

(19)



(11)

EP 3 374 643 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:

10.05.2023 Bulletin 2023/19

(51) International Patent Classification (IPC):

F04D 13/08 ^(2006.01) **F04D 25/06** ^(2006.01)
F04D 29/041 ^(2006.01) **F04D 29/051** ^(2006.01)
F04D 29/10 ^(2006.01)

(21) Application number: **16784932.2**

(52) Cooperative Patent Classification (CPC):

F04D 25/0686; F04D 13/086; F04D 13/10;
F04D 13/12; F04D 19/024; F04D 29/0416;
F04D 29/0516; F04D 29/104; F04D 29/108

(22) Date of filing: **24.10.2016**

(86) International application number:

PCT/EP2016/075561

(87) International publication number:

WO 2017/080804 (18.05.2017 Gazette 2017/20)

(54) **AXIAL BEARING OFFLOADING IN FLUID PROCESSING MACHINES**

AXIALLAGERENTLASTUNG BEI FLÜSSIGKEITSVERARBEITUNGSMASCHINEN

DÉLESTAGE DE PALIER AXIAL DANS DES MACHINES DE TRAITEMENT DE FLUIDE

(84) Designated Contracting States:

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

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(30) Priority: **10.11.2015 US 201514936835**

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(43) Date of publication of application:

19.09.2018 Bulletin 2018/38

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Description

Technical Field

[0001] The present disclosure relates to subsea fluid processing machines. More particularly, the present disclosure relates to techniques for offloading a thrust bearing in rotating fluid processing machines such as subsea pumps and compressors.

Background

[0002] Known turbo compressors and pumps generate a differential pressure across one or more impeller stages attached to a rotating shaft. The generated differential pressure acts on the impeller and shaft arrangement, creating a thrust force in the axial direction pointing from the discharge end towards the suction end.

[0003] An axial thrust bearing is normally attached to the shaft to counteract this thrust force and keep the shaft in a stable position during various operating and load conditions. In some applications, a differential pressure is created across a balancing piston arranged such that both ends of the shaft arrangement are exposed to a similar pressure that can be either the suction or discharge pressure. In such cases, the balancing piston and shaft areas are exposed to the pressure so as to more or less balance, or counteract, the thrust force. Normally such an arrangement is combined with a smaller thrust bearing to counteract the thrust force that may be unbalanced under some conditions.

[0004] However, balance piston arrangements as described involve tight clearances that are exposed to the process medium. Therefore, balance piston arrangements may not be well suited in applications where the process medium is not a clean single phase fluid. Examples include where the process medium contains wear particles, such as sand or other solid particles, or where phase changes may occur in the process fluid such as the formation of ice or hydrates. In such cases the tight clearances of the balancing piston may be at risk of wear, partially blocking and/or fully blocking which would jeopardize the intended function of the balance piston.

[0005] An axial thrust bearing can be designed to compensate the entire thrust force without the use of a balance piston. However, such bearings may have to be very large and therefore suffer from disadvantages such as: (1) large associated frictional losses; (2) adverse effects on shaft rotor dynamics; (3) utilization of large amounts of space; and (4) substantial increases to the overall system weight. In such cases, the size of the axial thrust bearing required may constrain the effective differential pressure that can be provided by the turbo compressor or pump.

[0006] **[0006]** US 3960245 describes a high-pressure compressor comprising chambers and passages connected thereto for conveying a sealing and lubricating liquid to and from the impeller shaft. WO 2014/054440

describes a centrifugal compressor comprising a rotor with an impeller mounted thereon attached to a casing and a labyrinth seal attached to the casing and disposed to face the rotor. US 5256038 describes a canned motor pump in which an external supply of cooling and lubricating fluid is circulated through the motor. An internal seal arrangement is provided for restricting flow between the motor and the pump.

Summary

[0007] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to alter or limit the scope of the claimed subject matter.

[0008] The present invention resides in a fluid pressure increasing machine as defined in claim 1. Preferred embodiments are defined in claims 2 to 12.

[0009] In a second aspect, the present invention resides in a method for operating a fluid pressure increasing machine as defined in claim 13. Preferred embodiments are defined in claims 14 and 15.

Brief Description of the Drawings

[0010] The subject disclosure is further described in the following detailed description, in reference to the following drawings of non-limiting embodiments of the subject disclosure. The features depicted in the figures are not necessarily shown to scale. Certain features of the embodiments may be shown exaggerated in scale or in somewhat schematic form, and some details of elements may not be shown in the interest of clarity and conciseness. Like reference numbers and designations in the various drawings indicate like elements.

FIG. 1 is a diagram illustrating a subsea environment in which a compressor or pump having an offloaded axial bearing can be deployed, according to some embodiments;

FIG. 2 is a cross-sectional view showing further details of a wet gas compressor having an offloaded axial bearing, according to some embodiments;

FIG. 3 is a cross-sectional view showing further details of contra-rotating section of a wet gas compressor having an offloaded axial bearings, according to some embodiments;

FIG. 4 is a cross-sectional view showing further details of a thrust disk in a compressor having an offloaded axial bearings, according to some embodiments;

FIG. 5 is a perspective view showing further details of a thrust disk having impellers mounted thereon, according to some embodiments;

FIG. 6 is a perspective view showing a thrust disk having alternate fluid pressure increasing structures,

according to some embodiments; and
 FIG. 7 is a cross-sectional view showing further details of a thrust disk in a compressor having offloaded axial bearings, according to an example that does not form part of the present invention .

Detailed Description

[0011] One or more specific embodiments of the present disclosure will be described below. The particulars shown herein are by way of example, and for purposes of illustrative discussion of the embodiments of the subject disclosure only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the subject disclosure. In this regard, no attempt is made to show structural details of the subject disclosure in more detail than is necessary for the fundamental understanding of the subject disclosure, the description taken with the drawings making apparent to those skilled in the art how the several forms of the subject disclosure may be embodied in practice. Additionally, in an effort to provide a concise description of these exemplary embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0012] When introducing elements of various embodiments of the present invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are used in an openended fashion, and thus should be interpreted to mean "including, but not limited to." Also, any use of any form of the terms "connect," "engage," "couple," "attach," or any other term describing an interaction between elements is intended to mean either an indirect or a direct interaction between the elements described. In addition, as used herein, the terms "axial" and "axially" generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms "radial" and "radially" generally mean perpendicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a radial distance means a distance measured perpendicular to the central axis. The use of "top," "bottom," "above," "below," and variations of these terms is made for convenience, but does not require any particular orientation of the components.

[0013] Certain terms are used throughout the descrip-

tion and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function.

[0014] According to some embodiments, techniques are described for off-loading the axial thrust bearing without the use of a conventional balancing piston that is exposed to the process. In many compressor and/or pumping applications, the process medium is not a clean single phase fluid, but may include wear particles such as sand or other solid particles, and/or may be prone to phase changes such as the formation of ice or hydrates. In such cases, the design may involve techniques for keeping critical and exposed components such as bearings and couplings separate from the process fluid. One way to achieve this is to have the critical components submerged in a barrier fluid at a pressure higher than the process fluid (at an "overpressure"). For many such designs it is desirable to omit a balancing piston and let the axial thrust bearing counteract the full thrust force created by the generated differential pressure.

[0015] According to some embodiments, impeller blades or a pump ring are provided on the outside end of a thrust disc that forms part of the thrust bearing and is attached to the rotating shaft.

[0016] The impeller blades or pump ring affixed to the outside end of the thrust disc will, when the shaft rotates, create a differential pressure in the barrier fluid across the thrust disc. By arranging this differential pressure such that the low-pressure side of the thrust disc is towards the process outlet end, a thrust force that off-loads the axial thrust bearing is created.

[0017] FIG. 1 is a diagram illustrating a subsea environment in which a compressor or pump having an offloaded axial bearing can be deployed, according to some embodiments. On sea floor 100 a subsea station 120 is shown which is downstream of several wellheads being used, for example, to produce hydrocarbon-bearing fluid from a subterranean rock formation. Station 120 includes a subsea compressor module 140, which is powered by one or more electric motors, such as induction motors or permanent magnet motors. According to some embodiments, compressor module 140 includes a contra rotating wet gas compressor. The station 120 is connected to one or more umbilical cables, such as umbilical 132. The umbilicals in this case are being run from a platform 112 through seawater 102, along sea floor 100 and to station 120. In other cases, the umbilicals may be run from some other surface facility such as a floating production, storage and offloading unit (FPSO), or a shore-based facility. The umbilical 132 is also used to supply barrier fluid to station 120. The umbilical 132 can also be used to supply other fluids to station 120, as well as include control and data lines for use with the subsea equipment in station 120. Although a compressor module 140 is shown in FIG. 1, according to some embodiments

the module 140 can be configured for other subsea fluid processing functions, such as a subsea pumping module and/or a subsea separator module. In all embodiments described herein, it is understood that references to subsea compressors and compressor modules can alternatively refer to subsea pump and pumping modules. Furthermore, references herein to subsea compressors and subsea pumps should be understood to refer equally to subsea compressors and pumps for single phase liquids, single phase gases, or multiphase fluids. According to some embodiments, the compressor designs with offloaded axial bearings described herein are used in connection with an electrical submersible pump (ESP) 150 which can either be located downhole, as shown in wellbore 154 in FIG. 1, or it can be located in a subsea location such as on the sea floor in a Christmas tree at wellhead 152.

[0018] FIG. 2 is a cross-sectional view showing further details of a wet gas compressor having an offloaded axial bearing, according to some embodiments. Compressor module 140 includes an upper motor section 240, lower motor section 250 and a contra rotating compressor section 210. Lower motor 252 within lower motor section 250 drives a lower shaft 254 that rotates an inner hub within compressor section 210 on which impellers are fixed. Likewise, upper motor 242 within upper motor module 240 drives an upper shaft 244 that rotates an outer sleeve within compressor section 210 on which impellers are fixed. Notably, the rotation direction of the upper and lower shafts 244 and 254 are opposite to one another. Compressor section 210 has an inlet 212 and outlet 214.

[0019] The compressor section 210 has interleaved rows of impellers mounted to the inner hub and outer sleeve that are stacked successively to each other and rotate in opposite directions. The interleaved rows impellers mounted on the inner hub and outer sleeve are shaped to successively increase the pressure in the process fluid as the fluid is moved upwards. The resultant axial force on both the upper shaft 244 and lower shaft 254 is therefore in the downwards direction. Each shaft 244, 254 has associated with it a thrust disk having a lower surface thereon that forms a bearing surface. In particular, upper shaft 244 has an upper thrust disk 246 and the lower shaft 254 has a lower thrust disk 256. Each thrust disk 246 and 256 is surrounded by barrier fluid that is maintained at an overpressure with respect to the process fluid pressure. In general, barrier fluid acts as a barrier against an outside environment and/or process fluid. Barrier fluid can also serve other functions such as lubricating various bearing surfaces and seals, cooling of various elements, and electrical insulation. Barrier fluid is typically an oil, and is "clean" when compared to the process fluid in that it contains far lower levels of wear-inducing matter such as sand and other solid particles. According to some embodiments, each of the thrust disks 246 and 256 have structures such as impellers, that are shaped to increase barrier fluid pressure on the lower side of the thrust disk such that the barrier fluid pressure

is higher on the bottom side of the thrust disk than on the top side.

[0020] FIG. 3 is a cross-sectional view showing further details of a contra-rotating section of a wet gas compressor having offloaded axial bearings, according to some embodiments. Portions of the compressor section 210 are shown. The lower shaft 254 is fixed to inner hub 350 and is driven about main longitudinal axis 300 in the direction shown by arrow 314. The inner hub 350 has multiple rows of impellers 352 mounted thereon which are shaped and positioned to increase fluid pressure of the process fluid and move the process fluid in an upwards direction, as shown by dotted arrows 302 and 304. A reactionary force is imparted on the lower shaft 254 in the downwards axial direction as shown by the dashed arrow 308. Lower thrust disk 256 is mounted to the shaft 254 and is configured to counteract at least a part of the downward force through engagement with thrust bearing pads 354 on the upper surface of the thrust bearing. According to some embodiments, the thrust disk 256 includes impellers 356 mounted on its outer edge as shown (i.e., the radially outer edge of disk 256). The impellers 356 are shaped and positioned so as to increase fluid pressure of the surrounding barrier fluid in the downwards direction, such that the lower surface of thrust disk 256 is exposed to a higher barrier fluid pressure than the upper surface of thrust disk 256. Due to the relative surface areas and the differential barrier fluid pressure, an upward force is imparted on the thrust disk 256 that partially counteracts the downward force from the main hub-mounted impellers 352. In this way a significant portion of the downward imparted force on the shaft 254 and thrust disk 256 can be offloaded from the thrust disk bearing surface.

[0021] Similarly, the upper shaft 244 is fixed to outer sleeve 340 and is driven about axis 300 in the direction shown in arrow 312. Note that the upper shaft 244 and the lower shaft 254 are driven in opposite, contra-rotating directions. The outer sleeve 340 has multiple rows of impellers 342 mounted thereon and interleave with the hub-mounted impellers 352. The sleeve-mounted impellers 342 are shaped and positioned to increase fluid pressure in the process fluid and move the process fluid in an upwards direction, as shown by dotted arrows 302 and 304. A reactionary force is imparted on the upper shaft 244 in the downward axial direction as shown by the dashed arrow 306. Upper thrust disk 246 is mounted to the shaft 244 and is configured to counteract at least a part of the downward force through engagement with thrust bearing pads 344 on the upper surface of the thrust bearing. According to some embodiments, the thrust disk 246 includes impellers 346 mounted on its outer edge as shown (i.e., the radially outer edge of disk 246). The impellers 346 are shaped and positioned so as to increase fluid pressure of the surrounding barrier fluid in the downwards direction such that the lower surface of thrust disk 246 is exposed to a higher barrier fluid pressure than the upper surface of thrust disk 246. Due to the relative sur-

face areas and the differential barrier fluid pressure, an upward force is imparted on the thrust disk 246, which partially counteracts the downward force from the main sleeve-mounted impellers 342. In this way a significant portion of the downward imparted force on the shaft 244 and thrust disk 246 can be offloaded from the thrust disk bearing surfaces.

[0022] FIG. 4 is a cross-sectional view showing further details of a thrust disk in a compressor having offloaded axial bearings, according to some embodiments. The thrust disk 256 is shown mounted to shaft 254 that is being driven about main longitudinal axis 300 in the direction shown by arrow 314 by an electric motor (not shown in FIG. 4). Thrust disk 256 is surrounded by a barrier fluid, which is provided at a higher pressure than the process fluid. The shaft 254 has a downward force imparted upon it by main impellers (e.g. impellers 352 in FIG. 3). The downward force is partially counteracted by the thrust disk lower bearing surface 404 engaging with thrust bearing pad 354. According to some embodiments, the thrust disk 256 also includes multiple impellers 356 mounted on its outer surface as shown. The thrust disk impellers 356 are shaped and positioned to increase barrier fluid pressure along the downward direction as shown by dotted arrows 410 and 412. As a result of the increase in barrier fluid pressure from the impellers 356, the lower surface 404 of thrust disk 256 is exposed to a higher pressure than the upper surface 402 of thrust disk 256. The resultant pressure differential causes an upward force on the thrust disk 256, which in combination with force imparted from impellers 356 at least partially counteracts the downward force imparted by the main impellers (e.g. impellers 352 in FIG. 3). In this way the thrust bearing pads 354 are at least partially offloaded. This offloading effect can be used to greatly reduce the maximum force that the bearing surfaces are expected to see during operation. This reduction can allow for compressor operation at higher differential pressures and/or it can be used to reduce the overall size and loss associated with the thrust disk. Note that the clearance between the tips of impellers 356 and the stationary housing 420 (i.e., the radial clearance) can be made sufficiently large to ensure mechanical robustness and integrity of the arrangement.

[0023] FIG. 5 is a perspective view showing further details of a thrust disk having impellers mounted thereon, according to some embodiments. In the example shown, thrust disk 256 includes two rows of impellers 356. The impellers are shaped and positioned to increase the pressure of the surrounding barrier fluid along a downward direction, as shown by dotted arrows 502 and 504 when the thrust disk is rotated about axis 300 in the direction shown by arrow 304. The pressure increase causes the lower side 404 of disk 256 to be exposed to a higher fluid pressure than the upper side 402 of disk 256. Note that although two rows of impellers are shown in FIG. 4, in practice other numbers of rows and other numbers of impellers per row can be used. For examples, a single

row, or three or more rows of impellers can be used. In other cases the impellers can be positioned in other arrangements beside horizontal rows such as a staggered arrangement. Further, the shape and size of the impellers can be different than the example shown. In particular the radial dimension of the impellers in FIG. 5 has been exaggerated for simplicity. In practice the impellers 356 may be substantially lower profile in the radial dimension than shown in FIG. 5.

[0024] FIG. 6 is a perspective view showing a thrust disk having alternate fluid pressure increasing structures, according to some embodiments. According to some embodiments, other structural mechanisms besides conventional impellers such as vanes, pump rings, labyrinths, grooves etc. can be incorporated into the thrust disk to increase the barrier fluid pressure in a manner that counteracts the force imparted on the shaft by the main compressor impellers. In the example shown, a number of spiral shaped grooves 656 are incorporated into the outer surface of the thrust disk 256 which cause a differential pressure across the thrust disk when it is rotated.

[0025] FIG. 7 is a cross-sectional view showing further details of a thrust disk in a compressor having offloaded axial bearings, according to an example that does not form part of the claimed invention. In this case, rather than using impellers or other structures on the thrust disk, a separate pumping or circulation means is used to create a differential pressure across the thrust disk 756. As in the previous cases, the thrust disk 756 is mounted to shaft 254 that is being driven (e.g., rotated) about main longitudinal axis 300 in the direction shown by arrow 314 by an electric motor (such as motor 252 shown in FIG. 2). Thrust disk 756 is surrounded by a barrier fluid, which is provided at a higher pressure than the process fluid. The shaft 254 has a downward force imparted upon it by main impellers (e.g. impellers 352 in FIG. 3). The downward force is partially counteracted by the thrust disk lower bearing surface 704 engaging with thrust bearing pad 354. In this case, barrier fluid pump 720 is schematically shown supplying clean barrier fluid as shown by arrow 712.

The barrier fluid pump 720 could supply the barrier fluid to another location such as into volume 754. A narrow gap 758 is provided between the outer surface of thrust disk 756 and stationary housing body 420. The narrow gap 758 forms a flow restriction between the lower side 704 and the upper side 702 of thrust disk 756. Note that some small amount of fluid will flow upwards through gap 758 as shown by arrow 710. As a result of the increase in barrier fluid pressure from the pump 720 and the narrow gap 758, the lower surface 704 of thrust disk 756 is exposed to a higher pressure than the upper surface 702 of thrust disk 756. The resultant pressure differential causes an upward force on the thrust disk 756, which at least partially counteracts the downward force imparted by the main impellers (e.g. impellers 352 in FIG. 3). In this way the thrust bearing pads 354 are at least partially offloaded. This offloading effect can be used to greatly

reduce the maximum force that the bearing surfaces are expected to see during operation. This reduction can allow for compressor operation at higher differential pressures and/or it can be used to reduce the overall size and loss associated with the thrust disk. The barrier fluid pump 720 may be a separate circulation pump and/or impeller that is located elsewhere in the barrier circuit, such as at a different position on the shaft 254 as is common on subsea pumps and compressors. The pump 720 may be an external pump positioned outside the pump and/or compressor compartment. In an embodiment of the present invention, instead of a narrow gap 758, structures such as impellers, vanes, pump rings, labyrinths, or grooves are provided on the outside of disk 756 such as shown in FIGs. 4, 5 and 6 in combination with barrier fluid pump 720 to further support the pressure differential across disk 756.

[0026] Thus, according to some embodiments, a means for off-loading an axial thrust bearing is provided without the use of a process exposed balance piston. The disclosed techniques allow for: a smaller thrust bearing used for a given differential pressure; a larger effective differential pressure; or a combination of both. In this way an axial thrust bearing can be off-loaded without the use of a process exposed balance piston. The benefits of the disclosed techniques include the use of a smaller thrust bearing for a given differential pressure, and/or the ability to safely achieve larger effective differential pressures. This has been found to be particularly beneficial for applications where the process medium is not a clean single phase fluid but may include wear particles such as sand or other solid particles or where phase changes may occur in the process fluid, such as the formation of ice or hydrates and therefore the use of a process exposed balance piston is not practical.

[0027] While the subject disclosure is described through the above embodiments, modifications to and variations of the illustrated embodiments may be made without departing from the invention as defined in the claims. These and other variations and modifications will become apparent to those skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications insofar as these fall within the scope of the invention as defined in the claims.

Claims

1. A fluid pressure increasing machine (140, 150), comprising:

a fluid processing chamber (210) configured to contain a process fluid and including an inlet (212) and an outlet (214);
a first member (254) rotatable about a central longitudinal axis (300);
a motor system (252) mechanically engaged to

the first member so as to rotate the member about the longitudinal axis in a rotation direction (314);

a plurality of impellers (352) being fixedly mounted to the first member and exposed to the process fluid within the fluid processing chamber such that when the first member is rotated in the rotation direction the impellers act on the process fluid thereby increasing pressure of the process fluid towards the outlet and a reaction force (308) is imparted on the first member in an axial direction from the outlet toward the inlet; and a first rotating element (256, 756) surrounded by a barrier fluid (712) and fixedly attached to the first member, the rotating element having a higher pressure surface (404, 704) exposed to the barrier fluid at a higher pressure and a lower pressure surface (402, 702) exposed to the barrier fluid at a lower pressure, the difference between the higher and lower pressures acting on the respective higher and lower pressure surfaces generating a force (510) on the first member that at least partially counteracts the reaction force, wherein the difference between the higher and lower pressure is at least partially caused by structures (356, 656) on the first member (254) configured to increase the barrier fluid pressure by rotating the first member;

characterized in that the first rotating element (256) is a thrust disk (256) and the structures (356, 656) include a plurality of one of: impellers (356), vanes, pump rings, labyrinths and grooves (656) on an outer edge of the thrust disk (256).

2. The fluid processing machine (140, 150) of claim 1, wherein the difference between the higher and lower pressures of barrier fluid (712) is at least 10 bars or wherein the generated force on the first member (254) counteracts at least 25% of the reaction force (308).

3. The fluid processing machine (140, 150) of claim 1, wherein the first member (254) is a thrust member (256, 756) having a bearing surface (354) configured to bear the reaction force that is not counteracted by said force generated by the difference between the higher and lower pressures of the barrier fluid (712).

4. The fluid processing machine (140, 150) of claim 1, wherein the machine is a subsea compressor (140).

5. The fluid processing machine (140, 150) of claim 4, wherein the machine is subsea wet gas compressor.

6. The fluid processing machine (140, 150) of claim 4, wherein the process fluid is a wet hydrocarbon gas being produced from a subterranean rock formation.

7. The fluid processing machine (140, 150) of claim 1, wherein the machine is a multiphase pump configured to be deployed in a subsea environment and the process fluid contains multiple phases.

8. The fluid processing machine (140, 150) of claim 7, wherein the multiple phases preferably include solid particles and/or hydrates.

9. The fluid processing machine (140, 150) of claim 1, wherein the machine is an electrical submersible pump (150) deployable within a wellbore (154).

10. The fluid processing machine (140, 150) of claim 1, wherein the first member (254) includes a hub (350) on which the plurality of impellers (352) are mounted in a plurality of rows, and the machine further comprising:

a second member (244) rotatable about the central longitudinal axis (300), the second member including a sleeve;

a second motor system (242) mechanically engaged to the second member so as to rotate the second member about the longitudinal axis in a second rotation direction (312) which is opposite to the rotation direction (314) of the first member; and

a plurality of second impellers (342) being fixedly mounted to the sleeve of the second member in a plurality of second rows such that the second rows interleave with the rows of impellers on the hub of the first member, the second impellers being exposed to the process fluid within the fluid processing chamber such that when the second member is rotated in the second rotation direction the second impellers act on the process fluid thereby increasing pressure of the process fluid towards the outlet (214) and a second reaction force (306) is imparted on the second member in an axial direction from the outlet toward the inlet (212); and

a second rotating element (246) surrounded by the barrier fluid and fixedly attached to the second member, the rotating element having a higher pressure surface (404, 704) exposed to the barrier fluid at a higher pressure and a lower pressure surface (402, 702) exposed to the barrier fluid at a lower pressure, the difference between the higher and lower pressure acting on the respective higher and lower pressure surfaces generating a force on the second member that at least partially counteracts the second reaction force.

11. The fluid processing machine (140, 150) of claim 1, wherein the difference between the higher and lower pressures fluid is further partially caused by a barrier

fluid pump (720).

12. The fluid processing machine (140, 150) of claim 1 wherein the barrier fluid (712) is less wear inducing than the processing fluid.

13. A method for operating the fluid pressure increasing machine of any preceding claim, comprising:

rotating the first member about the central longitudinal axis (300) so as to cause the plurality of impellers (352) to engage and increase fluid pressure of the process fluid along a first axial direction (304), thereby causing a reaction force (308) to be imparted on the first member in a second axial direction opposite to the first axial direction; rotating the thrust disk having structures so as to increase the barrier fluid pressure thereby

causing a pressure differential in the barrier fluid (712) wherein the higher pressure surface (404, 704) of the thrust disk is exposed to the higher pressure barrier fluid and the lower pressure surface (402, 702) of the thrust disk is exposed to a lower pressure barrier fluid, the pressure differential in the barrier fluid generating a force on the thrust disk (256) that partially counteracts the reaction force and off-loads the lower bearing surface of the thrust disk (256).

14. The method of claim 13, wherein the process fluid is a hydrocarbon effluent and is produced from a subterranean rock formation.

15. The method according to claim 13, wherein the method is carried out in a subsea environment.

Patentansprüche

1. Fluiddruckerhöhungsmaschine (140, 150), umfassend:

eine zum Aufnehmen eines Prozessfluids ausgelegte Fluidprozesskammer (210), die einen Einlass (212) und einen Auslass (214) umfasst; ein erstes Glied (254), das um eine Mittellängsachse (300) rotierbar ist;

ein Motorsystem (252), das mechanisch mit dem ersten Glied in Eingriff steht, um das Glied um die Mittellängsachse in einer Rotationsrichtung (314) zu rotieren;

mehrere fest am ersten Glied angebrachte Laufräder (352), die dem Prozessfluid innerhalb der Fluidprozesskammer ausgesetzt sind, so dass, wenn das erste Glied in der Rotationsrichtung rotiert wird, die Laufräder auf das Prozessfluid einwirken, wodurch der Druck des Prozessfluids

- zum Auslass hin erhöht wird und das erste Glied mit einer Reaktionskraft (308) in einer Axialrichtung vom Auslass zum Einlass hin beaufschlagt wird; und
 ein von einem Sperrfluid (712) umgebenes erstes rotierendes Element (256, 756), das fest am ersten Glied befestigt ist, wobei das rotierende Element eine Höherdruck-Oberfläche (404, 704), die dem Sperrfluid mit einem höheren Druck ausgesetzt ist, und eine Niedrigerdruck-Oberfläche (402, 702), die dem Sperrfluid mit einem niedrigeren Druck ausgesetzt ist, aufweist, wobei die Differenz zwischen dem auf die betreffende Höher- und Niedrigerdruck-Oberfläche einwirkenden höheren und niedrigeren Druck eine Kraft (510) auf das erste Glied erzeugt, die der Reaktionskraft wenigstens teilweise entgegenwirkt, wobei die Differenz zwischen dem höheren und dem niedrigeren Druck wenigstens teilweise durch Strukturen (356, 656) auf dem ersten Glied (254) bewirkt wird, die dazu ausgelegt sind, den Sperrfluiddruck durch Rotieren des ersten Glieds zu erhöhen;
dadurch gekennzeichnet, dass das erste rotierende Element (256) eine Druckscheibe (256) ist und die Strukturen (356, 656) mehrere von einem aus Laufrädern (356), Flügeln, Pumpenringen, Labyrinthen und Nuten (656) an einem Außenrand der Druckscheibe (256) umfassen.
2. Fluidprozessmaschine (140, 150) nach Anspruch 1, wobei die Differenz zwischen dem höheren und dem niedrigeren Druck des Sperrfluids (712) wenigstens 10 Bar beträgt, oder wobei die erzeugte Kraft auf das erste Glied (254) wenigstens 25 % der Reaktionskraft (308) entgegenwirkt.
 3. Fluidprozessmaschine (140, 150) nach Anspruch 1, wobei das erste Glied (254) ein Druckglied (256, 756) ist, das eine Lagerfläche (354) aufweist, die dazu ausgelegt ist, die Reaktionskraft, der nicht von der durch die Differenz zwischen dem höheren und dem niedrigeren Druck des Sperrfluids (712) erzeugten Kraft entgegengewirkt wird, aufzunehmen.
 4. Fluidprozessmaschine (140, 150) nach Anspruch 1, wobei die Maschine ein Unterwasserkompressor (140) ist.
 5. Fluidprozessmaschine (140, 150) nach Anspruch 4, wobei die Maschine ein Unterwasser-Feuchtgas-kompressor ist.
 6. Fluidprozessmaschine (140, 150) nach Anspruch 4, wobei das Prozessfluid ein feuchtes Kohlenwasserstoffgas ist, das aus einer Untergrundgesteinsformation gefördert wird.
 7. Fluidprozessmaschine (140, 150) nach Anspruch 1, wobei die Maschine eine Mehrphasenpumpe ist, die dazu ausgelegt ist, in einer Unterwasserumgebung eingesetzt zu werden, und das Prozessfluid mehrere Phasen enthält.
 8. Fluidprozessmaschine (140, 150) nach Anspruch 7, wobei die mehreren Phasen vorzugsweise Feststoffpartikel und/oder Hydrate umfassen.
 9. Fluidprozessmaschine (140, 150) nach Anspruch 1, wobei die Maschine eine innerhalb eines Bohrlochs (154) einsetzbare Elektro-Tauchkreislaspumpe (150) ist.
 10. Fluidprozessmaschine (140, 150) nach Anspruch 1, wobei das erste Glied (254) eine Nabe (350) umfasst, an welcher die mehreren Laufräder (352) in mehreren Reihen angebracht sind, und die Maschine ferner umfasst:
 ein zweites Glied (244), das um die Mittellängsachse (300) rotierbar ist, wobei das zweite Glied eine Hülse umfasst;
 ein zweites Motorsystem (242), das mechanisch mit dem zweiten Glied in Eingriff steht, um das zweite Glied um die Längsachse in einer zweiten Rotationsrichtung (312) zu drehen, die zur Rotationsrichtung (314) des ersten Glieds entgegengesetzt ist; und
 mehrere zweite Laufräder (342), die fest an der Hülse des zweiten Glieds in mehreren zweiten Reihen angebracht sind, so dass die zweiten Reihen mit den Reihen von Laufrädern auf der Nabe des ersten Glieds kämmen, wobei die zweiten Laufräder dem Prozessfluid innerhalb der Fluidprozesskammer ausgesetzt sind, so dass, wenn das zweite Glied in der zweiten Rotationsrichtung rotiert wird, die zweiten Laufräder auf das Prozessfluid einwirken, wodurch der Druck des Prozessfluids zum Auslass (214) hin erhöht wird und das zweite Glied mit einer zweiten Reaktionskraft (306) in einer Axialrichtung vom Auslass zum Einlass (212) hin beaufschlagt wird; und
 ein vom Sperrfluid umgebenes zweites rotierendes Element (246), das fest am zweiten Glied befestigt ist, wobei das rotierende Element eine Höherdruck-Oberfläche (404, 704), die dem Sperrfluid mit einem höheren Druck ausgesetzt ist, und eine Niedrigerdruck-Oberfläche (402, 702), die dem Sperrfluid mit einem niedrigeren Druck ausgesetzt ist, aufweist, wobei die Differenz zwischen dem auf die betreffende Höher- und Niedrigerdruck-Oberfläche einwirkenden höheren und niedrigeren Druck eine Kraft auf das zweite Glied erzeugt, die der zweiten Reaktionskraft wenigstens teilweise entgegenwirkt.

11. Fluidprozessmaschine (140, 150) nach Anspruch 1, wobei die Differenz zwischen dem Fluid mit dem höheren und dem niedrigeren Druck ferner teilweise durch eine Sperrfluidpumpe (720) bewirkt wird.

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12. Fluidprozessmaschine (140, 150) nach Anspruch 1, wobei das Sperrfluid (712) weniger verschleißinduzierend ist als das Prozessfluid.

13. Verfahren zum Betreiben der Fluidrunderhöhungsmaschine nach einem der vorhergehenden Ansprüche, umfassend:

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Rotieren des ersten Glieds um die Mittellängsachse (300), um zu bewirken, dass die mehreren Laufräder (352) in das Prozessfluid entlang einer ersten Axialrichtung (304) eingreifen und dessen Druck erhöhen, wodurch bewirkt wird, dass das erste Glied in einer zur ersten Axialrichtung entgegengesetzten zweiten Axialrichtung mit einer Reaktionskraft (308) beaufschlagt wird,

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Rotieren der Strukturen aufweisenden Druckscheibe, um den Sperrfluiddruck zu erhöhen, wodurch eine Druckdifferenz im Sperrfluid (712) bewirkt wird, wobei die Höherdruck-Oberfläche (404, 704) der Druckscheibe dem Höherdruck-Sperrfluid ausgesetzt ist und die Niedrigerdruck-Oberfläche (402, 702) der Druckscheibe einem Niedrigerdruck-Sperrfluid ausgesetzt ist, wobei die Druckdifferenz im Sperrfluid eine Kraft auf die Druckscheibe (256) erzeugt, die der Reaktionskraft teilweise entgegenwirkt und die untere Lagerfläche der Druckscheibe (256) entlastet.

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14. Verfahren nach Anspruch 13, wobei das Prozessfluid ein Kohlenwasserstoffausstrom ist und aus einer Untergrundgesteinsformation gefördert wird.

15. Verfahren nach Anspruch 13, wobei das Verfahren in einer Unterwasserumgebung ausgeführt wird.

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Revendications

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1. Machine d'augmentation de la pression de fluide (140, 150), comprenant :

une chambre de traitement de fluide (210) conçue pour contenir un fluide de traitement et comprenant une entrée (212) et une sortie (214) ;
un premier élément (254) pouvant tourner autour d'un axe longitudinal central (300) ;
un système de moteur (252) en prise mécaniquement sur le premier élément de manière à faire tourner l'élément autour d'un axe longitudinal dans une direction de rotation (314) ;
une pluralité d'hélices (352) montées à demeure

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sur le premier élément et exposée au fluide de traitement à l'intérieur de la chambre de traitement de fluide de sorte que lorsque le premier élément est mis en rotation dans la direction de rotation, les hélices agissent sur le fluide de traitement, ce qui permet d'augmenter la pression de fluide de traitement vers la sortie et une force de réaction (308) est communiquée au premier élément dans une direction axiale de la sortie vers l'entrée ; et

un premier élément rotatif (256, 756) entouré d'un fluide de barrière (712) et fixé à demeure au premier élément, l'élément rotatif présentant une surface de pression supérieure (404, 704) exposée au fluide de barrière à une pression supérieure et une surface de pression inférieure (402, 702) exposée au fluide de barrière à une pression inférieure, la différence entre les pressions supérieure et inférieure agissant sur les surfaces de pression supérieure et inférieure respectives générant une force (510) sur le premier élément qui contrebalance au moins partiellement la force de réaction,

dans laquelle la différence entre la pression supérieure et inférieure est au moins partiellement produite par des structures (356, 656) sur le premier élément (254) conçues pour augmenter la pression de fluide de barrière en faisant tourner le premier élément ;

caractérisé en ce que le premier élément rotatif (256) est un disque de poussée (256) et les structures (356, 656) comportent une pluralité de l'un parmi les éléments suivants : roues (356), aubes, anneaux de pompe, labyrinthes et rainures (656) sur un bord extérieur du disque de poussée (256).

2. Machine de traitement de fluide (140, 150) selon la revendication 1, dans laquelle la différence entre les pressions supérieure et inférieure du fluide de barrière (712) est d'au moins 10 bars ou dans laquelle la force générée sur le premier élément (254) contrebalance au moins 25 % de la force de réaction (308).

3. Machine de traitement de fluide (140, 150) selon la revendication 1, dans laquelle le premier élément (254) est un élément de poussée (256, 756) présentant une surface d'appui (354) conçue pour supporter la force de réaction qui n'est pas contrecarrée par ladite force générée par la différence entre les pressions supérieure et inférieure du fluide de barrière (712).

4. Machine de traitement de fluide (140, 150) selon la revendication 1, dans laquelle la machine est un compresseur sous-marin (140).

5. Machine de traitement de fluide (140, 150) selon la revendication 4, dans laquelle la machine est un compresseur de gaz humide sous-marin.
6. Machine de traitement de fluide (140, 150) selon la revendication 4, dans laquelle le fluide de traitement est un gaz d'hydrocarbure humide produit à partir d'une formation rocheuse souterraine.
7. Machine de traitement de fluide (140, 150) selon la revendication 1, dans laquelle la machine est une pompe multiphase conçue pour être déployée dans un environnement sous-marin et le fluide de traitement contient des phases multiples.
8. Machine de traitement de fluide (140, 150) selon la revendication 7, dans laquelle les phases multiples comportent de préférence des particules solides et/ou des hydrates.
9. Machine de traitement de fluide (140, 150) selon la revendication 1, dans laquelle la machine est une pompe électrique submersible (150) pouvant être déployée à l'intérieur d'un puits de forage (154).
10. Machine de traitement de fluide (140, 150) selon la revendication 1, dans laquelle le premier élément (254) comprend un moyeu (350) sur lequel la pluralité de roues (352) est montée en une pluralité de rangées, et la machine comprenant en outre :
 - un second élément (244) pouvant tourner autour de l'axe longitudinal central (300), le second élément comprenant un manchon ;
 - un second système de moteur (242) en prise mécaniquement avec le second élément de manière à faire tourner le second élément autour de l'axe longitudinal dans une seconde direction de rotation (312) qui est opposé à la direction de rotation (314) du premier élément ; et
 - une pluralité de secondes hélices (342) étant montées à demeure sur le manchon du second élément dans une pluralité de secondes rangées de sorte que les secondes rangées s'entrelacent avec les rangées d'hélices sur le moyeu un premier élément, les seconds éléments étant exposés au fluide de traitement à l'intérieur de la chambre de traitement de fluide de sorte que lorsque le second élément est mis en rotation dans la seconde direction de rotation, les secondes hélices agissent sur le fluide de traitement, ce qui permet d'augmenter la pression de fluide de traitement vers la sortie et (214) une seconde force de réaction (306) est communiquée au second élément dans une direction axiale de la sortie vers l'entrée (212) ; et
 - un second élément rotatif (246) entouré d'un fluide de barrière et fixé à demeure au second élé-

ment, l'élément rotatif présentant une surface de pression supérieure (404, 704) exposée au fluide de barrière à une pression supérieure et une surface de pression inférieure (402, 702) exposée au fluide de barrière à une pression inférieure, la différence entre les pressions supérieure et inférieure agissant sur les surfaces de pression supérieure et inférieure respectives générant une force sur le second élément qui contrebalance au moins partiellement la seconde force de réaction,

11. Machine de traitement de fluide (140, 150) selon la revendication 1, dans laquelle la différence entre le fluide à pression supérieure et le fluide à pression inférieure est en outre partiellement produit par une pompe à fluide de barrière (720).
12. Machine de traitement de fluide (140, 150) selon la revendication 1, dans laquelle le fluide de barrière (712) est moins inducteur d'usure que le fluide de traitement.
13. Procédé destiné à faire fonctionner la machine d'augmentation de la pression d'un fluide selon une quelconque revendication précédente comprenant :

la mise en rotation du premier élément autour de l'axe longitudinal central (300) de façon à amener la pluralité de roues (352) à entrer en prise et à augmenter la pression de fluide de traitement le long d'une première direction axiale (304), ce qui permet d'amener l'application d'une force de réaction (308) sur le premier élément dans une seconde direction axiale opposée à la première direction axiale la mise en rotation du disque de poussée présentant des structures de façon à augmenter ainsi la pression de fluide de barrière l'amenée d'une différence de pression dans le fluide de barrière (712) dans lequel la surface de pression supérieure (404, 704) du disque de poussée exposée au fluide de barrière de pression supérieure et la surface de pression inférieure (402, 702) du disque de poussée exposée à un fluide de barrière de pression inférieure, la différence de pression dans le fluide de barrière générant une force sur le disque de poussée (256) qui contrebalance partiellement la force de réaction et décharge la surface d'appui inférieure du disque de poussée (256).

14. Procédé selon la revendication 13, dans lequel le fluide de traitement est un effluent d'hydrocarbures et est produit à partir d'une formation rocheuse souterraine.
15. Procédé selon la revendication 13, dans lequel le

procédé est effectué dans un environnement sous-marin.

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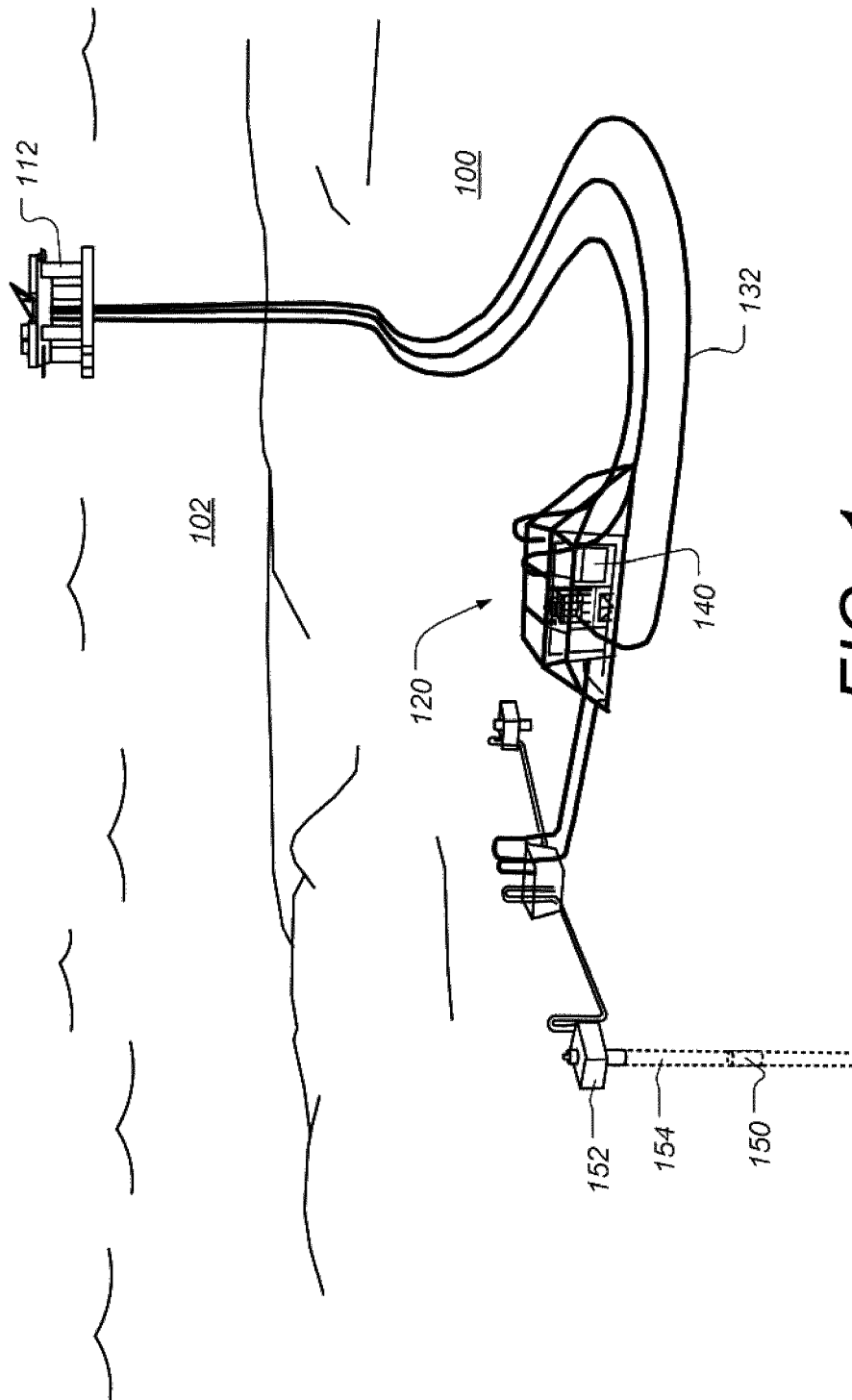


FIG. 1

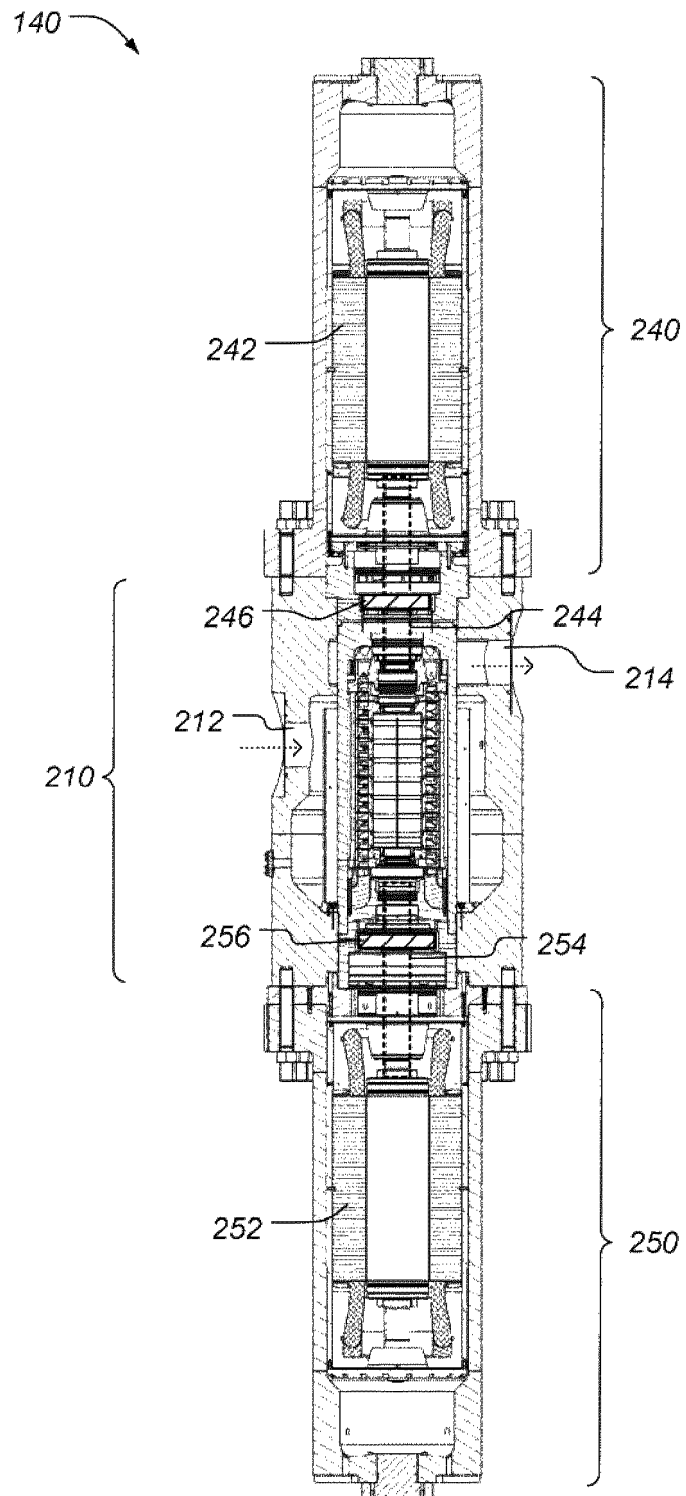


FIG. 2

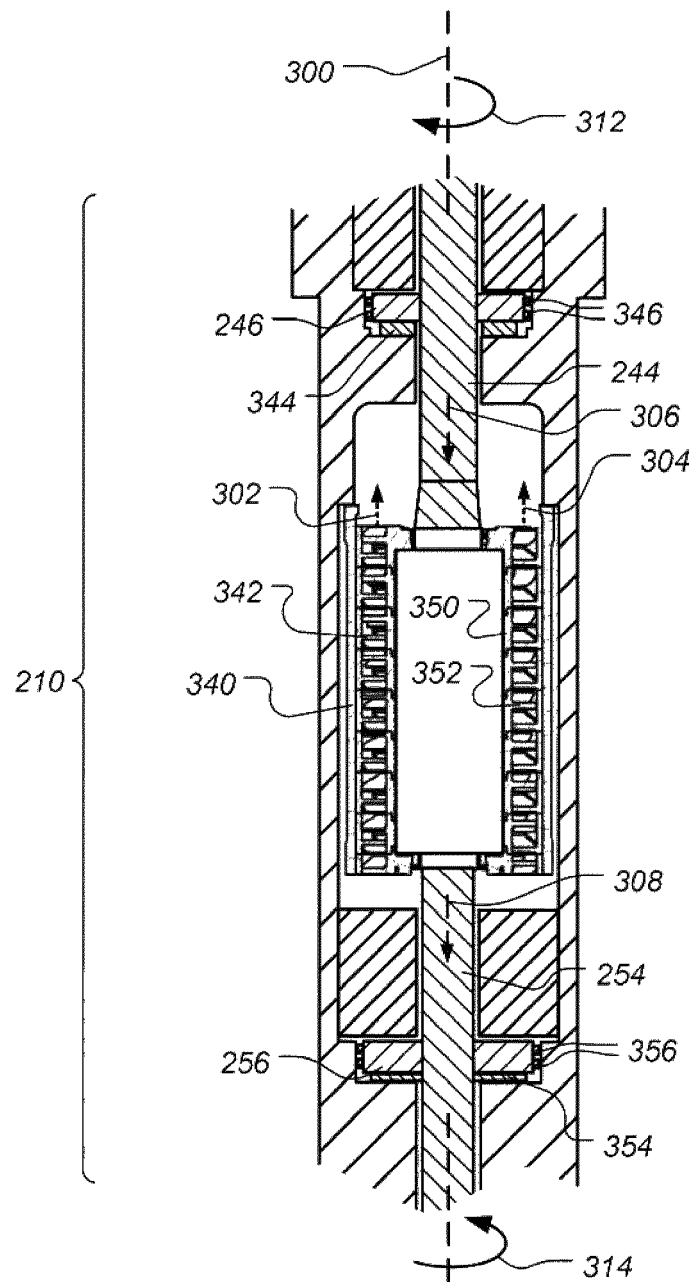
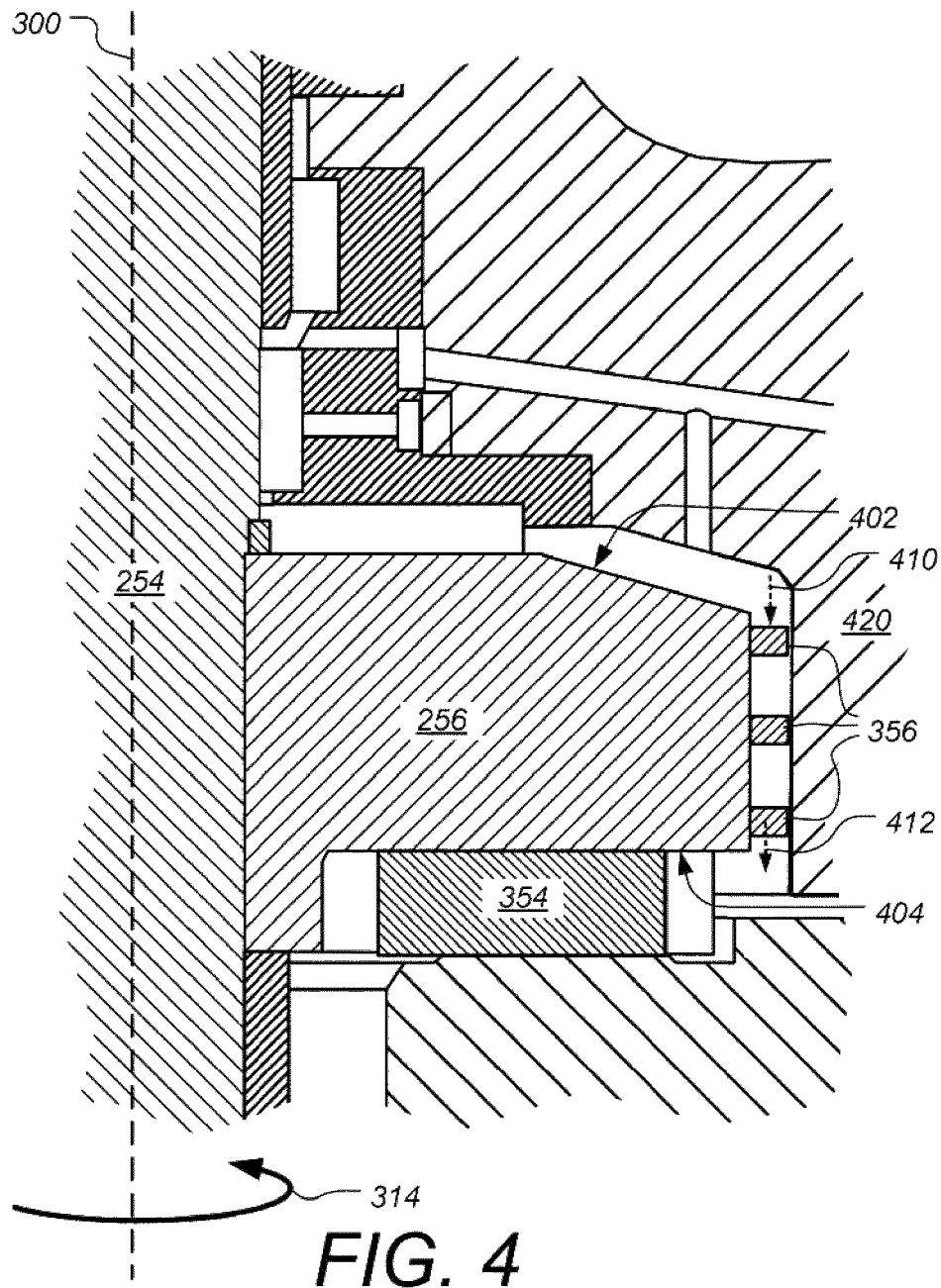


FIG. 3



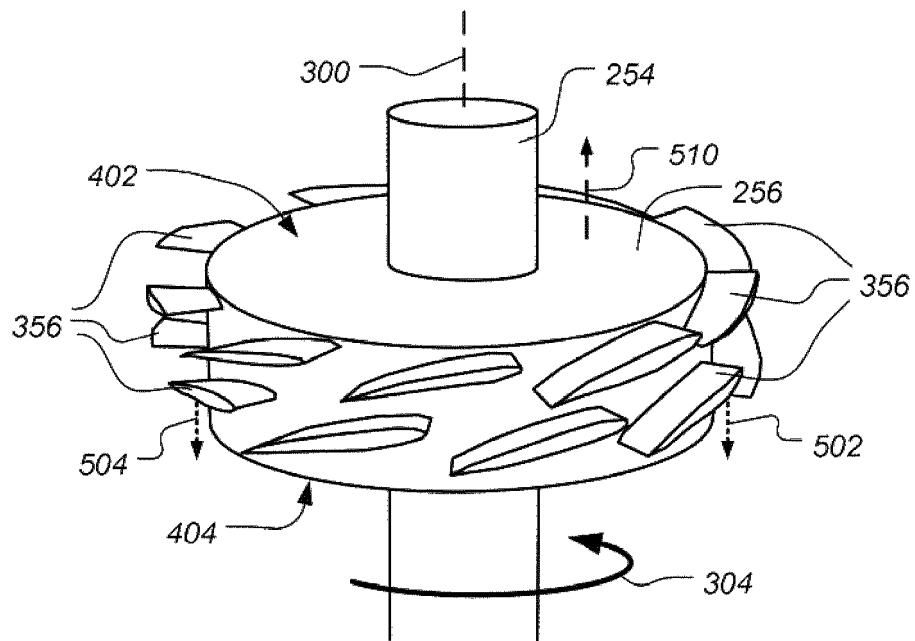


FIG. 5

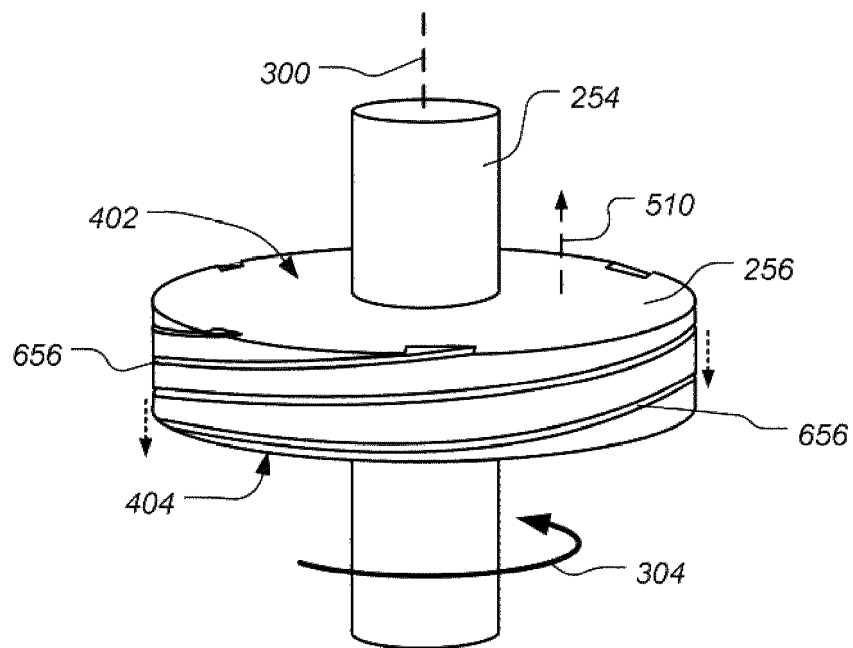
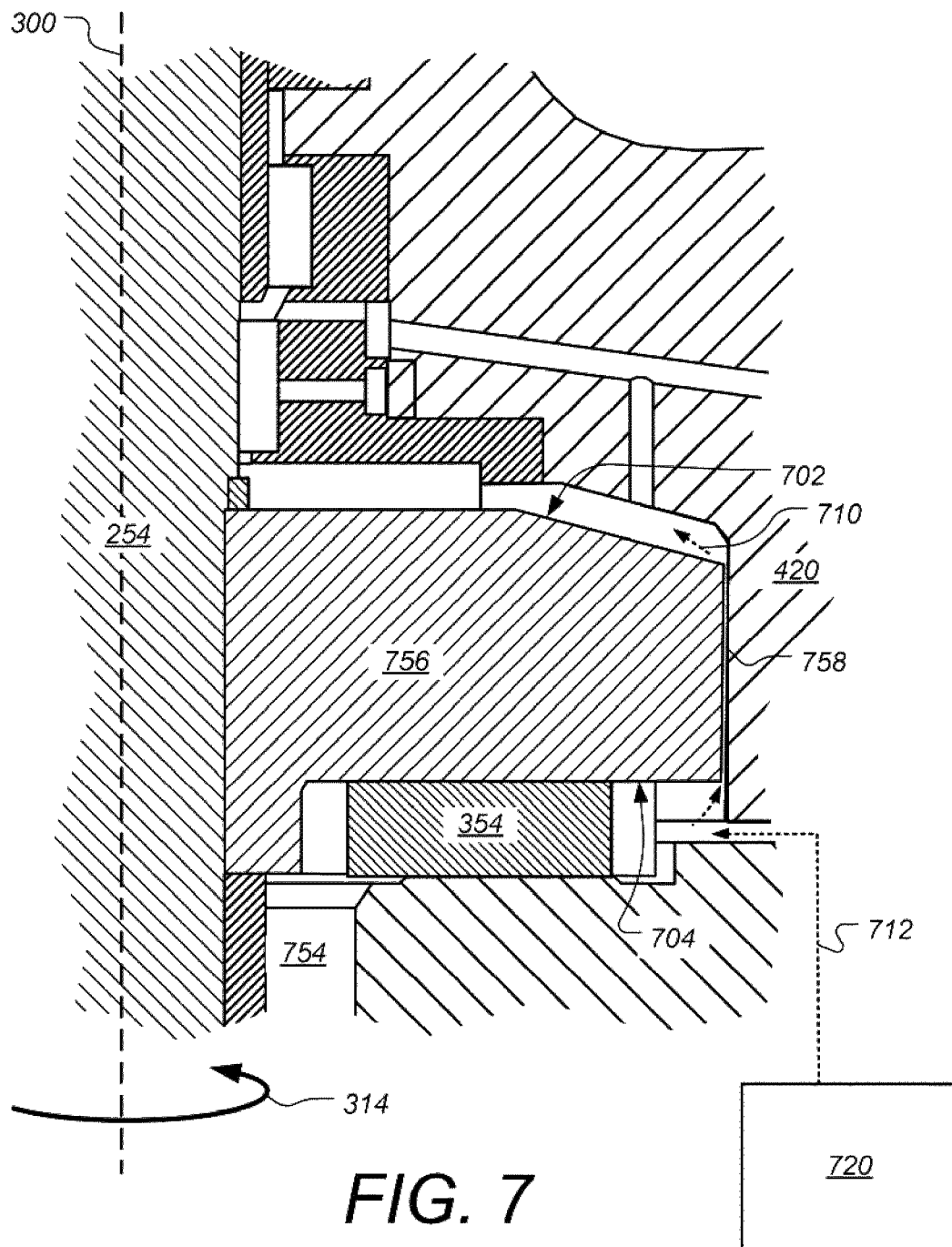


FIG. 6



REFERENCES CITED IN THE DESCRIPTION

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