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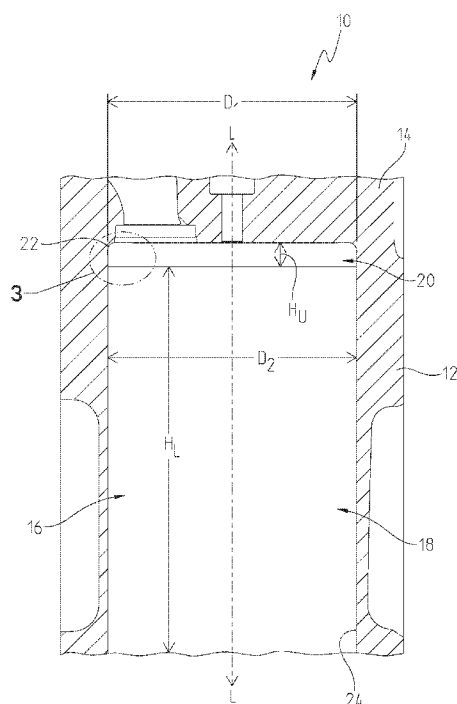


Fig. 2

(57) Abstract: An internal combustion engine includes a cylinder block, a cylinder head integral with the cylinder block, and a cylinder bore extending along a longitudinal axis within the cylinder block body. The cylinder bore has an upper portion adjacent the cylinder head and a lower portion longitudinally inward of the upper portion. The upper portion of the cylinder bore has a first radius and the lower portion of the cylinder bore having a second radius which is less than the first radius.



CYLINDER BORE WITH AN ANGLED RADIUS FOR AN ENGINE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Patent Application Serial No. 62,324,403, filed April 19, 2016, and titled “CYLINDER BORE WITH AN ANGLED RADIUS FOR AN ENGINE,” the complete disclosure of which is expressly incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention relates generally to a cylinder bore of an engine and, more particularly, to a blind cylinder bore for a monoblock internal combustion engine with an angled upper portion formed through cold working.

BACKGROUND OF THE DISCLOSURE

[0003] An engine includes a cylinder block which has a cylinder bore for receiving a piston. The piston is configured to reciprocate within the cylinder bore (which may include a cylinder liner) with rotation of the crankshaft of the engine.

[0004] In one embodiment, an internal combustion engine may be a monoblock engine with a cylinder block and cylinder head formed as a single or integral unit. Because of the singular and integral construction of the cylinder block and head, a monoblock engine may have increased mechanical stiffness relative to an engine with a cylinder head which is separated from the cylinder block. By forming the cylinder head and block together as one piece (e.g., through a casting process), the monoblock engine does not include a head gasket because the cylinder head is not separate from the cylinder block. Without a head gasket, the number of components on the engine is reduced and, therefore, the number of components which may deteriorate from wear or fail over time also is reduced.

[0005] During formation of the cylinder block, a honing tool may be positioned within the cylinder bore to apply grooves, indentations, recesses, or any other cuts or marks to an inner surface of the cylinder bore. These cuts or marks define lubrication passages along the inner surface of the cylinder bore to facilitate movement of the piston within the cylinder bore. More particularly, honing is a process of abrasive machining in which the honing tool includes abrasive stones or a stone assembly which are configured to rotate within the cylinder bore and against the inner surface of the cylinder bore. The honing tool makes numerous small indentations, cuts, recesses, or grooves within the inner surface of the cylinder bore which allow lubricant, such as grease or oil, to flow along the inner surface of the cylinder bore. In this way, the cylinder block maintains its structural integrity but the inner surface of the cylinder bore has undergone a roughening process for the flow of lubrication.

[0006] However, when the honing tool moves in reverse, for example, in an upward direction when being removed from the cylinder bore, the honing tool may contact the upper portion of the cylinder bore in an undesirable manner. More particularly, the cylinder block may have a sharp or 90° angle at an upper surface of the cylinder bore and this sharp corner may damage or prematurely wear the honing tool when it is removed from the cylinder bore. Therefore, a need exists to form a cylinder bore in a manner that retains the structural integrity of the cylinder block but also allows a honing tool to be removed or moved in a reverse direction without premature wear to the honing tool.

SUMMARY OF THE DISCLOSURE

[0007] In one embodiment, an internal combustion engine includes a cylinder block, a cylinder head integral with the cylinder block, and a cylinder bore extending along a longitudinal axis within the cylinder block body. The cylinder bore has an upper portion adjacent the cylinder head and a lower portion longitudinally inward of the upper portion. The upper portion of the cylinder bore has a first radius and the lower portion of the cylinder bore having a second radius which is less than the first radius.

[0008] In another embodiment, a method of forming a cylinder block of a monoblock internal combustion engine comprises integrally forming together a cylinder block body and a cylinder head, forming a cylinder bore within the cylinder block body, and deforming an upper

portion of the cylinder block body in an outward direction relative to a lower portion of the cylinder block body.

[0009] In a further embodiment, a method of forming a cylinder block of a monoblock internal combustion engine comprises integrally forming together a cylinder block body and a cylinder head, forming a cylinder bore within the cylinder block body, cold working an upper portion of the cylinder block body to deform the upper portion in an outward direction relative to a lower portion of the cylinder block body, and forming a plurality of cuts on an inner surface of the cylinder bore.

[0010] Additional features and advantages of the present invention will become apparent to those skilled in the art upon consideration of the following detailed description of the illustrative embodiment exemplifying the best mode of carrying out the invention as presently perceived.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing aspects and many of the intended advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description when taken in conjunction with the accompanying drawings.

[0012] Fig. 1 is a perspective view of a cylinder block of a monoblock internal combustion engine of the present disclosure;

[0013] Fig. 2 is a cross-sectional view of the cylinder block of Fig. 1, taken along line 2-2 of Fig. 1;

[0014] Fig. 3 is a detailed cross-sectional view of an upper portion of a cylinder bore within the cylinder block of Fig. 2; and

[0015] Fig. 4 is a block diagram of a method of forming the cylinder block of Fig. 1.

[0016] Corresponding reference characters indicate corresponding parts throughout the several views. Although the drawings represent embodiments of various features and components according to the present disclosure, the drawings are not necessarily to scale and certain features may be exaggerated in order to better illustrate and explain the present disclosure. The exemplifications set out herein illustrate embodiments of the invention, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION OF THE DRAWINGS

[0017] For the purposes of promoting an understanding of the principals of the invention, reference will now be made to the embodiments illustrated in the drawings, which are described below. The embodiments disclosed below are not intended to be exhaustive or limit the invention to the precise form disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may utilize their teachings. It will be understood that no limitation of the scope of the invention is thereby intended. The invention includes any alterations and further modifications in the illustrative devices and described methods and further applications of the principles of the invention which would normally occur to one skilled in the art to which the invention relates.

[0018] Referring to Fig. 1, a cylinder block 10 for a monoblock internal combustion engine includes a cylinder block body 12 and an integral cylinder head 14. For example, cylinder block body 12 and cylinder head 14 may be integrally formed through a casting or machining process, or through any other process configured to produce cylinder block 10 as single or one-piece unit. By integrally forming cylinder block body 12 with cylinder head 14, there is no separation between cylinder block body 12 and cylinder head 14 and, therefore, a head gasket is not required on cylinder block 10. Cylinder block body 12 may define the lower portion of cylinder block 10 while cylinder head 14 defines the upper portion of cylinder block 10.

[0019] In the illustrative embodiment of Fig. 2, cylinder block 10 includes an internal cylinder bore 16 extending along a longitudinal axis L. Illustratively, cylinder bore 16 may be a blind bore of cylinder block 10. Cylinder bore 16 receives a piston (not shown) of the engine along an inner surface 24 of cylinder bore 16 and the piston is configured to reciprocate within cylinder bore 16 during operation of the engine. Cylinder bore 16 also receives fuel and air such that a combustion process occurs within cylinder bore 16 during operation of the engine.

[0020] As shown in Figs. 2 and 3, cylinder bore 16 has a lower portion 18 and an upper portion 20. Upper portion 20 is longitudinally above lower portion 18 and positioned longitudinally below and adjacent cylinder head 14 of cylinder block 10. As such, cylinder bore 16 is formed within cylinder block body 12 and is positioned longitudinally below cylinder head 14.

[0021] As shown in Figs. 2 and 3, the longitudinal length or height H_U of upper portion 20 of cylinder bore 16 may be less than the longitudinal length or height H_L of lower portion 18 of cylinder bore 16. In one embodiment, H_U may be approximately 0.1-2.0 inches and, more particularly, may be approximately 0.4 inches. As such, upper portion 20 defines the upper 0.1-2.0 inches of cylinder bore 16 and, illustratively, defines the upper 0.4 inches of cylinder bore 16.

[0022] In one embodiment, an outer corner of upper portion 20 of cylinder bore 16 defines an interface 22 between cylinder head 14 and cylinder block body 12. As shown in Figs. 2 and 3, interface 22 defines the outer uppermost corners or extent of cylinder bore 16. Interface 22 has a rounded or curved configuration such that the outer corners of cylinder bore 16 are rounded. In this way, inner surface 24 of cylinder bore 16 at upper portion 20 is not perpendicular to cylinder head 14, thereby eliminating a 90-degree angle and a sharp corner at interface 22.

[0023] Additionally, and still referring to Figs. 2 and 3, upper portion 20 of cylinder bore 16 is tapered or angled outwardly relative to lower portion 18 and longitudinal axis L. More particularly, and referring still to Figs. 2 and 3, upper portion 20 defines a first diameter D_1 of cylinder bore 16 and lower portion 18 defines a second diameter D_2 of cylinder bore 16. Second diameter D_2 of cylinder bore 16 is less than first diameter D_1 of cylinder bore 16. In one embodiment, first diameter D_1 is greater than second diameter D_2 by approximately 0.0005-.008 inches (0.013-0.20 mm). In other words, the outermost extent of inner surface 24 of cylinder bore 16 at upper portion 20 is approximately 0.0005-.008 inches (0.013-0.20 mm) laterally outward relative to the outermost extent of inner surface 24 at lower portion 18, as shown as distance W in Fig. 3. Additionally, an angle α which extends from inner surface 24 of cylinder bore 16 at lower portion 18 to inner surface 24 of cylinder bore 16 at upper portion 20 is approximately 180.1-183°. In other words, inner surface 24 of cylinder bore 16 at upper portion 20 is angled outwardly relative to longitudinal axis L by approximately 0.1-3.0°, as shown as angle β in Fig. 3. In one embodiment, angle β is approximately 1.4° relative to longitudinal axis L. In this way, inner surface 24 of cylinder bore 16 extends parallel to longitudinal axis L in lower portion 18 but angles outwardly by angle β in upper portion 20.

[0024] Referring to Fig. 4, a method 100 of forming cylinder block 10 is disclosed. Beginning with Step 102, to form cylinder bore 16 with the tapered or angled configuration,

cylinder block 10 is first formed through a conventional forming process, such as casting, machining, or any other type of manufacturing method configured to form cylinder block 10 as a single unit. In one embodiment, cylinder bore 16 may be defined during the formation of cylinder block 10. Alternatively, during a subsequent Step 104, cylinder bore 16 may be formed after forming cylinder block 10, for example through a machining process.

[0025] Initially, cylinder bore 16 is formed with a continuous inner surface 24 extending parallel to longitudinal axis L. However, in Step 106, a cold working process is applied to inner surface 24 of cylinder bore 16 at upper portion 20. More particularly, inner surface 24 at upper portion 20 may be cold rolled to deform inner surface 24 at upper portion 20 by moving the material defining inner surface 24 at upper portion 20 outwardly. As the material comprising inner surface 24 at upper portion 20 deforms, upper portion 20 begins to angle outwardly relative to lower portion 18. Because inner surface 24 is cold rolled in Step 106, material from cylinder block body 12 is not removed, but rather, is deformed. The rolling process may allow for the material comprising inner surface 24 at upper portion 20 to have greater mechanical strength relative to the material comprising inner surface 24 at lower portion 18. Inner surface 24 at upper portion 20 is rolled until the desired outward taper or angle is achieved, for example, until angles α and β are defined. In one embodiment, the cold working process of Step 106 occurs at room temperature, for example 60-80° F.

[0026] With upper portion 20 of cylinder bore 16 angled outwardly in Step 106, inner surface 24 of cylinder bore 16 may be cut, etched, or otherwise roughened to provide grooves, indentations, or recesses which allow for lubricant to be maintained on inner surface 24 in Step 108. Roughening inner surface 24 may occur through a honing process, in which a honing tool (not shown) with at least one abrasive stone is positioned within cylinder bore 16. The honing tool rotates the stone(s) against inner surface 24 which cuts, marks, or etches small grooves, recesses, indentations, or any other type of cut mark along inner surface 24. To fully roughen inner surface 24, the honing tool is advanced within cylinder bore 16 such that inner surface 24 at both lower and upper portions 18, 20 is roughened. The cuts, recesses, grooves, or indentations formed in inner surface 24 during Step 108 allow for grease, oil, or any other lubricant to remain along inner surface 24 for continuous reciprocation of the piston within cylinder bore 16.

[0027] When the roughening process is finished, the roughening tool, for example the honing tool, is removed from cylinder bore 16 in Step 110. To remove the honing tool from cylinder bore 16, the direction of the honing tool may be reversed such that the honing tool moves upwardly toward upper portion 20 of cylinder bore 16. Once at upper portion 20 of cylinder bore 16, the honing tool is able to be removed without contacting inner surface 24 due to the angled configuration of inner surface 24 at upper portion 20. In this way, the honing tool is not accidentally bumped or pushed into inner surface 24 at upper portion 20 during removal, thereby decreasing the likelihood that the honing tool will be damaged or have premature wear caused by removing the honing tool from cylinder bore 16. Additionally, because interface 22 between cylinder block body 12 and cylinder head 14 is laterally outward relative to inner surface 24 at lower portion 18 and is curved, rather than defined by a 90-degree angle or other sharp edge or surface, the honing tool is able to be fully removed from cylinder bore 16 without contacting any angled or sharp surfaces which also could cause damage or prematurely wear the abrasive stones of the honing tool. Therefore, the outwardly angled configuration of inner surface 24 of cylinder bore 16 at upper portion 20 resulting from the deformation process of Step 106 both increases the mechanical strength of the material comprising inner surface 24 at upper portion 20 and also defines an undercut which decreases the likelihood that a honing tool will be damaged when being removed from cylinder bore 16 by allowing for runout of the honing tool without contacting inner surface 24 at upper portion 20.

[0028] Conversely, if the angled configuration of inner surface 24 at upper portion 20 was formed through a machining process or another process which removed material at upper portion 20 rather than deforming it, then the material comprising inner surface 24 at upper portion 20 would have decreased mechanical strength relative to the material comprising inner surface 24 at lower portion 18.

[0029] While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practices in the art to which this invention pertains.

WHAT IS CLAIMED IS:

1. An internal combustion engine, comprising:
a cylinder block comprising a cylinder block body, a cylinder head integral with the cylinder block body, and a cylinder bore extending along a longitudinal axis within the cylinder block body, and the cylinder bore having a lower portion and an upper portion disposed between the lower portion and the cylinder head, the upper portion of the cylinder bore having a first radius and the lower portion of the cylinder bore having a second radius which is less than the first radius.
2. The engine of claim 1, wherein the upper portion is angled outwardly from the lower portion relative to the longitudinal axis.
3. The engine of claim 2, wherein the upper portion is angled outwardly by 0.1-3.0 degrees relative to the longitudinal axis.
4. The engine of claim 3, wherein the upper portion is angled outwardly by 1.4 degrees relative to the longitudinal axis.
5. The engine of claim 1, wherein the upper portion defines an upper 0.1-2.0 inches of the cylinder bore.
6. The engine of claim 5, wherein the upper portion defines an upper 0.4 inches of the cylinder bore.
7. The engine of claim 1, wherein an interface between the cylinder block body and the cylinder head is rounded.
8. A method of forming a cylinder block of a monoblock internal combustion engine, comprising:
integrally forming a cylinder block body with a cylinder head;
forming a cylinder bore within the cylinder block body; and
deforming an upper portion of the cylinder block body in an outward direction relative to a lower portion of the cylinder block body.
9. The method of claim 8, wherein deforming the upper portion of the cylinder block body includes rolling the upper portion of the cylinder block body to angle the upper portion outwardly.
10. The method of claim 9, wherein rolling the upper portion of the cylinder block body occurs at room temperature.

11. The method of claim 8, wherein deforming the upper portion of the cylinder block body includes moving the upper portion outwardly by 0.0005-.008 inch relative to the lower portion of the cylinder block body.
12. The method of claim 8, wherein deforming the upper portion of the cylinder block body includes angling the upper portion outwardly by 0.1-3.0 degrees relative to a longitudinal axis of the cylinder bore.
13. The method of claim 12, wherein deforming the upper portion of the cylinder block body includes angling the upper portion outwardly by 1.4 degrees relative to the longitudinal axis.
14. A method of forming a cylinder block of a monoblock internal combustion engine, comprising:
 - integrally forming together a cylinder block body and a cylinder head;
 - forming a cylinder bore within the cylinder block body;
 - cold working an upper portion of the cylinder block body to deform the upper portion in an outward direction relative to a lower portion of the cylinder block body; and
 - forming a plurality of cuts on an inner surface of the cylinder bore.
15. The method of claim 14, wherein forming the plurality of cuts includes receiving a honing tool within the cylinder bore and moving the honing tool against the inner surface of the cylinder bore.
16. The method of claim 15, further comprising removing the honing tool from the cylinder bore after forming the plurality of cuts and spacing the honing tool apart from the upper portion of the cylinder block body when removing the honing tool.
17. The method of claim 14, wherein cold working the upper portion of the cylinder block body includes rolling the upper portion of the cylinder block body.
18. The method of claim 17, wherein rolling the upper portion of the cylinder block body occurs at room temperature.
19. The method of claim 14, wherein cold working the upper portion of the cylinder block body includes moving the upper portion outwardly by 0.0005-.008 inch relative to the lower portion of the cylinder block body.
20. The method of claim 14, further comprising providing a rounded interface between the cylinder block body and the cylinder head.

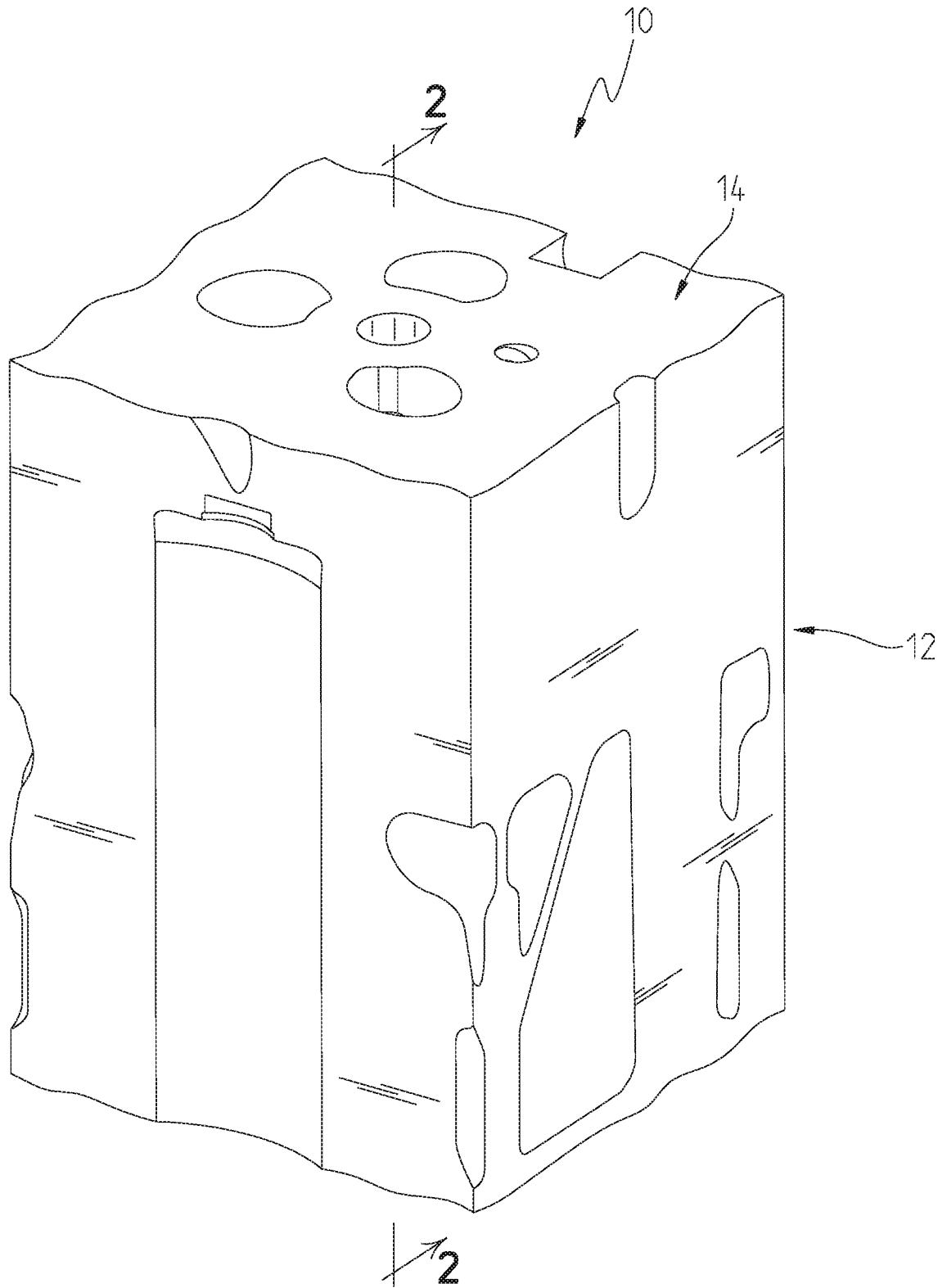


Fig. 1

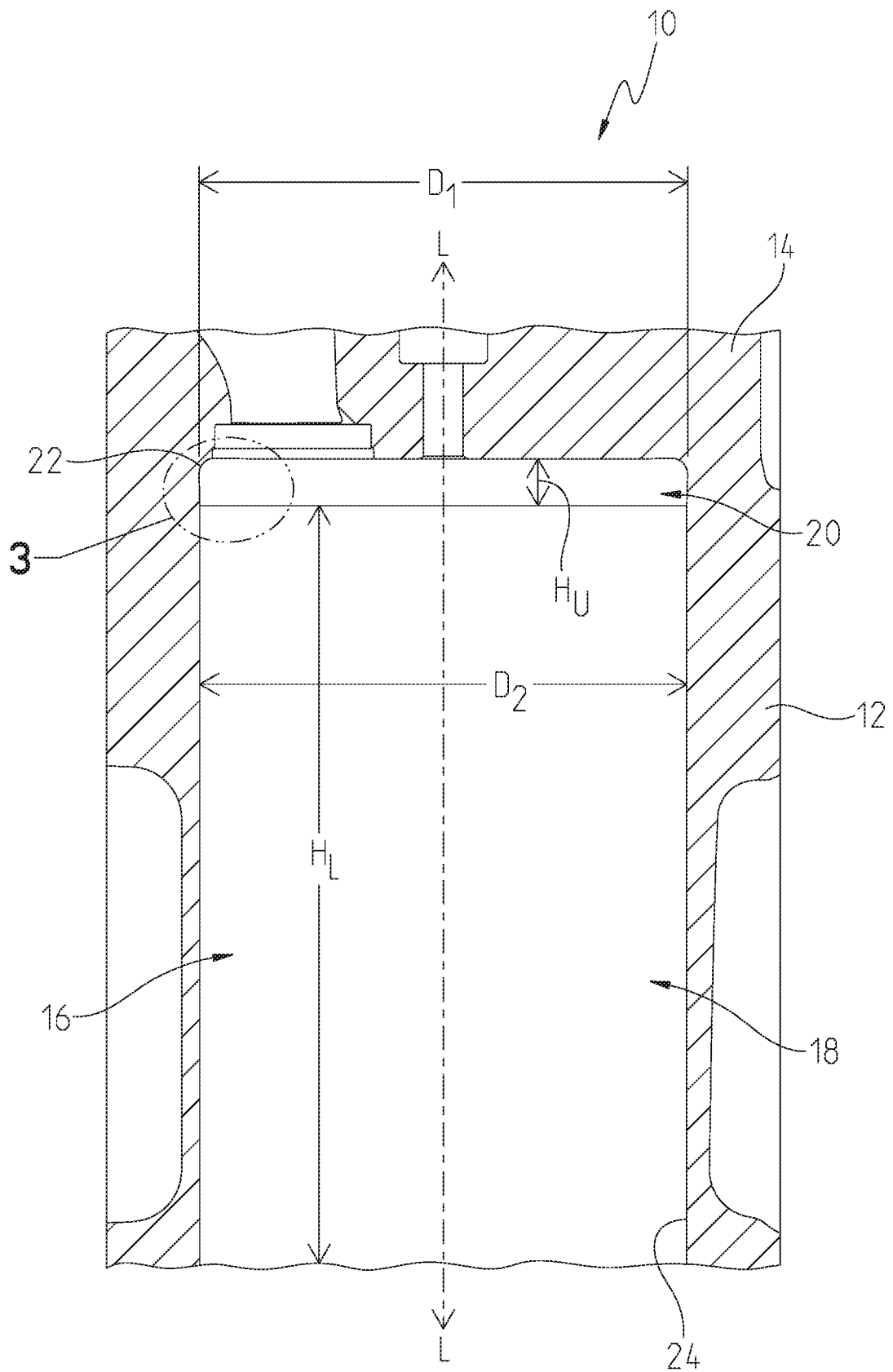


Fig. 2

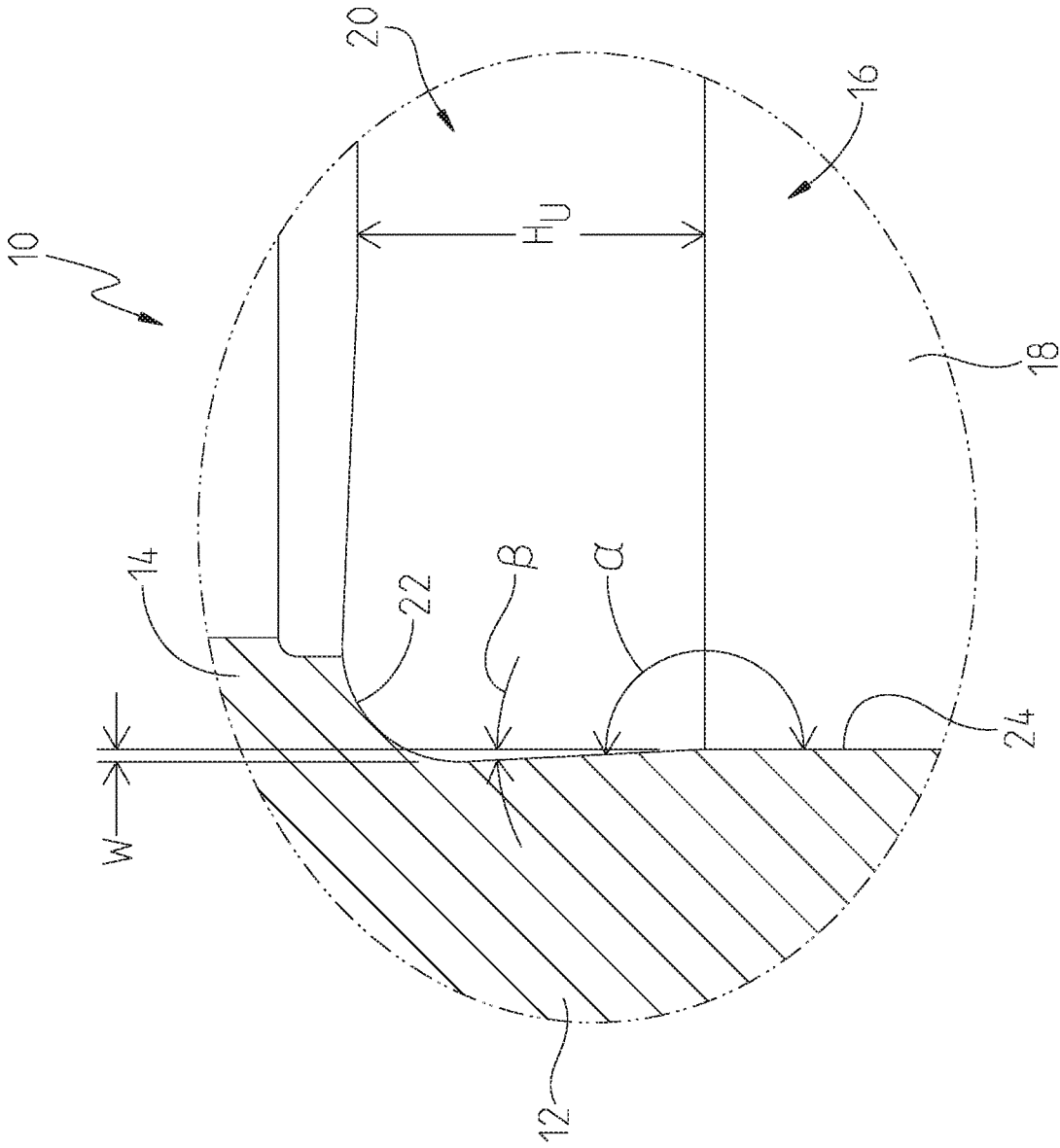


Fig. 3

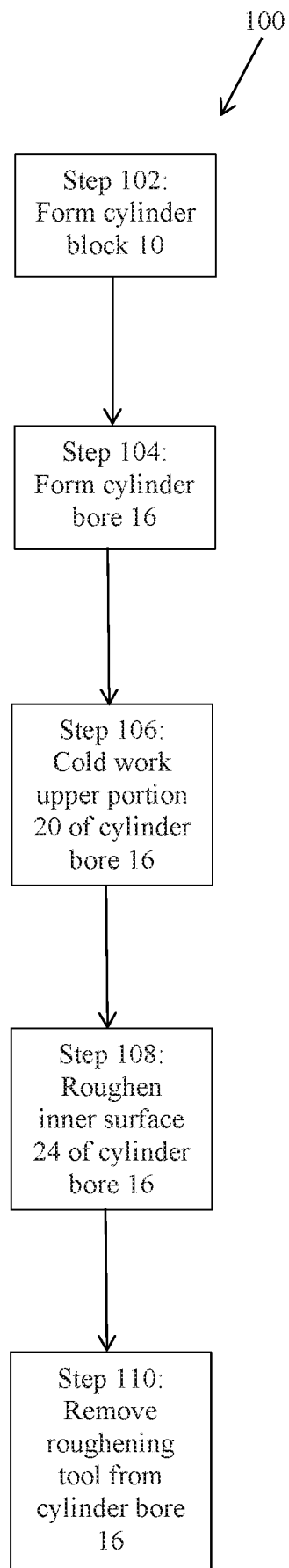


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2017/026962

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F02F 1/00; F02F 1/18; F16J 10/00; F16J 10/02 (2017.01)

CPC - F02F 1/002; F02F 1/00; F02F 1/18; F16J 10/00; F16J 10/02 (2017.05)

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)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 29/888.06; 123/193.1; 123/193.2; 123/193.3; 123/193.4; 123/193.5; 123/657 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,382,167 B1 (TOMINAGA) 07 May 2002 (07.05.2002) entire document	1-8, 11-13
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Y		9, 10, 14-20
Y	DE 197 43 627 A1 (MTU FRIEDRICHSHAFEN GMBH) 15 April 1999 (15.04.1999) see machine translation	9, 10, 14-20
A	US 5,419,037 A (BAILEY) 30 May 1995 (30.05.1995) entire document	1-20
A	US 4,699,100 A (LEYDORF, JR. et al) 13 October 1987 (13.10.1987) entire document	1-20

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

15 June 2017

Date of mailing of the international search report

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