseite des Kolbens her gekühlt werden; die Temperatur der Brennraumwand im Bereich der Kraftstoffaufspritzung kann auch bei stark wechselnder Belastung des Motors durch Regelung der Ölkühlung innerhalb des für den jeweils verwendeten Kraftstoff günstigsten Temperaturbereich gehalten werden. Für eine solche örtlich begrenzte Spritzölkühlung erweist es sich als vorteilhaft, wenn die die Brennraumachse und die beiden Mittelpunkt der gegeneinander versetzten Halbkreisbogen in sich aufnehmende Ebene mit der die Kolbenbolzenachse in sich aufnehmenden Axialebene des Brennraumes einen von 90° abweichenden Winkel, vorzugsweise einen Winkel von etwa 45° , einschließt. Bei einer solchen Gestaltung des Kolbens liegen die mittleren Bereiche der beiden Ausschnitthalbkreisbogen stets so weit seitlich von der Kolbenbolzenachse entfernt, daß die ihnen ent-

sprechenden Stellen auf der Unterseite des Kolbens durch das eingespritzte Kühlöl leicht erreicht werden können. Die Ölkühlung kann verbessert werden, wenn die Unterseite des Kolbenbodens im Bereich der Auftreffstellen der Kraftstoffstrahlen auf die Brennraumwand mit Kühlrippen versehen wird, die sich zwischen der Brennraumwand und dem Kolbenmantel im Bereich der Verdichtungsringe vorteilhaft radial nach außen erstrecken, wobei ein fächerartiger Kühlölstrahl von unten gegen die Kühlrippen bzw. die Kolbenunterseite in dem erwähnten Auftreffbereich des Kraftstoffes gerichtet wird.

Dabei kann durch die Ausführung des Kolbens mit den Kühlrippen bei entsprechend tiefer Ausbildung der Taschen zwischen den Kühlrippen Kolbenmaterial eingespart und das Kolbengewicht ohne Gefahr für die Festigkeit des Kolbenbodens verringert werden, was besonders bei modernen kurzhubigen Brennkraftmaschinen vorteilhaft ist, bei denen sich das Verhältnis von Hub zu Bohrung dem Wert 1 nähert.

In der Zeichnung ist die Erfindung beispielsweise veranschaulicht; es zeigt

Fig. 1 einen erfindungsgemäß gestalteten Brennraum in einem Längsschnitt nach der Linie I-I der Fig. 2,

Fig. 2 den Brennraum gemäß Fig. 1 in einer Ansicht von oben,

Fig. 3 einen mit einem Brennraum gemäß den Fig. 1 und 2 versehenen und in einem Zylinder eingebauten Kolben in einer Ansicht von oben (diese Figur veranschaulicht zugleich die kreisende Einströmung der Verbrennungsluft in den Brennraum),

Fig. 4 den Kolben gemäß Fig. 3 in einem Längsschnitt nach der Linie III-III der Fig. 5,

Fig. 5 den Kolben gemäß Fig. 4 in einer Ansicht von oben, aus der zugleich die Ausbildung der Unterseite des Kolbenbodens zu erkennen ist.

Der dem dargestellten Ausführungsbeispiel entsprechende Brennraum führt mittels seiner Seitenwandung 1 ohne Hals — oder eines sonstigen besonders abgesetzten Überganges — unmittelbar bis zum Kolbenboden 2. Der Brennraum selbst ist als Toroid mit einer unteren zentralen Kuppe ausgebildet, könnte jedoch statt dessen auch (wie es in Fig. 1 gestrichelt angedeutet ist) die Form eines Ellipsoids aufweisen. Die obere Öffnung des Brennraumes ist von zwei gegenseitig symmetrisch zur Brennraumachse versetzten Halbkreisbogen 3, 3' begrenzt, deren am weitesten nach der Mitte des Brennraumes zu gelegene Enden Kanten 4, 4' bilden und deren am weitesten außerhalb der Mitte des Brennraumes gelegene Enden 5, 5' in einer verhältnismäßig scharfen Krümmung mit den jeweils benachbarten Kanten 4' bzw. 4 des anderen Halbkreisbogens verbunden sind. Die Mittelpunkte 6, 6' der beiden Halbkreisbogen 3 und 3' sind gegenüber der Längsachse 7 des Brennraumes gegenüberliegend jeweils um die Exzentrizität $\frac{e}{2}$ versetzt, so daß sich ein Gesamtabstand der beiden Mittelpunkte 6 und 6' von e ergibt. Der Radius jedes Halbkreisbogens 3 bzw. 3' beträgt bei dem Ausführungsbeispiel $\frac{D_k}{2}$, d. h. die Hälfte des größten Durchmessers D_k des eigentlichen Brennraumes.

Gemäß Fig. 1 wird der vom oberen Rand des Brennraumes ausgehende Teil der Seitenwandung 1 durch an den eigentlichen Brennraum jeweils inner-

halb radialer Ebenen gelegte Tangenten gebildet, die zugleich durch den dortigen Punkt des oberen Brennraumrandes verlaufen. Durch diese Konstruktion ändert sich der zwischen der Seitenwand 1 und dem Kolbenboden 2 außerhalb des Brennraumes eingeschlossene Winkel (α) von einem Wert α' größer als 90° an den gegenüber dem Brennraum außenliegenden Enden 5, 5' der Halbkreisbogen 3, 3' entlang den Kreisbogen stetig bis zu einem Wert α'' kleiner als 90° an den in bezug auf den Brennraum innenliegenden Enden bzw. Kanten 4, 4' der Halbkreisbogen 3, 3'.

Wie aus Fig. 3 hervorgeht, ist die Anordnung der Halbkreisbogen 3, 3' derart auf die kreisende Bewegung der einströmenden Verbrennungsluft abgestimmt, daß die Halbkreisbogen sich dem spiralförmigen Verlauf der Einströmung bzw. dem Verlauf der hierbei gebildeten Stromlinien 8 bestmöglich anpassen. Die Stromlinien 8 der — im Zylinderraum zunächst über dem Kolben kreisenden — Luft verlaufen an den äußeren Enden 5, 5' der beiden Halbkreisbogen 3, 3' etwa entlang dem Kreisbogen und damit auch entlang dem dortigen Teil der Seitenwandung 1 des Brennraumes, während sie nach den jeweils anderen, innenliegenden Enden (Kanten 4, 4') der Kreisbogen hin eine zunehmende stärker werdende Radialkomponente aufweisen und dementsprechend zunehmend quer zu den Halbkreisbogen von außen radial nach innen verlaufen. Da an diesen Stellen die Seitenwandung 1 vom oberen Rand der Brennraumöffnung aus zugleich unter Bildung des spitzen Winkels α'' (vgl. Fig. 1) ausgeht, löst sich die dort in den Brennraum einströmende Luftströmung am oberen Rand der Brennraumöffnung ab. Die Temperaturen der Brennraumwandung 1 liegen demnach an den äußeren Enden 5, 5' der Halbkreisbogen 3, 3' verhältnismäßig niedrig und steigen entlang den Halbkreisbogen stetig zunehmend bis auf einen wesentlich höheren Wert an der Stelle der Kanten 4, 4' an.

Aus den Fig. 4 und 5 ist die Lage der Einspritzdüse 9 ersichtlich, die sich im Bereich des äußeren Endes 5' des einen Halbkreisbogens 3' und — nach dem Ausführungsbeispiel — mit ihrer Düsenöffnung innerhalb der durch die beiden Kreisbogen-Mittelpunkte 6, 6' verlaufenden axialen Ebene des Brennraumes befindet. Die Einspritzdüse 9 kann im (nicht dargestellten) Zylinderkopf der Brennkraftmaschine in einer beliebigen Lage gehalten sein. Bei in seiner oberen Totpunktlage befindlichem Kolben liegt die Düsenöffnung in unmittelbarer Nähe des dortigen Randes der Brennraumöffnung, wobei die Kraftstoffstrahlen I und II von der Düse 9 etwa in Umfangsrichtung der Brennraumöffnung und zugleich etwa in Strömungsrichtung der dort kreisend einströmenden Verbrennungsluft ausgehen. Beide Kraftstoffstrahlen I und II treffen mit ihren Strahlkernen in üblicher Weise auf die Brennraumwand 1 knapp unterhalb des oberen Brennraumrandes auf, wobei der Strahl II, der bereits nach einem kürzeren Strahlweg verhältnismäßig steil gegen die Seitenwandung 1 auftrifft, mit einem sehr kleinen Anteil über den oberen Rand der Brennraumöffnung gelangt. Der andere Strahl (I) mit wesentlich längerer freier Strahllänge trifft mit seinem Strahlkern etwa im mittleren Bereich des dortigen Halbkreisbogens 3' unterhalb des Brennraumrandes auf die dortige Seitenwandung.

Fig. 5 zeigt weiterhin, daß die die beiden Mittelpunkte 6, 6' in sich aufnehmende Axialebene des Brennraumes gegenüber der die Kolbenbolzenachse in sich aufnehmenden Axialebene des Brennraumes bzw. Kolbens im Drehsinn der kreisend einströmenden Verbrennungsluft um einen Winkel β von 45° versetzt ist. Durch diese Lage der die Mittelpunkte 6, 6' der beiden Halbkreisbogen enthaltenden Axialebene gelangt der die Auftreffstellen der Kraftstoffstrahlen I, II enthaltende Teil der Seitenwandung 1 des Brennraumes in den zwischen den beiden Kolbenbolzenaugen 10 und zugleich seitlich des (nicht dargestellten) Kolbenbolzens befindlichen Bereich des Kolbens, wo auf der Unterseite des Kolbenbodens 2 zwischen dem Brennraum und den (ebenfalls nicht dargestellten) Verdichtungsringen radial nach außen gerichtete Rippen 11 angeordnet sind. Gegen diese Rippen 11, die — wie in Fig. 4 gestrichelt angedeutet ist — auch am gegenüberliegenden Teil der Kolbenbodenunterseite angebracht sein könnten, wird beim Betrieb der Brennkraftmaschine ein fächerförmiger Kühlölstrahl 12 gespritzt. Die Stärke dieses Kühlölstrahles läßt sich durch eine außerhalb des Kolbens befindliche (nicht dargestellte) Drosselvorrichtung, die z. B. aus einer in dem vom Ölkreislauf der Brennkraftmaschine getrennten Kühlölkreislauf befindlichen Drosselklappe einem Drosselventil oder einem Drosselschieber bestehen könnte, regeln, damit die günstigste Temperatur des Kolbenbodens 2 an den Auftreffstellen des Kraftstoffes auch während des Betriebes leicht einreguliert werden kann.

Die in Fig. 4 gestrichelt angedeutete Anordnung der weiteren Kühlrippen verursacht bei entsprechend ausgeführten Kolben zwar eine gewisse Gewichtsvermehrung, bringt demgegenüber aber den Vorteil mit sich, daß beim Einbau des Kolbens nicht mehr darauf geachtet werden muß, daß sich die Kühlrippen 11 auch tatsächlich an der Stelle der über dem Kolben befindlichen Einspritzdüse 9 befinden.

Zu der erfindungsgemäßen Kolbenform ist noch zu bemerken, daß sich eine solche Brennraumform zur maschinellen Bearbeitung nicht eignet. Andererseits läßt sich aber bei dem heutigen Stande der Gießereitechnik ein genügend genaues und sauberes Gießen des Kolbens mit dem erfindungsgemäßen Brennraum in einer Kokille ohne jede Schwierigkeit erzielen. Für einen solchen Kokillenguß eignet sich die Brennraumform — trotz der Notwendigkeit zweier Kerne — recht gut, so daß solche im Kokillenguß hergestellten Kolben wesentlich billiger ausfallen als Kolben mit einem in bisher üblicher Weise maschinell bearbeiteten Brennraum. Sollten bei den im Kokillenguß hergestellten Kolben kleine Unebenheiten an der Brennraumwandung im Bereich der Auftreffstellen des Kraftstoffes auftreten, so sind diese der einwandfreien Ausbreitung, Zerstäubung und Verdampfung des auftreffenden Kraftstoffes keineswegs abträglich, weil sie die Zerstäubung und Durchmischung des aufgespritzten Kraftstoffes mit der einströmenden Verbrennungsluft sogar begünstigen.

Die Erfindung ist nicht an die konstruktiven Einzelheiten des Ausführungsbeispiels gebunden. So braucht z. B. der Radius der Halbkreisbogen 3, 3' nicht genau dem größten Halbmesser des Brennraumes zu gleichen. Der Radius der Halbkreisbogen könnte vielmehr auch größer oder kleiner als der ge-

nannte Durchmesser sein. Ebenso braucht der Winkel β zwischen der die beiden Mittelpunkte 6, 6' enthaltenden Axialebene und der die Kolbenbolzenachse enthaltenden Axialebene nicht gerade 45° zu sein, obgleich ein solcher Winkel wegen der sich daraus ergebenden günstigen Kühlmöglichkeit für die Kolbenunterseite an der Auftreffstelle der Kraftstoffstrahlen bevorzugt wird. Dagegen soll dieser Winkel β zumindest größer als 0 und kleiner als 90° sein.

Patentansprüche:

1. Brennkraftmaschine mit direkter Kraftstoffeinspritzung und Verdichtungszündung, mit einem im Kolbenboden symmetrisch oder beinahe symmetrisch zur Zylinderachse angeordneten und im wesentlichen rotationskörperförmigen Brennraum, in welchem sich gegen Ende des Verdichtungshubes nahezu das gesamte angesaugte Luftvolumen befindet, das vorher in eine heftige Drehbewegung um die Brennraumachse versetzt wurde, und mit einer zu diesem Brennraum außermittig angeordneten Einspritzdüse, die den Kraftstoff in mindestens zwei Kraftstoffstrahlen von verschiedener freier Länge im wesentlichen in Richtung der in den Brennraum einströmenden Verbrennungsluft an verschiedenen heißen Wandstellen des Brennraumes spritzt, von denen der kürzeste Kraftstoffstrahl mit einem kleinen Anteil über den Rand der Brennraumwand gegen den Boden des Kolbens gespritzt wird, während der übrige, weitaus größere Teil dieses »Zündstrahles« noch gegen den unmittelbar neben dem Rand befindlichen Teil der Brennraumwand gerichtet ist, nach Patent 1 175 486, dadurch gekennzeichnet, daß die Verbindungsöffnung vom Brennraum zum Zylinderraum am Kolbenboden (2) von zwei gegenseitig symmetrisch zur Brennraumachse (7) versetzten Halbkreisbogen (3, 3') begrenzt ist, wobei die von den beiden Halbkreisbogen (3, 3') in den nach dem Brennraumboden zu gelegenen Brennraumunterteil führenden Seitenwände (1) des Brennraumes mit dem benachbarten Kolbenboden je einen Winkel (α) einschließen, der sich von einem Wert (α) größer als 90° an den gegenüber dem Brennraum außenliegenden Enden (5, 5') der Halbkreisbogen (3, 3') im Drehsinn der kreisend einströmenden Verbrennungsluft stetig bis zu einem Wert (α') kleiner als 90° an den in bezug auf den Brennraum innenliegenden Enden (4, 4') der Halbkreisbogen (3, 3') verkleinert, und daß der Mantelanteil des Zündstrahls (II) den Brennraumrand in dem im Sinne der Luftströmung noch etwas vor der Mitte liegenden Abschnitt eines der Halbkreisbogen überspritzt, während der Kraftstoff des bzw. der weiteren Kraftstoffstrahlen (I) etwa unterhalb des mittleren Bereiches des Halbkreisbogens auf den oberen Teil der Brennraum-Seitenwand (1) auftritt.

2. Brennkraftmaschine nach Anspruch 1, dadurch gekennzeichnet, daß die Einspritzdüse (9) an einer Stelle liegt, die sich bei in seiner oberen Totpunktlage befindlichem Kolben im Bereich des äußeren Endes (5') eines (3') der beiden Halbkreisbogen (3, 3') befindet, und ihre Kraftstoffstrahlen (I, II) im wesentlichen nach dem

11

mittleren Bereich des Halbkreisbogens (3') gerichtet sind.

3. Brennkraftmaschine nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Brennräumachse (7) und die Mittelpunkte (6, 6') der beiden Halbkreisbogen (3, 3') in sich aufnehmende Ebene mit der die Brennräumachse (7) und die Kolbenbolzenachse in sich aufnehmenden Ebene einen Winkel (β) größer als 0 und kleiner als 90° einschließt.

4. Brennkraftmaschine nach Anspruch 3, dadurch gekennzeichnet, daß der Winkel (β) von der die Brennräumachse (7) und die Mittelpunkte (6, 6') der beiden Halbkreisbogen (3, 3') aufnehmenden Ebene aus, entgegen dem Drehsinn der kreisend einströmenden Verbrennungsluft gemessen, einen Wert von etwa 45° aufweist.

5. Brennkraftmaschine nach den Ansprüchen 3 und 4, dadurch gekennzeichnet, daß der Kolbenboden (2) an seiner Unterseite zumindest im Bereich der Auftreffstelle der Kraftstoffstrahlen (I, II) auf die Brennräumwand (1) mit Kühlrippen (11) versehen ist, die für eine an sich be-

12

kannte Ölkühlung vom Kurbelraum der Brennkraftmaschine her bestimmt sind.

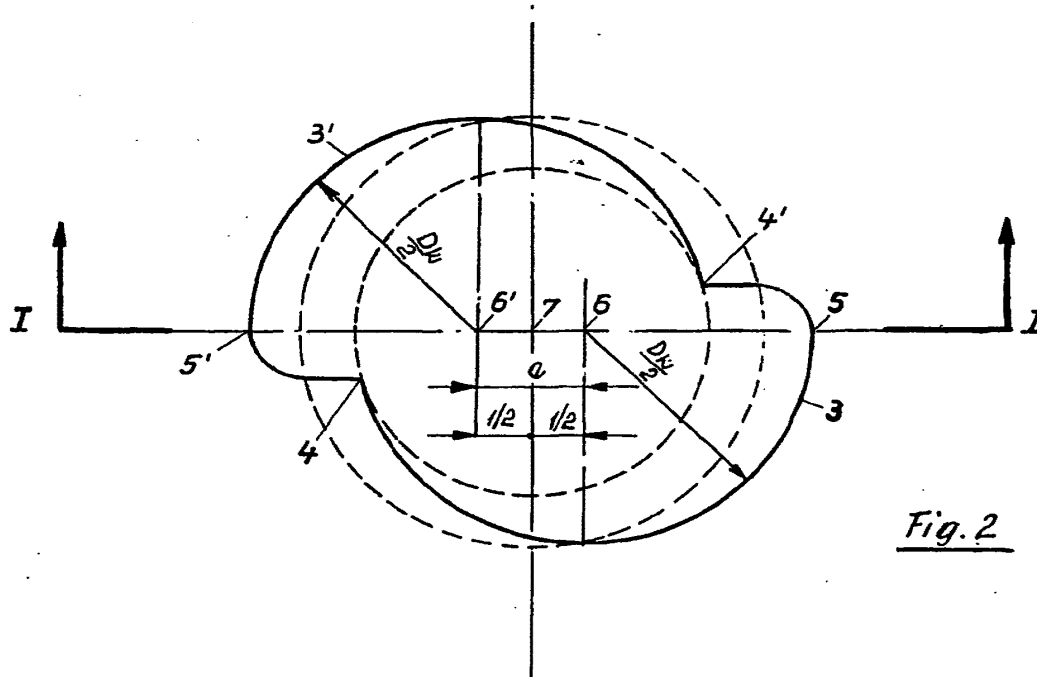
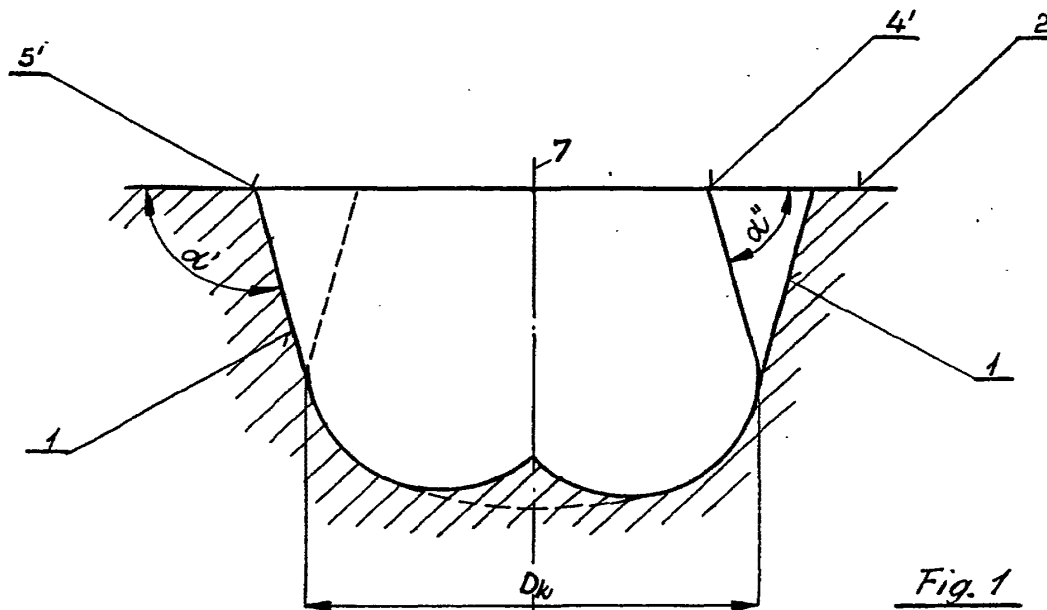
6. Brennkraftmaschine nach Anspruch 5, dadurch gekennzeichnet, daß die Kühlrippen (11) sich zwischen dem Brennräumboden und dem Kolbenmantel im Bereich der Verdichtungsringe radial nach außen erstrecken.

7. Brennkraftmaschine nach Anspruch 5 oder 6, dadurch gekennzeichnet, daß zur Ölkühlung der Unterseite des Kolbenbodens ein fächerartiger Kühlölstrahl dient und die Menge des Kühlöls regelbar ist.

In Betracht gezogene Druckschriften:

Deutsche Patentschrift Nr. 804 048;
deutsche Patentanmeldung K 16079 Ia/46 a² (bekanntgemacht am 29. 9. 1955);
deutsche Auslegeschrift M 23017 Ia/46 c⁴ (bekanntgemacht am 9. 5. 1956);
französische Patentschriften Nr. 65 833, Zusatz zu Nr. 1 067 634, 1 127 202;
USA.-Patentschrift Nr. 2 762 347.

Hierzu 1 Blatt Zeichnungen



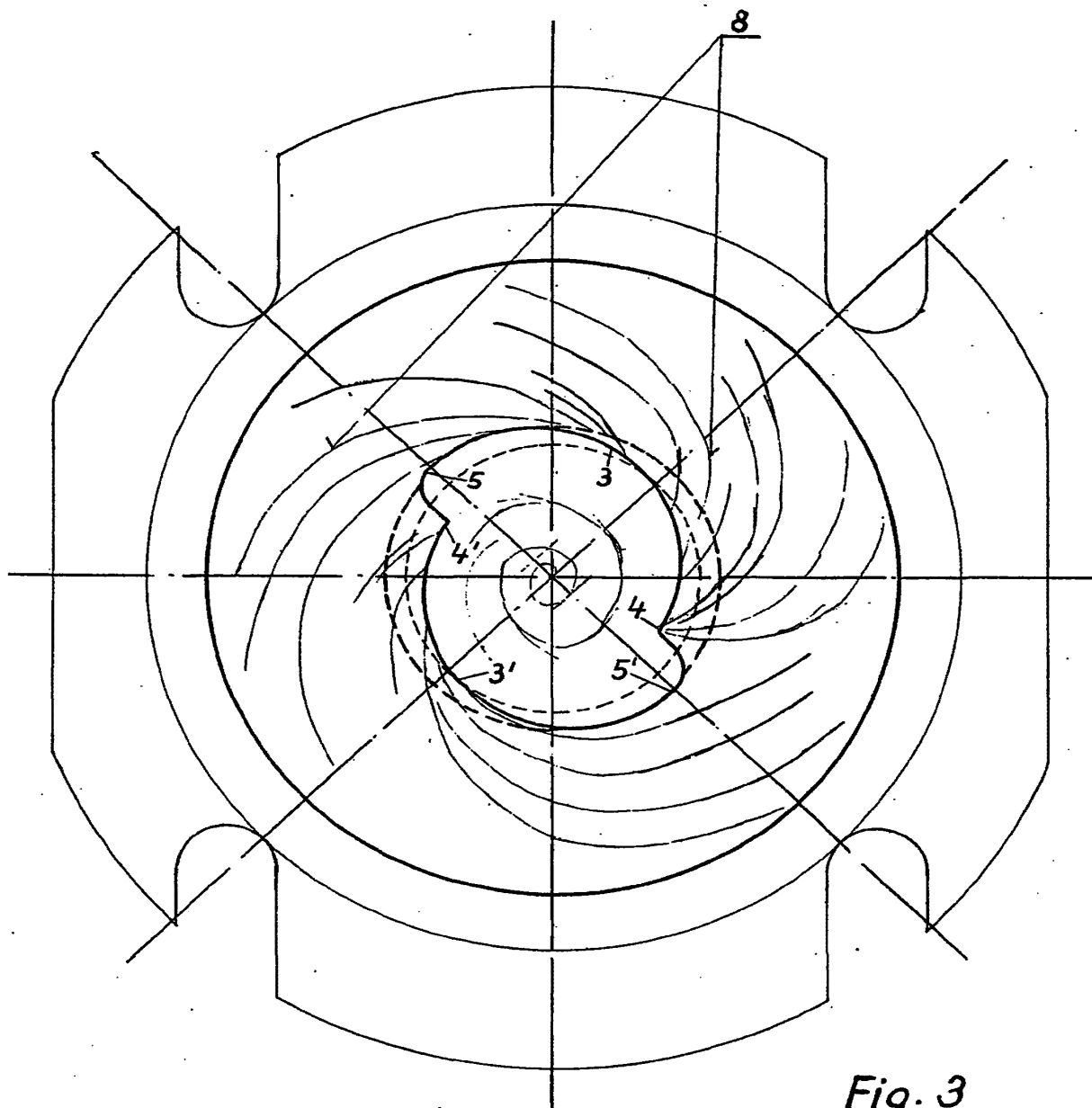


Fig. 3



Direct injection Diesel engine with combustion chamber in piston

Patent number: DE19649052

Publication date: 1998-05-28

Inventor: VELJI AMIN DR ING (DE); DANCKERT BERND DIPL
ING (DE); DONAUER GEORG (DE); DORNER
WALTER (DE)

Applicant: MOTOREN TURBINEN UNION (DE)

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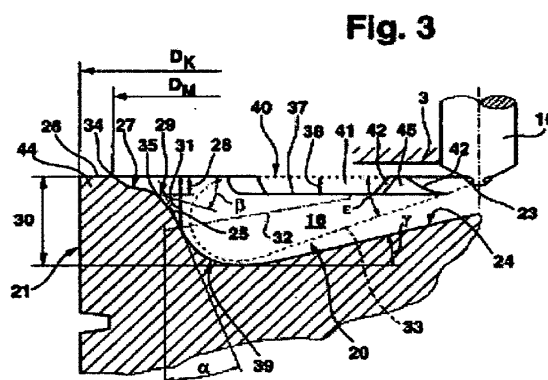
 EP0845589 (A1)

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Abstract not available for DE19649052

Abstract of corresponding document: **EP0845589**

The diesel engine has a trough (18) in the piston crown, the bottom (24) of which runs divergently from the plane (26) of the crown top. The circular input aperture surface of the trough has a diameter at least 0.8 of that of the piston. There is a diffuser recess (27) at the edge of the trough which is co-axial with the trough. It rises from a transition sector (29) of the circumferential wall (25) at decreasing diameter towards the top of the crown, eliminating sharp edges in the regions of the combustion chamber not used in mixture formation.



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①9 BUNDESREPUBLIK
DEUTSCHLAND



DEUTSCHES
PATENTAMT

⑫ **Offenlegungsschrift**
⑩ **DE 196 49 052 A 1**

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⑦① Anmelder:
MTU Motoren- und Turbinen-Union
Friedrichshafen GmbH, 88045 Friedrichshafen, DE

⑦② Erfinder:
Velji, Amin, Dr.-Ing., 88677 Markdorf, DE; Danckert,
Bernd, Dipl.-Ing., 88046 Friedrichshafen, DE;
Donauer, Georg, 88048 Friedrichshafen, DE; Dörner,
Walter, 88677 Markdorf, DE

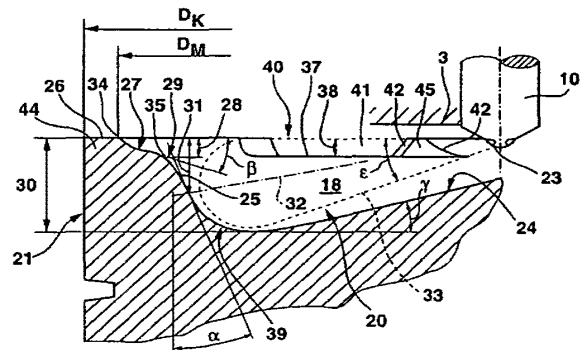
⑤⑥ Entgegenhaltungen:
DE 37 42 574 C1
DE 35 01 271 C2
GB 10 93 341
US 39 54 089
MTZ, 57, 1996, S. 336-348;

Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen

Prüfungsantrag gem. § 44 PatG ist gestellt

⑤④ Dieselmotor mit Direkteinspritzung und einer Kolbenmulde

⑤⑦ Bei einem Dieselmotor mit drallarmer luftverteilernder Direkteinspritzung über ein Druckspeichereinspritzsystem (Common-Rail) in einen flachen Brennraum (11) ist im Kolbenboden (21) eine Kolbenmulde (18) vorgesehen, die vom Muldengrund (24) aus zur Planfläche (26) des Kolbenbodens (21) hin divergent ausgebildet ist und deren kreisförmige Eintrittsöffnungsfläche (40) einen Durchmesser (DM) aufweist, der mindestens dem 0,8fachen des Kolbendurchmessers (DK) entspricht. Am Muldenrand ist eine zur Kolbenmulde (18) koaxial angeordnete Diffusorausnehmung (27) vorgesehen, die ausgehend von einem im Abstand (28) unterhalb der Planfläche (26) des Kolbenbodens (21) ausgebildeten, abgerundeten Übergang (9) der Umfangswand (25) mit zunehmendem Muldendurchmesser (DM) zur Planfläche (26) des Kolbenbodens (21) hin ansteigt. Der dadurch minimierte Anteil nicht zur Gemischbildung nutzbarer Brennraumbereiche, wie zum Beispiel der Quetschspalt- und der Ventiltaschenanteil sowie wenige scharfe Kanten im Übergangsbereich zwischen Quetschspalt und Brennraummulde bewirken eine Ladungsberuhigung, durch die über das Druckspeichereinspritzsystem eine weitgehend kennfeldunabhängige Steuerung der Hochdruckeinspritzung zur Darstellung eines Brennverlaufs mit erheblich reduziertem Schadstoffausstoß bei unverändert hohem Wirkungsgrad des Dieselmotors erreicht wird.



DE 196 49 052 A 1

Beschreibung

Die Erfindung betrifft einen Dieselmotor mit drallamer luftverteiler Direkteinspritzung und einem flach ausgebildeten Brennraum gemäß dem Oberbegriff des Patentanspruchs 1.

Von einem hochaufgeladenen Dieselmotor (MTZ, Motor-technische Zeitschrift, Heft 6, 1996) der eingangs genannten Art, ist es bekannt, daß durch den Übergang auf ein drallarmes Diesel-Gemischbildungs- bzw. Brennverfahren in Kombination mit einem leistungsfähigen Einspritzsystem ein deutlich günstigerer Kompromiß hinsichtlich Kraftstoffverbrauch und Stickoxid- bzw. Partikelaustritt erreicht wird. Eine Reduzierung der Zylinderladungsbewegung wird dort durch Absenken des Einlaßdrallniveaus sowie Aufweiten des Kolbenmuldendurchmessers erreicht, während eine gleichzeitige Verbesserung der Kraftstoffzerstäubungsgüte durch Anheben des Einspritzdrucks auf über 1000 bar den für die Dieselmischbildung notwendigen Massentransport bewerkstelligt. Ferner wurde für weitere Untersuchungen darauf hingewiesen, daß sich eine weitere Steigerung der Leistungsfähigkeit des Einspritzsystems in Kombination mit einer weiteren Absenkung des Einlaßdrallniveaus positiv hinsichtlich des Partikel-/Stickoxid-Zielkonflikt nutzen läßt. Versuche der Anmelderin haben gezeigt, daß bei dem bekannten Dieselmotor mit offener Brennraummulde besonders im oberen Leistungsbereich der Schadstoffausstoß nicht zufriedenstellende Werte erreicht.

Der Erfindung liegt die Aufgabe zugrunde, einen gattungsgemäßen Dieselmotor derart weiterzubilden, daß eine zusätzliche Reduzierung der Schadstoffemissionen, insbesondere Partikel- und Stickoxidemission, durch weitere Verbesserung der Gemischbildung bei Brennverfahren mit vorwiegender Luftverteilung, unter Beibehalten eines hohen Wirkungsgrades erreicht wird.

Erfindungsgemäß wird diese Aufgabe durch die Gesamtheit der Merkmale des Anspruchs 1 gelöst. Vorteilhafte Weiterbildungen der Erfindung sind durch die Unteransprüche gekennzeichnet.

Dabei bestehen die mit der erfindungsgemäßen Ausgestaltung der weiten divergenten Kolbenmulde bei einem Dieselmotor mit einem Kraftstoffversorgungssystem hoher hydraulischer Leistungsfähigkeit erzielten Vorteile in einer deutlich verbesserten Lufterfassung und einer wesentlichen Beruhigung der Zylinderladung. Beides begünstigt eine optimale Durchmischung des Kraftstoffs mit der gesamten Luft im Brennraum durch die kinetische Energie der Kraftstoffeinspritzstrahlen und verringert so die Abgasemissionen, insbesondere den Partikelaustritt und die Stickoxidanteile, erheblich.

Durch die Form der zur Planfläche des Kolbenbodens hin divergenten Kolbenmulde mit der am Kolbenrand ausgebildeten Diffusorausnehmung wird der Anteil bisher nicht zur drallarmen Gemischbildung nutzbarer Brennraumbereiche minimiert. Die Kolbenmulde ist dadurch an die Lage und Kontur der sich bei den jeweils vorherrschenden Einspritzbedingungen durch das Kraftstoffeinspritzsystem und die Einspritzmimik bei Vollast gebildeten Einspritzstrahlkegel mit großen Strahllängen in einer Weise angepaßt, die ein direktes Benetzen der Kolbenmulde verhindert. Über diese erfindungsgemäß geschaffenen großen freien Strahllängen durchdringen die hochenergetischen Einspritzstrahlen den Brennraum. Mit zunehmender Strahlausbreitung entzündet sich der fein zerstäubte Kraftstoffnebel, wobei die divergente Muldenform und speziell die mit zunehmendem Durchmesser ansteigende Diffusorausnehmung die Flammenausbreitung in radial außen liegende Brennraumbereiche bei Annäherung des Kolbens an die obere Totpunktstel-

lung und während der Kolbenabwärtsbewegung im Expansionstakt begünstigt.

Die Aufweitung des Muldendurchmessers an der Kolbenmuldeneintrittsfläche auf mindestens das 0,8-fache des Kolbendurchmessers trägt neben der verbesserten Lufterfassung zu einer bedeutenden Reduzierung des strömungsmechanischen Einflusses der Kolbenhubbewegung auf die Gemischbildung bei. Durch den damit auf maximal das 0,2-fache des Kolbendurchmessers festgelegten sogenannten Kolbensteg ist der verbleibende Planflächenanteil des Kolbenbodens auf ein bedeutungsloses Maß reduziert. Der im verbleibenden Minimalquetschspalt zwischen dem Kolbensteg und dem Zylinderkopfboden während der Aufwärtsbewegung des Kolbens erzeugte, zur Kolbenmuldenmitte orientierte Strömungsimpuls ist soweit abgesenkt, daß davon keine Quetschströmung mehr aufgebaut wird, die der Einspritzstrahlausbreitung entgegengerichtet wirkt. Eine Behinderung der Strahl- und/oder Flammausbreitung bedingt durch ein Abbremsen der Strahlen in radialer Richtung, was zu einer örtlichen Kraftstoffanhäufung und erhöhtem Partikelaustritt führt, wird vermieden.

Der vom Rest-Quetschspalt ausgehende Strömungsimpuls wird ferner über die radiale Strecke der zur Mulde hin abfallenden Diffusorausnehmung und im Zusammenwirken mit einem strömungsgünstig gewählten Radius des Übergangs zur Umfangswand der Kolbenmulde soweit abgebaut, daß die bisher im Bereich des scharfkantigen Randes einer herkömmlichen Kolbenmulde in der Vertikalebene gebildeten Wirbelgebiete bedeutend reduziert werden. Deshalb zeichnet sich die erfindungsgemäße Kolbenmulde durch schwache wandnahe Wirbelgebiete aus und verhindert auf diese Weise Kraftstoffniederschlag auf der Wand der Kolbenmulde und dem Muldengrund. Dies sind Vorteile, die insbesondere im oberen Leistungsbereich des Dieselmotors ein Ansteigen des Rußpartikelaustritts verhindern.

Schließlich bietet die erfindungsgemäße Gestalt der Kolbenmulde neben dem Abbau von durch die Kolbenbodengestaltung bedingten Ladungsturbulenzen den Vorteil einer über den Kompressionstakt und die gesamte Dauer der Kraftstoffeinspritzung gleichförmigen Drehbewegung der Zylinderladung in der Kolbenmulde. Insbesondere findet auch bei Annäherung des Kolbens an seine obere Totpunktstellung keine Drallüberhöhung statt. Vielmehr stellt sich in der Mulde über die gesamte Einspritzdauer eine geordnete Luftbewegung mit konstanter Winkelgeschwindigkeit ein, die in Form einer Festkörper-Drehströmung jeweils den gesamten Brennraumsektor zwischen benachbarten Einspritzstrahlen überstreicht und so ein Ineinanderwehen der Einspritzstrahlen verhindert.

Eine zusätzliche Beruhigung der Zylinderladung schafft die erfindungsgemäße Gestaltung der Kolbenmulde bei Dieselmotoren mit im Kolbenboden ausgebildeten Ventiltaschen. Durch die divergente Umfangswand und die Diffusorausnehmung der aufgeweiteten Kolbenmulde verbleiben lediglich segmentförmige Ventiltaschenanteile im äußeren Rand des Kolbenbodens. Diese bilden in Abhängigkeit der Tiefe der Diffusorausnehmung bzw. von dem Abstand des Übergangs von der Umfangswand in die Diffusorausnehmung zur Planfläche des Kolbens sowie deren Neigungsverlauf deutlich weniger Verschneidungskanten und Flächenanteile aus als herkömmliche Kolbenmulden. Dadurch werden der einströmenden Ladeluft bedeutend weniger Turbulenzen aufgeprägt, die als wandnahe Wirbelgebiete im Bereich dieser Kanten zu lokalen Kraftstoffanhäufungen führen und die dann unter erhöhter Ruß- und Hitzeentwicklung verbrennen.

Ferner schaffen die auf kleinere Muldenbereiche reduzierten Ventiltaschenanteile der erfindungsgemäßen Mul-

dengestalt günstige Voraussetzungen für die Verwendung einer Einspritzdüse mit mehr als sechs Einspritzbohrungen zur Intensivierung der Gemischbildung. Insbesondere kann durch den Einsatz einer Neun-Lochdüse eine besonders hohe Strahlzerstäubungsgüte erzielt werden.

Bei einer bevorzugten Ausführungsform der Kolbenmulde ist der Übergang der Umfangswand in die Diffusorausnehmung in einem Abstand zur Planfläche des Kolbenbodens ausgebildet, der der erforderlichen Tiefe der Ventiltaschen entspricht. Die segmentförmigen Ventiltaschen gehen dabei harmonisch in den Radius des Übergangs über und verlaufen so ohne Ausbildung einer senkrecht zur Strahl- bzw. Flammenausbreitung liegenden Kante in die Kolbenmulde. Strömungsturbulenzen sowie die Bildung von Hitzerrissen in diesem Bereich infolge thermischer Überbeanspruchung werden vermieden.

Durch das von der Kolbenbewegung bzw. Kolbenstellung weitgehend unabhängige neutrale Verhalten der erfindungsgemäßen Kolbenmulde auf die Strömungsverhältnisse der Zylinderladung im Brennraum wird bei dem drallarmen Brennverfahren eine verbrauchs- und partikelgünstigere Steuerung des Verbrennungsablaufs über das Einspritzsystem erreicht. Insbesondere bei Verwendung eines Druckspeicher-Einspritzsystems, wie z. B. dem Common-Rail-System, kann im Zusammenwirken mit der erfindungsgemäßen Kolbenmulde eine NO_x-optimierte Einspritzmen-
 20 genmodulierung dargestellt werden, während eine optimale Diesel-Gemischbildung durch den unabhängig von der Motordrehzahl im Druckspeicher kontinuierlich verfügbaren Einspritzdruck unter Ausnutzung der kinetischen Energie der Einspritzstrahlen sichergestellt ist.

Nachfolgend ist die Erfindung anhand eines in der Zeichnung dargestellten Ausführungsbeispiels genauer beschrieben. Es zeigt:

Fig. 1, die Kolben-Zylinder-Anordnung des erfindungsgemäßen Dieselmotors mit einem Druckspeicher-Einspritzsystem;

Fig. 2, den erfindungsgemäßen Kolbenboden mit Einspritzstrahlmuster in Draufsicht;

Fig. 3, eine Schnittansicht des Kolbenbodens entlang des Schnittverlaufs III-III in Fig. 2.

Bei dem in Fig. 1 dargestellten Dieselmotor wird ein flacher Brennraum 11 durch einen Zylinder 2, durch den Kolbenboden 21 eines im Zylinder 2 verschieblich angeordneten Kolbens 1 sowie einem ebenen Zylinderkopfboden 3 begrenzt. In den Brennraum 11 ragt ein Einspritzventil 10 einer Einspritzvorrichtung 4, die zentrisch zum Brennraum 11 im Zylinderkopfboden 3 angeordnet ist. Die Einspritzvorrichtung 4 ist Teil eines Druckspeicher-Einspritzsystems, bei dem eine Kraftstoffpumpe 6 Kraftstoff aus einem Kraftstofftank 5 über eine Kraftstoffleitung 7 unter hohem Druck in einen Druckspeicher 17 (Common-Rail) fördert, der über eine Einspritzleitung 8 und ein Zumeßventil 9 mit dem Einspritzventil 10 verbunden ist. In bekannter Weise regelt eine Steuereinheit 12 den Kraftstoffdruck im Druckspeicher 17, unabhängig von der Motordrehzahl, auf ein über Eingang 13 vorgegebenes Druckniveau von über 1000 bar durch entsprechende Ansteuerung der Kraftstoffpumpe 6 über die Signalleitung 16 aus. Gleichzeitig steuert die Steuereinheit 12 über die Ansteuerleitung 15 das Öffnungsverhalten des Zumeßventils 9 und darüber den Einspritzvorgang. Alternativ zu dem Druckspeicher-Einspritzsystem können auch andere Hochdruck-Einspritzsysteme mit ausreichender hydraulischer Leistungsfähigkeit, wie z. B. ein Pumpe-Düse-Einspritzsystem, zur Dieselmischbildung verwendet werden.

Während der Einspritzphase, bei geöffnetem Zumeßventil 9, wird bei dem dargestellten Ausführungsbeispiel der Kraftstoff über acht Einspritzbohrungen 23 des Einspritz-

ventils 10 im wesentlichen radial und unter einem Spritzwinkel δ von 150° bis 170°, hier 160°, in den Brennraum 11 abgespritzt. Die Einspritzbohrungen 23 haben einen Durchmesser von 0,32 mm und bilden einen Strahlöffnungswinkel ϵ von 20° aus.

Der Kolbenboden 21 des in den Fig. 1 und 3 jeweils in oberer Totpunktstellung gezeigten Kolbens 1 bildet eine zentrisch angeordnete rotationssymmetrische offene Kolbenmulde 18 mit einer Eintrittsöffnung 40 aus, deren Durchmesser DM das 0,8-fache des Kolbendurchmessers DK beträgt. Umfangswand 25 und Muldengrund 24 der Kolbenmulde 18 sind an die durch den Spritzwinkel δ vorgegebene Lage und die Kontur 33 der bei maximaler Leistung des Einspritzsystems ausgebildeten Strahlkegel 20 derart angepaßt, daß in der oberen Totpunktstellung des Kolbens 1 eine Kollision der Strahlkeulen 20 sowohl mit der Umfangswand 25 als auch dem Muldengrund 24 vermieden wird. Dazu ist der Muldengrund 24 kegelförmig ausgebildet und steigt unter einem Neigungswinkel γ von 11° zur Kolbenmitte hin an. Radial nach außen geht der Muldengrund 24 im Bereich zwischen der maximalen Muldentiefe 30 und dem Abstand 31, wo die gedachten Strahlachsen 32 der Strahlkeulen 20 die Umfangswand 25 der Kolbenmulde 18 schneiden, in die Umfangswand 25 über. Der Verlauf des Übergangsbereichs 29 ist exakt an die Kontur 33 der Einspritzkegel 20 angepaßt. Ausgegangen wird hierbei von einer Form der Einspritzstrahlen bzw. einer Kontur 33 der Einspritzkegel 20, wie sie sich in Abhängigkeit der hydraulischen Leistungsfähigkeit des Einspritzsystems durch Simulation aus den empirischen Formeln von Hiroyasu/Arai ergeben. Bei dem hier dargestellten Ausführungsbeispiel entspricht dies im Übergangsbereich 29 einem Radius von 13 mm. Aus dem gleichen Simulationsmodell für die Einspritzstrahlkontur 33 ergibt sich die maximale Muldentiefe 30 von hier 15,8 mm bei einem Einspritzdruck von 1200 bar und einem Verdichtungsverhältnis von $\epsilon = 14$.

Die Umfangswand 25 ist konisch ausgebildet und weist einen Neigungswinkel α von etwa 15° bis 45° auf. In einem Abstand 28 unterhalb der Planfläche 26 des Kolbenbodens 21 geht die Umfangswand 25 in eine Diffusorausnehmung 27 über. Der Abstand 28 ist hier gleich der Tiefe 38 der weiter unten beschriebenen Ventiltaschen 37 gewählt. Grundsätzlich kann er je nach Ausbildung des Einspritzsystems, bzw. der durch obiges Simulationsmodell ermittelten Strahlkeulenform, auf einen Wert zwischen der Tiefe 38 der Ventiltaschen 37 und dem durch die Schnittebene der Strahlachse 32 definierten Abstand 31 festgelegt werden.

Die Diffusorausnehmung 27 ist am Muldenrand kreisförmig und koaxial zur Kolbenmulde 18 als konische Ausdehnung dargestellt. Sie schließt mit dem ebenen Zylinderkopfboden 3 einen Winkel β im Bereich von etwa 10° bis 30° ein. Die Ausbildung der Diffusorausnehmung 27 ist nicht auf die konische Ausdehnung beschränkt; vielmehr kann anstelle des linearen Anstiegs unter einem Winkel β jeder stetige Verlauf mit positiver Steigerung zur Planfläche 26 des Kolbenbodens 21 hin vorgesehen sein. Wesentlich dabei ist allerdings, daß der Übergang 29 von der Umfangswand 25 auf die Diffusorausnehmung 27 abgerundet ist, wobei der den Übergang bildende Radius 35 so gewählt ist, daß sich die in der Kolbenmulde 18 einstellende Festkörper-Drehströmung der Zylinderladung nicht von der Wand ablöst. Bei dem Ausführungsbeispiel wird dies mit einem Radius 35 von 4 mm erreicht der grundsätzlich zwischen 4 mm und 15 mm variieren kann. Die Diffusorausnehmung 27 geht über einen Radius 34 in die Planfläche 26 des Kolbenbodens 21 über. Dieser Radius 34 beträgt zwischen 2 mm und 4 mm.

Wie Fig. 2 zeigt, sind vier Ventiltaschen 30 symmetrisch

verteilt im Bereich der erfindungsgemäßen Diffusorausnehmung 27 und der verbleibenden ringförmigen Planfläche 26 ausgebildet, die aufgrund der erfindungsgemäßen Aufweitung und Gestaltung der Kolbenmulde 18 lediglich noch segmentförmige Grundflächen im Kolbenboden 21 annehmen. Die Tiefe 38 und Größe der Ventiltaschen 37 ist konstruktiv durch den erforderlichen Hub der Gaswechselventile und die Spaltbreite zwischen Kolbensteg 44 und dem Zylinderkopfboden 3 in oberer Totpunktstellung des Kolbens bestimmt. Die Ventiltaschen 37 bilden zusammen mit dem verbleibenden Kolbensteg 44 Verschneidungskanten 43 sowie dadurch festgelegte Schnittflächen 45 aus, deren Verlauf und Länge durch die Gestaltung der Diffusorausnehmung 27 bestimmt sind. Bei dem dargestellten Ausführungsbeispiel ist der Abstand 28 des Übergangs 29 zur Planfläche 26 des Kolbenbodens 21 gleich groß gewählt, wie die Tiefe 38 der Ventiltaschenausnehmung 27. Dadurch gehen die Ventiltaschen 37 harmonisch in den abgerundeten Übergang 29 über, was im Hinblick auf oben beschriebene Strömungsmechanik und thermische Beanspruchung Vorteile 20 bietet.

Durchbrüche 41 im Kolbensteg 44 erhöhen die mechanische und thermische Standfestigkeit des Kolbenbodens 21 in Bereichen wo die Ventiltaschen 37 zu einer ausgeprägten Schwächung der Kolbenstegdickte führen. Die Durchbrüche 41 bilden in Umfangsrichtung Anfasungen 42 aus, um einerseits die thermische Standfestigkeit des Kolbenstegs 44 zu gewährleisten andererseits der einströmenden Ladeluft möglichst geringen Strömungswiderstand zu bieten. Aus gleichen Gründen sind auch sämtliche verbleibenden Kanten und/oder Stufen abgerundet. 30

Bezugszeichenliste

1 Kolben
2 Zylinder
3 Zylinderkopfboden
4 Einspritzvorrichtung
5 Kraftstofftank
6 Kraftstoffpumpe
7 Kraftstoffleitung
8 Einspritzleitung
9 Zumeßventil
10 Einspritzventil
11 Brennraum
12 Einspritzstauleitung
13 Eingang
14 Eingang
15 Ansteuerleitung
16 Signalleitung
17 Druckspeicher
18 Kolbenmulde
19 Einspritzstrahl
20 Strahlkegel
21 Kolbenboden
22 Gaswechselventil
23 Einspritzbohrung
24 Muldengrund
25 Umfangswand
26 Planfläche
27 Diffusorausnehmung
28 Abstand
29 Übergang
30 Muldentiefe
31 Abstand
32 Strahlachsen
33 Kontur
34 Radius

35 Radius
36 Gaswechselventil
37 Ventiltaschen-Ausnehmung
38 Tiefe Ventiltasche
39 Übergangsbereich
40 Eintrittsöffnung
41 Durchbruch
42 Anfasung
43 Verschneidungskante
44 Kolbenstellung
45 Schnittfläche
 α Winkel, Umfangswand
 β Winkel, Diffusorausnehmung
 γ Winkel, Muldengrund
 δ Spritzwinkel
 ϵ Strahlöffnungswinkel

Patentansprüche

1. Dieselmotor mit drallarmer luftverteilernder Direktein-spritzung und mit einem flach ausgebildeten Brennraum (11), der von einem Zylinder (2), einem Zylinderkopfboden (3) und einem Kolbenboden (21) begrenzt ist, wobei im Kolbenboden (21) eine kreisförmige offene Kolbenmulde (18) mit einer Umfangswand (25) und einem Muldengrund (24) vorgesehen ist, sowie einer zentrisch zur Kolbenmulde (18) angeordneten, von einer Kraftstoffpumpe (6), insbesondere über einen Druckspeicher (17), unter hohem Druck mit Kraftstoff versorgten Einspritzvorrichtung (4), durch deren Einspritzöffnungsgeometrie (23) Kraftstoff in mehreren Strahlkegeln (20) im wesentlichen radial abgespritzt wird, wobei die Strahlachsen (32) der Strahlkegel (20) die Kolbenmulde (18) etwa in einer Schnittebene unterhalb der Planfläche (26) des Kolbenbodens treffen, **dadurch gekennzeichnet**, daß der Kolbenboden (21) eine vom Muldengrund (24) aus zur Planfläche (26) des Kolbenbodens hin divergent verlaufende Kolbenmulde (18) ausbildet, deren Durchmesser (DM) mindestens dem 0,8-fachen des Kolbendurchmesser (DM) entspricht, wobei am Muldenrand eine zur Kolbenmulde (18) koaxial angeordnete, kreisringförmige Diffusorausnehmung (27) vorgesehen ist, die ausgehend von einem im Abstand (28) unterhalb der Planfläche (26) des Kolbenbodens (21) ausgebildeten abgerundeten Übergang (29) der Umfangswand (25) mit zunehmendem Muldendurchmesser (DM) zur Planfläche (26) des Kolbenbodens hin ansteigt.

2. Dieselmotor nach Anspruch 1, dadurch gekennzeichnet, daß die Kolbenmulde (18) derart an die Lage (8) und die Konturen (33) der Strahlkegel (20) bei maximaler Leistung des Einspritzsystems angepaßt ist, daß in der oberen Totpunktlage des Kolbens (1) ein Benetzen der Kolbenmulde (18) mit Kraftstoff vermieden wird, wobei mindestens die Umfangswand (25) der Kolbenmulde (18) im Bereich zwischen der maximalen Muldentiefe (30) und dem Abstand (31) der Schnittebene der Strahlachsen (32) an die Kontur (33) der Einspritzkegel (20) angepaßt ist.

3. Dieselmotor nach Anspruch 1, dadurch gekennzeichnet, daß der den Übergang (29) von der Umfangswand (25) der Kolbenmulde (18) auf die Diffusorausnehmung (27) bildende Radius (35) einen Wert im Bereich von 4 mm bis 15 mm beträgt.

4. Dieselmotor nach Anspruch 1, dadurch gekennzeichnet, daß die Kolbenmulde (18) eine konische Umfangswand (25) aufweist, die mit einem Neigungswinkel (α) von etwa 15 bis 45°.

5. Dieselmotor nach Anspruch 1, dadurch gekennzeichnet, daß die Diffusorausnehmung (27) in Form einer konischen Ausdrehung ausgebildet ist, die mit dem Zylinderkopfboden (3) einen Winkel ((3) von etwa 10 bis 30° bildet. 5
6. Dieselmotor nach Anspruch 1, dadurch gekennzeichnet, daß die Diffusorausnehmung (27) in einem Radius (34) von 2 mm bis 4 mm in die Planfläche (26) des Kolbenbodens übergeht. 5
7. Dieselmotor nach Anspruch 1, dadurch gekennzeichnet, daß der Abstand (28) des Übergangs (29) unterhalb der Planfläche (26) des Kolbenbodens kleiner oder gleich dem Abstand (31) der Schnittebene der Strahlachsen (32) der Strahlkegel (20) und der Kolbenmulde (18) ist. 10 15
8. Dieselmotor nach Anspruch 1 oder 7, dadurch gekennzeichnet, daß mindestens eine einem Gaswechselventil (22) zugeordnete Ventiltaschen-Ausnehmung (37) im Kolbenboden (21) ausgebildet ist, und daß der durch einen Radius (35) gebildete Übergang (29) der Kolbenmuldenumfangswand (25) in die Diffusorausnehmung (27) in einem Abstand (28) zur Planfläche (26) des Kolbenbodens (21) ausgebildet ist, der gleich oder größer der Tiefe (38) der Ventiltaschen-Ausnehmung (37) ist. 20 25
9. Dieselmotor nach Anspruch 1, dadurch gekennzeichnet, daß die Einspritzöffnungsgeometrie der Einspritzvorrichtung (4) einen Spritzwinkel (δ) von 150 bis 170° aufweist.
10. Dieselmotor nach Anspruch 1, dadurch gekennzeichnet, daß die Einspritzöffnungsgeometrie der Einspritzvorrichtung (4) als Neun-Lochdüse ausgebildet ist. 30
11. Dieselmotor nach einem oder mehreren der Ansprüche 1 bis 10, dadurch gekennzeichnet, daß ein Druckspeicher-Einspritzsystem mit elektronischer Einspritzsteuerung vorgesehen ist. 35

Hierzu 2 Seite(n) Zeichnungen

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- Leerseite -

Fig. 1

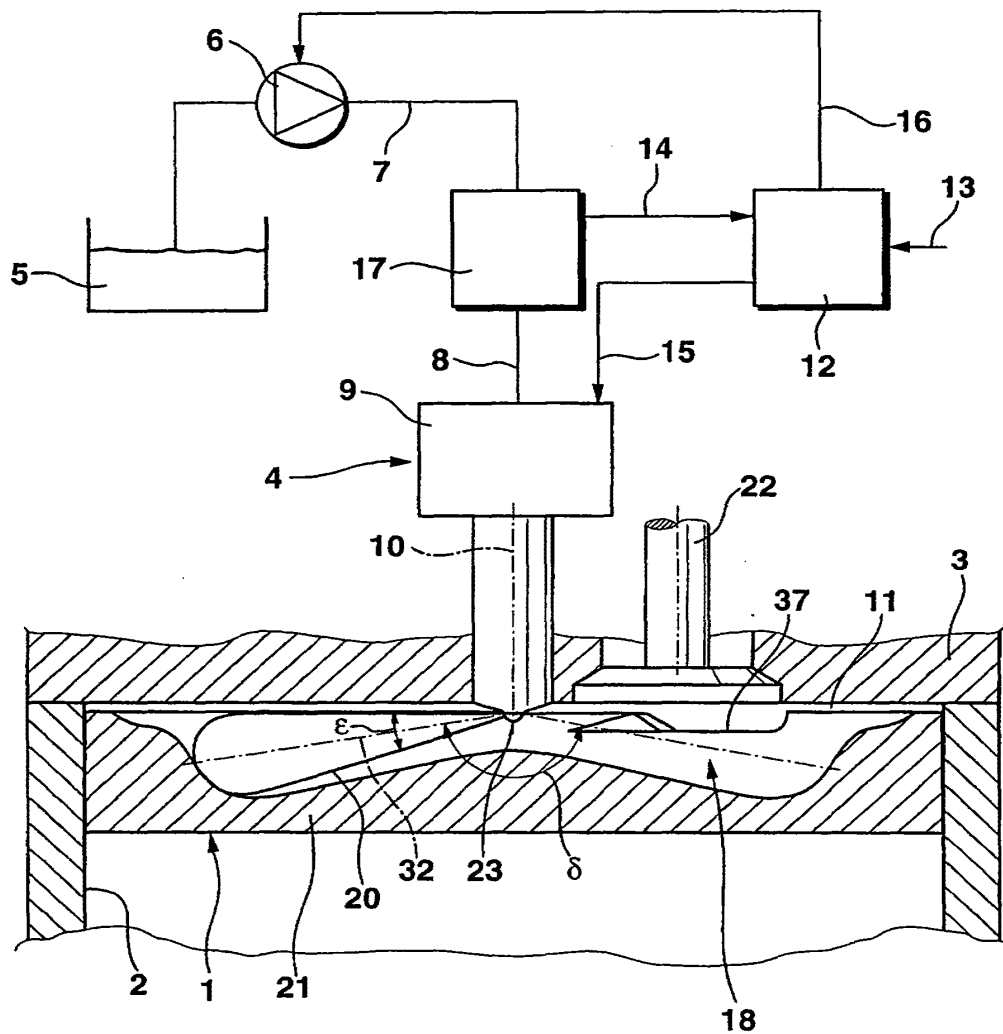


Fig. 2

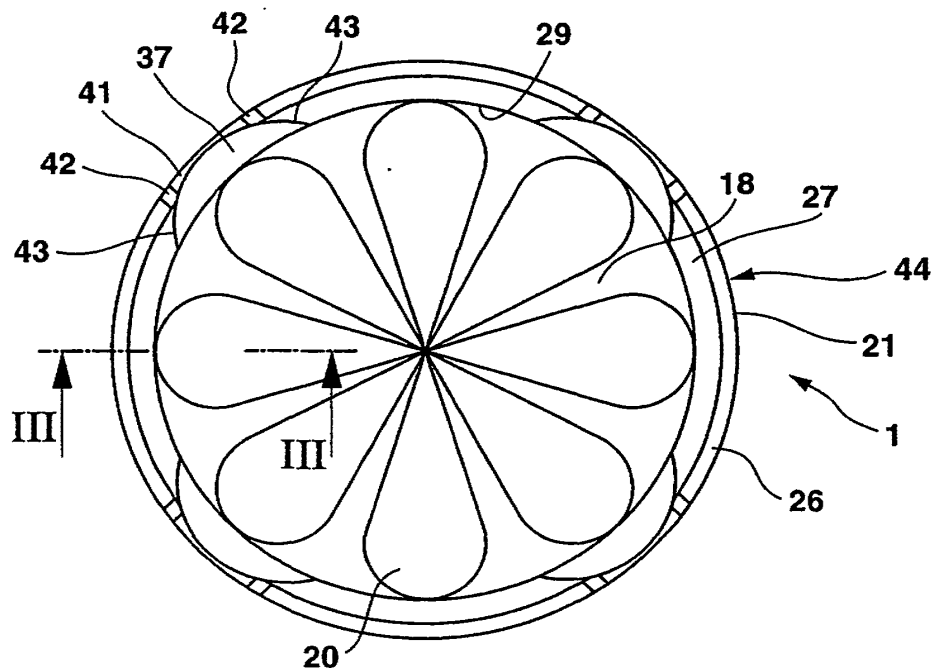
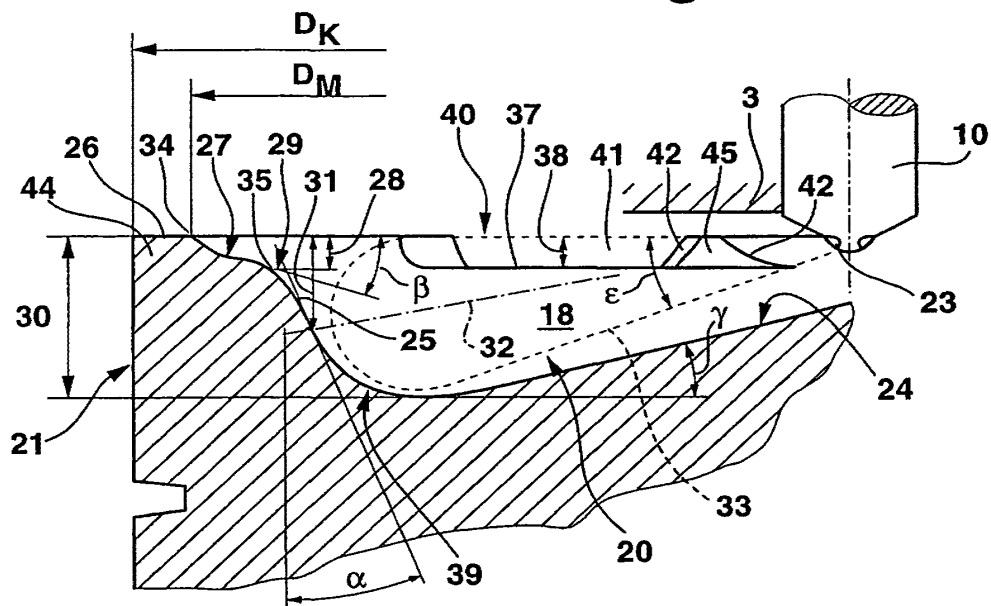


Fig. 3



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APPLICATION DATA SHEET

APPLICATION INFORMATION

Application Number::	Not Yet Assigned
Filing Date::	Herewith
Application type::	PCT
Subject Matter::	Utility
Title::	Directly Injecting Internal Combustion Engine
Attorney Docket No.::	095309.57635US
Request for Early Publication::	No
Request for Non-Publication::	No
Total Drawing Sheets::	Four (4)
Small Entity::	No
Petition included::	No

10/577797
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APPLICANT INFORMATION

Applicant one Authority Type::	Inventor
Primary Citizenship Country::	GERMANY
Status::	Full Capacity
Given name::	Ruediger
Family name::	PFAFF
City of Residence::	Stuttgart
Country of Residence::	GERMANY
Street of mailing address::	Im Wolfbusch 46
City of mailing address::	Stuttgart
Country of mailing address::	GERMANY
Postal or Zip Code of mailing address::	70499

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Applicant two Authority Type::	Inventor
Primary Citizenship Country::	GERMANY
Status::	Full Capacity
Given name::	Martin
Family name::	SCHNABEL
City of Residence::	Aalen
Country of Residence::	GERMANY
Street of mailing address::	Bischof-Fischer-Strasse 50
City of mailing address::	Aalen
Country of mailing address::	GERMANY
Postal or Zip Code of mailing address::	73430

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Applicant three Authority Type::	Inventor
Primary Citizenship Country::	GERMANY
Status::	Full Capacity
Given name::	Joachim
Family name::	SUESS
City of Residence::	Ludwigsburg
Country of Residence::	GERMANY
Street of mailing address::	Brueckenstrasse 17
City of mailing address::	Ludwigsburg
Country of mailing address::	GERMANY
Postal or Zip Code of mailing address::	71642

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CORRESPONDENCE INFORMATION

Correspondence customer number:: 23911

REPRESENTATIVE INFORMATION

Representative customer number:: 23911

DOMESTIC PRIORITY INFORMATION

	Type::	Application::	Filing Date::
This application	National Phase	PCT/EP2004/011637	October 15, 2004

FOREIGN PRIORITY INFORMATION

Country::	Application Number::	Filing Date::	Priority Claimed::
GERMANY	103 50 795.7	October 29, 2003	Yes

ASSIGNEE INFORMATION

ASSIGNEE NAME:: DAIMLERCHRYSLER AG
STREET OF MAILING ADDRESS:: EPPELSTRASSE 225
CITY OF MAILING ADDRESS:: STUTTGART
COUNTRY OF MAILING ADDRESS:: GERMANY
POSTAL OR ZIP CODE OF MAILING ADDRESS:: 70567

PATENT COOPERATION TREATY

IPM/C		From the INTERNATIONAL BUREAU
Eing.	09. Juni 2005	To:
PCT 3BH		KREISER, André DaimlerChrysler AG Intellectual Property Management IMP - C106 70546 Stuttgart ALLEMAGNE

FIRST NOTICE INFORMING THE APPLICANT OF
THE COMMUNICATION OF THE INTERNATIONAL
APPLICATION (TO DESIGNATED OFFICES WHICH
DO NOT APPLY THE 30 MONTH TIME LIMIT
UNDER ARTICLE 22(1))

(PCT Rule 47.1(c))

Date of mailing (day/month/year) 02 June 2005 (02.06.2005)		IMPORTANT NOTICE	
Applicant's or agent's file reference P803662/WO/1			
International application No. PCT/EP2004/011637	International filing date (day/month/year) 15 October 2004 (15.10.2004)	Priority date (day/month/year) 29 October 2003 (29.10.2003)	
Applicant DAIMLERCHRYSLER AG et al			

1. **ATTENTION:** For any designated Office(s), for which the time limit under Article 22(1), as in force from 1 April 2002 (30 months from the priority date), **does apply**, please see Form PCT/IB/308(Second and Supplementary Notice) (to be issued promptly after the expiration of 28 months from the priority date).

2. Notice is hereby given that the following designated Office(s), for which the time limit under Article 22(1), as in force from 1 April 2002, **does not apply**, has/have requested that the communication of the international application, as provided for in Article 20, be effected under Rule 93bis.1. The International Bureau has effected that communication on the date indicated below:
26 May 2005 (26.05.2005)

CH

In accordance with Rule 47.1(c-bis)(i), those Offices will accept the present notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

3. The following designated Offices, for which the time limit under Article 22(1), as in force from 1 April 2002, **does not apply**, have not requested, as at the time of mailing of the present notice, that the communication of the international application be effected under Rule 93bis.1 :

LU, SE, TZ, UG, ZM

In accordance with Rule 47.1(c-bis)(ii), those Offices accept the present notice as conclusive evidence that the Contracting State for which that Office acts as a designated Office does not require the furnishing, under Article 22, by the applicant of a copy of the international application.

4. **TIME LIMITS for entry into the national phase**

For the designated Office(s) listed above, and unless a demand for international preliminary examination has been filed before the expiration of **19 months** from the priority date (see Article 39(1)), the applicable time limit for entering the national phase will, **subject to what is said in the following paragraph**, be **20 MONTHS** from the priority date.

In practice, **time limits other than the 20-month time limit** will continue to apply, for various periods of time, in respect of certain of the designated Offices listed above. For **regular updates on the applicable time limits** (20 or 21 months, or other time limit), Office by Office, refer to the *PCT Gazette*, the *PCT Newsletter* and the *PCT Applicant's Guide*, Volume II, National Chapters, all available from WIPO's Internet site, at <http://www.wipo.int/pct/en/index.html>.

It is the applicant's **sole responsibility** to monitor all these time limits.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Agnes Wittmann-Regis
Facsimile No.+41 22 740 14 35	Facsimile No.+41 22 338 89 70

IAP6 Rec'd PCT/PTO 28 APR 2006

PTO-1390 (Rev. 07-2005)

Approved for use through 3/31/2007. OMB 0651-0021

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NUMBER 095309.57635US	
INTERNATIONAL APPLICATION NO. PCT/EP2004/011637	INTERNATIONAL FILING DATE October 15, 2004	U.S. APPLICATION NO. (if known, see 37 CFR 1.55) 10/577797	
		PRIORITY DATE CLAIMED October 29, 2003	
TITLE OF INVENTION DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE			
APPLICANT(S) FOR DO/EO/US Ruediger PFAFF, et al.			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
1. ☒ This is a FIRST submission of items concerning a submission under 35 U.S.C. 371. 2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a submission under 35 U.S.C. 371. 3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below. 4. ☐ The US has been elected (Article 31). 5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)) a. ☐ is attached hereto (required only if not communicated by the International Bureau). b. ☒ has been communicated by the International Bureau. c. ☐ Is not required, as the application was filed in the United States Receiving Office (RO/US). 6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)). a. ☒ is attached hereto. b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4). 7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) a. ☐ are attached hereto (required only if not communicated by the International Bureau). b. ☐ have been communicated by the International Bureau. c. ☐ have not been made; however, the time limit for making such amendments has NOT expired. d. ☐ have not been made and will not be made. 8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)). Items 11 to 20 below concern document(s) or information included: 11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98 (Int'l. Search Report; refs.) 12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. ☒ A preliminary amendment. 14. ☒ An Application Data Sheet under 37 CFR 1.76. 15. ☒ A substitute specification (clean/marked-up versions) 16. ☐ A power of attorney and/or change of address letter. 17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 37 CFR 1.821- 1.825. 18. ☐ A second copy of the published International Application under 35 U.S.C. 154(d)(4). 19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4). 20. ☒ Other items or information: PCT/IB/308; Credit Card Payment Form; four (4) sheets of drawings consisting of Figs. 1-10.			

This collection of information is required by 37 CFR 1.414 and 1.491-1.492. The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 15 minutes to complete, including gathering information, preparing, and submitting the completed form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

IAP17 Rec'd PCT/PTO 28 APR 2006

PTO-1390 (Rev. 02-2005)

Approved for use through 3/31/2007. OMB 0651-0021

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

U.S. APPLICATION NO. (if known, see 37 CFR 1.53)		INTERNATIONAL APPLICATION NO.		ATTORNEY'S DOCKET NUMBER	
107577797		PCT/EP2004/011637		095309.57635US	
The following fees have been submitted				CALCULATIONS	
				PTO USE ONLY	
21.	☒	Basic national fee (37 C.F.R. §1.492(a))	\$300.00	\$	300.00
22.	☒	Examination fee (37 C.F.R. §1.492(c))			
If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4)					
				\$	200.00
All other situations				\$	200.00
23.	☒	Search fee (37 C.F.R. §1.492(b))			
If the written opinion of the ISA/US or the International preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4)					
Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority					
International Search Report prepared by an ISA other than the US and provided to the Office or previously communicated to the US by the IB				\$	400.00
All other situations				\$	500.00
TOTAL OF 21, 22 AND 23 =				\$	900.00
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is \$250 for each additional 50 sheets of paper or fraction thereof.					
Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof (round up to a whole number)	RATE		
- 100	/ 50 =		x 250	\$	
Surcharge of \$130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(h)).				\$	130.00
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	18	0	x 50	\$	0.00
Independent claims	1	0	x 200	\$	0.00
MULTIPLE DEPENDENT CLAIM(S) (if applicable)					
TOTAL OF ABOVE CALCULATIONS =				\$	1030.00
☐ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.					
SUBTOTAL =				\$	1030.00
Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)).				\$	
TOTAL NATIONAL FEE =				\$	1030.00
Fee for recording the enclosed assignment (37 CFR 1.21 (h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				\$	
TOTAL FEES ENCLOSED =				\$	1030.00
				Amount to be refunded:	\$
				Amount to be charged:	\$
a. ☐ A check in the amount of \$ to cover the above fees is enclosed.					
b. ☐ Please charge my Deposit Account No. 05-1323 (Attorney Docket No. 095309.57635US) in the amount of \$ to cover the above fees. A duplicate copy of this sheet is enclosed.					
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 05-1323 (Attorney Docket No. 095309.57635US). A duplicate copy of this sheet is enclosed.					
d. ☒ Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.					
NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.					
SEND ALL CORRESPONDENCE TO:					
Crowell & Moring, LLP					
Intellectual Property Group					
P.O. Box 14300					
Washington, D.C. 20044-4300					
Tel. No. (202) 624-2500					
Fax No. (202) 628-8844					
/xxx (doc no.)					
SIGNATURE					
James F. McKeown					
NAME					
25.406					
REGISTRATION NUMBER					
April 28, 2006					
DATE					

FORM PTO-1390 (REV. 02-2005)

Page 2 of 2

2760229

Direkteinspritzende Brennkraftmaschine

Die Erfindung betrifft eine direkteinspritzende Brennkraftmaschine mit wenigstens einem Zylinder, welcher einen Brennraum aufweist und in welchem ein Kolben eine Oszillationsbewegung ausführt, nach der im Oberbegriff von Anspruch 1 näher definierten Art.

Eine gattungsgemäße Brennkraftmaschine ist aus der US 2002/0117146 A1 bekannt. Hierbei wird der Kraftstoff unter einem relativ steilen Einspritzwinkel in den Brennraum eingespritzt und die Kolbenmulde ist zumindest teilweise an den Einspritzwinkel angepasst.

Bei einer in der DE 196 49 052 A1 beschriebenen Brennkraftmaschine ist ebenfalls eine besondere Form der Kolbenmulde vorgesehen, um eine zusätzliche Reduzierung der von der Brennkraftmaschine ausgestoßenen Schadstoffe zu erreichen.

Wenn beim Betrieb einer Brennkraftmaschine, insbesondere einer Dieselmotorkraftmaschine, eine frühe Homogenisierung innerhalb des Brennraums erreicht werden soll, so müssen Einspritzzeitpunkte von ca. 130 bis 30° vor dem oberen Totpunkt des Kolbens gewählt werden, da zu diesem Zeitpunkt der Brennraumdruck noch relativ gering ist, sodass der eingespritzte Kraftstoff sehr tief in den Brennraum eindringen kann. Um ein Auftreffen des Einspritzstrahls auf die Zylinderwandung bzw. die Laufbuchse zu verhindern, sollte ein möglichst steiler Einspritzwinkel an der Einspritzdüse gewählt werden, um eine

möglichst große freie Strahllänge zu gewährleisten. Dies erfordert auch, dass die Form der Kolbenmulde an diese Einspritzung angepasst ist, wie dies beispielsweise bei der US 2002/0117146 A1 der Fall ist.

Da es jedoch nicht möglich ist, die Brennkraftmaschine über ihr gesamtes Kennfeld mit einem homogenen Brennverfahren zu betreiben, muss die Kolbenmulde sowohl für die homogene als auch für die konventionelle Gemischbildung konzipiert sein. Dies ist bei bekannten Lösungen nicht problemlos möglich.

Es ist daher Aufgabe der vorliegenden Erfindung, eine direkt-einspritzende Brennkraftmaschine zu schaffen, bei welcher die Form der Kolbenmulde so ausgebildet ist, dass die Brennkraftmaschine sowohl mit einem homogenen als auch mit einem konventionellen Brennverfahren betrieben werden kann.

Erfindungsgemäß wird diese Aufgabe durch die in Anspruch 1 genannten Merkmale gelöst.

Die erfindungsgemäße Lösung stellt sicher, dass der Einspritzstrahl stets so auf der Kolbenmulde auftrifft, dass sich der eingespritzte Kraftstoff optimal mit der in dem Brennraum sich befindlichen Luft vermischen kann, und zwar unabhängig vom Zeitpunkt der Einspritzung. Insbesondere die Tatsache, dass ein zum spätest möglichen Zeitpunkt eingespritzter Einspritzstrahl stets auf die sich an die Erhebung anschließende Fläche auftrifft, stellt sicher, dass der Impuls des auftreffenden Einspritzstrahls nicht vernichtet wird, wodurch er nicht mehr optimal zur Gemischbildung verwendet werden könnte, was wiederum erhöhte Schwarzrauchbildung nach sich ziehen würde.

Auf diese Weise ergibt sich eine Brennkraftmaschine, welche problemlos sowohl mit einem homogenen als auch mit einem konventionellen Brennverfahren betrieben werden kann.

Vorteilhafte Ausgestaltungen der Erfindung ergeben sich aus den Unteransprüchen. Nachfolgend ist ein Ausführungsbeispiel der Erfindung anhand der Zeichnung prinzipmäßig dargestellt.

Dabei zeigen:

Fig. 1 eine erfindungsgemäße Brennkraftmaschine mit einem in einem Brennraum derselben oszillierenden Kolben und mit einem auf einer Kolbenmulde des Kolbens auftretenden Einspritzstrahl;

Fig. 2 die Gestaltung der Kolbenmulde des Kolbens aus Fig. 1 in einem ersten Bereich;

Fig. 3 die Gestaltung der Kolbenmulde des Kolbens aus Fig. 1 in einem zweiten Bereich;

Fig. 4 die Gestaltung der Kolbenmulde des Kolbens aus Fig. 1 in einem dritten Bereich;

Fig. 5 die Ablenkung des eingespritzten Kraftstoffstrahls in dem in Fig. 4 dargestellten Bereich der Kolbenmulde;

Fig. 6 die Gestaltung der Kolbenmulde des Kolbens aus Fig. 1 in einem vierten Bereich;

Fig. 7 die Lufterfassung in einem sechsten Bereich der Kolbenmulde;

Fig. 8 eine erste Ausführungsform eines fünften Bereichs eines Kolbens aus Fig. 1;

Fig. 9 eine zweite Ausführungsform eines fünften Bereichs eines Kolbens aus Fig. 1; und

Fig. 10 eine dritte Ausführungsform eines fünften Bereichs eines Kolbens aus Fig. 1.

Fig. 1 zeigt eine Brennkraftmaschine 1, welche ein Kurbelgehäuse 2 und einen Zylinderkopf 3 aufweist. Innerhalb des Kurbelgehäuses 2 der Brennkraftmaschine 1 befindet sich wenigstens ein Zylinder 4, welcher einen Brennraum 5 aufweist und in welchem ein Kolben 6 in an sich bekannter Weise eine Oszillationsbewegung ausführt. In dem Zylinderkopf 3 ist eine Einspritzdüse 7 angeordnet, welche mehrere Einspritzöffnungen 8 aufweist, aus denen ein Einspritzstrahl 9 austritt. Der Öffnungswinkel α des Einspritzstrahls 9 ist im vorliegenden Fall relativ steil und liegt in einem Bereich zwischen 50° und 120° . Auf diese Weise wird also Kraftstoff direkt in den Brennraum 5 eingespritzt, sodass es sich um eine direkt einspritzende Brennkraftmaschine 1 handelt.

In Fig. 1 sind zwei unterschiedliche Einspritzstrahlen abgebildet, nämlich ein Einspritzstrahl 9a, welcher sich ergibt, wenn sich der Kolben 6 in einem oberen Totpunkt befindet, und ein Einspritzstrahl 9b, der sich bei einer Kraftstoffeinspritzung zum spätest möglichen Einspritzzeitpunkt ergibt. Die Einspritzstrahlen 9a und 9b sind jeweils lediglich als Achsen eines sich innerhalb des Brennraumes 5 verteilenden Einspritzkegels dargestellt.

Der Kolben 6 weist an seiner dem Zylinderkopf 3 zugewandten Seite eine Kolbenmulde 10 auf. In den nachfolgenden Figuren wird die Kontur der Kolbenmulde 10 sowie deren Anpassung an die Einspritzstrahlen 9 näher erläutert, wobei in den einzelnen Figuren aus Übersichtlichkeitsgründen jeweils nur diejenigen Bezugszeichen angegeben sind, die für die Beschreibung der jeweiligen Figur relevant sind. Die Kolbenmulde 10 ist bei allen Figuren identisch.

Wie in Fig. 2 erkennbar ist, weist die Kolbenmulde 10 in ihrem zentralen Bereich eine sich in Richtung des Zylinderkopfes 3 erstreckende Erhebung 11 auf. Die Erhebung 11 weist hierbei einen Winkel β gegenüber der Achse des Kolbens auf,

der kleiner als der halbe Einspritzwinkel α ist, so dass der äußerste Rand des hier als Mittelachse dargestellten Einspritzstrahls 9a nicht mit der Erhebung 11 in Berührung kommt.

Wie in Fig. 2 und Fig. 3 zu erkennen, schließt sich in Richtung eines Muldenrandes 12, also dem Ende der Kolbenmulde 10, eine Fläche 13 an die Erhebung 11 an, welche mit der Erhebung 11 über einen Radius 14 derart verbunden ist, dass der zum frühest möglichen Zeitpunkt eingespritzte Einspritzstrahl 9a an einem Auftreffpunkt 15 auf die Fläche 13 auftrifft und sich sowohl in Richtung der Erhebung 11 als auch in Richtung des Muldenrandes 12 verteilt. Diese Verteilung des Einspritzstrahls 9a ist wichtig, um den Kraftstoff möglichst gut mit der sich in dem Brennraum 5 befindlichen Luft zu vermischen. Durch den oben beschriebenen steileren Winkel β der Erhebung 11 im Vergleich mit dem Einspritzwinkel α ist in dem Bereich von dem Auftreffpunkt 15 des Einspritzstrahls 9a auf der Fläche 13 zu der Erhebung 11 noch genügend Freiraum, so dass sich die in Richtung der Erhebung 11 abgelenkte Kraftstoffmenge gut verteilen kann. Der in Richtung der Erhebung 11 abgelenkte Kraftstoff ist mit dem Pfeil 16 bezeichnet, wohingegen der in Richtung des Muldenrandes 12 abgelenkte Kraftstoff mit dem Pfeil 17 bezeichnet ist. Es ist hier zu erkennen, dass die in Richtung des Muldenrandes 12 gelenkte bzw. verteilte Kraftstoffmenge größer ist als die in Richtung der Erhebung 11 abgelenkte Kraftstoffmenge. Der Radius 14 sollte in diesem Zusammenhang so gewählt werden, dass eine Stauung des rückströmenden Kraftstoffs vermieden wird.

In Fig. 4 ist zu erkennen, dass die sich in Richtung des Muldenrandes 12 an die Erhebung 11 anschließende Fläche 13 im wesentlichen eben ausgebildet ist und eine Steigung in Richtung des Muldenrandes 12 aufweist. Mit anderen Worten, die Fläche 13 bildet eine Ebene, die über die gesamte maximale Einspritzdauer in einem konstanten Winkel γ zu dem Einspritzstrahl 9 steht. Der Winkel γ kann in Abhängigkeit der erfor-

derlichen Impulsablenkung eines in diesem Fall im mittleren Bereich der Fläche 13 auftreffenden Einspritzstrahls 9c verändert werden, wobei der Hauptimpuls, wie bereits oben erwähnt, in Richtung des Muldenrandes 12 erfolgt. Gegebenenfalls kann es auch sinnvoll sein, die sich in Richtung des Muldenrandes 12 an die Erhebung 11 anschließende Fläche 13 gekrümmt auszuführen.

In Fig. 5 ist anhand von Pfeilen 18 und 19 dargestellt, dass auf diese Weise während der gesamten Kraftstoffeinspritzung ein geringerer Anteil des Einspritzstrahls 9 in Richtung der Erhebung 11 und ein größerer Anteil in Richtung des Muldenrandes 12 geleitet wird. Der Pfeil 18 zeigt hierbei die in Richtung der Erhebung 11 geleitete Kraftstoffmenge, wohingegen der Pfeil 19 die in Richtung des Muldenrandes 12 geleitete Kraftstoffmenge zeigt.

Der Abstand der Fläche 13 zu der Einspritzdüse 7 sollte so gewählt werden, dass der Einspritzstrahl 9 eine ausreichend freie Strahllänge und somit eine optimale Strahlgeschwindigkeit und den optimalen Impuls erreichen kann. Je nach Anzahl der Einspritzöffnungen 8 der Einspritzdüse 7 ist eine Interaktion des an der Kolbenmulde 10 abgelenkten Kraftstoffs zwischen zwei Einspritzstrahlen 9 möglich, was zusätzlich zur Lufterfassung in dem Brennraum 5 beiträgt. Zusätzlich kann die Aufteilung des Kraftstoffs auch durch Drall unterstützt werden.

In Fig. 6 ist der zum spätest möglichen Zeitpunkt eingespritzte Einspritzstrahl 9b dargestellt. Dabei ist erkennbar, dass die Fläche 13 eine derartige Erstreckung in Richtung des Muldenrandes 12 aufweist, dass der zum spätest möglichen Zeitpunkt eingespritzte Einspritzstrahl 9b auf die Fläche 13 auftrifft. Auch in diesem Bereich ist die Fläche 13 derart ausgeführt, dass der Einspritzstrahl 9b sich sowohl in Richtung der Erhebung 11 als auch in Richtung des Muldenrandes 12 verteilt. Die sich in Richtung der Erhebung 11 verteilende

Kraftstoffmenge ist mit eine Pfeil 20 und die sich in Richtung des Muldenrandes 12 verteilende Kraftstoffmenge mit einem Pfeil 21 bezeichnet. Auf diese Weise wird ein senkrechtes Auftreffen des Einspritzstrahls 9 auf der Kolbenmulde 10 verhindert und es wird gewährleistet, dass der Impuls des Einspritzstrahls 9b erhalten bleibt.

Aus Fig. 7 geht hervor, dass sich an die Fläche 13 eine mit dem Muldenrand 12 über einen Radius 22 verbundene Fläche 23 anschließt. An dem Muldenrand 12 entsteht ein sogenannter Quetschspaltbereich 24 an bzw. oberhalb einer oberen Fläche 25 des Kolbens 6, der das Kraftstoff-Luft-Gemisch im Randbereich in Richtung der Kolbenmulde 10 quetscht und auf diese Weise die Emission von Kohlenwasserstoffen und Kohlenmonoxid reduziert. Der Quetschspaltbereich 24 sollte nicht zu groß gewählt werden, da auch in diesem Bereich eine Lufterfassung erforderlich ist. Die Fläche 23 trägt dazu bei, dass der dem Pfeil 21 folgende Kraftstoffstrahl so abgelenkt wird, dass ein vermehrter Eintrag von Kraftstoff in den Quetschspaltbereich 24 verhindert wird.

In den Figuren 8, 9 und 10 sind verschiedene Anbindungen der Fläche 23 an die obere Fläche 25 des Kolbens 6 dargestellt.

Bei der Ausführungsform gemäß Fig. 8 bildet die mit dem Muldenrand 12 verbundene Fläche 23 einen spitzen Winkel mit der oberen Fläche 25 des Kolbens 6. Hierdurch kann die Zuführung von Kraftstoff an eine nicht dargestellte Glühkerze oder Zündkerze verbessert werden.

Bei der Ausführung gemäß Fig. 9 geht die Fläche 23 in einem Radius 26 in die obere Fläche 25 des Kolbens 6 über.

In Fig. 10 ist eine Ausführung dargestellt, bei welcher die mit dem Muldenrand 12 verbundene Fläche 23 einen stumpfen Winkel mit der oberen Fläche 25 des Kolbens 6 bildet.

Patentansprüche

1. Direkteinspritzende Brennkraftmaschine mit wenigstens einem Zylinder, welcher einen Brennraum aufweist und in welchem ein Kolben eine Oszillationsbewegung ausführt, und mit einer Einspritzdüse zur Einspritzung von Kraftstoff in den Brennraum, wobei der Kolben eine Kolbenmulde aufweist, welche in ihrem zentralen Bereich eine sich in Richtung eines Zylinderkopfes erstreckende Erhebung aufweist,
d a d u r c h g e k e n n z e i c h n e t ,
dass eine sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) der Kolbenmulde (10) mit der Erhebung (11) über einen Radius (14) derart verbunden ist, dass ein in diesem Bereich auftreffender, zum frühest möglichen Zeitpunkt eingespritzter Einspritzstrahl (9a) sich sowohl in Richtung der Erhebung (11) als auch in Richtung des Muldenrandes (12) verteilt, und dass die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) eine derartige Erstreckung in Richtung des Muldenrandes (12) aufweist, dass ein zum spätest möglichen Zeitpunkt eingespritzter Einspritzstrahl (9b) auf die Fläche (13) auftrifft, wobei sich der zum spätest möglichen Zeitpunkt eingespritzte Einspritzstrahl (9b) sowohl in Richtung der Erhebung (11) als auch in Richtung des Muldenrandes (12) verteilt.
2. Direkteinspritzende Brennkraftmaschine nach Anspruch 1,
d a d u r c h g e k e n n z e i c h n e t ,

dass sich an die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) eine mit dem Muldenrand (12) verbundene Fläche (23) anschließt.

3. Direkteinspritzende Brennkraftmaschine nach Anspruch 2, dadurch gekennzeichnet, dass die mit dem Muldenrand (12) verbundene Fläche (23) über einen Radius (22) mit der sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) verbunden ist.
4. Direkteinspritzende Brennkraftmaschine nach Anspruch 2 oder 3, dadurch gekennzeichnet, dass die mit dem Muldenrand (12) verbundene Fläche (23) einen spitzen Winkel mit der oberen Fläche (25) des Kolbens (6) bildet.
5. Direkteinspritzende Brennkraftmaschine nach Anspruch 2 oder 3, dadurch gekennzeichnet, dass die mit dem Muldenrand (12) verbundene Fläche (23) einen stumpfen Winkel mit der oberen Fläche (25) des Kolbens (6) bildet.
6. Direkteinspritzende Brennkraftmaschine nach einem der Ansprüche 2 bis 5, dadurch gekennzeichnet, dass die mit dem Muldenrand (12) verbundene Fläche (23) in einem Radius (26) in die obere Fläche (25) des Kolbens (6) übergeht.
7. Direkteinspritzende Brennkraftmaschine nach einem der Ansprüche 1 bis 6, dadurch gekennzeichnet, dass die sich in Richtung des Muldenrandes (12) an die

Erhebung (11) anschließende Fläche (13) eine Steigung in Richtung des Muldenrandes (12) aufweist.

8. Direkteinspritzende Brennkraftmaschine nach Anspruch 7, dadurch gekennzeichnet, dass die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) im wesentlichen eben ausgebildet ist.
9. Direkteinspritzende Brennkraftmaschine nach Anspruch 7, dadurch gekennzeichnet, dass die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) gekrümmt ausgebildet ist.
10. Direkteinspritzende Brennkraftmaschine nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, dass der Einspritzwinkel (α) der Einspritzdüse (7) zwischen 50° und 120° beträgt.

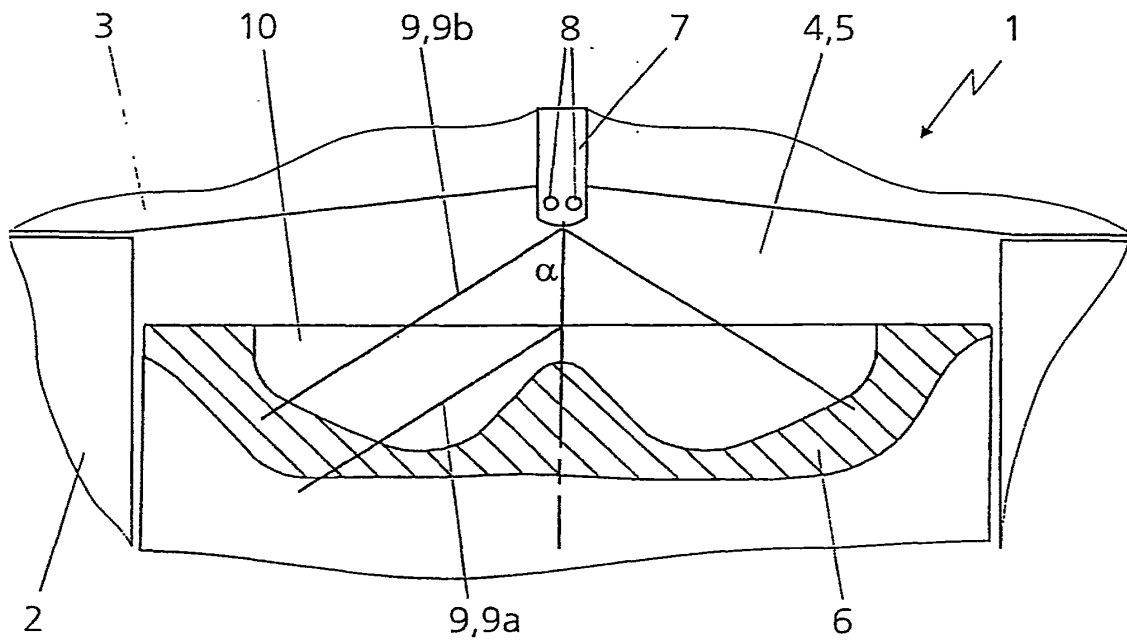


Fig. 1

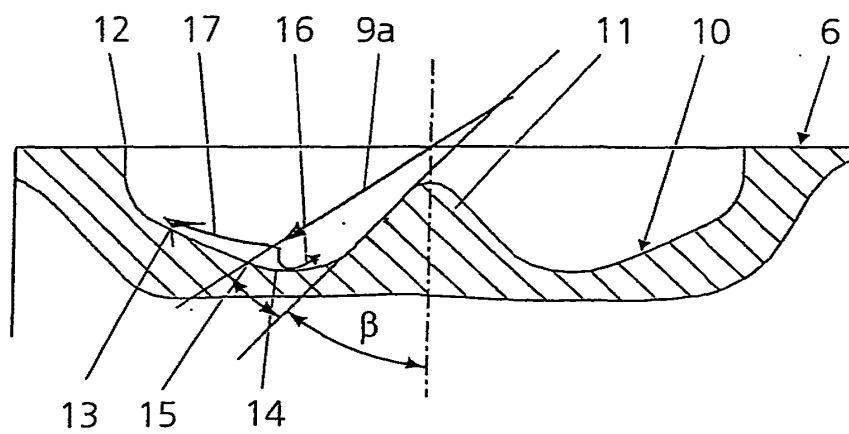


Fig. 2

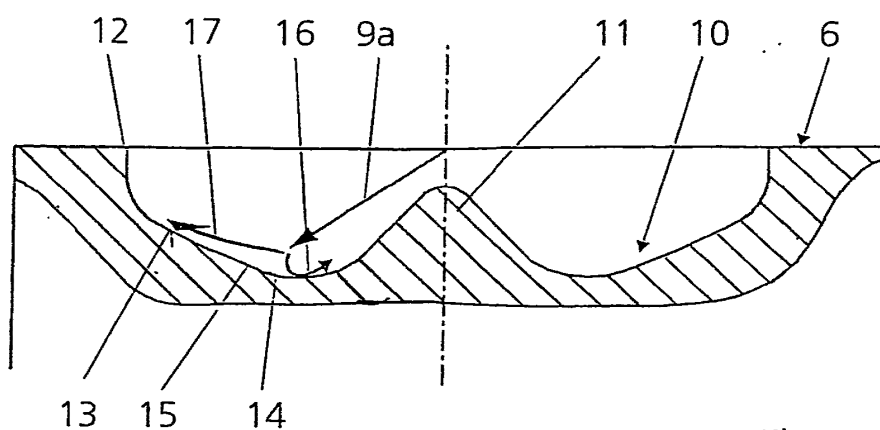


Fig. 3

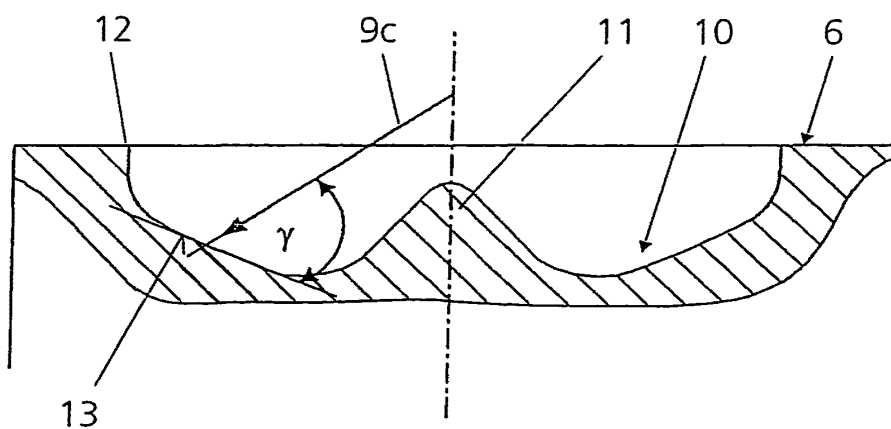
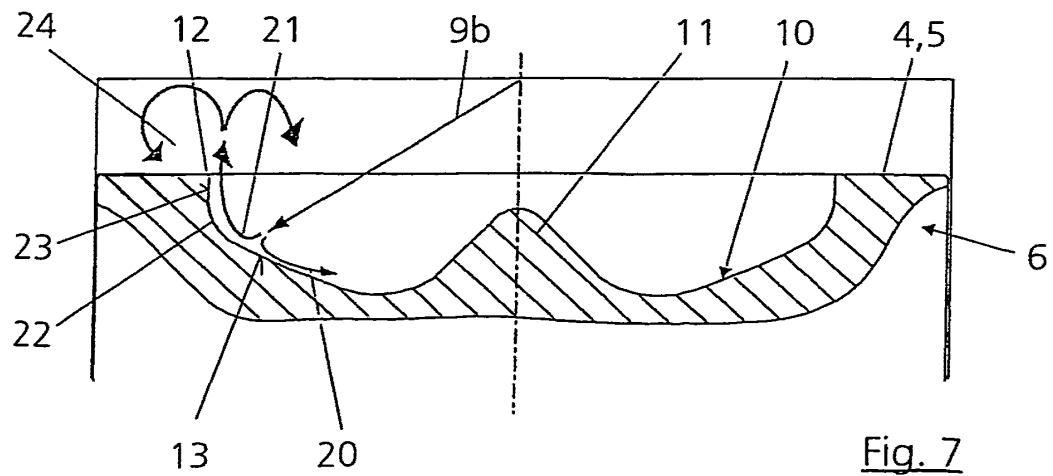
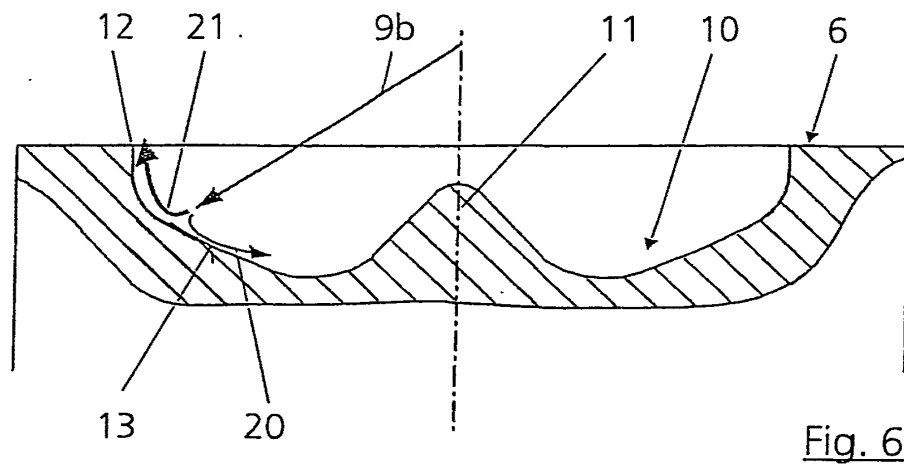
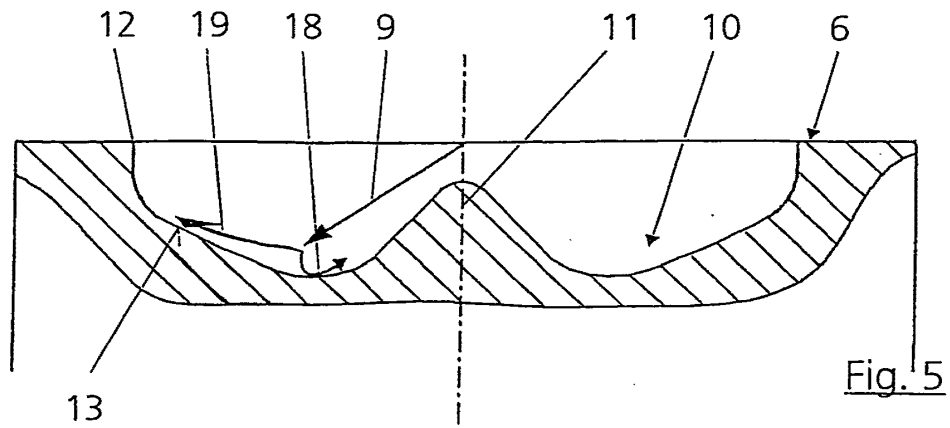


Fig. 4



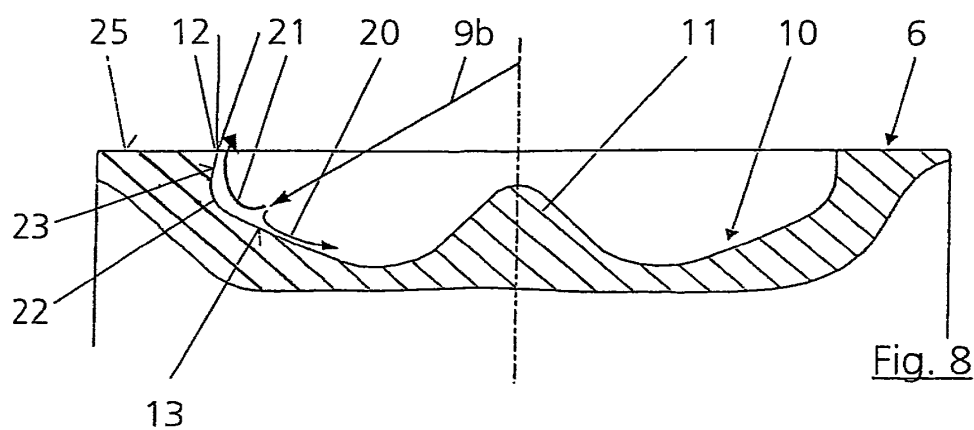


Fig. 8

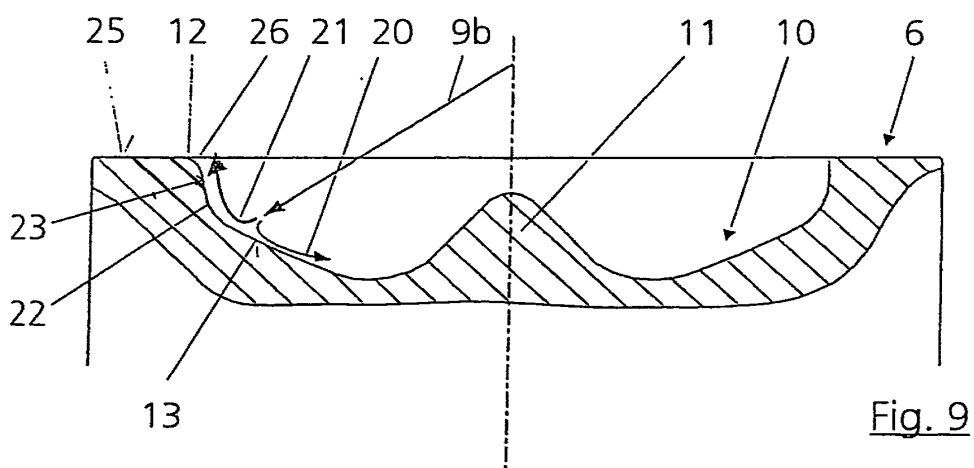


Fig. 9

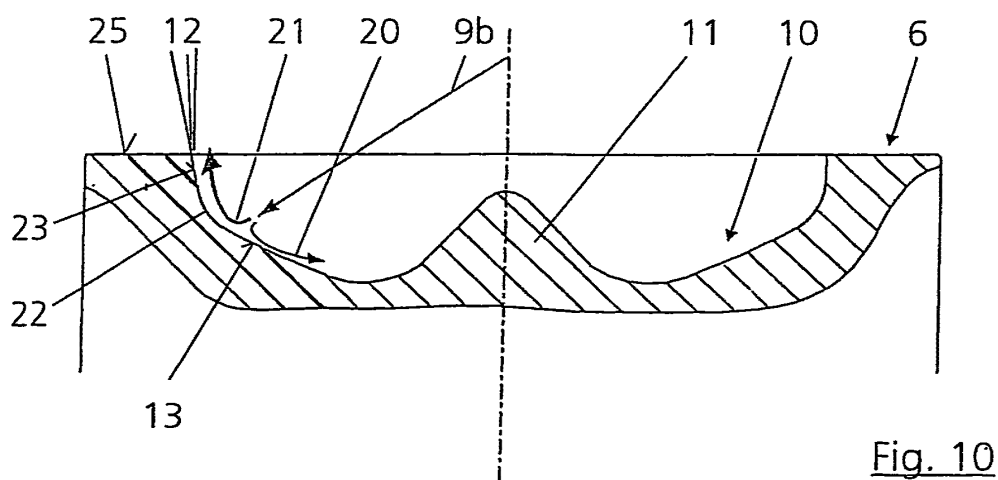


Fig. 10

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2004/011637

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F02B23/06

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)

IPC 7 F02B

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 practical, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 291 516 A (ISUZU MOTORS LTD) 12 March 2003 (2003-03-12) abstract column 3, paragraph 22 - column 4, paragraph 27; figure 1	1-3,5,7, 9,10
A	US 2002/117146 A1 (GATELLIER ET AL) 29 August 2002 (2002-08-29) cited in the application the whole document	1-3,5,10
A	DE 196 49 052 A (MOTOREN TURBINEN UNION) 28 May 1998 (1998-05-28) cited in the application abstract column 3, line 42 - column 4, line 67; figures 1,3	1-3,5-7
	----- -/-	

☒ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

20 January 2005

Date of mailing of the international search report

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+31-70) 340-3016

Authorized officer

Van Zoest, A

INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International Application No
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DE 1219283	B	16-06-1966	NONE	

INTERNATIONALER RECHERCHENBERICHT

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C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	EP 1 291 516 A (ISUZU MOTORS LTD) 12. März 2003 (2003-03-12) Zusammenfassung Spalte 3, Absatz 22 - Spalte 4, Absatz 27; Abbildung 1	1-3,5,7, 9,10
A	US 2002/117146 A1 (GATELLIER ET AL) 29. August 2002 (2002-08-29) in der Anmeldung erwähnt das ganze Dokument	1-3,5,10
A	DE 196 49 052 A (MOTOREN TURBINEN UNION) 28. Mai 1998 (1998-05-28) in der Anmeldung erwähnt Zusammenfassung Spalte 3, Zeile 42 - Spalte 4, Zeile 67; Abbildungen 1,3	1-3,5-7
	----- -/-	

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20. Januar 2005

Absenddatum des internationalen Recherchenberichts

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Fax (+31-70) 340-3016

Bevollmächtigter Beauftragter

Van Zoest, A

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/EP2004/011637

C.(Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN		
Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Beitr. Anspruch Nr.
A	DE 12 19 283 B (TATRA NP) 16. Juni 1966 (1966-06-16) Spalte 7, Zeile 39 - Spalte 8, Zeile 12; Abbildung 1	1-5

INTERNATIONALER RECHERCHENBERICHT

Angaben zu Veröffentlichungen, die zur selben Patentfamilie gehören

Internationales Aktenzeichen

PCT/EP2004/011637

Im Recherchenbericht angeführtes Patentdokument			Datum der Veröffentlichung		Mitglied(er) der Patentfamilie		Datum der Veröffentlichung	
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			EP	0845589	A1		03-06-1998	
DE 1219283	B	16-06-1966	KEINE					

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES
PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
Internationales Büro



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PCT

(10) Internationale Veröffentlichungsnummer
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(51) Internationale Patentklassifikation⁷: F02B 23/06

73430 Aalen (DE). SÜSS, Joachim [DE/DE]; Brücken-
strasse 17, 71642 Ludwigsburg (DE).

(21) Internationales Aktenzeichen: PCT/EP2004/011637

(22) Internationales Anmeldedatum:
15. Oktober 2004 (15.10.2004)

(74) Anwälte: KREISER, André usw.; DaimlerChrysler AG,
Intellectual Property Management, IMP - C106, 70546
Stuttgart (DE).

(25) Einreichungssprache: Deutsch

(81) Bestimmungsstaaten (soweit nicht anders angegeben, für
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AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH,
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TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM,
ZW.

(26) Veröffentlichungssprache: Deutsch

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(71) Anmelder (für alle Bestimmungsstaaten mit Ausnahme von
US): DAIMLERCHRYSLER AG [DE/DE]; Epplestrasse
225, 70567 München (DE).

(72) Erfinder; und

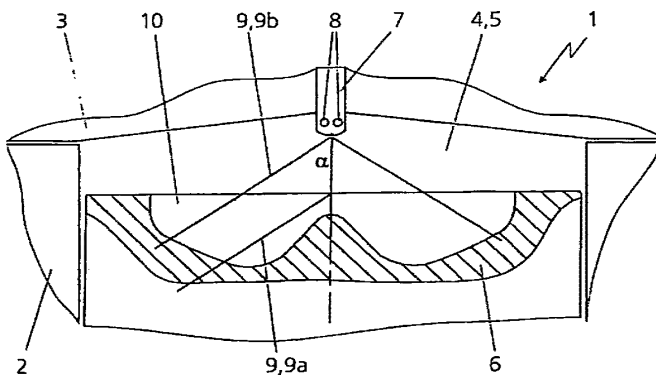
(75) Erfinder/Anmelder (nur für US): PFAFF, Rüdiger
[DE/DE]; Im Wolfbusch 46, 70499 Stuttgart (DE). SCHN-
ABEL, Martin [DE/DE]; Bischof-Fischer-Strasse 50,

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[Fortsetzung auf der nächsten Seite]

(54) Title: DIRECTLY INJECTING INTERNAL COMBUSTION ENGINE

(54) Bezeichnung: DIREKTEINSPRITZENDE BRENNKRAFTMASCHINE



(57) Abstract: The invention relates to a direct injecting internal combustion engine (1), comprising at least one cylinder (4) which comprises a combustion chamber (5) and a piston (6) which is displaced in a oscillating manner, and an injection nozzle (7) for injecting fuel into the combustion chamber (5). The piston (6) comprises a piston cavity (10) which comprises a projection extending in the central region thereof in the direction of a cylinder head (3). A surface (13) of the piston cavity (10), which is connected to the elevation (11) in the direction of the edge of the cavity (12), is connected to the elevation (11) by means of a radius (14), in such a manner that an injection jet (9a) injected at the earliest possible moment and reaching said area is distributed in the direction of the elevation (11) and also in the direction of the edge of the cavity (12). The surface (13), which is connected to the projection (11) in the direction of the edge of the cavity (12), comprises said type of extension in the direction of the edge of the cavity (12), such that an injection jet (9b) injected at the latest possible moment impacts upon the surface (13). The injection jet (9b) injected at the latest possible moment is distributed in the direction of the elevation (11) and also in the direction of the edge of the cavity (12).

[Fortsetzung auf der nächsten Seite]

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ZM, ZW), eurasisches (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), europäisches (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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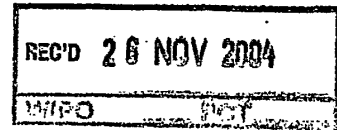
(57) Zusammenfassung: Eine direkteinspritzende Brennkraftmaschine (1) weist wenigstens einen Zylinder (4), welcher einen Brennraum (5) aufweist und in welchem ein Kolben (6) eine Oszillationsbewegung ausführt, eine Einspritzdüse (7) zur Einspritzung von Kraftstoff in den Brennraum (5) auf. Der Kolben (6) weist eine Kolbenmulde (10) auf, welche in ihrem zentralen Bereich eine sich in Richtung eines Zylinderkopfes (3) erstreckende Erhebung aufweist. Eine sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) der Kolbenmulde (10) ist mit der Erhebung (11) über einen Radius (14) derart verbunden, dass ein in diesem Bereich auftreffender, zum frühest möglichen Zeitpunkt eingespritzter Einspritzstrahl (9a) sich sowohl in Richtung der Erhebung (11) als auch in Richtung des Muldenrandes (12) verteilt. Die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) weist eine derartige Erstreckung in Richtung des Muldenrandes (12) auf, dass ein zum spätest möglichen Zeitpunkt eingespritzter Einspritzstrahl (9b) auf die Fläche (13) auftrifft. Der zum spätest möglichen Zeitpunkt eingespritzte Einspritzstrahl (9b) verteilt sich sowohl in Richtung der Erhebung (11) als auch in Richtung des Muldenrandes (12).

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Prioritätsbescheinigung über die Einreichung einer Patentanmeldung

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IPC: F 02 B, F 02 F

Die angehefteten Stücke sind eine richtige und genaue Wiedergabe der ursprünglichen Unterlagen dieser Patentanmeldung.

München, den 04. November 2004
Deutsches Patent- und Markenamt
Der Präsident
 Im Auftrag

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Direkteinspritzende Brennkraftmaschine

5 Die Erfindung betrifft eine direkteinspritzende Brennkraftmaschine mit wenigstens einem Zylinder, welcher einen Brennraum aufweist und in welchem ein Kolben eine Oszillationsbewegung ausführt, nach der im Oberbegriff von Anspruch 1 näher definierten Art.

10

Eine gattungsgemäße Brennkraftmaschine ist aus der US 2002/0117146 A1 bekannt. Hierbei wird der Kraftstoff unter einem relativ steilen Einspritzwinkel in den Brennraum eingespritzt und die Kolbenmulde ist zumindest teilweise an den
15 Einspritzwinkel angepasst.

Bei einer in der DE 196 49 052 A1 beschriebenen Brennkraftmaschine ist ebenfalls eine besondere Form der Kolbenmulde vorgesehen, um eine zusätzliche Reduzierung der von der Brennkraftmaschine ausgestoßenen Schadstoffe zu erreichen.
20

Wenn beim Betrieb einer Brennkraftmaschine, insbesondere einer Dieselmotorkraftmaschine, eine frühe Homogenisierung innerhalb des Brennraums erreicht werden soll, so müssen Einspritzzeitpunkte von ca. 130 bis 30° vor dem oberen Totpunkt des Kolbens gewählt werden, da zu diesem Zeitpunkt der Brennraumdruck noch relativ gering ist, sodass der eingespritzte Kraftstoff sehr tief in den Brennraum eindringen kann. Um ein Auftreffen des Einspritzstrahls auf die Zylinderwandung bzw.
25 die Laufbuchse zu verhindern, sollte ein möglichst steiler
30 Einspritzwinkel an der Einspritzdüse gewählt werden, um eine

möglichst große freie Strahllänge zu gewährleisten. Dies erfordert auch, dass die Form der Kolbenmulde an diese Einspritzung angepasst ist, wie dies beispielsweise bei der US 2002/0117146 A1 der Fall ist.

5

Da es jedoch nicht möglich ist, die Brennkraftmaschine über ihr gesamtes Kennfeld mit einem homogenen Brennverfahren zu betreiben, muss die Kolbenmulde sowohl für die homogene als auch für die konventionelle Gemischbildung konzipiert sein.

10 Dies ist bei bekannten Lösungen nicht problemlos möglich.

Es ist daher Aufgabe der vorliegenden Erfindung, eine direkt-einspritzende Brennkraftmaschine zu schaffen, bei welcher die Form der Kolbenmulde so ausgebildet ist, dass die Brennkraftmaschine sowohl mit einem homogenen als auch mit einem konventionellen Brennverfahren betrieben werden kann.

15

Erfindungsgemäß wird diese Aufgabe durch die in Anspruch 1 genannten Merkmale gelöst.

20

Die erfindungsgemäße Lösung stellt sicher, dass der Einspritzstrahl stets so auf der Kolbenmulde auftrifft, dass sich der eingespritzte Kraftstoff optimal mit der in dem Brennraum sich befindlichen Luft vermischen kann, und zwar unabhängig vom Zeitpunkt der Einspritzung. Insbesondere die Tatsache, dass ein zum spätest möglichen Zeitpunkt eingespritzter Einspritzstrahl stets auf die sich an die Erhebung anschließende Fläche auftrifft, stellt sicher, dass der Impuls des auftreffenden Einspritzstrahls nicht vernichtet wird, wodurch er nicht mehr optimal zur Gemischbildung verwendet werden könnte, was wiederum erhöhte Schwarzrauchbildung nach sich ziehen würde.

25

30

Auf diese Weise ergibt sich eine Brennkraftmaschine, welche problemlos sowohl mit einem homogenen als auch mit einem konventionellen Brennverfahren betrieben werden kann.

35

Vorteilhafte Ausgestaltungen der Erfindung ergeben sich aus den Unteransprüchen. Nachfolgend ist ein Ausführungsbeispiel der Erfindung anhand der Zeichnung prinzipmäßig dargestellt.

5 Dabei zeigen:

Fig. 1 eine erfindungsgemäße Brennkraftmaschine mit einem in einem Brennraum derselben oszillierenden Kolben und mit einem auf einer Kolbenmulde des Kolbens auftretenden Einspritzstrahl;

Fig. 2 die Gestaltung der Kolbenmulde des Kolbens aus Fig. 1 in einem ersten Bereich;

Fig. 3 die Gestaltung der Kolbenmulde des Kolbens aus Fig. 1 in einem zweiten Bereich;

Fig. 4 die Gestaltung der Kolbenmulde des Kolbens aus Fig. 1 in einem dritten Bereich;

Fig. 5 die Ablenkung des eingespritzten Kraftstoffstrahls in dem in Fig. 4 dargestellten Bereich der Kolbenmulde;

Fig. 6 die Gestaltung der Kolbenmulde des Kolbens aus Fig. 1 in einem vierten Bereich;

Fig. 7 die Lufterfassung in einem sechsten Bereich der Kolbenmulde;

Fig. 8 eine erste Ausführungsform eines fünften Bereichs eines Kolbens aus Fig. 1;

Fig. 9 eine zweite Ausführungsform eines fünften Bereichs eines Kolbens aus Fig. 1; und

Fig. 10 eine dritte Ausführungsform eines fünften Bereichs eines Kolbens aus Fig. 1.

Fig. 1 zeigt eine Brennkraftmaschine 1, welche ein Kurbelgehäuse 2 und einen Zylinderkopf 3 aufweist. Innerhalb des Kurbelgehäuses 2 der Brennkraftmaschine 1 befindet sich wenigstens ein Zylinder 4, welcher einen Brennraum 5 aufweist und in welchem ein Kolben 6 in an sich bekannter Weise eine Oszillationsbewegung ausführt. In dem Zylinderkopf 3 ist eine Einspritzdüse 7 angeordnet, welche mehrere Einspritzöffnungen 8 aufweist, aus denen ein Einspritzstrahl 9 austritt. Der Öffnungswinkel α des Einspritzstrahls 9 ist im vorliegenden Fall relativ steil und liegt in einem Bereich zwischen 50° und 120°. Auf diese Weise wird also Kraftstoff direkt in den Brennraum 5 eingespritzt, sodass es sich um eine direkt einspritzende Brennkraftmaschine 1 handelt.

In Fig. 1 sind zwei unterschiedliche Einspritzstrahlen abgebildet, nämlich ein Einspritzstrahl 9a, welcher sich ergibt, wenn sich der Kolben 6 in einem oberen Totpunkt befindet, und ein Einspritzstrahl 9b, der sich bei einer Kraftstoffeinspritzung zum spätest möglichen Einspritzzeitpunkt ergibt. Die Einspritzstrahlen 9a und 9b sind jeweils lediglich als Achsen eines sich innerhalb des Brennraumes 5 verteilenden Einspritzkegels dargestellt.

Der Kolben 6 weist an seiner dem Zylinderkopf 3 zugewandten Seite eine Kolbenmulde 10 auf. In den nachfolgenden Figuren wird die Kontur der Kolbenmulde 10 sowie deren Anpassung an die Einspritzstrahlen 9 näher erläutert, wobei in den einzelnen Figuren aus Übersichtlichkeitsgründen jeweils nur diejenigen Bezugszeichen angegeben sind, die für die Beschreibung der jeweiligen Figur relevant sind. Die Kolbenmulde 10 ist bei allen Figuren identisch.

Wie in Fig. 2 erkennbar ist, weist die Kolbenmulde 10 in ihrem zentralen Bereich eine sich in Richtung des Zylinderkopfes 3 erstreckende Erhebung 11 auf. Die Erhebung 11 weist hierbei einen Winkel β gegenüber der Achse des Kolbens auf,

der kleiner als der halbe Einspritzwinkel α ist, so dass der äußerste Rand des hier als Mittelachse dargestellten Einspritzstrahls 9a nicht mit der Erhebung 11 in Berührung kommt.

5

Wie in Fig. 2 und Fig. 3 zu erkennen, schließt sich in Richtung eines Muldenrandes 12, also dem Ende der Kolbenmulde 10, eine Fläche 13 an die Erhebung 11 an, welche mit der Erhebung 11 über einen Radius 14 derart verbunden ist, dass der zum
10 frühest möglichen Zeitpunkt eingespritzte Einspritzstrahl 9a an einem Auftreffpunkt 15 auf die Fläche 13 auftrifft und sich sowohl in Richtung der Erhebung 11 als auch in Richtung des Muldenrandes 12 verteilt. Diese Verteilung des Einspritzstrahls 9a ist wichtig, um den Kraftstoff möglichst gut mit
15 der sich in dem Brennraum 5 befindlichen Luft zu vermischen. Durch den oben beschriebenen steileren Winkel β der Erhebung 11 im Vergleich mit dem Einspritzwinkel α ist in dem Bereich von dem Auftreffpunkt 15 des Einspritzstrahls 9a auf der Fläche 13 zu der Erhebung 11 noch genügend Freiraum, so dass
20 sich die in Richtung der Erhebung 11 abgelenkte Kraftstoffmenge gut verteilen kann. Der in Richtung der Erhebung 11 abgelenkte Kraftstoff ist mit dem Pfeil 16 bezeichnet, wohingegen der in Richtung des Muldenrandes 12 abgelenkte Kraftstoff mit dem Pfeil 17 bezeichnet ist. Es ist hier zu erkennen,
25 dass die in Richtung des Muldenrandes 12 gelenkte bzw. verteilte Kraftstoffmenge größer ist als die in Richtung der Erhebung 11 abgelenkte Kraftstoffmenge. Der Radius 14 sollte in diesem Zusammenhang so gewählt werden, dass eine Stauung des rückströmenden Kraftstoffs vermieden wird.

30

In Fig. 4 ist zu erkennen, dass die sich in Richtung des Muldenrandes 12 an die Erhebung 11 anschließende Fläche 13 im wesentlichen eben ausgebildet ist und eine Steigung in Richtung des Muldenrandes 12 aufweist. Mit anderen Worten, die
35 Fläche 13 bildet eine Ebene, die über die gesamte maximale Einspritzdauer in einem konstanten Winkel γ zu dem Einspritzstrahl 9 steht. Der Winkel γ kann in Abhängigkeit der erforder-

derlichen Impulsablenkung eines in diesem Fall im mittleren Bereich der Fläche 13 auftreffenden Einspritzstrahls 9c verändert werden, wobei der Hauptimpuls, wie bereits oben erwähnt, in Richtung des Muldenrandes 12 erfolgt. Gegebenenfalls kann es auch sinnvoll sein, die sich in Richtung des Muldenrandes 12 an die Erhebung 11 anschließende Fläche 13 gekrümmt auszuführen.

In Fig. 5 ist anhand von Pfeilen 18 und 19 dargestellt, dass auf diese Weise während der gesamten Kraftstoffeinspritzung ein geringerer Anteil des Einspritzstrahls 9 in Richtung der Erhebung 11 und ein größerer Anteil in Richtung des Muldenrandes 12 geleitet wird. Der Pfeil 18 zeigt hierbei die in Richtung der Erhebung 11 geleitete Kraftstoffmenge, wohingegen der Pfeil 19 die in Richtung des Muldenrandes 12 geleitete Kraftstoffmenge zeigt.

Der Abstand der Fläche 13 zu der Einspritzdüse 7 sollte so gewählt werden, dass der Einspritzstrahl 9 eine ausreichend freie Strahllänge und somit eine optimale Strahlgeschwindigkeit und den optimalen Impuls erreichen kann. Je nach Anzahl der Einspritzöffnungen 8 der Einspritzdüse 7 ist eine Interaktion des an der Kolbenmulde 10 abgelenkten Kraftstoffs zwischen zwei Einspritzstrahlen 9 möglich, was zusätzlich zur Lufterfassung in dem Brennraum 5 beiträgt. Zusätzlich kann die Aufteilung des Kraftstoffs auch durch Drall unterstützt werden.

In Fig. 6 ist der zum spätest möglichen Zeitpunkt eingespritzte Einspritzstrahl 9b dargestellt. Dabei ist erkennbar, dass die Fläche 13 eine derartige Erstreckung in Richtung des Muldenrandes 12 aufweist, dass der zum spätest möglichen Zeitpunkt eingespritzte Einspritzstrahl 9b auf die Fläche 13 auftrifft. Auch in diesem Bereich ist die Fläche 13 derart ausgeführt, dass der Einspritzstrahl 9b sich sowohl in Richtung der Erhebung 11 als auch in Richtung des Muldenrandes 12 verteilt. Die sich in Richtung der Erhebung 11 verteilende

Kraftstoffmenge ist mit eine Pfeil 20 und die sich in Richtung des Muldenrandes 12 verteilende Kraftstoffmenge mit einem Pfeil 21 bezeichnet. Auf diese Weise wird ein senkrechtes Auftreffen des Einspritzstrahls 9 auf der Kolbenmulde 10 verhindert und es wird gewährleistet, dass der Impuls des Einspritzstrahls 9b erhalten bleibt.

Aus Fig. 7 geht hervor, dass sich an die Fläche 13 eine mit dem Muldenrand 12 über einen Radius 22 verbundene Fläche 23 anschließt. An dem Muldenrand 12 entsteht ein sogenannter Quetschspaltbereich 24 an bzw. oberhalb einer oberen Fläche 25 des Kolbens 6, der das Kraftstoff-Luft-Gemisch im Randbereich in Richtung der Kolbenmulde 10 quetscht und auf diese Weise die Emission von Kohlenwasserstoffen und Kohlenmonoxid reduziert. Der Quetschspaltbereich 24 sollte nicht zu groß gewählt werden, da auch in diesem Bereich eine Lufterfassung erforderlich ist. Die Fläche 23 trägt dazu bei, dass der dem Pfeil 21 folgende Kraftstoffstrahl so abgelenkt wird, dass ein vermehrter Eintrag von Kraftstoff in den Quetschspaltbereich 24 verhindert wird.

In den Figuren 8, 9 und 10 sind verschiedene Anbindungen der Fläche 23 an die obere Fläche 25 des Kolbens 6 dargestellt.

Bei der Ausführungsform gemäß Fig. 8 bildet die mit dem Muldenrand 12 verbundene Fläche 23 einen spitzen Winkel mit der oberen Fläche 25 des Kolbens 6. Hierdurch kann die Zuführung von Kraftstoff an eine nicht dargestellte Glühkerze oder Zündkerze verbessert werden.

Bei der Ausführung gemäß Fig. 9 geht die Fläche 23 in einem Radius 26 in die obere Fläche 25 des Kolbens 6 über.

In Fig. 10 ist eine Ausführung dargestellt, bei welcher die mit dem Muldenrand 12 verbundene Fläche 23 einen stumpfen Winkel mit der oberen Fläche 25 des Kolbens 6 bildet.

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Patentansprüche

- 5 1. Direkteinspritzende Brennkraftmaschine mit wenigstens einem Zylinder, welcher einen Brennraum aufweist und in welchem ein Kolben eine Oszillationsbewegung ausführt, und mit einer Einspritzdüse zur Einspritzung von Kraftstoff in den Brennraum, wobei der Kolben eine Kolbenmulde aufweist, welche in ihrem zentralen Bereich eine sich in
10 Richtung eines Zylinderkopfes erstreckende Erhebung aufweist,
dadurch gekennzeichnet,
dass eine sich in Richtung des Muldenrandes (12) an die
15 Erhebung (11) anschließende Fläche (13) der Kolbenmulde (10) mit der Erhebung (11) über einen Radius (14) derart verbunden ist, dass ein in diesem Bereich auftreffender, zum frühest möglichen Zeitpunkt eingespritzter Einspritzstrahl (9a) sich sowohl in Richtung der Erhebung (11) als
20 auch in Richtung des Muldenrandes (12) verteilt, und dass die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) eine derartige Erstreckung in Richtung des Muldenrandes (12) aufweist, dass ein zum spätest möglichen Zeitpunkt eingespritzter
25 Einspritzstrahl (9b) auf die Fläche (13) auftrifft, wobei sich der zum spätest möglichen Zeitpunkt eingespritzte Einspritzstrahl (9b) sowohl in Richtung der Erhebung (11) als auch in Richtung des Muldenrandes (12) verteilt.
- 30 2. Direkteinspritzende Brennkraftmaschine nach Anspruch 1, dadurch gekennzeichnet,

dass sich an die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) eine mit dem Muldenrand (12) verbundene Fläche (23) anschließt.

- 5 3. Direkteinspritzende Brennkraftmaschine nach Anspruch 2,
d a d u r c h g e k e n n z e i c h n e t ,
dass die mit dem Muldenrand (12) verbundene Fläche (23)
über einen Radius (22) mit der sich in Richtung des Mul-
denrandes (12) an die Erhebung (11) anschließende Fläche
10 (13) verbunden ist.
4. Direkteinspritzende Brennkraftmaschine nach Anspruch 2 o-
der 3,
d a d u r c h g e k e n n z e i c h n e t ,
15 dass die mit dem Muldenrand (12) verbundene Fläche (23)
einen spitzen Winkel mit der oberen Fläche (25) des Kol-
bens (6) bildet.
5. Direkteinspritzende Brennkraftmaschine nach Anspruch 2 o-
der 3,
20 d a d u r c h g e k e n n z e i c h n e t ,
dass die mit dem Muldenrand (12) verbundene Fläche (23)
einen stumpfen Winkel mit der oberen Fläche (25) des Kol-
bens (6) bildet.
25
6. Direkteinspritzende Brennkraftmaschine nach einem der An-
sprüche 2 bis 5,
d a d u r c h g e k e n n z e i c h n e t ,
dass die mit dem Muldenrand (12) verbundene Fläche (23)
30 in einem Radius (26) in die oberen Fläche (25) des Kol-
bens (6) übergeht.
7. Direkteinspritzende Brennkraftmaschine nach einem der An-
sprüche 1 bis 6,
35 d a d u r c h g e k e n n z e i c h n e t ,
dass die sich in Richtung des Muldenrandes (12) an die

Erhebung (11) anschließende Fläche (13) eine Steigung in Richtung des Muldenrandes (12) aufweist.

5 8. Direkteinspritzende Brennkraftmaschine nach Anspruch 7, dadurch gekennzeichnet, dass die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) im wesentlichen eben ausgebildet ist.

10 9. Direkteinspritzende Brennkraftmaschine nach Anspruch 7, dadurch gekennzeichnet, dass die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) gekrümmt ausgebildet ist.

15 10. Direkteinspritzende Brennkraftmaschine nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, dass der Einspritzwinkel (α) der Einspritzdüse (7) zwischen 50° und 120° beträgt.

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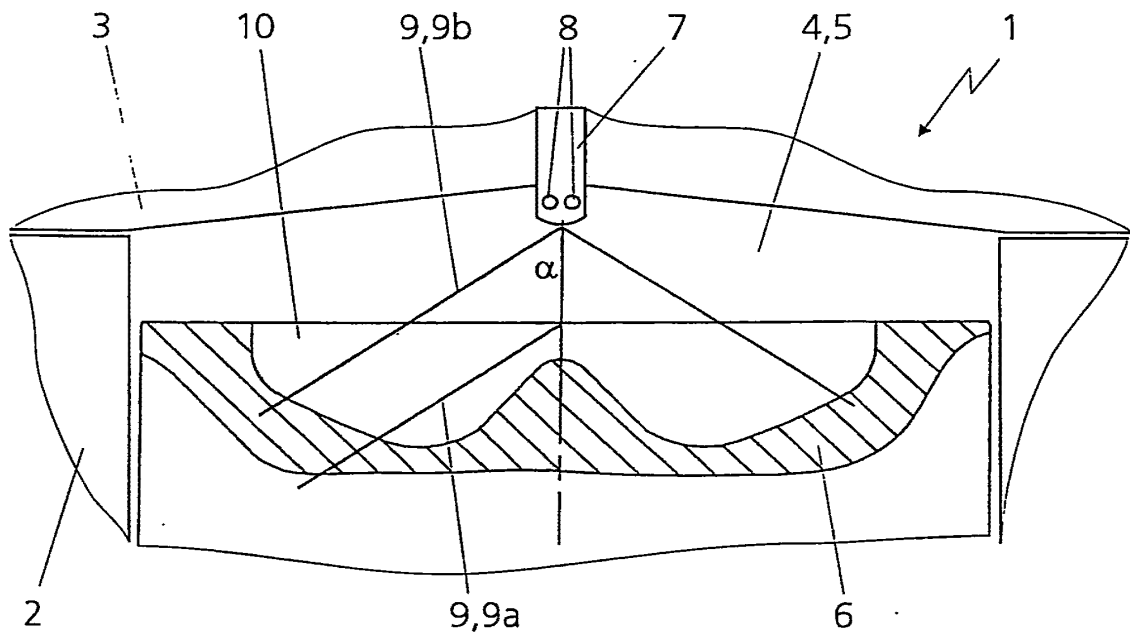


Fig. 1

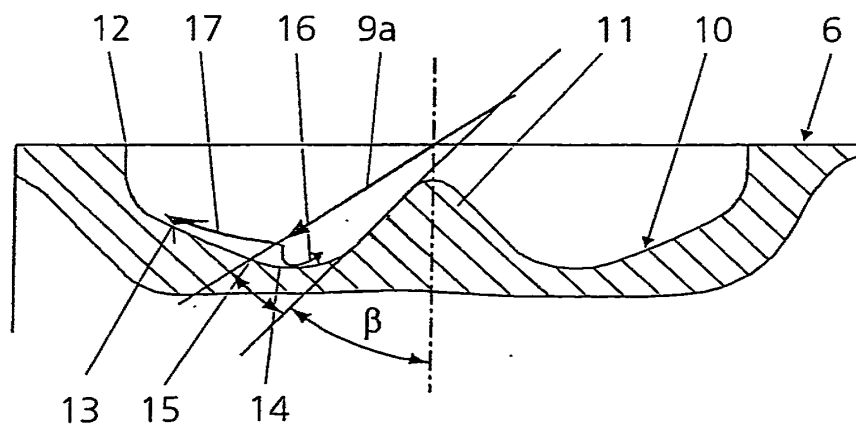
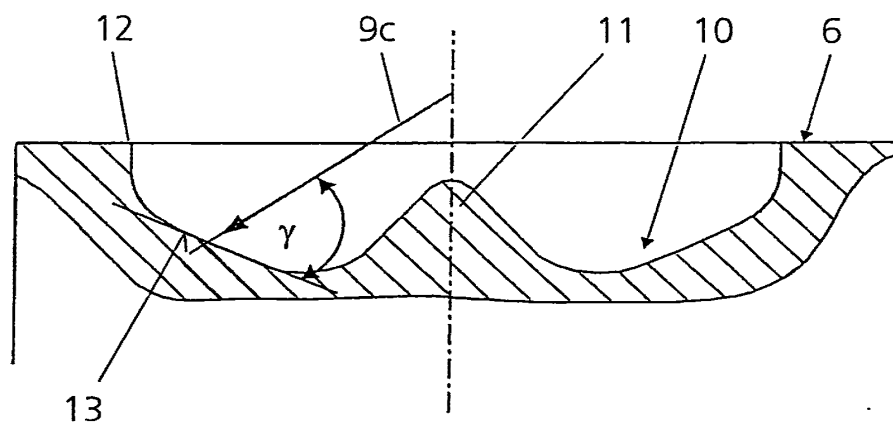
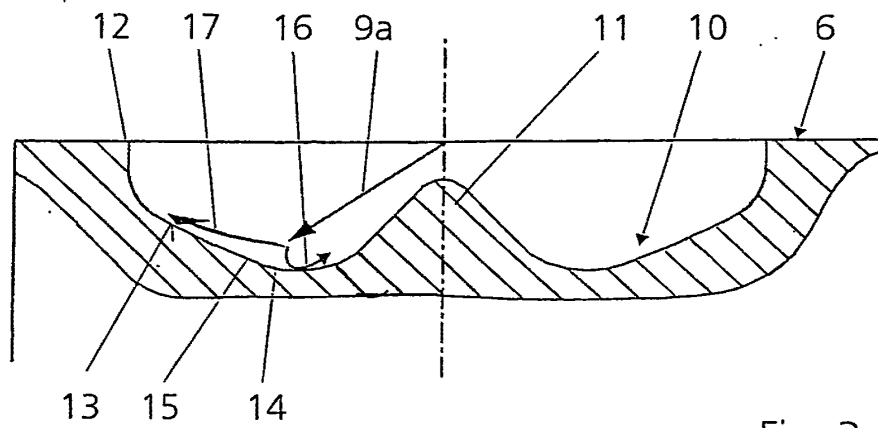


Fig. 2



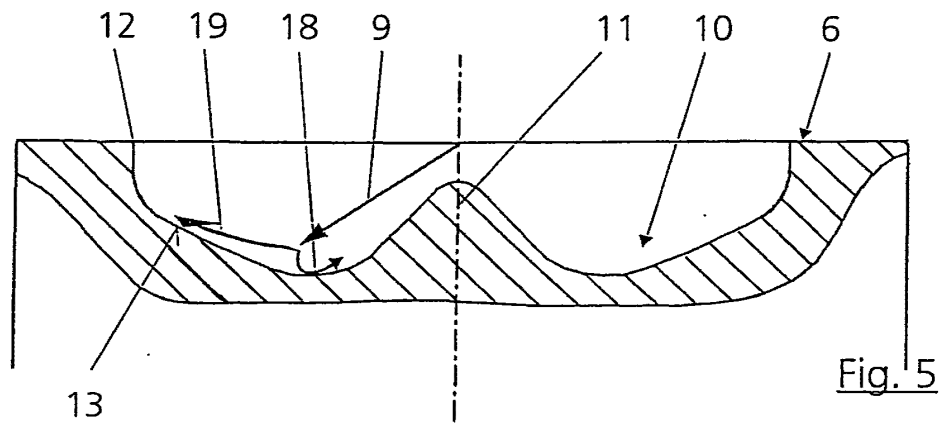


Fig. 5

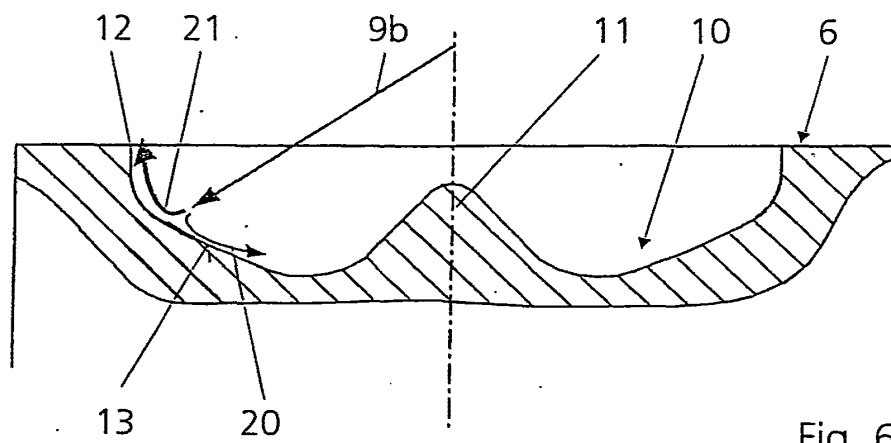


Fig. 6

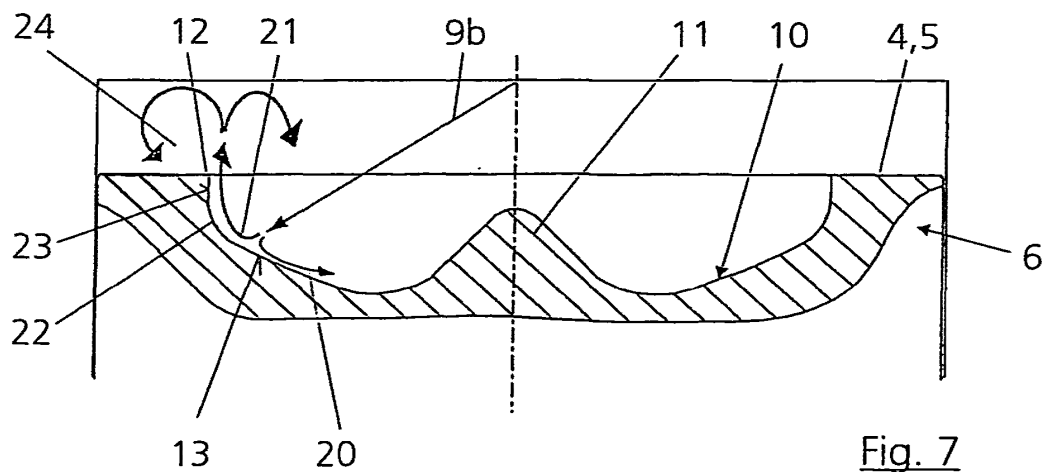
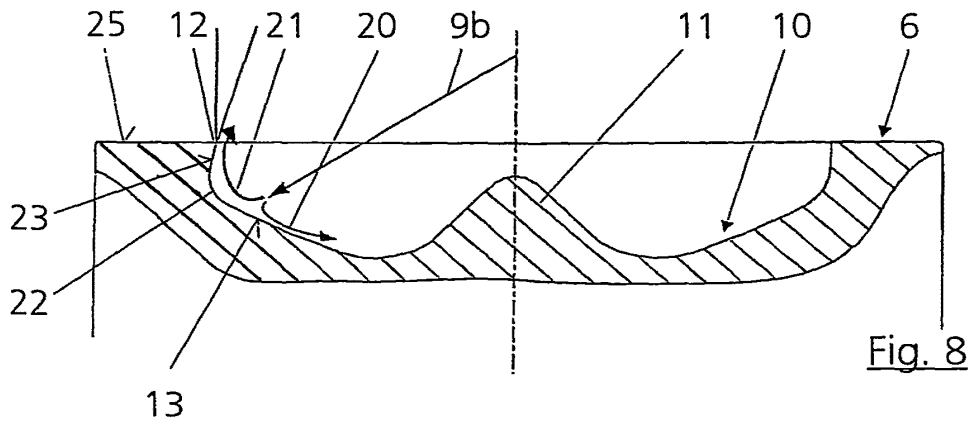
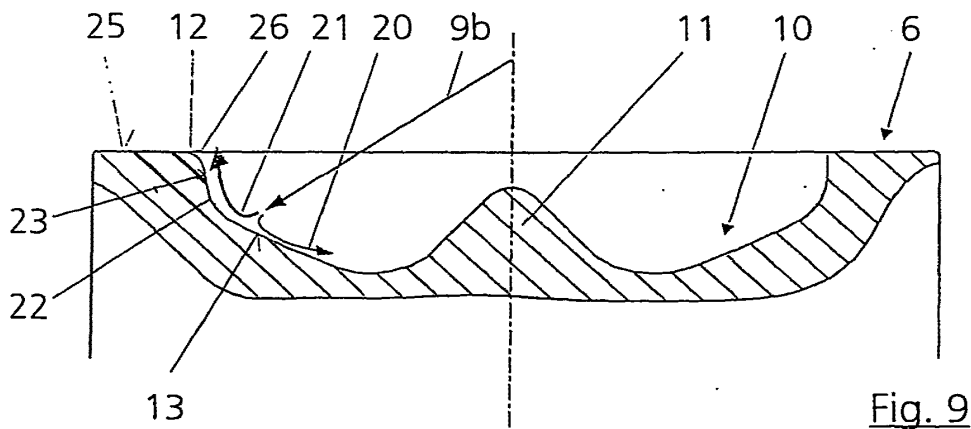
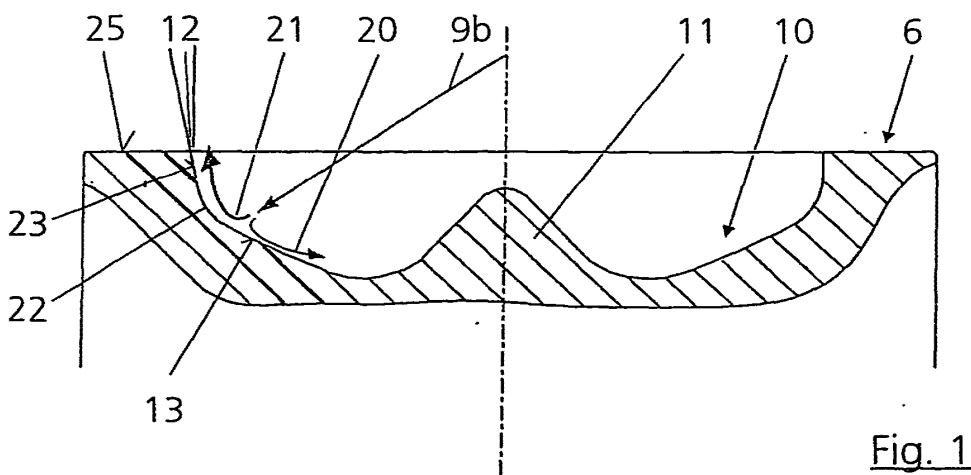


Fig. 7

Fig. 8Fig. 9Fig. 10

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Aifan

29.10.2003

Zusammenfassung

Eine direkteinspritzende Brennkraftmaschine (1) weist wenigstens einen Zylinder (4), welcher einen Brennraum (5) aufweist und in welchem ein Kolben (6) eine Oszillationsbewegung ausführt, eine Einspritzdüse (7) zur Einspritzung von Kraftstoff in den Brennraum (5) auf. Der Kolben (6) weist eine Kolbenmulde (10) auf, welche in ihrem zentralen Bereich eine sich in Richtung eines Zylinderkopfes (3) erstreckende Erhebung aufweist. Eine sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) der Kolbenmulde (10) ist mit der Erhebung (11) über einen Radius (14) derart verbunden, dass ein in diesem Bereich auftreffender, zum frühest möglichen Zeitpunkt eingespritzter Einspritzstrahl (9a) sich sowohl in Richtung der Erhebung (11) als auch in Richtung des Muldenrandes (12) verteilt. Die sich in Richtung des Muldenrandes (12) an die Erhebung (11) anschließende Fläche (13) weist eine derartige Erstreckung in Richtung des Muldenrandes (12) auf, dass ein zum spätest möglichen Zeitpunkt eingespritzter Einspritzstrahl (9b) auf die Fläche (13) auftrifft. Der zum spätest möglichen Zeitpunkt eingespritzte Einspritzstrahl (9b) verteilt sich sowohl in Richtung der Erhebung (11) als auch in Richtung des Muldenrandes (12).

25 (Fig. 1)

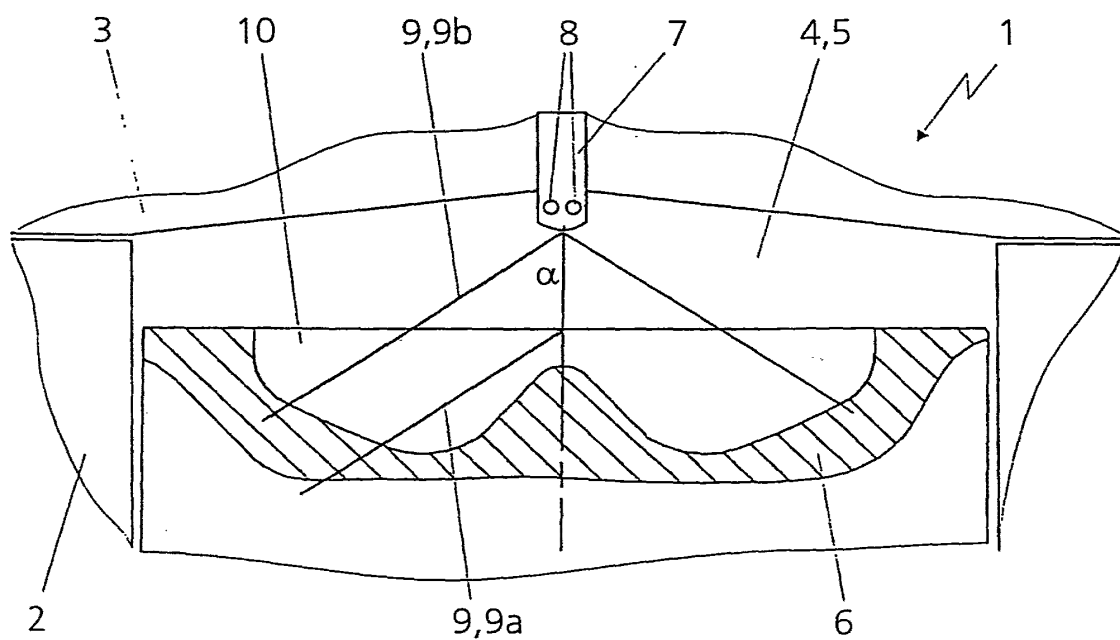


Fig. 1

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DO/ EO WORKSHEET

Virginia Irby, Patent Application Specialist/ National Stage Division

U.S. Appl. No. 10/577797

International Appl. No. PCT/EP04/11637

Application filed by : ☐ 20 months ☒ 30 months

WIPO PUBLICATION INFORMATION :

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☐ French ☐ Spanish ☐ Russian ☐ Other : _____

Publication Date : 26 May 2005

Not Published : ☐ U.S. only designated ☐ EP request

Published : ☐ EP request

INTERNATIONAL APPLICATION PAPERS IN THE APPLICATION FILE :

☒ International Application (RECORD COPY)
☐ Article 19 Amendments
☐ PCT/IPEA/409 IPER : ☐ EP ☐ JP ☐ SE ☐ AU
☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ _____

☐ PCT/IB/306
☐ Request form PCT/RO/101
☒ PCT/ISA/210 - Search Report : ☒ EP ☐ JP ☐ SE ☐ AU
☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ _____ ☐ NONE

☐ Annexes to 409
☐ PCT/ISA/237 : ☐ EP ☐ JP ☐ SE ☐ AU
☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ _____
☐ PCT/IPEA/409 or PCT/ISA/237 was NOT AVAILABLE at the time of paralegal review

☐ Search Report References
☒ Priority Document (s) No. 1
☐ N/A
☐ Priority Document was NOT AVAILABLE at the time of paralegal review
☐ Other : _____

RECEIPTS FROM THE APPLICANT (other than checked above) :

☒ Basic National Fee (or authorization to charge) .

☒ Preliminary Amendment(s) Filed on :
1. ☒ same as 371 request date 2. _____ 3. _____

☒ Description ☒ Claims ☒ Abstract

☒ Information Disclosure Statement(s) Filed on :
1. ☒ same as 371 request date 2. _____ 3. _____

☒ Drawing Figure(s) - (# of drwgs. 4)

☐ Assignment Document (forwarded to Assignment Branch)

☐ Translation of Article 19 Amendments
☐ entered ☐ not entered :

☐ Assignee Statement Under 37 CFR 3.73(b)
☐ Assignee PG Publication Notice

☐ not a page for page substitution
☐ replaced by Article 34 Amendment

☐ Annexes to 409
☐ entered ☐ not entered :

☒ Substitute Specification Filed on :
1. ☒ same as 371 request date 2. _____ 3. _____

☐ not a page for page substitution
☐ no translation ☐ other : _____

☒ Application Data Sheet

☐ Oath/ Declaration (executed)

☐ Power of Attorney

☐ Oath/ Declaration ☐ unsigned ☐ no citizenship ☐ other

☐ Change of Address

☐ DNA Diskette ☐ Sequence Listing

☐ Other : _____

NOTES : ☐ I.A. used as Specification ☐ Other :

35 U.S.C. 371 : Receipt of Request (PTO-1390)

28 April 2006

Date Acceptable Oath/ Declaration Received

Date of Completion of requirements under 35 U.S.C. 371

Date of Completion of DO/ EO 903 - Notification of Acceptance

Date of Completion of DO/ EO 905 - Notification of Missing Requirements 05 March 2007

Date of Completion of DO/ EO 909 - Notification of Abandonment

Date of Completion of DO/ EO 916 - Notification of Defective Response

Date of Completion of DO/ EO 922 - Notification to Comply w/ Requirements for Patent Applications Containing Nucleotide and/or Amino Acid Sequence Disclosures

Date of Completion of DO/ EO 923

PATENT APPLICATION FEE DETERMINATION RECORD Effective December 8, 2004						Application or Docket Number 10/577797	
CLAIMS AS FILED - PART I							
		(Column 1)	(Column 2)				
U.S. NATIONAL STAGE FEES							
BASIC FEE							
EXAMINATION FEE							
SEARCH FEE							
FEE FOR EXTRA SPEC. PGS.			minus 100 =	/ 50 =			
TOTAL CHARGEABLE CLAIMS		20	minus 20 =	*			
INDEPENDENT CLAIMS		1	minus 3 =	*			
MULTIPLE DEPENDENT CLAIM PRESENT ☐							
* If the difference in column 1 is less than zero, enter "0" in column 2							
CLAIMS AS AMENDED - PART II							
		(Column 1)	(Column 2)	(Column 3)			
AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		
	Total	*	Minus	**	=		
	Independent	*	Minus	***	=		
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐						
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than '20', enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than '3', enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.							

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE		OR	BASIC FEE	300
EXAM. FEE			EXAM. FEE	200
SEARCH FEE			SEARCH FEE	400
X \$ 125 =			X \$ 250 =	
X \$ 25 =		OR	X \$ 50 =	
X \$ 100 =		OR	X \$ 200 =	
+ \$ 180 =		OR	+ \$ 360 =	
TOTAL		OR	TOTAL	900

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X \$ 25 =		OR	X \$ 50 =	
X \$ 100 =		OR	X \$ 200 =	
+ \$ 180 =		OR	+ \$ 360 =	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

		(Column 1)	(Column 2)	(Column 3)			
AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		
	Total	*	Minus	**	=		
	Independent	*	Minus	***	=		
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐						
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than '20', enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than '3', enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.							

**MULTIPLE DEPENDENT CLAIM
FEE CALCULATION SHEET**
(FOR USE WITH FORM PTO-875)

SERIAL NO.

10/577797

FILING DATE

APPLICANT(S)

CLAIMS

	AS FILED		AFTER 1 st AMENDMENT		AFTER 2 nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
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TOTAL IND.		↓	1	↓		↓
TOTAL DEP.		←	19	←		←
TOTAL CLAIMS			20			

	AS FILED		AFTER 1 st AMENDMENT		AFTER 2 nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
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100						
TOTAL IND.		↓		↓		↓
TOTAL DEP.		←		←		←
TOTAL CLAIMS						

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 10/577,797		Filing Date 03/27/2007		☐ To be Mailed	
APPLICATION AS FILED – PART I										
(Column 1)		(Column 2)		SMALL ENTITY ☐ OR		OTHER THAN SMALL ENTITY				
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	OR	RATE (\$)	FEE (\$)			
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A				
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A				
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A				
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$ =		OR	X \$ =				
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$ =			X \$ =				
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL				
APPLICATION AS AMENDED – PART II										
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT	04/28/2006	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X \$ =		OR	X \$50=	0
	Independent (37 CFR 1.16(h))	* 1	Minus	*** 3	= 0	X \$ =		OR	X \$200=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE			OR	TOTAL ADD'L FEE	0
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =		OR	X \$ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =		OR	X \$ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE			OR	TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

Legal Instrument Examiner:
Eva Gillis

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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