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(54) Title: CONNECTING ROD ASSEMBLY FOR ENHANCING A FLOW OF LUBRICATION IN A RECIPROCATING MECHANICAL SYSTEM

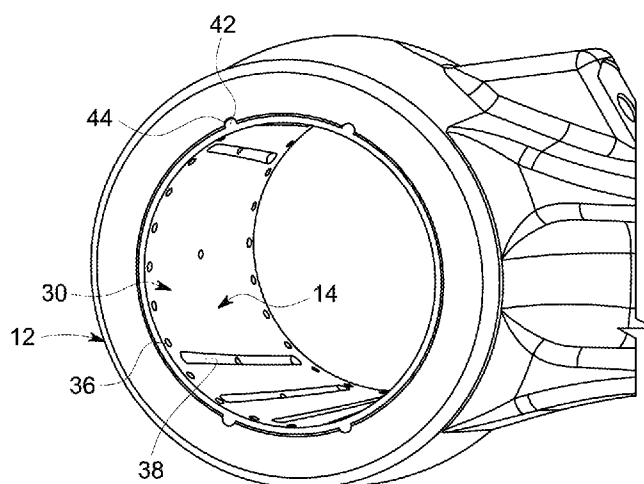


FIG. 11

(57) Abstract: A connecting rod assembly (10) is disclosed. The connecting rod assembly (10) includes a connecting rod (12), a connecting rod bushing (14) at least partially disposed within the connection rod (12); and a piston pin (16) at least partially disposed within the connecting rod bushing (14). The connecting rod (12) may include axial lubrication grooves (20) on an inner diametric surface (22) of the connecting rod (12). In addition, one of the connecting rod bushing (14) and the piston pin (16) may include a surface feature (24, 32, 34, 38) for enhancing delivery of lubrication at the interface between the connecting rod bushing (14) and the piston pin (16). The surface features can be, for example, axial or helical lubrication grooves (24) on the piston pin (16), axial grooves (32) on the bushing (16), and dimples (34) on the piston pin (16). The connecting rod assembly (10) also includes an anti-rotation feature (42, 44).



SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
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- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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CONNECTING ROD ASSEMBLY FOR ENHANCING A FLOW OF LUBRICATION IN A RECIPROCATING MECHANICAL SYSTEM

FIELD OF THE INVENTION

[0001] The invention relates, in general, to connecting rod assemblies, and in particular to an assembly comprising a connecting rod, a piston pin and a connecting rod bushing with surface features, such as circumferential coolant grooves, dimples, and the like, on the inner and outer diametric surfaces for enhanced delivery of lubrication during operation of a reciprocating mechanical system such as a gas compressor, a reciprocating compressor, a piston compressor, and the like.

BACKGROUND OF THE INVENTION

[0002] Rod loading is a major consideration for the designers and operators of reciprocating mechanical systems, such as a gas compressor, a reciprocating compressor, a piston compressor, and the like. One must ascertain that the net rod load does not exceed the design limitations placed upon the reciprocating mechanical system. These limitations are determined by consideration of many stresses; the rod compressive and tensile stresses, the rod column stresses, crosshead compressive and tensile stresses, the rod and crosshead thread stresses, and the crosshead pin (i.e., wrist pin) shear and bearing (i.e., bushing) stresses. These stresses are evaluated for their strength of material integrity, including the stress at crosshead pin bushing. The crosshead pin bushing stress must be considered not only for its magnitude, but also, and more importantly, for its direction of application.

[0003] The load that is applied to the crosshead pin bushing is developed from two sources: the forces of inertia of the reciprocating piston, rod, and crosshead assembly, and the forces resulting from compression of the

gas in the cylinder. The inertial load is that force that develops because of the weight (mass) of the piston, rod, and crosshead assembly (including piston rings, nuts, crosshead pin, and balance weights) being in reciprocating motion. Typically, the inertial load changes with the square of the rotative speed of the reciprocating mechanical system. One should note that the inertial load is a “reversing” load in that it changes from tension to compression (and back to tension again) during one complete rotation of the crankshaft.

[0004] The direction of the rod load has a paramount effect on the lubrication of the crosshead pin bushing. When the load is being applied to one side of the bushing, some finite amount of clearance develops on the opposite side. This clearance is filled with lubricant, such as oil, and the like, thereby lubricating and cooling that side of the bushing. A clearance must also develop on the other side of the bushing to lubricate the other side of the bushing. A reversal in the direction of application of the load must occur for this to happen. In addition, it is also evident that the magnitude and duration of this reversal must be such that a complete filling of this clearance space with lubricant can be effected. This is necessary to achieve adequate lubrication and cooling.

[0005] Reciprocating mechanical systems operating with non-reversing loads are highly subject to bushing damage. Many past instances have shown that a bushing can fail within a few minutes while operating under non-reversing loads. The damage will usually appear in the direction of the applied non-reversing load, or in the direction of the dominant load if the reversal is marginal. Thus, it is desirable to maintain sufficient lubrication in a reciprocating mechanical system while operating under non-reversing loads.

SUMMARY OF THE INVENTION

[0006] Embodiments of the invention offer new and inventive ways of providing sufficient lubrication in a reciprocating mechanical system under reversing loads and non-reversing loads. The reciprocating system includes, but is not limited to, a gas compressor, a reciprocating compressor, a piston compressor, and the like. In one embodiment, a connecting rod assembly comprises a connecting rod; a connecting rod bushing at least partially disposed within a connecting rod; and a piston pin at least partially disposed within the connecting rod bushing to form an interface therebetween. The connecting rod has one or more lubrication grooves in an inner diametric surface for enhancing delivery of a lubricant at the interface between the connecting rod bushing and the piston pin.

[0007] In another embodiment, a connecting rod assembly comprises a connecting rod; a connecting rod bushing at least partially disposed within a connecting rod; and a piston pin at least partially disposed within the connecting rod bushing to form an interface therebetween. At least one of the connecting rod bushing and the piston pin includes a surface feature for enhancing delivery of a lubricant at the interface between the connecting rod bushing and the piston pin.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] While various embodiments of the invention are illustrated, the particular embodiments shown should not be construed to limit the claims. It is anticipated that various changes and modifications may be made without departing from the scope of this invention.

[0009] FIG. 1 shows a perspective view of a connecting rod assembly and a connecting rod for a compressor according to an embodiment of the invention;

- [0010] FIG. 2 shows a perspective view of a connecting rod with axial grooves on an inner diametric surface of the connecting rod according to an embodiment of the invention;
- [0011] FIG. 3 shows a perspective view of a connecting rod with helical grooves on an inner diametric surface of the connecting rod according to an embodiment of the invention;
- [0012] FIG. 4 shows an enlarged perspective view of a pin with axial grooves on the inner diametric surface of the pin according to an embodiment of the invention;
- [0013] FIG. 5 shows an enlarged perspective view of a pin with helical grooves on the inner diametric surface of the pin according to an embodiment of the invention;
- [0014] FIG. 6 shows an enlarged perspective view of a bushing with axial grooves on the inner and outer diametric surfaces of the bushing according to an embodiment of the invention;
- [0015] FIG. 7 shows an enlarged perspective view of a pin with dimples on the outer diametric surface to contain/hold lubricant and allow better heat transfer according to an embodiment of the invention;
- [0016] FIG. 8 shows an enlarged perspective view of a bushing including a number of axial grooves that are spaced around the inner diametric surface to avoid the key loading plane, resulting in an improved flow of lubrication that helps in efficient heat removal according to an embodiment of the invention;
- [0017] FIG. 9 shows another enlarged perspective view of the bushing of FIG. 8;
- [0018] FIG. 10 shows an enlarged perspective view of a bushing with an anti-rotation feature, such as a raised projection, and the like, according to an embodiment of the invention; and

[0019] FIG. 11 shows an enlarged perspective view of the bushing with the anti-rotation feature, such as a raised projection, and the like, mounted in a connecting rod with a slot or groove to accommodate the raised projection on the bushing according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring now to FIG. 1, a connecting rod assembly, shown generally at 10, is shown according to an embodiment of the invention. The connecting rod assembly 10 includes a connecting rod 12, a connecting rod bushing 14 (commonly referred to as a “bushing”) at least partially disposed within the connection rod 12, and a piston pin 16 (commonly referred to as a “pin”) at least partially disposed within the bushing 14. The connecting rod 12 includes a fluid port 18 at one end for delivering pressurized lubricant to the interface between the bushing 14 and the pin 16. The lubricant can any suitable lubricant for use in a reciprocating mechanical system, such as oil, and the like. The port 18 extends entirely through the connecting rod 12 such that lubricant entering the port 18 at one end of the connecting rod 12 exits the opposite end of the connecting rod 12 proximate the connecting rod assembly 10.

[0021] FIG. 2 shows a perspective view of the connecting rod 12 according to an embodiment of the invention. The connecting rod 12 includes one or more spaced apart axial lubrication grooves 20 on an inner diametric surface 22 of the connecting rod 12. The purpose of the lubrication grooves 20 is to act as a reservoir to collect a larger volume of lubricant at the interface between the bushing 14 and the connecting rod 12. The axial lubrication grooves 20 extend in a direction that is substantially parallel to a longitudinal axis 21 of the connecting rod 12. The inner diametric surface 22 may also include a central circumferential lubrication groove 23 that is in fluid communication

with the fluid port 18 for supplying lubricant to the axial lubrication grooves 20.

[0022] FIG. 3 shows a perspective view of the connecting rod 12 according to another embodiment of the invention. The connecting rod 12 includes one or more spaced apart helical lubrication grooves 20 on the inner diametric surface 22 of the connecting rod 12. Similar to the axial lubrication grooves 20, the purpose of the helical lubrication grooves 20 is to act as a reservoir to collect a larger volume of lubricant at the interface between the bushing 14 and the connecting rod 12. It will be appreciated that the invention is not limited by the angle at which the helical lubrication grooves 20 are formed on the inner diametric surface 22, and that the helical lubrication grooves 20 could also be purely tangential.

[0023] FIG. 4 shows a perspective view of a piston pin 16 according to an embodiment of the invention. In the illustrated embodiment, the piston pin 16 includes one or more axial lubrication grooves 24 formed on an inner diametric surface 29 of the piston pin 16. The purpose of the lubrication grooves 24 is to act as a reservoir to collect a larger volume of lubricant at the interface between the bushing 14 and the piston pin 16. The axial lubrication grooves 24 extend in a direction that is substantially parallel to a longitudinal axis 25 of the piston pin 16. The piston pin 16 can be coated with a low friction coating, such as diamond-like carbon (DLC), and the like.

[0024] FIG. 5 shows a perspective view of a piston pin 16 according to another embodiment of the invention. In this embodiment, the piston pin 16 includes one or more helical lubrication grooves 24 on the inner diametric surface 29 of the piston pin 16. Similar to the axial lubrication grooves 24, the purpose of the helical lubrication grooves 24 is to act as a reservoir to collect a larger volume of lubricant at the interface between the bushing 14 and the piston pin 16. In this

embodiment, the piston pin 16 can be coated with a low friction coating, such as diamond-like carbon (DLC), and the like.

[0025] As shown in FIG. 5, the piston pin 16 comprises a lobed piston pin having a first outer segment 16a, an inner segment 16b and a second outer segment 16c. It will be appreciated that the disclosure is not limited by the number of segments 16a, 16b, 16c, and that the embodiments of the invention can be practiced with any desirable number of segments. The piston pin 16 has an open ended, hollow, circumferential, cylindrical shape with a plurality of circumferential feed holes 36 extending entirely through the piston pin 16 from an outer diametric surface 28 to the inner diametric surface 29. The feed holes 36 are in fluid communication with the pressurized oil feed port 18 passing through the connecting rod 12 to deliver lubricant to the interface between the bushing 14 and the pin 16. The feed holes 36 may have the same cross-sectional surface area (or diameter) or different cross-sectional surface areas (or diameters). In the illustrated embodiment, the feed holes 36, spaced approximately equidistant from each other, are formed in the inner segment 16b of the piston pin 16. However, it will be appreciated that the invention is not limited by the feed holes 36 being formed in the inner segment 16b, and that the invention can be practiced with the feed holes 36 formed in any or all the segments 16a, 16b, 16c.

[0026] FIG. 6 shows a perspective view of the connecting rod bushing 14, such as a rocking journal bearing, and the like, according to an embodiment of the invention. In this embodiment, the bushing 14 includes one or more axial grooves 32 formed on the inner diametric surface 30 and one or more helical grooves 32 formed on the outer diametric surface 31 of the bushing 14. The purpose of the grooves 32 on the inner diametric surface 30 is to act as a reservoir to collect a larger volume of lubricant at the interface between the bushing 14 and the piston pin 16. The purpose of the grooves 32 on the outer

diametric surface 31 is to aid in heat transfer from the bushing 14. However, it will be appreciated that the invention is not limited by the type of lubrication grooves 32, and that the invention can be practiced with any combination of type of lubrication grooves 32 formed on the inner diametric surface 30 and the outer diametric surface 31. For example, the lubrication grooves 32 can be any combination of axial, tangential and helical lubrication grooves 32.

[0027] The bushing 14 can be coated with a low friction coating, such as MoS₂, and the like. In one embodiment, the bushing 14 can be made out of an alloy developed for toughness in a harsh environment. Any suitable alloy may be used. For example, one suitable alloy is a copper-nickel-tin alloy, commercially available under the tradename ToughMet®, sold by Materion of Mayfield Heights, Ohio (<https://materion.com/Products/Alloys/ToughMet-Copper-Nickel-Tin-Alloys.aspx>).

[0028] FIG. 7 shows a perspective view of a piston pin 16 according to an embodiment of the invention. In this embodiment, the outer diameter surface 28 of the piston pin 16 includes at least one feature 34, such as a plurality of dimples, and the like, for holding lubricant, such as oil, and the like. The purpose of the dimples 34 is to act as a reservoir to collect a larger volume of lubricant at the interface between the bushing 14 and the piston pin 16. The dimples 34 can be formed in a series of rows and columns that are equally spaced from each other, as shown in the illustrated embodiment. However, it will be appreciated that the dimples 34 can be formed in any desirable pattern on the outer diametric surface 28 of the piston pin 16. The piston pin 16 can be coated with a low friction coating, such as diamond-like carbon (DLC), and the like.

[0029] FIGS. 8 and 9 show a perspective view of a bushing 14 according to an embodiment of the invention. The bushing 14 includes a plurality of feed holes 36 extending from the outer diametric surface 31 to the

inner diametric surface 30. Each feed hole 36 is in fluid communication with an axial lubrication groove 38 formed in the inner diametric surface 30 of the bushing 14. Thus, the inner diametric surface 30 of the bushing 14 includes a series of spaced apart axial lubrication grooves 32 formed in the inner diametric surface 30 of the bushing 14, with one axial groove per feed hole. The purpose of the lubrication grooves 32 is to act as a reservoir to collect a larger volume of lubricant at the interface between the bushing 14 and the pin 16. Because each feed hole 36 is spaced apart, each corresponding axial groove 38 is also spaced apart. Each axial groove 38 is positioned to align with and overlap its corresponding feed hole 36 and extend substantially parallel to a longitudinal axis 40 of the bushing 14. A width of each axial groove 38 is approximately equal to a diameter of its corresponding feed hole 36. A length of each axial groove 38 extends across the entire width of the inner diametric surface 30 of the connecting rod bushing 14.

[0030] In the illustrated embodiment, the feed holes 36 are only located along a central region of the connecting rod bushing 14 to provide an enhanced supply of lubricant to the interface between the bushing 14 and the pin 16. However, it will be appreciated that the invention is not limited by the feed holes 36 only being in central region of the bushing 14, and that the invention can be practiced with the circumferential feed holes 36 located at any desired location of the bushing 14.

[0031] It is noted that the lubrication grooves 32 are not formed entirely on the inner diametric surface 30 of the bushing 14. It has been found a balance exists between delivering lubrication in a region of maximum film squeeze with the axial lubrication grooves 32, and providing lubrication with an uninterrupted surface against which to form the film of lubrication. In other words, it was found to be advantageous to not provide the axial lubrication grooves 32 in a 45-degree to 90-

degrees section of the inner diametric surface 30 of the bushing 14 where the non-reversing loads and the reversing loads are the highest.

[0032] FIG. 10 shows a perspective view of a bushing 14 with an anti-rotation feature 42 according to an embodiment of the invention. In one embodiment, the anti-rotation feature 42 comprises a raised projection on the outer diametric surface 31 of the bushing 14. The raised projection 42 can be in the form of a semi-hemispherical shaped bump, as shown in FIG. 10. It is noted that the anti-rotation feature 42 is interrupted by a feed hole 36 formed in the central region of the bushing 14. In another embodiment, the feed hole 36 in the central region can be omitted to allow the anti-rotation feature 42 to be continuous (i.e., non-interrupted). It will be appreciated that the invention is not limited by the specific shape of the anti-rotation feature 42, and that the invention can be practiced with any desirable shape, so long as the anti-rotation feature 42 cooperates with a complimentary shaped-anti-rotation feature on the connecting rod 12.

[0033] FIG. 11 shows a perspective view of the bushing of FIG. 10 mounted in the connecting rod 12 such that the anti-rotation feature 42 on the bushing 14 cooperates with complimentary-shaped anti-rotation feature 44, such as a groove or slot, formed in the inner diametric surface 22 of the connecting rod 12. The anti-rotation feature 42 on the bushing 14 and the anti-rotation feature 44 on the connecting rod 12 prevent relative movement between the connecting rod 12 and the bushing 14, but allows relative movement between the bushing 14 and the piston pin 16. Thus, the anti-rotation features 42, 44 ensures that: 1) the pin 16 and bushing 14 rotate relative to one another with every compressor cycle, but prevent relative movement between the pin 16 and the connecting rod 12, and 2) properly orientates the pin 16 relative to the bushing 14 for optimizing the flow of lubricant between the pin 16 and the bushing 14.

- [0034] As described above, embodiments of a new, novel and inventive connecting rod assembly for a reciprocating mechanical system is disclosed. A benefit of this new connecting rod assembly is that sufficient film thickness of a lubricant is maintained at the interface between the bushing 14 and the pin 16 during reversing loads and non-reversing loads. To accomplish this, the connecting rod 12 includes lubrication grooves 20 formed on the inner diametric surface 22 of the connecting rod 12. In addition, the bushing 14 and the pin 16 may include one or more surface features, which includes, but is not limited to, the axial grooves 24 on the inner diametric surface 29 of the piston pin 16, the axial grooves 32 on the inner diametric surface 30 and/or the outer diametric surface 31 of the connecting rod bushing 14, and one or more dimples 34 on the outer diametric surface 28 of the piston pin 16.
- [0035] In addition, an anti-rotation feature is incorporated to maintain the relative motion between the piston pin 16 (i.e., pin) and the connecting rod bushing (i.e., bushing) and proper alignment therebetween. In one embodiment, the pin 16 and bushing 14 are coated with a low friction coating, such as diamond-like carbon (DLC), MoS₂, and equivalents, to improve wear-resistance and assist in maintaining sufficient film thickness at the interface between the pin and bushing, during full reversing loads and non-reversing loads, which keeps the reciprocating mechanical system operational in the event of a valve failure. Simulation results have shown that sufficient film thickness between the pin and bushing is maintained under reversing loads and non-reversing loads experienced in a reciprocating mechanical system.
- [0036] Having described presently preferred embodiments the invention may be otherwise embodied within the scope of the appended claims

WHAT IS CLAIMED IS:

1. A connecting rod assembly (10), comprising:
 - a connecting rod (12);
 - a connecting rod bushing (14) at least partially disposed within a connecting rod (12); and
 - a piston pin (16) at least partially disposed within the connecting rod bushing to form an interface therebetween,wherein the connecting rod (12) has one or more lubrication grooves (20) in an inner diametric surface (22) for enhancing delivery of a lubricant at the interface between the connecting rod bushing (14) and the piston pin (16).
2. The connecting rod assembly (10) of Claim 1, wherein the connecting rod (12) further comprises a central circumferential lubrication groove (23) in fluid communication with a fluid port (18) of the connecting rod (12) for supplying lubricant to the one or more lubrication grooves (20).
3. The connecting rod assembly (10) of Claim 1, wherein the one or more grooves (20) are parallel to a central, longitudinal axis (21) of the connecting rod (12).
4. The connecting rod assembly (10) of Claim 1, further comprising an anti-rotation feature (42), and wherein the connecting rod (12) further comprises an anti-rotation feature (44) to prevent unwanted movement between the connecting rod (12) and the connecting rod bushing (14).
5. The connecting rod assembly (10) of Claim 4, wherein the anti-rotation feature (42) of the connecting rod bushing (14) comprises a raised projection extend outwardly from an outer diametric surface (31) of the connecting rod bushing (14), and wherein the anti-rotation feature (44) of the connecting rod (12) comprises a groove (44) formed in inner diametric surface (22) of the connecting rod (12).
6. A connecting rod assembly (10), comprising:

a connecting rod (12);

a connecting rod bushing (14) at least partially disposed within a connecting rod (12); and

a piston pin (16) at least partially disposed within the connecting rod bushing to form an interface therebetween,

wherein at least one of the connecting rod bushing (14) and the piston pin (16) includes a surface feature (24, 32, 34) for enhancing delivery of a lubricant at the interface between the connecting rod bushing (14) and the piston pin (16).

7. The connecting rod assembly (10) of Claim 6, wherein the surface feature (24, 32, 34) comprises one of an axial or helical lubrication groove (24) on an inner diametric surface (29) of the piston pin (16), an axial groove (32) on an inner diametric surface (30) of the connection rod bushing (14), an axial groove (32) on an outer diametric surface (31) of the connecting rod bushing (14), and one or more dimples (34) on an outer diametric surface (28) of the piston pin (16).

8. The connecting rod assembly (10) of Claim 7, wherein the axial groove (24) is formed parallel with respect to a central, longitudinal axis (25) of the piston pin (16).

9. The connecting rod assembly (10) of Claim 7, wherein the axial groove (32) is formed parallel with respect to a central, longitudinal axis (39) of the connecting rod bushing (14).

10. The connecting rod assembly (10) of Claim 7, wherein the axial groove (32) is not formed in a 45-degree to a 90-degree section of the inner diametric surface (30) of the connecting rod bushing (14).

11. The connecting rod assembly of Claim 6, wherein the connecting rod (12) has one or more lubrication grooves (20) in an inner diametric surface (22) for

enhancing delivery of a lubricant at the interface between the connecting rod bushing (14) and the piston pin (16).

12. The connecting rod assembly (10) of Claim 11, wherein the connecting rod (12) further comprises a central circumferential lubrication groove (23) in fluid communication with a fluid port (18) of the connecting rod (12) for supplying lubricant to the one or more lubrication grooves (20).

13. The connecting rod assembly (10) of Claim 11, wherein the one or more lubrication grooves (20) are parallel to a central, longitudinal axis (21) of the connecting rod (12).

14. The connecting rod assembly (10) of Claim 6, further comprising an anti-rotation feature (42), and wherein the connecting rod (12) further comprises an anti-rotation feature (44) to prevent unwanted movement between the connecting rod (12) and the connecting rod bushing (14).

15. The connecting rod assembly (10) of Claim 14, wherein the anti-rotation feature (42) of the connecting rod bushing (14) comprises a raised projection extend outwardly from an outer diametric surface (31) of the connecting rod bushing (14), and wherein the anti-rotation feature (44) of the connecting rod (12) comprises a groove (44) formed in inner diametric surface (22) of the connecting rod (12).

16. The connecting rod assembly (10) of Claim 6, wherein the piston pin (16) is coated with a low friction coating.

17. The connecting rod assembly (10) of Claim 16, wherein the low friction coating comprises diamond-like carbon (DLC).

18. The connecting rod assembly (10) of Claim 6, wherein the connecting rod bushing (14) is coated with a low friction coating.

19. The connecting rod assembly (10) of Claim 19, wherein the low friction coating comprises MoS₂.

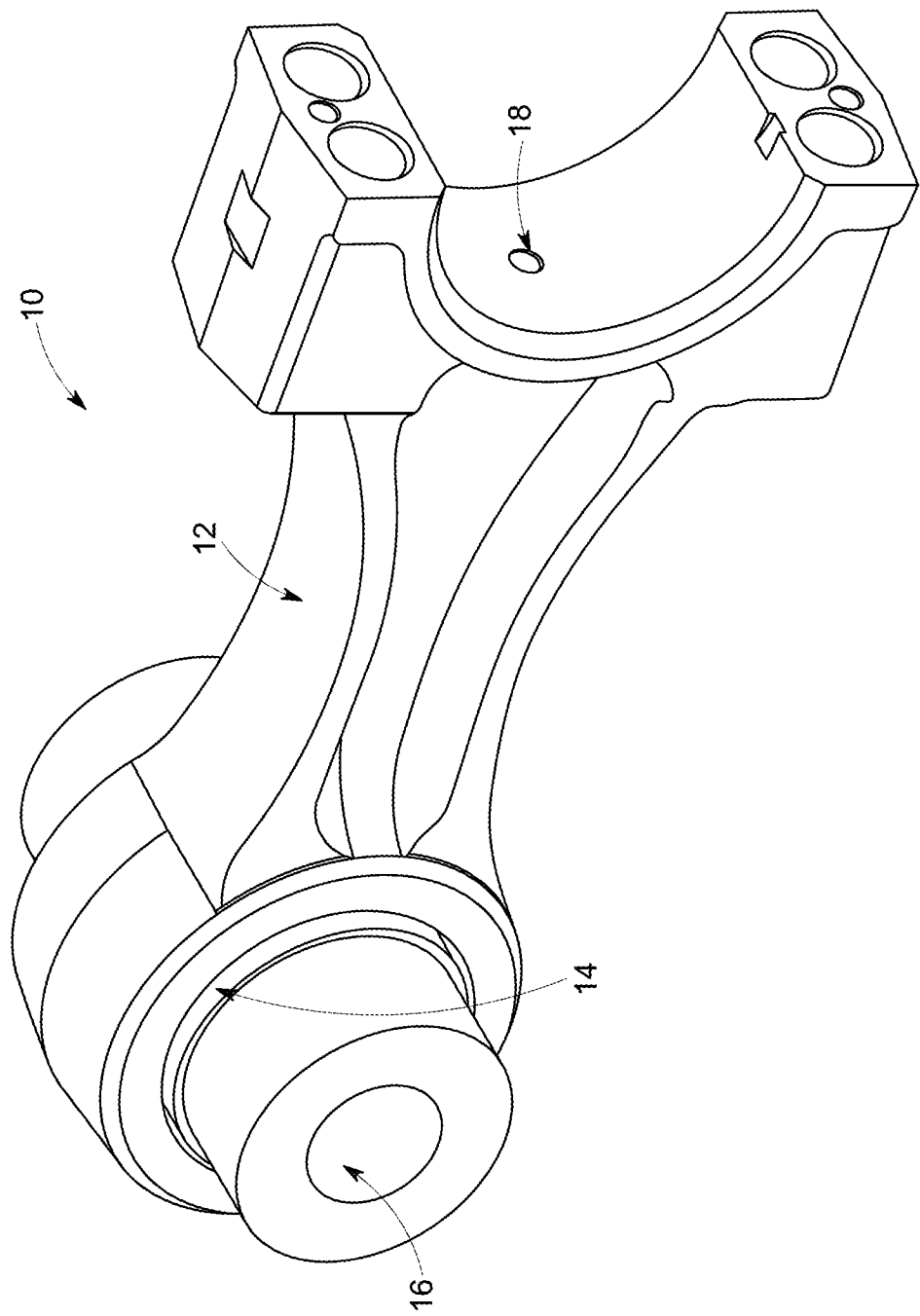


FIG. 1

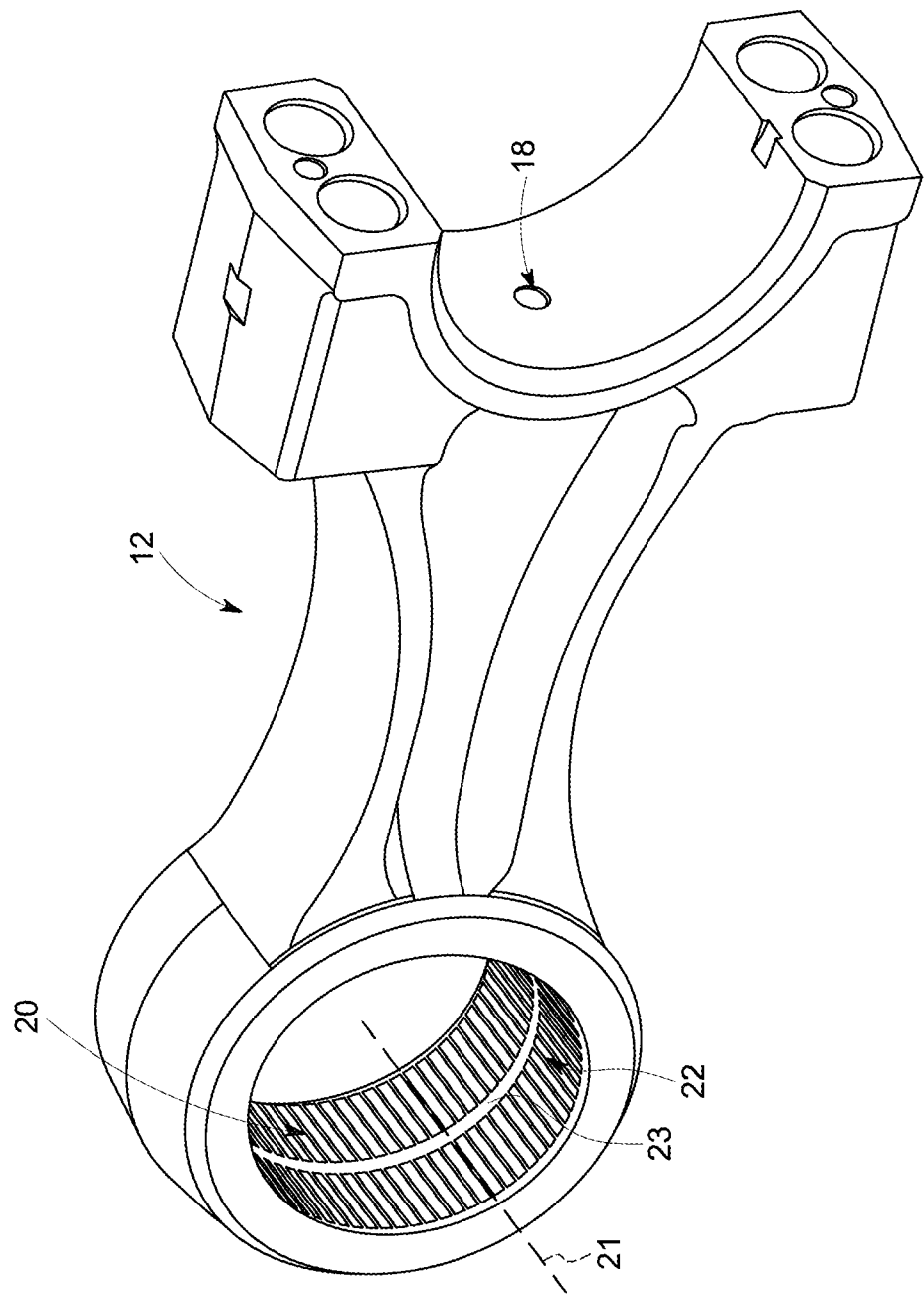


FIG. 2

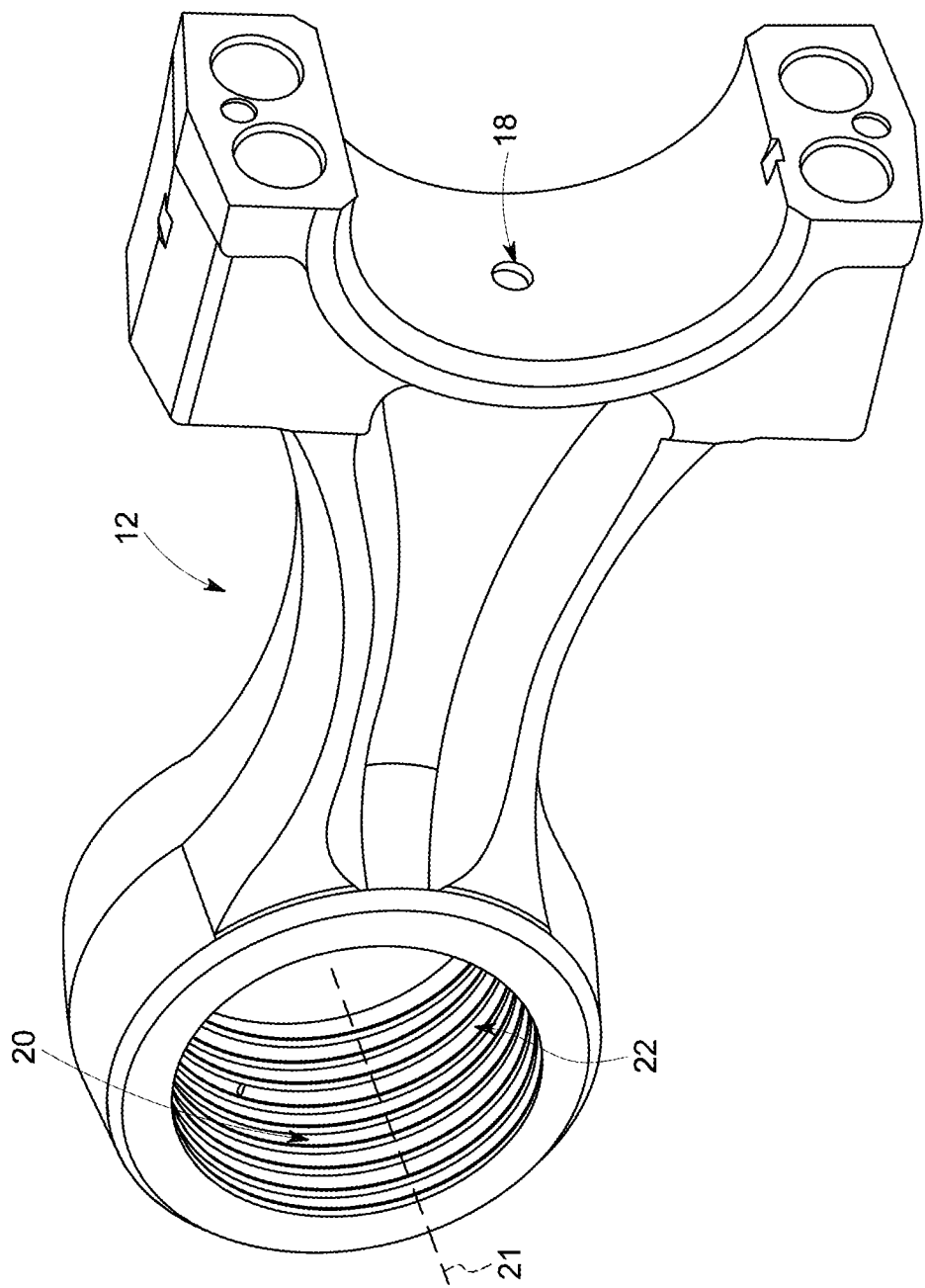


FIG. 3

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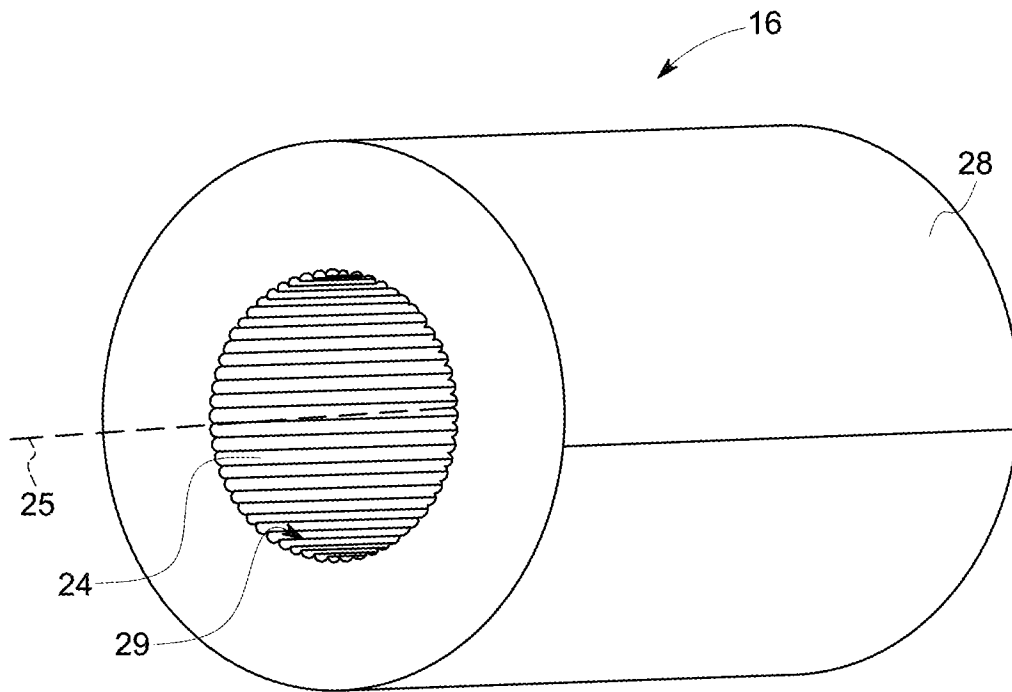


FIG. 4

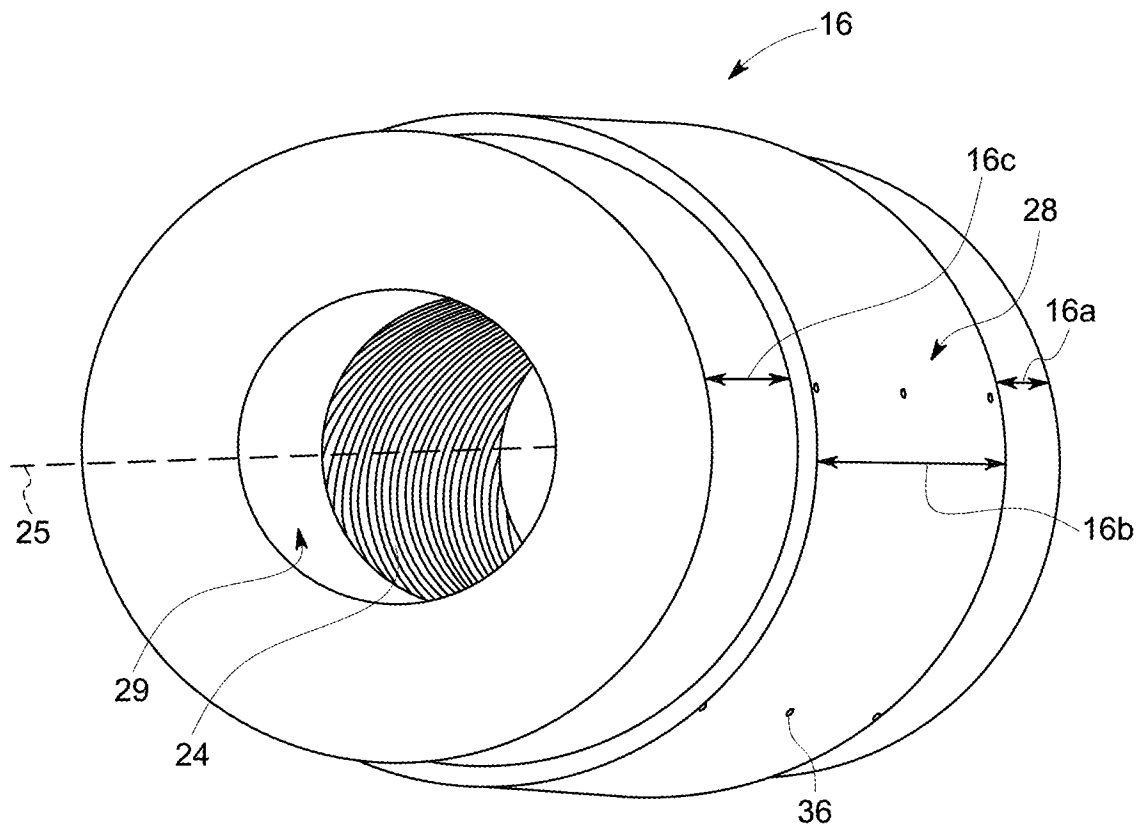


FIG. 5

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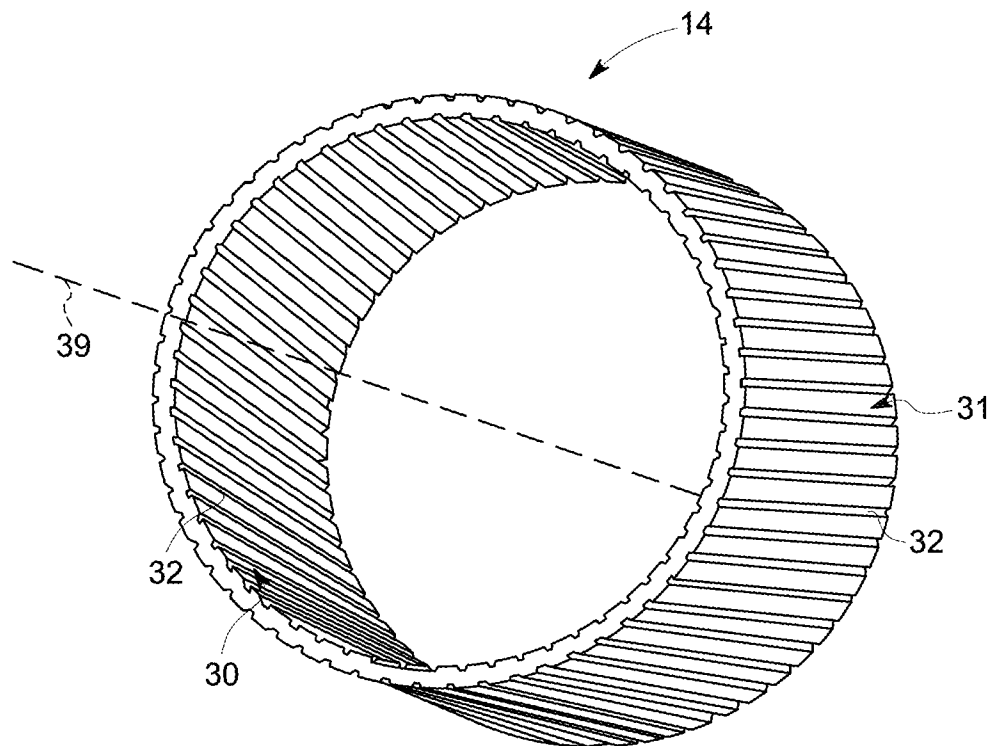


FIG. 6

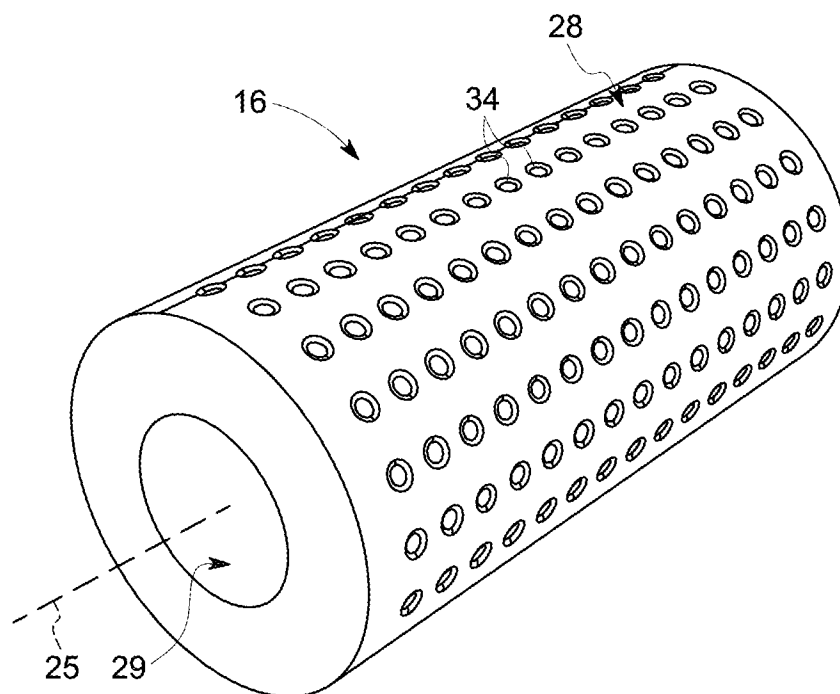


FIG. 7

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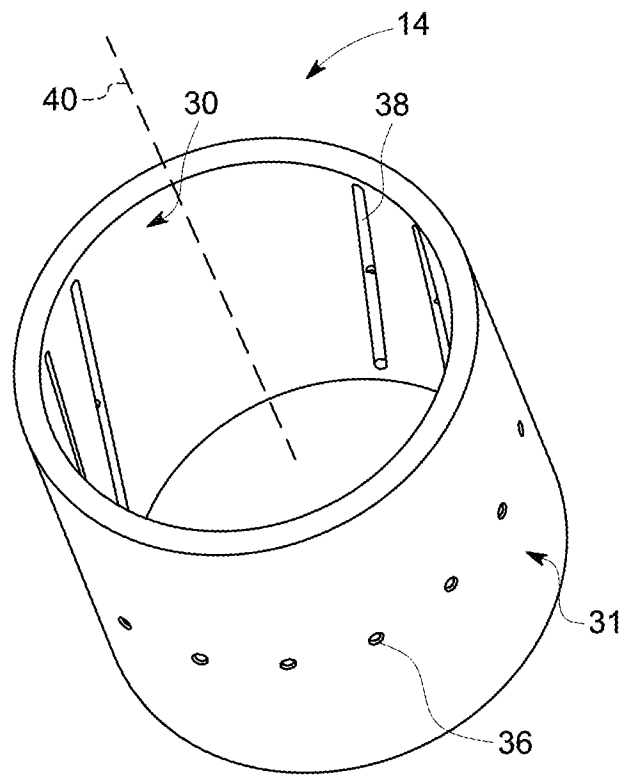


FIG. 8

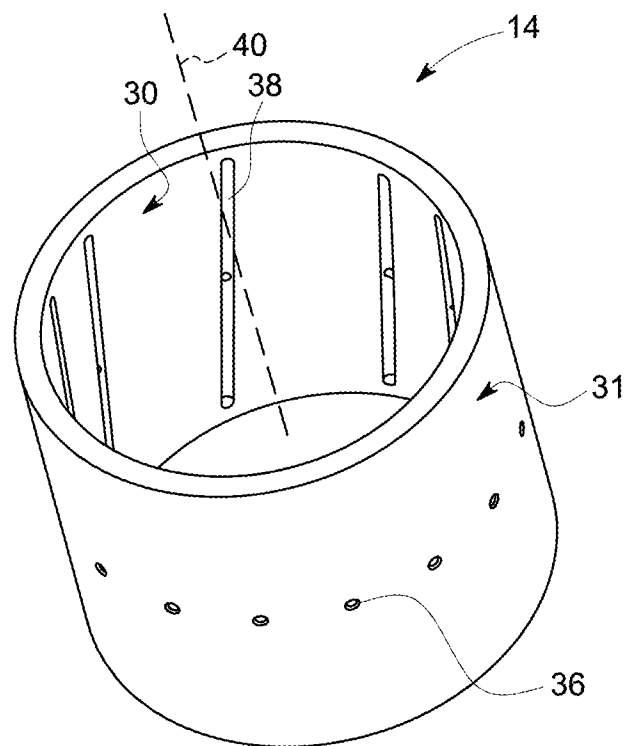


FIG. 9

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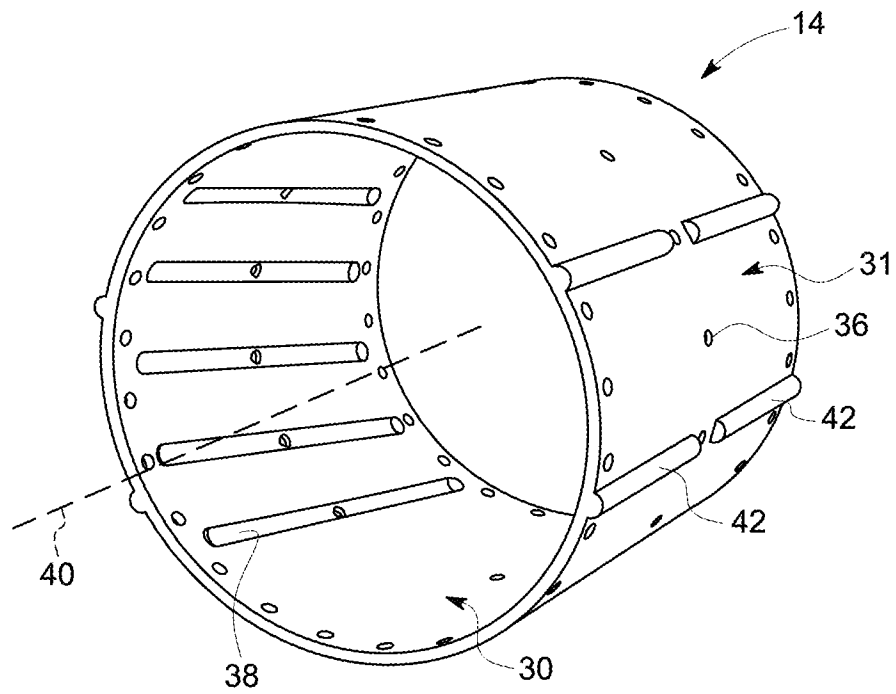


FIG. 10

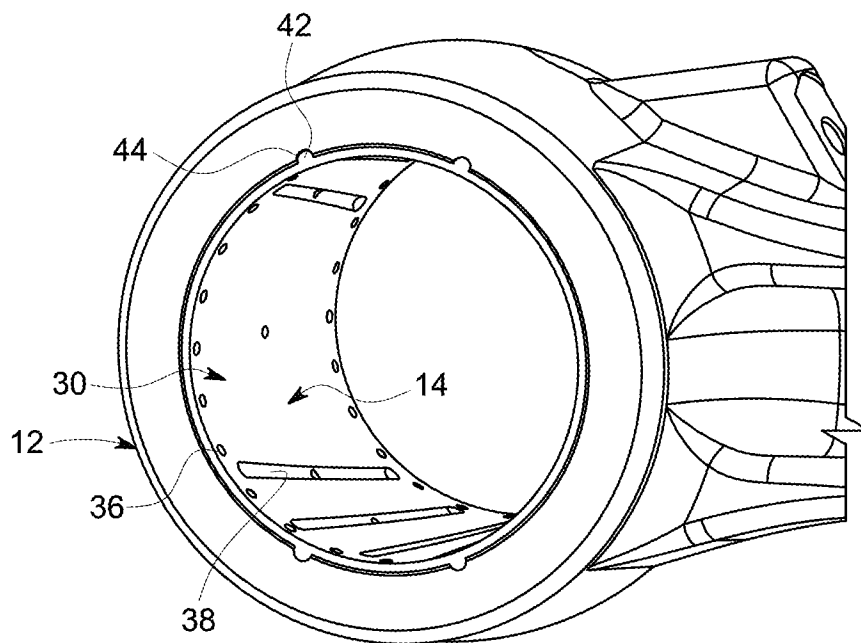


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/053428

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16J7/00 F16J1/16 F16C33/10 F16C7/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16J F16C F01M

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/076858 A1 (BEARDMORE JOHN M [US]) 14 April 2005 (2005-04-14) paragraph [0022] - paragraph [0032]; figures 1-6 -----	1-4, 6-14, 16-19
X	WO 2015/200432 A1 (MEACHAM KIRBY G B [US]) 30 December 2015 (2015-12-30) page 23, line 18; figures 8-12 -----	1,3,4,6, 7,10,11, 13,14, 16-19
X	WO 2015/149872 A1 (HOWDEN THOMASSEN COMPRESSORS BV [NL]) 8 October 2015 (2015-10-08) paragraph [0018] - paragraph [0022]; figures 1-3 ----- -/-	6,7,11, 12,14, 16-19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 December 2017

Date of mailing of the international search report

21/12/2017

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Authorized officer

Kepka, Maciek

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/053428

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 673 767 A (PAUL SCHOEPPNER KARL) 30 March 1954 (1954-03-30) the whole document -----	1,4, 6-10,14, 16-19
A	WO 2007/031160 A1 (THYSSEN KRUPP AUTOMOTIVE AG [DE]; GUERREIRO SERGIO STEFANO [BR]) 22 March 2007 (2007-03-22) page 3, paragraph 3 - page 4, paragraph 1; figures 2,3 page 18, paragraph 2 page 18, paragraph 2 - page 19 -----	6,16-19

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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