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(54) Title: ELECTRIC SUBMERSIBLE PUMP FLOATING RING BEARING AND METHOD TO ASSEMBLE SAME

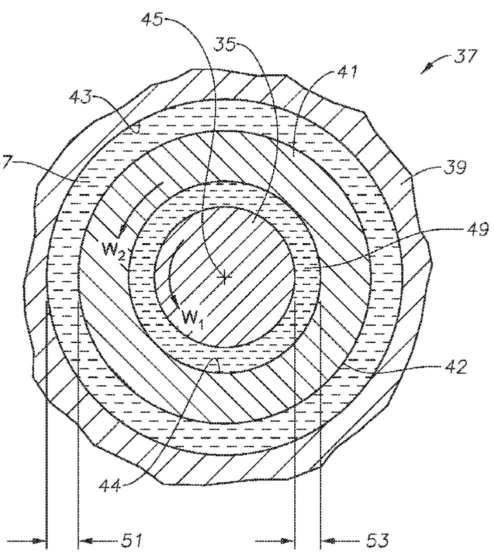

Fig. 2

(57) Abstract: A floating ring bearing for an electric submersible pump (ESP) assembly disposable within a cased wellbore and a method to assemble the same are disclosed. The ESP assembly includes a motor, a pump, and a shaft coupling the pump to the pump motor. One or more floating ring bearings are disposed within the motor and the pump, each floating ring bearing circumscribing the shaft to radially support the shaft. A floating ring is disposed within each floating ring bearing. The floating ring circumscribes the shaft so that the floating ring rotates about the shaft in response to rotation of the shaft.

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ELECTRIC SUBMERSIBLE PUMP FLOATING RING BEARING AND METHOD TO ASSEMBLE SAME

FIELD OF THE INVENTION

[0001] This invention relates in general to bearings supporting a rotating member and, in particular, to bearings supporting rotating shafts of an electric submersible pump and a method to assemble the same.

BRIEF DESCRIPTION OF RELATED ART

[0002] Wells may use an artificial lift system, such as an electric submersible pump (ESP) to lift well fluids to the surface. Where ESPs are used, the ESP may be deployed by connecting the ESP to a downhole end of a tubing string and then run into the well on the end of the tubing string. The ESP may be connected to the tubing string by any suitable manner. In some examples, the ESP connects to the tubing string with a threaded connection so that an uphole end or discharge of the ESP threads onto the downhole end of the tubing string.

[0003] ESPs generally include a pump portion and a motor portion. Generally, the motor portion is downhole from the pump portion, and a rotatable shaft connects the motor and the pump. The rotatable shaft is usually one or more shafts operationally coupled together. The motor rotates the shaft that, in turn, rotates components within the pump to lift fluid through a production tubing string to the surface. ESP assemblies may also include one or more seal sections coupled to the shaft between the motor and pump. In some embodiments, the seal section connects the motor shaft to the pump intake shaft. Some ESP assemblies include one or more gas separators. The gas separators couple to the shaft at the pump intake and separate gas from the wellbore fluid prior to the entry of the fluid into the pump.

[0004] The pump portion includes a stack of impellers and diffusers. The impellers and diffusers are alternatingly positioned in the stack so that fluid leaving an impeller will flow into an adjacent diffuser and so on. Generally, the diffusers direct fluid from a radially outward location of the pump back toward the shaft, while the impellers accelerate fluid from an area proximate to the shaft to the radially outward location of the pump. Each impeller and diffuser may be referred to as a pump stage. The shaft couples to the impeller to rotate the impeller within the non-rotating diffuser. In this manner, the stage may pressurize the fluid to lift the fluid through the tubing string to the surface.

[0005] The rotating shaft of the ESP may be supported on rotary bearings such as journal or plain bearings, sleeve bearings, or the like. These bearing assemblies include a sleeve surrounding and mounted to the rotating shaft, for example with a key, so that the sleeve rotates with the shaft. The sleeve is supported by an insert, for example a bushing, and a lubricant film between the sleeve and the insert. The sleeve and shaft rotate within the insert that is held in place by a race, in turn mounted to a pump housing or pump body through a T-ring that prevents rotation of the bearing relative to the pump housing or body. These types of bearings face problems in environments where high vibration may occur, for example in an eccentrically loaded shaft of an ESP or an imbalanced rotating shaft of the ESP. In addition, due to the relatively thin lubrication layer between the sleeve and the insert, the bearing may be subject to a high degree of wear at the high rotational operating speeds experienced by ESPs. This leads to a significantly shorter life that may necessitate frequent replacement of the bearings. Replacing rotary bearings in an ESP may be extremely costly, particularly where the ESP is positioned within increasingly deep wellbores. Therefore, there is a need for a bearing that may accommodate high vibration of a rotating member in an ESP while having increased wear resistance.

SUMMARY OF THE INVENTION

[0006] These and other problems are generally solved or circumvented, and technical advantages are generally achieved, by preferred embodiments of the present invention that provide an electric submersible pump floating ring bearing and a method to assemble the same.

[0007] In accordance with an embodiment of the present invention, an electric submersible pump (ESP) assembly disposable within a cased wellbore is disclosed. The ESP assembly includes a motor, a pump, and a shaft coupled between the pump and the motor. The ESP further includes an outer bearing surface circumscribing the shaft and fluid between the shaft and the bearing surface. An annular ring floats in the fluid and is rotatable with respect to the shaft and the outer bearing surface.

[0008] In accordance with another embodiment of the present invention, an electric submersible pump (ESP) assembly disposable within a cased wellbore is disclosed. The ESP assembly includes a motor, a pump, and a shaft coupled between the pump and the motor. A stationary journal defines a bore through which the shaft extends and fluid circumscribes the shaft in the stationary journal. An annular ring floats in the fluid coaxial with an axis of the shaft and rotatable with respect to the shaft to reduce the rotational inertia of the fluid resulting from rotation of the shaft, the annular ring rotating at a slower speed than the shaft so that fluid between the ring and the shaft has a higher rotational inertia than the fluid between the ring and the stationary journal.

[0009] In accordance with yet another embodiment of the present invention, a method to assemble a floating ring bearing for use in an electric submersible pump (ESP) to radially support one or more rotating shafts coupling a motor of the ESP to a pump portion of the ESP is disclosed. The method provides providing a stationary journal defining a bore having an axis. The journal is secured to a non-rotating member of the electric submersible pump. The method positions the shaft within the journal coaxial with the bore so that the shaft is rotatable relative to the journal. The method positions a floating ring coaxial with the bore between the journal and the shaft. The floating ring defines an outer annular cavity between the floating ring and the journal and an inner annular cavity between the floating ring and the shaft. The method fills the inner and outer cavities with a fluid freely flowing through the ESP to transfer rotational inertia of the shaft to the floating ring when the shaft rotates, thereby allowing the floating ring to rotate within the journal.

[0010] The disclosed embodiments provide a bearing that can offer improved damping and vibration characteristics. In addition, this bearing type may be used in a system with high vibration to improve the energy dissipation of the rotating shaft and, consequently, the vibration characteristics. Furthermore, the disclosed embodiments will experience reduced wear, such as abrasive wear, compared to similarly situated bearings. This is because the effective velocity between the shaft and the ring, and the ring and the journal is lower.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the features, advantages and objects of the invention, as well as others which will become apparent, are attained, and can be understood in more detail, more particular description of the invention briefly summarized above may be had by reference to the embodiments thereof which are illustrated in the appended drawings that form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the invention and are therefore not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

[0012] Figure 1 is a schematic representation of an electric submersible pump coupled inline to a tubing string and suspended within a casing string in accordance with an embodiment of the present invention.

[0013] Figure 2 is a sectional view of a floating ring bearing of Figure 1, taken along line 2—2 in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0014] The present invention will now be described more fully hereinafter with reference to the accompanying drawings which illustrate embodiments of the invention. This invention may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout, and the prime notation, if used, indicates similar elements in alternative embodiments.

[0015] In the following discussion, numerous specific details are set forth to provide a thorough understanding of the present invention. However, it will be obvious to those skilled in the art that the present invention may be practiced without such specific details. Additionally, for the most part, details concerning drilling rig operation, electric submersible pump construction and operation, and the like have been omitted inasmuch as such details are not considered necessary to obtain a complete understanding of the present invention, and are considered to be within the skills of persons skilled in the relevant art.

[0016] With reference now to FIG 1 an example of an electrical submersible pump (ESP) system 11 is shown in a side partial sectional view. ESP 11 is disposed in a wellbore 29 that is lined with casing 12. In the embodiment shown, ESP 11 includes a motor 15, a seal section 19 attached on the upper end of the motor 15, and a pump 13 above seal 19. Fluid inlets 23 shown on the outer housing of pump 13 provide an inlet for wellbore fluid 31 in wellbore 29 to enter into pump section 13. A gas separator (not shown) could be mounted between seal section 19 and pump section 13.

[0017] In an example of operation, pump motor 15 is energized via a power cable 17 and rotates an attached shaft assembly 35 (shown in dashed outline). Although shaft 35 is illustrated as a single member, it should be pointed out that shaft 35 may comprise multiple shaft segments. Shaft assembly 35 extends from motor 15 through seal section 19 to pump section 13. Impellers 25 (also shown in dashed outline) within pump section 13 are coupled to an upper end of shaft 35 and rotate in response to shaft 35 rotation. Impellers 25 can be a vertical stack of individual members alternatingly interspaced between static diffusers (not shown). Wellbore fluid 31, which may include liquid hydrocarbon, gas hydrocarbon, and/or water, enters wellbore 29 through perforations 33 formed through casing 12. Wellbore fluid 31 is drawn into pump 13 from inlets 23 and is pressurized as rotating impellers 25 urge wellbore fluid 31 through a helical labyrinth upward through pump 13. The pressurized fluid is directed to the surface via production tubing 27 attached to the upper end of pump 13.

[0018] Shaft 35 is radially supported within ESP 11 by bearings, such as floating ring bearings 37. A person skilled in the art will understand that any number of floating ring bearings 37 may be used to support shaft 35 as necessary. Similarly, a person skilled in the art will understand that floating ring bearings 37 may be placed within any portion of ESP 11, such as motor 15, seal section 19, or pump 13 so that each component of ESP 11 may radially support shaft 35 at one or more locations.

[0019] Referring to Figure 2, shown is an example of a floating ring bearing 37 that includes a journal 39, and a floating ring 41. Journal 39 may be a stationary component. In the illustrated embodiment, journal 39 may be an outer housing element of floating ring bearing 37 suitably mounted to a pump housing, shaft support, or shaft alignment member. A person skilled in the art will recognize that journal 39 may mount to the appropriate member in any suitable manner such that floating ring bearing 37 may support shaft 39 as disclosed herein. In other embodiments, journal 39 may be the pump housing, shaft support, or shaft alignment member adapted to function as described herein with respect to journal 39. In an example, journal 39 is a tubular member having a curved inner surface that defines a bore 43 having an axis 45. An inner diameter of bore 43 will be sufficient to accommodate placement of both shaft 35 and floating ring 41 as described in more detail below. Shaft 35 resides within bore 43 and is coaxial with axis 45. Floating ring 41 also resides within bore 43 and is coaxial with axis 45. Floating ring 41 has an outer diameter 42 smaller than the inner diameter of journal 39 so that an outer annular cavity 47 is formed between floating ring 41 and journal 39. Outer annular cavity 47 extends radially outward from the outer diameter 42 of floating ring 41 to the inner diameter of journal 39. Floating ring 41 has an inner diameter 44 larger than the outer diameter of shaft 35 to form an inner annular cavity 49 between shaft 35 and floating ring 41. Inner annular cavity 49 extends from the outer diameter of shaft 35 to inner diameter 44 of floating ring 41. Both outer and inner annular cavities 47, 49 may be respectively filled with a non-compressible fluid F_1, F_2, such as a lubricating oil, grease, gas, or a fluid within ESP 11. Inner and outer annular cavities 47, 49 allow shaft 35 and floating ring 41 to move radially relative to one another, and relative to journal 39. Floating ring 41 is not secured to shaft 35 for rotation therewith.

[0020] A person skilled in the art will understand that floating ring 41 has a length as needed to provide sufficient radial support of shaft 35. Similarly, outer and inner annular cavities 47, 49 may be defined in part by the length of floating ring 41. The length of floating ring 41 may vary based on the dimensional and material properties of shaft 35, the load carrying capacity of shaft 35 and floating ring bearing 37, and they dynamic characteristics of the rotation of shaft 35. A person skilled in the art will further understand that floating ring 41 may move axially relative to shaft 35 and journal 39. However, axial movement of floating ring 41 may be constrained by adjacent components of ESP 11. In some embodiments, a limiter pin (not shown), annular shoulder on journal 39 (not shown), or similar feature may be used axially above and axially below floating ring 41 to limit the overall axial movement of floating ring 41, provided floating ring 41 may still rotate relative to both journal 39 and shaft 35. Floating ring 41 may also have a width sufficient to maintain the ring-like shape of floating ring 41 when subjected to the pressure profile of the ESP 11 application of floating ring bearing 37 and the particular geometry of the ESP 11 component, i.e. pump 13, motor 15, seal section 19, etc., in which floating ring bearing 37 is used.

[0021] Shaft 35 may selectively rotate in response to operation of motor 15 (Figure 1). As shaft 35 rotates with a rotational velocity w_1, frictional forces between the exterior surface of shaft 35 and the surrounding fluid F_2 in inner annular cavity 49 will cause shaft 35 to impart rotational energy to the fluid F_2 in inner annular cavity 49 between shaft 35 and floating ring 41, causing that fluid F_2 to rotate in the same direction as shaft 35. In turn, the rotational motion of the fluid F_2 in cavity 49 will impart rotational energy to floating ring 41 causing floating ring 41 to rotate with a rotational velocity w_2 in the same direction as shaft 35. In the exemplary embodiment, w_2 is approximately $1/3w_1$ to $1/4w_1$. Similarly, frictional forces between floating ring 41 and the fluid F_1 in cavity 47 impart rotational energy from floating ring 41 to the fluid F_1, causing the fluid F_1 to rotate, although at a lower velocity than floating ring 41, the fluid F_2 in cavity 49, or shaft 35. Thus, shaft 35 may rotate within journal 39 with reduced wear between shaft 35 and journal 39. In addition, the reaction forces necessary to prevent rotation of journal 39 may be significantly decreased as the total energy that may be exerted on journal 39 is reduced through the successive energy transfers between shaft 35, fluid F_1, floating ring 41, and fluid F_2.

[0022] In the illustrated embodiment, the fluid F_1, F_2 in cavities 47, 49 is not sealed from the working fluid that is pumped up through pump 13 or the dielectric fluid that may fill seal section 19 and motor 15. As shown, floating ring bearing 37 is a hydrodynamic bearing lubricated with the working fluid or dielectric fluid of the component in which floating ring bearing 37 is positioned. In an exemplary embodiment, shaft 35 may rotate at slower rotational speeds during operation of ESP 11, for example at approximately 3500 revolutions per minute. These operating speeds permit use of the working fluid or dielectric fluid of ESP 11 to lubricate floating ring bearing 37 and provide the fluid films maintaining separation between shaft 35, floating ring 41, and journal 39. In these exemplary embodiments, no additional pressurization system or specialized sealing system is needed to provide fluid F_2 or Fluid F_1 to outer and inner annular cavities 47, 49, respectively. A person skilled in the art will understand that alternative embodiments may seal the fluid in outer and inner annular cavities 47, 49 from the working fluid or dielectric fluid in use in ESP 11.

[0023] Outer annular cavity 47 has a width 51 between journal 39 and floating ring 41. Similarly, outer annular cavity 49 has a width 53 between shaft 35 and floating ring 41. Widths 51, 53 are selected based on the design parameters of the particular ESP 11 into which floating ring bearing 37 is placed. For example, to decrease wear between shaft 35 and journal 39, widths 51, 53 may be larger to allow for a larger decrease in the rotational velocity of w_2 relative to w_1. However, a person skilled in the art will understand that knowledge of the particular ESP 11 application to which floating ring bearing 37 will be applied, including knowledge of the load and operational speed requirements of ESP 11, is necessary to accurately size widths 51, 53. A person skilled in the art will further understand that widths 51, 53 will be limited by the overall size of the ESP component.

[0024] A person skilled in the art will recognize that floating ring bearing 37 may be used in any suitable component of ESP 11. For example, floating ring bearings 37 may be used in pump 13, motor 15, and seal section 19. In addition, floating ring bearings 37 may be used in optional equipment such as gas separators, sand separators, and the like. A person skilled in the art will further understand that each floating ring bearing 37 used in individual components of ESP 11 may be sized according to the particular component of ESP 11 in which floating ring bearing 37 is used, provided that the particular floating ring bearing 37 may operate as described herein.

[0025] Accordingly, the disclosed embodiments provide numerous advantages. For example, the disclosed embodiments provide a bearing that can offer improved damping and vibration characteristics. In addition, this bearing type may be used in a system with high vibration to improve the energy dissipation of the rotating shaft and, consequently, the vibration characteristics. Furthermore, the disclosed embodiments will experience reduced wear, such as abrasive wear, compared to similarly situated bearings. This is because the effective velocity between the shaft and the ring, and the ring and the journal is lower.

[0026] This application claims priority to and the benefit of co-pending U.S. Provisional Application No. 61/448,470, by Forsberg, filed on March 2, 2011, entitled "ELECTRIC

SUBMERSIBLE PUMP FLOATING RING BEARING," which application is incorporated herein by reference.

[0027] It is understood that the present invention may take many forms and embodiments. Accordingly, several variations may be made in the foregoing without departing from the spirit or scope of the invention. Having thus described the present invention by reference to certain of its preferred embodiments, it is noted that the embodiments disclosed are illustrative rather than limiting in nature and that a wide range of variations, modifications, changes, and substitutions are contemplated in the foregoing disclosure and, in some instances, some features of the present invention may be employed without a corresponding use of the other features. Many such variations and modifications may be considered obvious and desirable by those skilled in the art based upon a review of the foregoing description of preferred embodiments. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

What is claimed is:

1. An electric submersible pump (ESP) assembly disposable within a cased wellbore, the ESP assembly comprising:

a motor;

a pump;

a shaft coupled between the pump and the motor;

an outer bearing surface circumscribing the shaft;

fluid between the shaft and the bearing surface; and

an annular ring floating in the fluid and rotatable with respect to the shaft and the outer bearing surface.

2. The ESP assembly of Claim 1, wherein the fluid comprises a lubricant for transferring rotational inertia of the shaft to the ring so that the ring rotates in response to rotation of the shaft.

3. The ESP assembly of Claim 1, wherein the outer bearing surface comprises a portion of a housing of the pump.

4. The ESP assembly of Claim 1, wherein the ring is disposed in the pump and the fluid comprises wellbore fluid being pressurized by the pump.

5. The ESP assembly of Claim 1, wherein ring is disposed in the motor and the fluid comprises dielectric fluid.

6. The ESP assembly of Claim 1, wherein the ring rotates at a slower rotation speed than the shaft.

7. The ESP assembly of Claim 1, wherein the ring rotates at about one-third to about one-fourth the rotation speed of the shaft.

8. An electric submersible pump (ESP) assembly disposable within a cased wellbore, the ESP assembly comprising:

a motor;

a pump;

a shaft coupled between the pump and the motor;

a stationary journal defining a bore through which the shaft extends;

fluid circumscribing the shaft in the stationary journal; and

an annular ring floating in the fluid coaxial with an axis of the shaft and rotatable with respect to the shaft to reduce the rotational inertia of the fluid resulting from rotation of the shaft, the annular ring rotating at a slower speed than the shaft so that fluid between the ring and the shaft has a higher rotational inertia than the fluid between the ring and the stationary journal.

9. The ESP assembly of Claim 8, wherein the fluid comprises a lubricant for transferring rotational inertia of the shaft to the ring so that the ring rotates in response to rotation of the shaft.

10. The ESP assembly of Claim 8, wherein the stationary journal comprises a portion of a housing of the pump.

11. The ESP assembly of Claim 8, wherein the ring is disposed in the pump and the fluid comprises wellbore fluid being pressurized by the pump.

12. The ESP assembly of Claim 8, wherein ring is disposed in the motor and the fluid comprises dielectric fluid.

13. The ESP assembly of Claim 8, wherein the ring rotates at about one-third to about one-fourth the speed of the shaft.

14. A method to assemble a floating ring bearing for use in an electric submersible pump (ESP) to radially support one or more rotating shafts coupling a motor of the ESP to a pump portion of the ESP, the method comprising:

(a) providing a stationary journal defining a bore having an axis, the journal secured to a non-rotating member of the electric submersible pump;

(b) positioning the shaft within the journal coaxial with the bore, the shaft rotatable relative to the journal;

(c) positioning a floating ring coaxial with the bore between the journal and the shaft, the floating ring defining an outer annular cavity between the floating ring and the journal and an inner annular cavity between the floating ring and the shaft; and

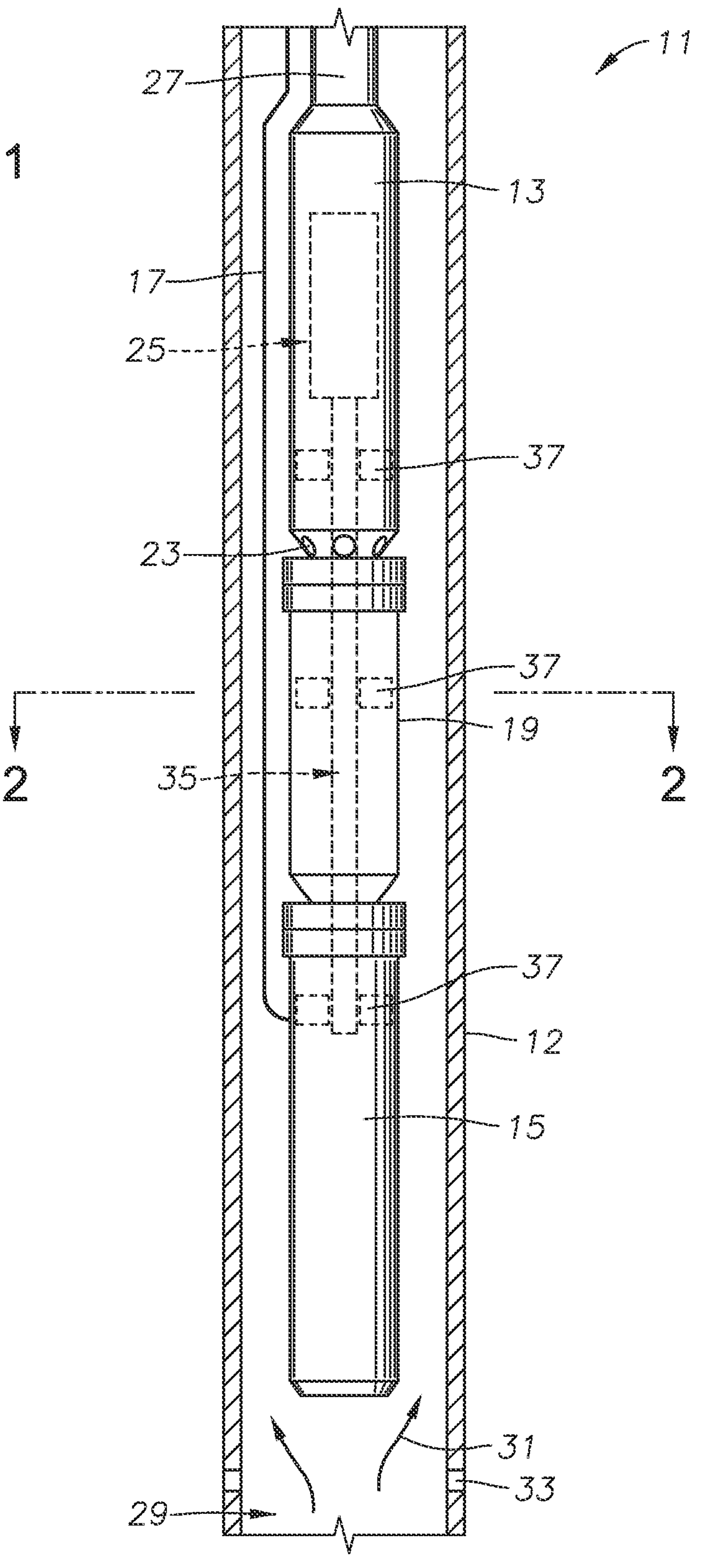
(d) filling ESP with a fluid so that the fluid flows through the ESP into the inner and outer cavities, the fluid to transfer rotational inertia of the shaft to the floating ring when the shaft rotates, thereby allowing the floating ring to rotate within the journal.

15. The method of Claim 14, further comprising providing the stationary journal in the pump portion of the ESP and the fluid comprising wellbore fluid pressurized by the pump portion.

16. The method of Claim 14, further comprising providing the stationary journal in the motor of the ESP and the fluid comprising dielectric fluid filling the motor.

17. The method of Claim 14, further comprising providing the stationary journal in a seal section coupled between the motor and the pump portion of the ESP and the fluid comprising dielectric fluid filling the seal section.

Fig. 1



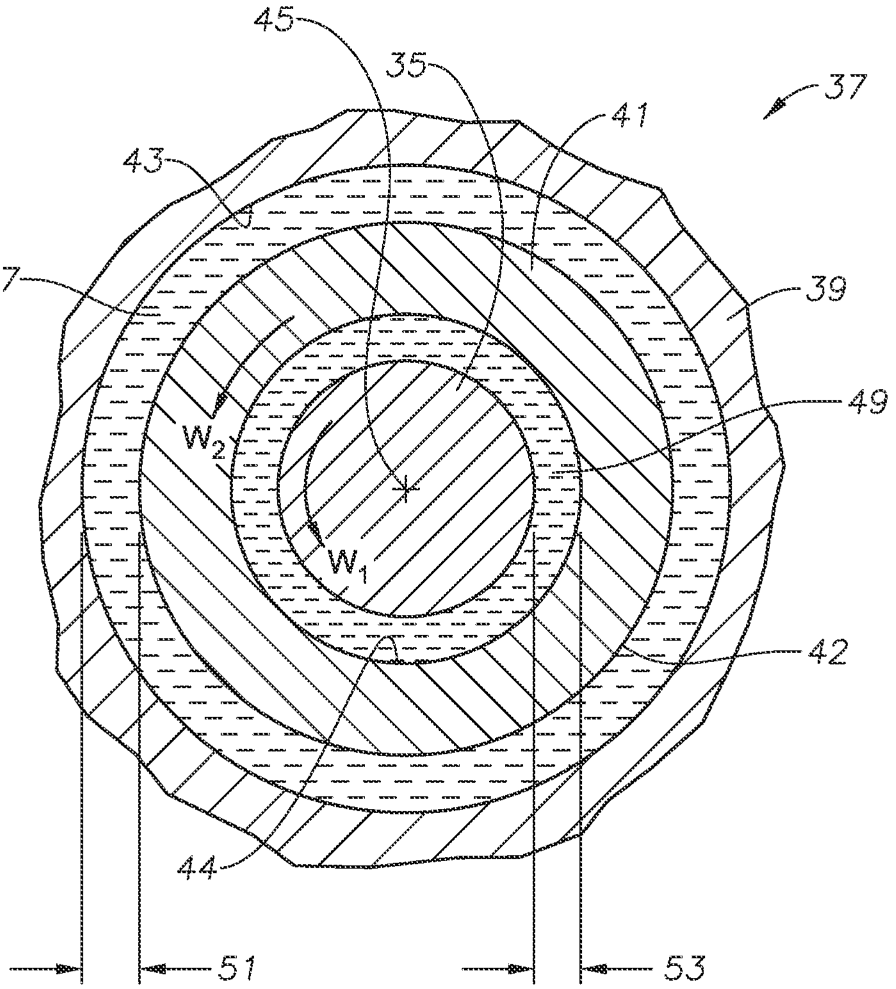


Fig. 2