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(54) **SYSTEM AND METHODOLOGY TO FACILITATE PUMPING OF FLUID**

(57) A technique facilitates operation of a pump such as a multiphase pump. The pump may be provided with an impeller having a plurality of impeller blades. The impeller blades have blade tips which extend over an axial length. A ring is positioned along the blade tips to stiffen

the impeller and to thus provide stability. However, the axial length of the ring is limited relative to the axial length of the impeller to enable flow, e.g. leakage, across the blade tips in a manner which causes active phase mixing during pumping of a fluid, e.g. a multiphase fluid.

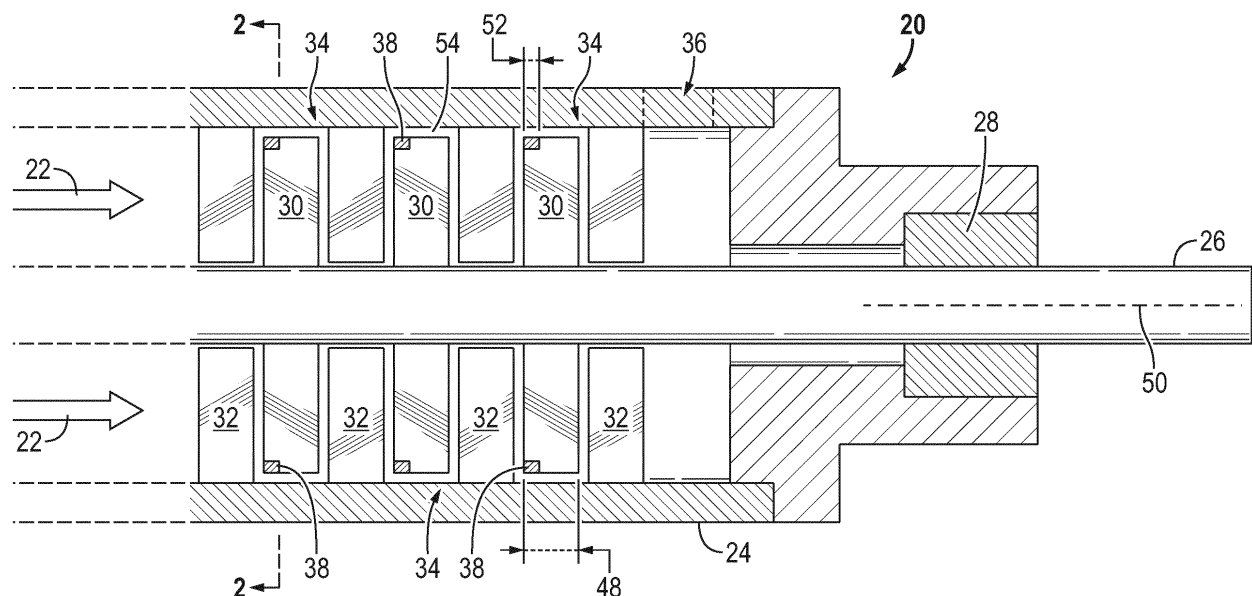


FIG. 1

Description

BACKGROUND

[0001] Multiphase pumps are used in a variety of pumping applications, including subsea pumping applications involving the movement of hydrocarbon fluids having a mixture of oil and gas. In multiphase pumps, open impellers provide open impeller blade tips which allow fluid to leak over the blade tips through a clearance at the blade tips. This blade tip clearance helps to mix the multiphase fluid but it also can be the origin of a fluid induced rotor dynamic instability particularly at high head generation. This induced instability is sometimes called the Thomas-Alford effect.

[0002] Modern pumping operations have demanded impeller systems which create increased differential pressures. The increased differential pressures, in turn, increase the fluid forces acting on radial support bearing systems of the multiphase pumps. The increased forces also have caused increased vibration levels for certain operating conditions where high energy is present in the hydraulics. In some applications, increased stability has been provided by using shrouds placed over the blade tips to thus eliminate the blade tip clearance and the leakage of fluid over the blade tips. However, when using such a shroud, the mixing effect across the blade tips is lost. Additionally, this type of shroud can be unstable during, for example, pumping of liquids with medium to high viscosity.

SUMMARY

[0003] In general, the present disclosure provides a system and methodology for facilitating operation of a pump, e.g. a multiphase pump. The pump may be provided with an impeller having a plurality of impeller blades. The impeller blades have blade tips which extend over an axial length. A ring is positioned along the blade tips to, for example, suppress fluid induced Alford effects and to add annular seal direct stiffness to the impeller and to thus provide rotor dynamic stability. However, the axial length of the ring is limited relative to the axial length of the impeller blade tips to enable flow, e.g. leakage, across the blade tips in a manner which causes active phase mixing during pumping of a multiphase fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Certain embodiments will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

Figure 1 is a schematic cross-sectional illustration

of an example of a multiphase pump, according to an embodiment of the disclosure;

Figure 2 is a schematic cross-sectional illustration taken generally along line 2-2 of Figure 1 and showing an example of an impeller, according to an embodiment of the disclosure;

Figure 3 is an illustration of a portion of a multiphase pump having an example of an impeller combined with a ring in a manner able to provide stability and phase mixing, according to an embodiment of the disclosure; and

Figure 4 is an illustration of a portion of a multiphase pump having another example of an impeller combined with a ring in a manner able to provide stability and phase mixing, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0005] In the following description, numerous details are set forth to provide an understanding of some illustrative embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0006] The disclosure herein generally relates to a system and methodology for enhancing pumping capabilities. For example, the system and methodology facilitate operation of a pump, e.g. a multiphase pump of the type that may be used to pump hydrocarbon-based fluids having various mixtures of oil and gas. The pump may be provided with at least one impeller having a plurality of impeller blades. In a variety of applications, the multiphase pump may comprise a plurality of impellers rotatably mounted within a pump housing. For example, the impellers may be rotationally fixed to a shaft which may be rotated to thus rotate the impellers.

[0007] The impeller blades have blade tips which extend over an axial length, as described in greater detail below. In some embodiments, the impellers may be combined with corresponding diffusers to establish a desired number of pump stages disposed in the pump housing. In such embodiments, the impellers are rotated with respect to the diffusers to effectively pump the fluid, e.g. the multiphase fluid. During operation of the pump, fluid flows through the diffusers as it moves from one sequential impeller to the next until being discharged from the pump housing.

[0008] In some embodiments, each impeller has an impeller hub which may be rotationally fixed to the shaft. The impeller blades extending radially outward from the impeller hub may each have an impeller blade base affixed to the impeller hub and an impeller tip located ra-

dially outward from the impeller blade base. A ring, e.g. a wear ring, may be positioned and affixed along the blade tips to, for example, suppress fluid induced Alford effects and to add annular seal direct stiffness to the impeller. The ring effectively suppresses fluid induced instability to the impeller, thus providing rotor dynamic stability during pump operation. In some embodiments, the ring extends from blade tip to blade tip along the entire circumference of the impeller. However, the ring may be constructed with breaks such that it extends along a portion of the impeller circumference.

[0009] The ring of a given impeller also has an axial length, however the ring axial length is limited relative to the axial length of the impeller blade tips. This reduced axial length relative to the blade tips enables flow, e.g. leakage, across the blade tips in a manner which ensures active phase mixing during pumping of a fluid, e.g. a multiphase fluid. The ring axial length relative to the impeller blade tip axial length may vary depending on the parameters of a given application. By way of example, the axial length of the ring may be 80% or less of the axial length of the impeller blade tips, e.g. 15% to 80%. In other embodiments, the ring axial length may be 50% or less of the axial length of the impeller blade tips, e.g. 15% to 50%. In various applications, the wear ring axial length may be from 10% to 95% of the axial length of the impeller blade tips.

[0010] The ring provides rotor dynamic stiffness to the corresponding impeller so as to limit fluid instabilities in the impeller, the shaft, and the shaft bearings. If the pump comprises multiple impellers, the impellers (or a desired number of the impellers) may be combined with corresponding rings to provide the desired stiffness so as to reduce undesirable fluid based instabilities, e.g. vibrations. In some embodiments, wear rings may be fixed along blade tips of helico axial impellers in multiphase pumps to reduce the fluid instabilities otherwise experienced by the impellers and the pump shaft.

[0011] The wear ring or rings may be constructed to reduce unstable viscosity effects and thus stabilize Lomakin effects while still allowing leakage past the blade tips to ensure sufficiently active phase mixing during pumping. It should be noted that instability may lead to a variety of unwanted vibrations in the impellers and/or shaft to which the impellers are mounted. For example, at operating conditions of low gas volume fractions and low flow rates with high differential pressures some synchronous, sub-synchronous, or super-synchronous vibrations can occur in both forward and backward modes. The vibrations can result from fluid induced de-stabilizing forces due to the Thomas-Alford effect. For example, such effects may occur in forward mode for pumping devices such as turbines and in both forward and backward modes for a variety of pumps, e.g. helico axial pumps.

[0012] With respect to helico axial impellers, for example, substantial destabilization forces may not be produced when the differential pressure (dP) at each pump stage is in the range of 2-5 bars. However, when this

differential pressure at each pump stage is increased to a range of, for example, 10-30 bar, the destabilizing fluid forces may overcome the pump bearing support forces. This can lead to unwanted vibration unless the impeller or impellers are stiffened via the ring(s), as described in greater detail below. The impeller construction effectively promotes active mixing of multiphase fluids while the increased stiffness afforded by the ring(s) enables operation of pumps at greater differential pressures and increased head without causing undue instability of impellers, shaft, or radial bearings.

[0013] Referring generally to Figure 1, a schematic illustration is provided of an example of a pump 20 for moving a fluid, as represented by arrows 22. The fluid 22 may be a multiphase fluid such as a hydrocarbon-based fluid containing oil and gas. By way of example, the pump 20 may be in the form of a helico axial pump. In subsea well operations, the pump 20 may be in the form of a helico axial pump operated to move hydrocarbon-based fluid which is in the form of multiphase mixtures of oil and natural gas.

[0014] In the embodiment illustrated in Figure 1, the pump 20 comprises a pump housing 24 and a shaft 26 rotatably mounted in the pump housing 24. The shaft 26 may be rotatably mounted on bearings 28 positioned, for example, between the housing 24 and shaft 26. By way of example, a plurality of radial bearings 28 may be positioned along the shaft 26. Additionally, the pump 20 may comprise at least one impeller 30 and at least one diffuser 32. In many applications, the pump 20 is constructed with a plurality of impellers 30 and a plurality of corresponding diffusers 32 arranged in stages 34 which may be referred to as compression stages. The number of stages 34 may vary depending on the pumping parameters for a given application and may comprise at least 10 stages, and sometimes at least 15 stages.

[0015] The impellers 30 may be mounted to shaft 26 for rotation with the shaft 26 during operation of pump 20. For example, the impellers 30 may be rotationally affixed to shaft 26 via engaged teeth, key and keyway arrangements, or other suitable mechanisms for rotationally affixing the impellers 30 to shaft 26. The diffusers 32 may be mounted stationary with respect to pump housing 24 and may operate to direct fluid 22 from one sequential impeller 30 to the next. The pump 20 also comprises a discharge opening 36 or a plurality of discharge openings 36 through which the fluid is discharged from the pump 20 after being pumped through stages 34. The discharge opening(s) 36 may be arranged in various configurations and locations to direct the fluid 22 into a corresponding component, e.g. a corresponding flow line.

[0016] To provide a desired rotor dynamic stiffness to each impeller 30, a ring 38 is positioned along the outer circumference of each impeller 30. By way of example, the ring 38 may be in the form of a wear ring. In some embodiments, the ring 38 is constructed from a different material than other portions of the impeller 30. For example, the ring 38 may be constructed from a hardened

steel, carbide based material, or other suitable wear resistant material. Other types of materials also may be selected for ring 38 to provide desired wear and/or operational characteristics different from those of the other impeller material. The ring 38 provides stiffness to the corresponding impeller 30 so as to limit fluid instabilities in both the impeller 30 and the shaft 26. If the pump comprises multiple impellers 30, the full set of impellers 30 or a desired number of the impellers 30, e.g. a reduced number of the impellers 30, may be combined with corresponding rings 38 to provide the desired stiffness so as to reduce undesirable vibrations or other fluid instabilities.

[0017] With additional reference to Figure 2, each impeller 30 may comprise an impeller hub 40 rotationally affixed to the shaft 26. Each impeller 30 further comprises a plurality of impeller blades 42 extending radially outward from the impeller hub 40. Each impeller blade 42 has an impeller blade base 44 and an impeller blade tip 46. The impeller blade bases 44 may be integrally formed with the impeller hub 40 or otherwise affixed to the impeller hub 40.

[0018] Additionally, the impeller blade tips 46 have an axial length 48 extending along an axis 50 of the pump 20. The ring 38 also has an axial length 52, but the ring axial length 52 is shorter than the impeller blade tip axial length 48. Each ring 38 may be located along the impeller blade tips 46 of the corresponding impeller 30, as illustrated in Figure 1. In some embodiments, the ring 38 extends around the entire circumference of the corresponding impeller 30, as illustrated in Figure 2. However, other embodiments may utilize rings 38 which extend along a portion (or portions) of the circumference of the corresponding impellers 30.

[0019] Additionally, the axial length 52 (see, for example, Figures 1 and 3) of the rings 38 relative to the axial length 48 of the corresponding impeller blade tips 46 may vary according to the parameters of a given pumping application. By way of example, the ring axial length 52 may be less than 80% of the axial length 48 of the corresponding impeller blade tips 46. In some embodiments, the ring axial length 52 may be in the range from 30% to 80% of the axial length 48 of the impeller blade tips 46. In other embodiments, however, the ring axial length 52 may be in the range from 30% to 50% of the axial length 48 of the corresponding impeller blade tips 46. Other ratios also may be used in some applications depending on various factors such as desired ring strength/stiffness, fluid parameters, differential pressures, and/or other pumping related parameters. It should be noted the wear ring 38 may be located at an inlet side of the impeller 30 as illustrated. However, the wear ring 38 also may be located at other axial positions and other positions along the blade tips 46 in some applications. For example, the wear ring 38 may be positioned along the impeller blade tips 46 at the impeller inlet side, the impeller outlet side, or at various positions therebetween.

[0020] The ratio of ring axial length 52 to impeller blade

tip axial length 48 is selected based on the desired stiffening of the corresponding impeller 30 and the desired mixing of multiphase fluids for a given set of pumping conditions and parameters. The desired mixing of multiphase fluids results from allowing leakage of fluid 22 past the impeller blade tips 46 to a gap 54, e.g. a clearance, between the impeller blade tips 46 and a surrounding housing. In other words, the axially shorter ring 38 does not prevent flow of fluid in a radially outward direction past impeller blade tips 46 and into gap 54 (thus promoting mixing). The surrounding housing may be an inside surface of pump housing 24, a portion of a corresponding diffuser 32 extending along the impeller 30, or another suitable housing. It should be noted the contact surface between the ring 38 and the impeller blade tips 46 may be a continuous fixed interphase or it may include bores, slots, and/or other features to provide for fluid flow and mixing through the bores, slots, and/or other features.

[0021] The leakage or flow of fluid through gap 54 past the impeller blade tips 46 ensures sufficiently active phase mixing during pumping. By limiting the axial extent of the ring 38, this flow past the impeller blade tips 46 and resultant mixing is allowed to occur. Thus, the reduced axial length 52 of ring 38 stiffens the impeller while still enabling substantial mixing of multiphase fluids to ensure, for example, stable performance of the impellers 30 even with high viscosity fluids 22.

[0022] Furthermore, the rings 38 are able to reduce or eliminate unstable Bernoulli effects and thus reduce unstable cross coupled stiffness. In some embodiments, each ring 38 may be positioned along the corresponding impeller 30 to allow for blade tip flow at a latter part (downstream part) of the impeller blade tips 46 to provide the desired, active phase mixing. Furthermore, the differential pressure acting on each impeller 30 is mainly created for the first half of the impeller 30. By positioning the ring 38 along the first half of the corresponding impeller 30, the ring 30 is exposed to the higher differential pressures, thus improving stabilization of the Lomakin effect.

[0023] Referring generally to Figure 3, an embodiment of impeller 30 is illustrated. In this example, ring 38 is in the form of a wear ring which extends radially outwardly of the impeller blade tips 46. In some embodiments, the wear ring 38 may be received in a corresponding slot 56 formed in a surrounding housing 58. As described above, the surrounding housing 58 may be a portion of the corresponding diffuser 32 as illustrated in Figure 3. However, the surrounding housing 58 also may be a portion of pump housing 24 or part of another component of pump 20.

[0024] The wear ring 38 may be integrally formed with impeller blades 42. However, the wear ring 38 also may be a separate component affixed to the impeller blade tips 46 of the impeller blades 42. By way of example, the wear ring 38 may be affixed to impeller blades 42 via brazing, welding, adhesive, or other suitable fastening technique. The fastening technique also may depend on

the similarity or dissimilarity of the materials used to form the wear ring 38 and the impeller blades 42. Additionally, the contact surface between the ring 38 and the impeller blade tips 46 may be a continuous fixed interphase or it may include features 60, e.g. bores or slots, to provide for fluid flow and mixing through the features 60.

[0025] Referring generally to Figure 4, another embodiment of impeller 30 is illustrated. In this example, the ring 38 also may be in the form of a wear ring. However, the wear ring 38 is radially coextensive with the impeller blade tips 46. In other words, the radially outlying surface of the wear ring 38 does not extend radially outwardly of the impeller tips 46. With either of these embodiments, gap 54 remains between the impeller blade tips 46 and the surrounding housing 58 along a portion of the axial length 48 to ensure a desired, substantial mixing of the multiphase fluid 22 as it is pumped along the interior of pump housing 24 during operation of pump 20.

[0026] It should be noted the ring 38, e.g. wear ring, may be combined with various types of impellers 30 at different positions along the impeller blade tips 46. In many types of pumping applications, the impellers 30 may be in the form of helico axial impellers. For example, each impeller blade 42 may be arranged along the impeller hub 40 in a generally helical shape. In some embodiments, individual impellers 30 may have more than one wear ring 38 positioned at desired locations along the impeller blade tips 46, e.g. inlet side, outlet side, and/or suitable positions therebetween. Additionally, a surface 62 of wear ring 38 adjacent surrounding housing 58 may act as a seal surface and may have various configurations. For example, the wear ring surface 62 may be in the form of a plain annular seal, a labyrinth seal, a pocket damper seal, or a stepped diameter segmented seal.

[0027] The use of wear rings 38 positioned along the blade tips 46 of impeller blades 42 provide impellers 30 with improved rotor dynamic stiffness and dampening. Effectively, the rings 38 work to stabilize an open axial impeller 30 where fluid mixing and viscosity effects may be important factors during pumping operations. However, the reduced axial length 52 of the rings 38 relative to the corresponding impeller blade tip axial length 48 ensures sufficient mixing of multiphase fluid 22 to maintain the multiphase fluid 22 in a desirable condition during pumping. Depending on the parameters of a given operation, the pump 20 may be used in subsea operations or surface operations.

[0028] Furthermore, the size and configuration of the pump 20 may vary according to the fluid to be pumped and the desired pumping capacity. The arrangement and number of pumping stages 34 also may vary according to the parameters of the desired pumping operations. The number and arrangement of impeller blades 42 as well as the style of impellers 30 also may vary according to the types of fluids 22, e.g. types of multiphase fluids, pumping environment, pump location, and/or other pumping operation parameters.

[0029] Although a few embodiments of the system and methodology have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

10 Claims

1. A system for moving fluid, comprising:
a pump having a pump housing, a shaft rotatably mounted in the pump housing, and a plurality of impellers mounted to the shaft, each impeller comprising:

an impeller hub rotationally fixed to the shaft;
and

a plurality of impeller blades extending radially outward from the impeller hub, each impeller blade having an impeller base proximate the impeller hub and in impeller tip, the impeller tips having an axial length; and

a wear ring disposed along the tips of the impeller blades and having a wear ring axial length shorter than the axial length of the impeller tips.

2. The system as recited in claim 1, wherein the wear ring axial length is less than 95% of the axial length of the impeller tips.
3. The system as recited in claim 1, wherein the pump comprises a plurality of diffusers alternating with the plurality of impellers.
4. The system as recited in claim 1, wherein the wear ring is formed from a different material than the plurality of impeller blades.
5. The system as recited in claim 1, wherein the wear ring extends radially outwardly of the impeller tips.
6. The system as recited in claim 5, wherein the wear ring is received in a slot formed in a surrounding wall.
7. The system as recited in claim 1, wherein the wear ring is provided with a seal surface having at least one of an annular seal shape; a labyrinth seal shape, a pocket damper seal shape; and a stepped diameter segmented seal shape.
8. The system as recited in claim 1, wherein the wear ring is radially coextensive with the impeller tips.
9. The system as recited in claim 1, wherein the impeller comprises a plurality of impellers disposed between corresponding diffusers to establish pump stages.

10. The system as recited in claim 9, wherein the impellers are helico axial impellers.
11. A method, comprising:
- providing a multiphase pump with an impeller having a plurality of impeller blades with blade tips extending an axial length;
securely positioning a ring along the blade tips to stiffen the impeller; and
limiting a ring axial length to less than the axial length of the blade tips to enable flow across the blade tips for active phase mixing.
12. The method as recited in claim 11, wherein providing the multiphase pump with the impeller comprises providing a plurality of helico axial impellers.
13. The method as recited in claim 11, wherein securely positioning comprises positioning the wear ring at a desired location between an inlet side and an outlet side of the impeller.
14. The method as recited in claim 11, further comprising providing features at a contact surface between the ring and the impeller blades to facilitate fluid flow and mixing.
15. The method as recited in claim 11, further comprising providing the ring with a seal surface having at least one of an annular seal shape; a labyrinth seal shape, a pocket damper seal shape; and a stepped diameter segmented seal shape.

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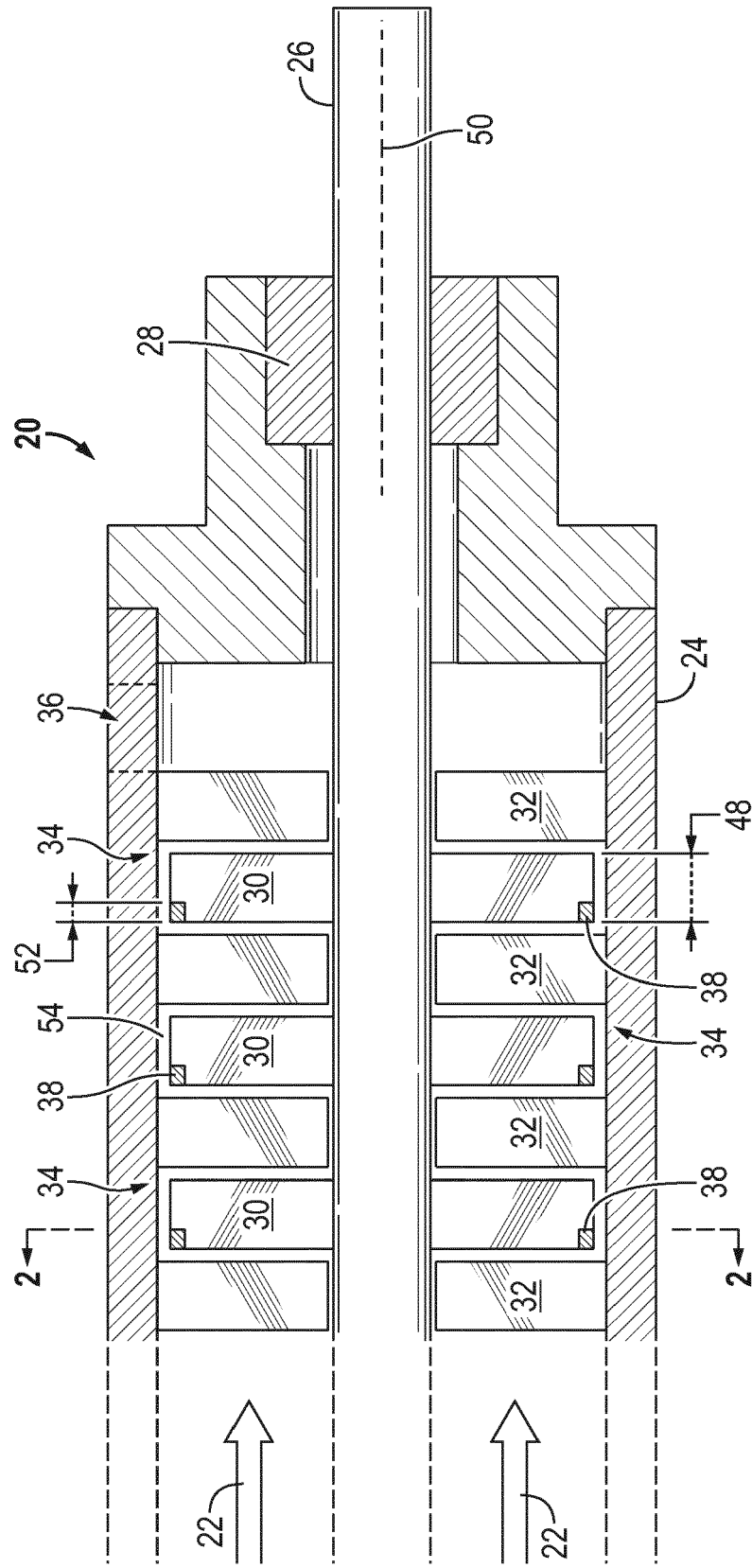
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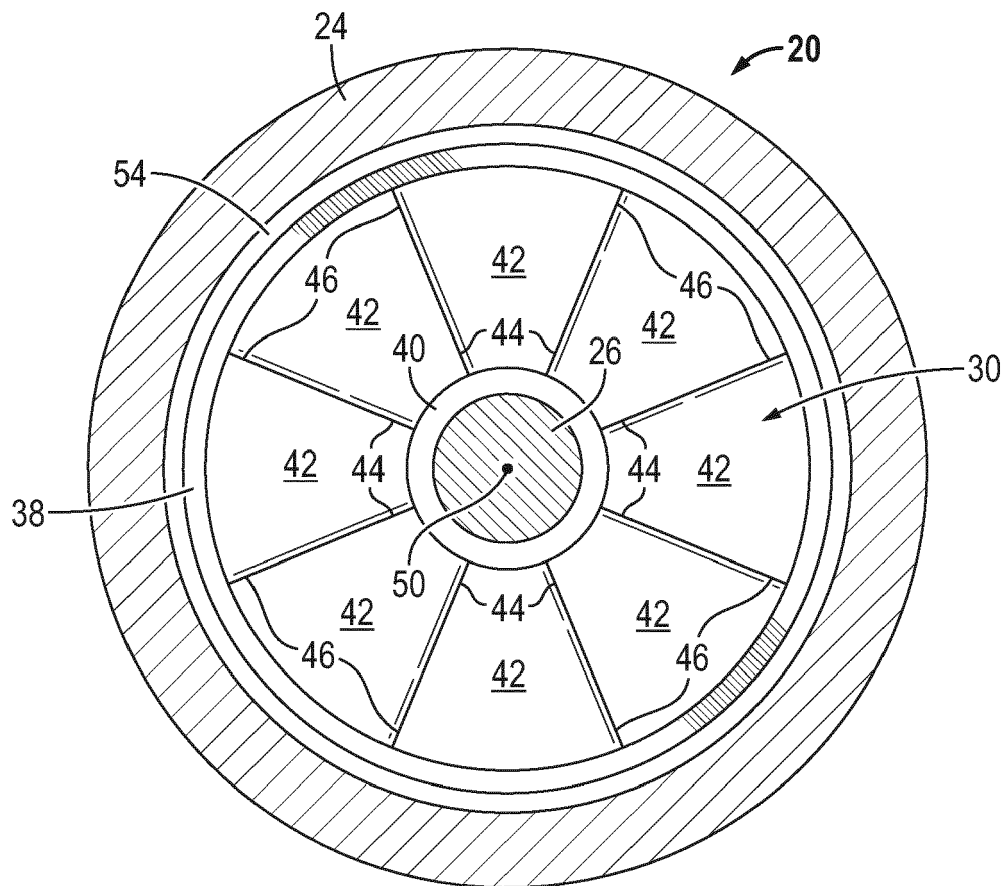


FIG. 2

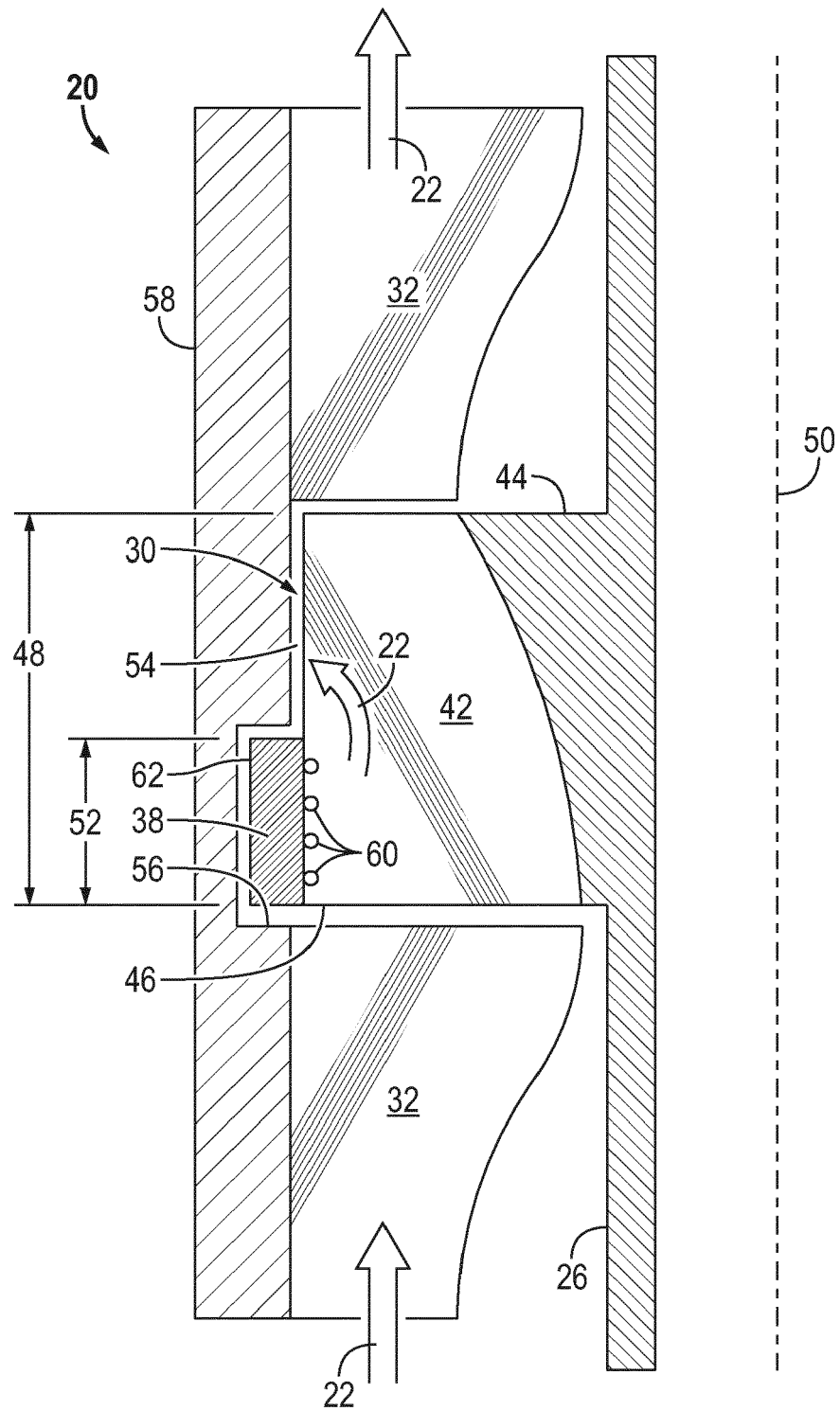


FIG. 3

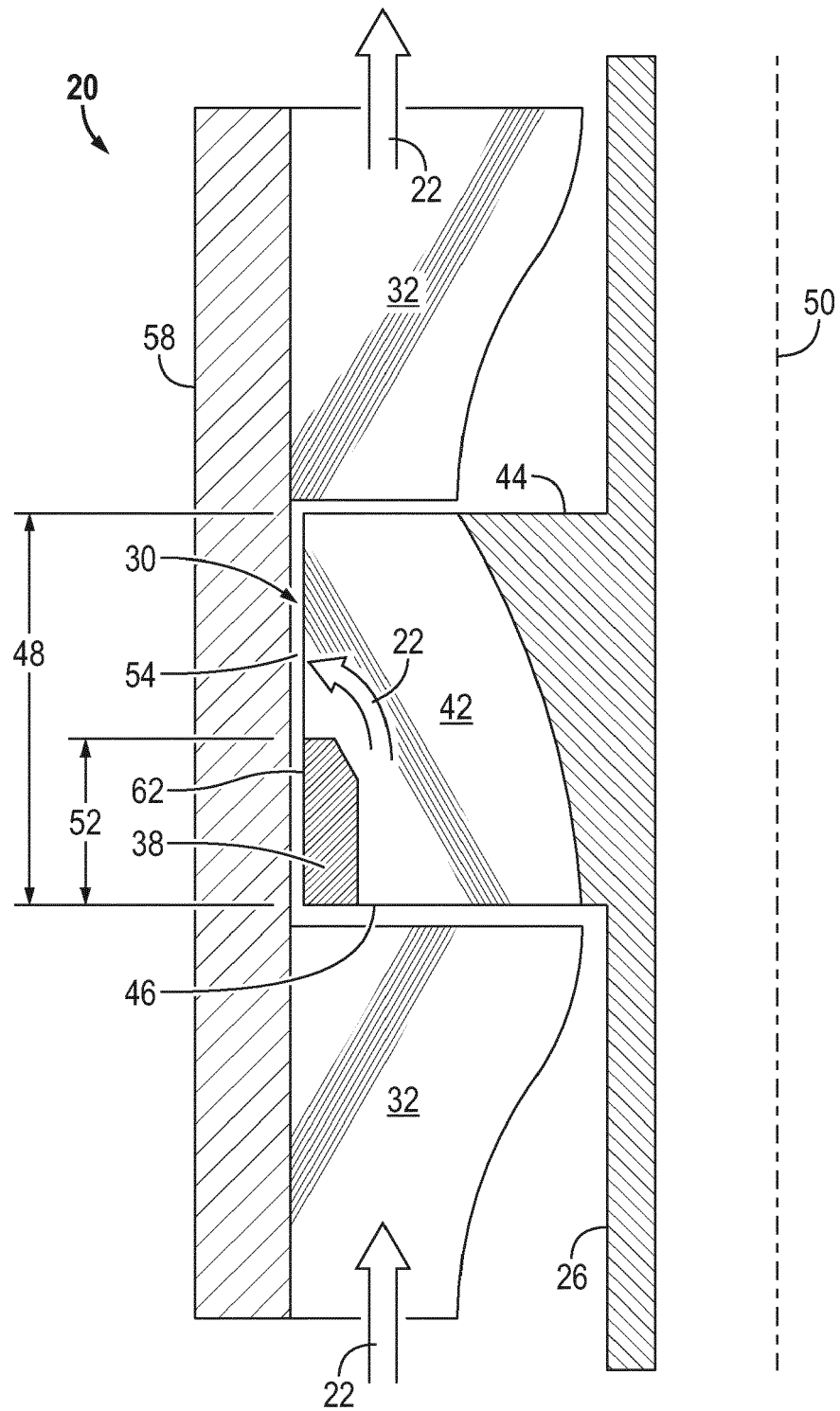


FIG. 4



EUROPEAN SEARCH REPORT

Application Number
EP 19 16 0495

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 16 July 2019	Examiner Lovergine, A
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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