

CANNED MOTOR FOR ELECTRIC SUBMERSIBLE PUMP

BACKGROUND

Field

[0001] The present disclosure generally relates to electric submersible pumps, and more particularly to canned motor architectures.

Description of the Related Art

[0002] Various types of artificial lift equipment and methods are available, for example, electric submersible pumps (ESPs). An ESP includes multiple centrifugal pump stages mounted in series, each stage including a rotating impeller and a stationary diffuser mounted on a shaft, which is coupled to a motor. In use, the motor rotates the shaft, which in turn rotates the impellers within the diffusers. Well fluid flows into the lowest stage and passes through the first impeller, which centrifuges the fluid radially outward such that the fluid gains energy in the form of velocity. Upon exiting the impeller, the fluid flows into the associated diffuser, where fluid velocity is converted to pressure. As the fluid moves through the pump stages, the fluid incrementally gains pressure until the fluid has sufficient energy to travel to the well surface.

SUMMARY

[0003] In some configurations, a motor for a submersible pumping system includes a housing; a canned stator comprising: a lamination stack and stator windings; and a can disposed within a central bore of the lamination stack and disposed adjacent an inner diameter of the lamination stack, an inner diameter of the can comprising a keyway; a shaft and rotor sub-assembly comprising: a shaft; a rotor disposed about the shaft; and at least one rotor bearing disposed about the shaft, the rotor bearing comprising a key configured to engage the keyway of the can when the shaft and rotor sub-assembly is disposed within the canned stator.

[0004] The motor can further include encapsulation material disposed between the housing and the can. The at least one rotor bearing can include an upper rotor bearing disposed proximate an upper end of the lamination stack, a lower rotor bearing disposed proximate a lower end of the lamination stack, and at least one intermediate rotor bearing disposed between the upper and lower rotor bearings.

[0005] In some configurations, a method of manufacturing a motor for a submersible pumping system includes inserting a can into a central bore of a stator, the stator comprising a

lamination stack disposed within a housing; and inserting a shaft and rotor sub-assembly into a central bore of the can, the shaft and rotor sub-assembly comprising a rotor disposed about a shaft and at least one rotor bearing disposed about the shaft.

[0006] The method can further include at least partially filling a space between the housing and the can with encapsulation material. The method can include pre-forming a keyway along an inner surface of the can prior to assembly with the lamination stack and housing. Alternatively, the method can include forming, e.g., hydroforming, a keyway along an inner surface of the can after inserting the can into the central bore of the stator. The method can further include aligning and engaging a key of the rotor bearing with a keyway in an inner surface of the can.

BRIEF DESCRIPTION OF THE FIGURES

[0007] Certain embodiments, features, aspects, and advantages of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein.

[0008] Figure 1 shows a schematic of an electric submersible pump (ESP) system.

[0009] Figure 2 shows a stator and a can sub-assembly.

[0010] Figure 3 shows a canned stator, including the stator and can of Figure 2, and a shaft-rotor sub-assembly.

[0011] Figure 4 shows an assembled canned motor, including the canned stator and shaft-rotor sub-assembly of Figure 3, and areas of the canned motor filled with encapsulation, oil, and well fluid.

[0012] Figure 5 shows a transverse cross-section of the canned motor of Figure 4.

[0013] Figure 6 shows a close-up view of a portion of the canned motor of Figure 4, showing a key of a rotor bearing engaged with a keyway of the can.

[0014] Figure 7 shows a longitudinal cross-sectional view of the canned motor of Figure 4, taken along line A-A shown in Figure 5.

[0015] Figure 8 shows a longitudinal cross-sectional view of the canned motor of Figure 4, taken along line B-B shown in Figure 5.

DETAILED DESCRIPTION

[0016] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the disclosure. These are, of course, merely examples and are not intended to be limiting. 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 are possible. This description is not to be taken in a limiting sense, but rather made merely for the purpose of describing general principles of the implementations. The scope of the described implementations should be ascertained with reference to the issued claims.

[0017] As used herein, the terms “connect”, “connection”, “connected”, “in connection with”, and “connecting” are used to mean “in direct connection with” or “in connection with via one or more elements”; and the term “set” is used to mean “one element” or “more than one element”. Further, the terms “couple”, “coupling”, “coupled”, “coupled together”, and “coupled with” are used to mean “directly coupled together” or “coupled together via one or more elements”. As used herein, the terms “up” and “down”; “upper” and “lower”; “top” and “bottom”; and other like terms indicating relative positions to a given point or element are utilized to more clearly describe some elements. Commonly, these terms relate to a reference point at the surface from which drilling operations are initiated as being the top point and the total depth being the lowest point, wherein the well (e.g., wellbore, borehole) is vertical, horizontal or slanted relative to the surface.

[0018] Various types of artificial lift equipment and methods are available, for example, electric submersible pumps (ESP). As shown in the example embodiment of Figure 1, an ESP 110 typically includes a motor 116, a protector 115, a pump 112, a pump intake 114, and one or more cables 111, which can include an electric power cable. The motor 116 can be powered and controlled by a surface power supply and controller, respectively, via the cables 111. In some configurations, the ESP 110 also includes gas handling features 113 and/or one or more sensors 117 (e.g., for temperature, pressure, current leakage, vibration, etc.). As shown, the well may include one or more well sensors 120.

[0019] The pump 112 includes multiple centrifugal pump stages mounted in series within a housing. Each stage includes a rotating impeller and a stationary diffuser. A shaft extends through the pump 112 and is operatively coupled to the motor 116. The shaft can be coupled to the protector 115 (e.g., a shaft of the protector), which in turn can be coupled to the motor 116 (e.g., a shaft of the motor). The impellers are rotationally coupled, e.g., keyed, to the shaft. The diffusers are coupled, e.g., rotationally fixed, to the housing. In use, the motor 116 causes rotation of the shaft (for example, by rotating the protector 115 shaft, which rotates the pump shaft), which in turn rotates the impellers relative to and within the stationary diffusers.

[0020] In use, well fluid flows into the first (lowest) stage of the ESP 110 and passes through an impeller, which centrifuges the fluid radially outward such that the fluid gains energy in the form of velocity. Upon exiting the impeller, the fluid makes a sharp turn to enter a diffuser, where the fluid's velocity is converted to pressure. The fluid then enters the next impeller and diffuser stage to repeat the process. As the fluid passes through the pump stages, the fluid incrementally gains pressure until the fluid has sufficient energy to travel to the well surface.

[0021] The motors of submersible pumping systems typically include a stator secured within a tubular housing and a rotor secured to a power transmission shaft that rotates within the stator. The rotor typically is made up of a number of rotor sections, the number of rotor sections depending upon the length and power rating of the motor. Generally, each rotor section includes laminated steel plates or disks secured by copper rods. The rotor sections are spaced apart from each other, and a rotor bearing assembly is located between each rotor section. Each rotor section is connected to the shaft so that all of the rotor sections rotate as the shaft rotates.

[0022] Each rotor bearing assembly within a rotor section acts to support the shaft and to maintain it in proper axial alignment. A rotor bearing assembly comprises a sleeve connected or keyed to the shaft so that the sleeve and shaft rotated together and a journal (e.g., bearing, bushing) disposed coaxially around the sleeve. The journal may be configured to engage the inner wall of the stator to prevent the journal from rotating and to maintain proper alignment of the shaft.

[0023] The present disclosure provides a canned motor, for example for a submersible pumping system, and methods of manufacturing or assembling such a canned motor. The canned motor can include a hermetically sealed stator, which may be encapsulated. In some configurations, canned motors according to the present disclosure include a plurality of rotor bearings, including rotor bearings positioned at intermediate locations along the shaft, for example

between rotor sections and between upper and lower ends of the stator. The sealed stator includes a can disposed along and forming an inner diameter or surface of the sealed stator. An inner diameter or surface of the can includes a keyway configured to receive a corresponding key of the rotor bearings.

[0024] To assemble a canned motor according to the present disclosure, a can sub-assembly, shown in Figure 2, is inserted into a central bore of a wound stator, also shown in Figure 2, to form a hermetically sealed canned stator, as shown in Figure 3. The wound stator includes a lamination stack, including a plurality of stator laminations, disposed within a housing. Stator windings can extend through slots of the stator laminations. As shown in Figure 3, available space between the housing and the can can be filled with encapsulation material. The hermetically sealed stator is advantageously tolerant to well fluid or water ingress, which improves the reliability of the motor.

[0025] As shown in, for example, Figure 6, the can includes a keyway. In some configurations, the inner diameter or surface of the stator laminations includes a keyway, and the can follows the profile of the inner surface of the lamination stack, including the keyway of the laminations. The keyway can be pre-formed in the can prior to assembly (e.g., prior to inserting the can into the lamination stack), or the keyway can be formed, e.g., hydroformed, in-situ after the can is assembled into the stator bore. The keyway can have various shapes or curvatures (e.g., transverse cross-sectional shapes or curvatures), such as square or circular. The keyway can extend along an entire length or axis of the stator, or may only extend along portions of the length of the stator in the location or area of the rotor bearings when assembled.

[0026] Figure 3 also shows a shaft-rotor sub-assembly. The shaft-rotor sub-assembly includes a shaft, one or more rotor sections disposed about the shaft, and one or more rotor bearings. As shown, a top rotor bearing can be disposed on top of the rotor (e.g., proximate or adjacent an upper end of an uppermost rotor section), a bottom rotor bearing can be disposed at the bottom of the rotor (e.g., proximate or adjacent a lower end of a lowermost rotor section), and one or more rotor bearings can be disposed at intermediate locations along the shaft between the top and bottom rotor bearings, for example, between consecutive rotor sections.

[0027] Each rotor bearing includes a bearing sleeve, which is keyed to the shaft, for example via a shaft key, as shown in Figures 5 and 7, a rotor bearing bushing disposed circumferentially about and co-axial to the bearing sleeve, and a rotor bearing key. In some

configurations, the rotor bearing key is disposed on or about a radially outer surface of the rotor bearing bushing or at least partially in a channel or groove formed in the radially outer surface of the rotor bearing bushing. At least a portion of the rotor bearing key can extend longitudinally or axially parallel to the shaft. In some configurations, for example as shown in Figure 7, top and bottom end portions of the rotor bearing key can be bent, for example at 90°, to help secure the rotor bearing key to the rotor bearing bushing. The key can be of a fixed type, which may require pre-alignment (before assembly of the shaft-rotor sub-assembly with the canned stator) with the keyway to properly engage the keyway. Alternatively, the key can be a spring-loaded key, which may not require pre-alignment.

[0028] The shaft-rotor sub-assembly is inserted into a central bore or cavity of the canned stator to form a canned motor assembly as shown in Figure 4. In some configurations, the rotor bearing key is pre-aligned and/or engaged with the stator and/or can keyway before or as the shaft-rotor sub-assembly is inserted into the cavity of the canned stator. Engagement of the rotor bearing key with the stator keyway provides an anti-rotation force and/or function for the rotor bearings.

[0029] Various volumes or areas within the canned motor can be at least partially or fully filled or occupied by different materials or fluids. For example, as shown in Figure 4, an encapsulation zone between the housing and can of the stator can be filled with encapsulation material. The encapsulation material can fully fill in all gaps, for example, in the laminations, windings, pothead terminal, and/or lead wires. A dielectric oil zone, for example, in a mechanical gap between the stator can and rotor, the volume within the head, at the area of the thrust bearing, and/or outside of a compensation bellow at the bottom of the motor (if included), can be filled with dielectric oil. A well fluid zone inside the compensation bellow can be filled with well fluid and can advantageously allow for expansion and contraction of the motor oil. As also shown in Figure 4, gauge connection and/or thermo couple wires are disposed in the clean oil zone and are routed through the motor base into an optional downhole gauge, which can be used for measurement of pressure, temperature, vibration, etc.

[0030] Language of degree used herein, such as the terms “approximately,” “about,” “generally,” and “substantially” as used herein represent a value, amount, or characteristic close to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms “approximately,” “about,” “generally,” and “substantially” may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1%

of, within less than 0.1% of, and/or within less than 0.01% of the stated amount. As another example, in certain embodiments, the terms “generally parallel” and “substantially parallel” or “generally perpendicular” and “substantially perpendicular” refer to a value, amount, or characteristic that departs from exactly parallel or perpendicular, respectively, by less than or equal to 15 degrees, 10 degrees, 5 degrees, 3 degrees, 1 degree, or 0.1 degree.

[0031] Although a few embodiments of the disclosure 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. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments described may be made and still fall within the scope of the disclosure. It should be understood that various features and aspects of the disclosed embodiments can be combined with, or substituted for, one another in order to form varying modes of the embodiments of the disclosure. Thus, it is intended that the scope of the disclosure herein should not be limited by the particular embodiments described above.

CLAIMS

What is claimed is:

1. A motor for a submersible pumping system, the motor comprising:
 - a housing;
 - a canned stator comprising:
 - a lamination stack and stator windings; and
 - a can disposed within a central bore of the lamination stack and disposed adjacent an inner diameter of the lamination stack, an inner diameter of the can comprising a keyway;
 - a shaft and rotor sub-assembly comprising:
 - a shaft;
 - a rotor disposed about the shaft; and
 - at least one rotor bearing disposed about the shaft, the rotor bearing comprising a key configured to engage the keyway of the can when the shaft and rotor sub-assembly is disposed within the canned stator.
2. The motor of Claim 1, further comprising encapsulation material disposed between the housing and the can.
3. The motor of Claim 1, wherein the at least one rotor bearing comprises an upper rotor bearing disposed proximate an upper end of the lamination stack, a lower rotor bearing disposed proximate a lower end of the lamination stack, and at least one intermediate rotor bearing disposed between the upper and lower rotor bearings.
4. A method of manufacturing a motor for a submersible pumping system, the method comprising:
 - inserting a can into a central bore of a stator, the stator comprising a lamination stack disposed within a housing; and
 - inserting a shaft and rotor sub-assembly into a central bore of the can, the shaft and rotor sub-assembly comprising a rotor disposed about a shaft and at least one rotor bearing disposed about the shaft.
5. The method of Claim 4, further comprising at least partially filling a space between the housing and the can with encapsulation material.

6. The method of Claim 4, further comprising pre-forming a keyway along an inner surface of the can prior to assembly with the lamination stack and housing.

7. The method of Claim 4, further comprising hydroforming a keyway along an inner surface of the can after inserting the can into the central bore of the stator.

8. The method of Claim, further comprising aligning and engaging a key of the rotor bearing with a keyway in an inner surface of the can.