An apparatus for steering a drill string that includes at least one blade fixedly disposed on an exterior surface of the drill string, such that the at least one blade is rotatable about the drill string in response to fluid flow through a fluid passage in association with said at least one blade, and the at least one blade rotates independent of the drill string for imparting an asymmetrical moment to the drill string in a selected direction for orienting a drill bit attached to the drill string, thereby steering the drill string.
ROTARY DIRECTIONAL DRILLING APPARATUS AND METHOD OF USE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 12/291,443, filed on Nov. 10, 2008.

BACKGROUND OF DISCLOSURE

[0002] 1. Field of the Disclosure
[0003] The embodiments herein relate generally to rotary directional drilling apparatuses for downhole steering of a drill bit and methods for steering a drill string.
[0004] 2. Background Art
[0005] During rotary drilling, a drill bit is rotated from the surface of the well by rotating a drill string. It is often desirable to control the direction in which the drill string proceeds through use of a downhole steerable drilling apparatus. Steerable drilling apparatuses include hydraulic devices that apply a lateral bias to a drill string, bent or bendable housing members for drilling at angles, and rotary devices that use a rotatable member, actuators, and/or retractable members to control the direction of the drill string.
[0006] Conventional downhole rotary directional drilling assemblies use gravity and compression to force an under gauge stabilizer to the bottom side of a hole, with a drill collar acting as a lever, and a near-bit stabilizer acting as a fulcrum. This lever-like motion pushes the drill bit upward, causing the drill bit to drill on the top of the hole, thereby increasing the angle of the hole. The angle of the drill string can be modified through changes in the length of the drill collar, the diameter of the stabilizers, or modifying one or more drilling parameters.
[0007] Conventional rotary directional drilling assemblies can steer a drill bit only within a single plane, and not along the azimuth.
[0008] A need exists for a rotary directional drilling apparatus that can allow an operator to steer a drill string in any direction, controlling directional changes both in hole angle and along the azimuth.
[0009] A need also exists for a rotary directional drilling apparatus that can utilize fixed steering elements without use of actuators, rather than conventional retractable and movable biasing and thrusting members.
[0010] A further need exists for a rotary directional drilling apparatus able to selectively adjust the orientation of a drill bit through control of the flow of drilling fluid or mud through the mud motor.
[0011] The present embodiments meet these needs.

SUMMARY OF DISCLOSURE

[0012] In an embodiment, the present apparatus for steering a drill string includes a downhole drilling motor having a rotor for imparting rotational movement to the drill bit, and a stator rotatably disposed about the rotor. The stator can be freely rotatable about the rotor, enabling counter rotation of the stator relative to the rotor. One or more bearings, rollers, and/or seals, as known in the art, can be disposed between the rotor and the stator to enable this rotation.
[0013] It should be noted that the drill string is connected to the rotor, rather than to the stator, while conventional rotary directional drilling assemblies typically utilize a connection between the drill string and the stator. Rotation of the drill string, such as when drilling, as known in the art, thereby imparts rotation to the rotor without imparting this rotation to the stator. Various bearings, rollers, and/or seals, as known in the art, can be disposed at each end of the motor to facilitate this rotation and prevent the loss of drilling fluid from the stator. In an embodiment, the drill string can have a concentric stabilizer connected thereon.
[0014] A first passage is disposed through the rotor for flowing drilling fluid through the rotor to the drill bit. One or more fluid passages are disposed through the rotor to flow drilling fluid between the first passage and the stator. The stator can include a fluid passage having vanes, lobes, or similar protrusions, as known in the art, adapted to enable the flow of fluid to impart rotational motion to the stator in a direction counter to the rotation of the rotor imparted by the drill string. The flow rate of drilling fluid or mud to the stator controls the rate of rotation of the stator. In an embodiment, the rotor can include an upper diverter passage disposed through a first end of the rotor and a lower diverter passage disposed through a second end of the rotor.
[0015] In a further embodiment, the first passage can include a flow restrictor for facilitating the flow of drilling fluid to at least one of the fluid passages to cause counter rotation of the stator relative to the rotor.
[0016] One or more seals can be disposed between the rotor and the stator, exterior to each of the fluid passages.
[0017] A valve is disposed in communication with the first passage and one of the fluid passages to the stator for selectively controlling the flow of drilling fluid between the first passage and the stator. The flow rate of drilling fluid conveyed to the stator can be controlled by the valve, thereby controlling the rotational speed of the stator.
[0018] In an embodiment, the valve can be in communication with a measurement while drilling device and can be controlled responsive to data from the measurement while drilling device. In a further embodiment, the valve can include an actuator, a power supply, or combinations thereof.
[0019] One or more blades can be fixedly disposed on the exterior surface of the stator. The one or more blades are usable to orient the drill bit and steer the drill string by providing an asymmetrical moment to the drill string. By selectively controlling the rate of counter rotation of the stator relative to the rotor, the direction of drilling operations can be controlled. The stator can be counter rotated at an equal rate with respect to the rotation of the rotor to maintain the one or more blades in a stationary orientation with respect to a fixed position within a borehole. The one or more blades thereby offset the apparatus' rotational center from the center of the borehole by providing the apparatus with an asymmetrical moment, thereby enabling reorientation of the drill bit in any horizontal or vertical direction through selective positioning of the blades. In an embodiment, the one or more blades can be over-gauge blades.
[0020] The blades are also usable to maintain the orientation of the drill bit and continue drilling in a straight direction by selectively controlling the flow rate of drilling fluid through the stator to maintain constant rotation of the one or more blades with respect to the rotor.
[0021] In an embodiment, the apparatus can include an electronic member in communication with the measurement while drilling device and with the valve for determining the current position of the one or more blades and controlling the valve in response to data obtained from the measurement while drilling device.
[0022] The present embodiments also relate to methods for steering a drill string using similar rotatable asymmetrical moments about a drill string. In an embodiment, a rotary directional drilling assembly, which can include a motor, valve, and blade, as described previously, is provided, coupled with a measurement while drilling device in communication with a drill string.

[0023] Data from the measurement while drilling device is received, and a position of the blade necessary to orient the drill bit in a desired direction is determined. The current location of the blade can be determined using the measurement while drilling device.

[0024] The valve is then controlled to achieve the necessary flow of drilling fluid to the stator, to cause counter rotation of the stator relative to the rotor until the desired position of the blade is reached. The valve can then be adjusted to change the rotational speed of the stator to maintain the blade in the desired position with respect to the borehole. The position of the blade causes reorientation of the drill bit. The valve can then be readjusted to change the rotational speed of the stator to cause drilling to continue in a generally straight direction.

[0025] The valve can be controlled to enable fluid flow to the stator such that the blade remains stationary with respect to a fixed point within the bore hole, thereby causing the drill string to change direction through reorientation of the drill bit. Alternatively, the valve can be controlled to regulate the flow of drilling fluid to the stator such that the stator continuously rotates relative to the rotor, thereby causing the drill string to drill in a constant direction.

[0026] The present embodiments thereby enable steering of a drill string through control of a rotatably moveable asymmetrical moment about a drill string, which can be rotated about the drill string through selective control of the flow of drilling fluid.

[0027] Other aspects and advantages of the disclosure will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0028] In the detailed description of the embodiments presented below, reference is made to the accompanying drawings, in which:

[0029] FIG. 1 depicts a cross-sectional view of an embodiment of the present rotary directional drilling apparatus attached to a drill string.

[0030] FIG. 2 depicts a cross-sectional view of an embodiment of the motor of the rotary directional drilling apparatus of FIG. 1.

[0031] FIG. 3 depicts a cross-sectional view of the diverter valve of the rotary directional drilling apparatus of FIG. 1.

[0032] FIGS. 4A and 4B depict an end view of an embodiment of the present rotary directional drilling apparatus showing the rotation of the rotor and the stator.

[0033] FIG. 5 depicts an isometric cross-sectional view of the downhole motor of FIG. 2.

[0034] The present embodiments are detailed below with reference to the listed Figures.

DETAILED DESCRIPTION

[0035] Before explaining the present embodiments in detail, it is to be understood that the embodiments are not limited to the particular descriptions and that the embodiments can be practiced or carried out in various ways.

[0036] Referring now to FIG. 1, a cross-sectional view of an embodiment of the present rotary directional drilling apparatus is depicted, usable to orient a drill bit 36 for steering a drill string 32.

[0037] The apparatus is shown having a downhole motor 10, which includes a rotor 12 and a stator 14. A passage 16 is shown extending through the rotor 12, which is depicted extending along the central axis of the rotor 12.

[0038] An upper diverter passage 18 and a lower diverter passage 20 are shown extending through the rotor 12 between the passage 16 and the stator 14. A blade 22, which in an embodiment, can include an over-gauge blade, is shown disposed on the exterior surface of the stator 14. The blade 22 offsets the apparatus' rotational center from the center of a borehole, thereby enabling reorientation of the drill bit 36 through selective placement of the blade 22.

[0039] The stator 14 is freely rotatable about the rotor 12, such that the blade 22 can be selectively maintained in a stationary position with respect to a bore hole, to reorient the drill bit 36, or selectively maintained in constant counter rotational motion with respect to the rotor 12, to maintain a straight drilling direction. One or more bearings, rollers, or similar devices, as known in the art, can be used to enable the stator 14 to rotate independent of the rotor 12. Due to the ability of the blade 22 to be positioned on any side of the drill string 32 through rotation of the stator 14, the blade 22 is usable to orient the drill bit 36 in any horizontal or vertical direction.

[0040] A valve 24 is shown disposed within the upper diverter passage 18 of the rotor 12, in communication with the passage 16. A sub 26, shown connected to the rotor 12, can contain electronic controls and/or a power supply for the valve 24 and/or a measurement while drilling device, or other similar devices in communication with the drill string 32.

[0041] The valve 24 is controllable to regulate the flow of drilling fluid from the passage 16, through the upper diverter passage 18, to a stator passage (25, FIG. 2) disposed in the stator 14. The stator passage can include one or more interior vanes 14A (e.g., lobes or similar protrusions), as known in the art, such that the flow of drilling fluid through the stator passage imparts rotation to the stator 14 as fluid impacts one or more of the vanes 14A. The flow rate of drilling fluid to the stator 14 controls the rate of counter rotation of the stator 14 with respect to the rotor 12.

[0042] FIG. 1 also depicts a measurement while drilling device 30 attached to the sub 26. The drill string 32 is depicted attached to the measurement while drilling device 30. A concentric stabilizer 34 is depicted attached to the drill string 32. Data from the measurement while drilling device 30 is usable to control the valve 24 for positioning of the blade 22 to reorient the drill bit 36.

[0043] It should be noted that the drill string 32 is attached to the rotor 12, via the measurement while drilling device 30 and the sub 26, rather than to the stator 14, while a conventional rotary directional drilling apparatus utilizes a connection between the drill string and the stator. The rotor 12 is also shown attached to a near-bit stabilizer 35, which is in turn attached to the drill bit 36. In an embodiment, the near-bit stabilizer 35 can include a reamer. Bearings and/or rollers, as are known in the art, can be disposed at each end of the rotor 12 to facilitate rotation of the rotor 12. Bearings and/or seals, as known in the art, can be disposed at each end of the stator 14 to facilitate rotation of the stator 14 and prevent the exodus of drilling fluid from the stator passage into the annulus.
Referring now to FIG. 2, a cross-sectional view of the downhole motor 10 is shown. The stator 14, having the blade 22 disposed thereon, is shown rotatably disposed about the rotor 12. Bearings and/or rollers, as known in the art, can be disposed between the rotor 12 and the stator 14 to facilitate rotation of the stator 14. The passage 16 is shown in communication with the upper diverter passage 18 and lower diverter passage 20 for conveying drilling fluid to and from a stator passage 25 within the stator 14. The stator passage 25 can include various vanes 14A and/or other similar protrusions adapted to provide counter rotation of the stator 14 as drilling fluid is flowed through the stator passage 25. The valve 24 is shown disposed within the upper diverter passage 18 in communication with the passage 16, for controlling the flow of drilling fluid from the passage 16 through the upper diverter passage 18 to the stator 14, thereby controlling the rotational speed of the stator 14 relative to the rotor 12.

An upper seal 38 is shown disposed between the rotor 12 and the stator 14 above the upper diverter passage 18. A lower seal 40 is shown disposed between the rotor 12 and the stator 14 below the lower diverter passage 20. Referring briefly to FIG. 5, a partial isometric cross sectional view of the downhole motor 10 is shown, which further illustrates the components of the motor 10 shown in FIG. 2, and as described herein. Referring again to FIG. 2, there may also be a flow restriction 42 within the passage 16, which facilitates the flow of drilling fluid to the upper diverter passage 18 via the valve 24, while allowing excess fluid to flow through the passage 16 to the drill bit.

Referring now to FIG. 3, a cross-sectional view of the valve 24 is depicted. FIG. 3 depicts an actuator and power supply 44 usable to actuate a movable member 46 until partially or fully aligned with the valve passage 48. While the actuator and power supply 44 are depicted in close proximity to the valve 24, in an embodiment, the actuator and power supply could be remote from the motor, such as disposed within an adjacent sub. Through selective actuation of the valve 24, the flow rate of drilling fluid to the stator can be controlled to achieve a desired rate of counter rotation of the stator relative to the rotor.

The present rotary directional drilling apparatus is thereby able to use the flow rate of drilling mud to selectively position an exterior blade with respect to a bore hole to orient the direction of a drill bit, without use of thrusting, actuating, or retractable steering members, by enabling counter rotation of the stator and blade relative to the rotor. FIGS. 4A and 4B depict end views of the rotor 12 having the fluid passage 16 extending therethrough, with the stator 14 rotatably disposed about the rotor 12. FIG. 4A depicts the blade 22 disposed on the exterior surface of the stator 14 in a first position, while FIG. 4B depicts the blade 22 in a second position rotationally displaced from the first position. A bearing surface 15, which can include various bearings and/or rollers as known in the art, can be disposed between the rotor 12 and stator 14 to facilitate the rotation of the stator 14 relative to the rotor 12. As a drill string connected to the rotor 12 is rotated, such as when drilling, rotation is imparted to the rotor 12 in a first direction 23.

Selectively, fluid that flows through the fluid passage 16 to the drill bit can be diverted through diverter passages (shown in FIGS. 1 and 2) to a stator passage 25 disposed within the stator 14, which can include vanes 14A (or similar protrusions) adapted to provide counter rotation to the stator 14 in a second direction 27 opposite the first direction 23. The blade 22 disposed on the exterior of the stator 14 can thereby be rotated to any position about the drill string, as illustrated. While the present disclosure has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised which do not depart from the scope of the disclosure as described herein. Accordingly, the scope of the disclosure should be limited only by the attached claims.

What is claimed:

1. An apparatus for steering a drill string, the apparatus comprising:
   - at least one blade disposed on an exterior surface of the drill string, wherein the at least one blade is independently rotatable about the drill string in response to fluid flow through a first fluid passage disposed within a rotor, and wherein the at least one blade is configured to impart a torque on the drill string in a direction responsive to the fluid flow in order to orient a drill bit attached to the drill string, thereby steering the drill string.
   - 2. The apparatus of claim 1, wherein said at least one blade is disposed on a rotatable portion of a drilling motor in communication with the drill string, and wherein the rotor is operatively disposed within the drilling motor.
   - 3. The apparatus of claim 2, wherein the drilling motor further comprises a stator disposed at least partially concentrically around the motor, and a second fluid passage in fluid communication with the first fluid passage.
   - 4. The apparatus of claim 3, wherein the rotor is disposed substantially longitudinally within the drill string and at least partially concentrically with the motor, and wherein the drilling motor comprises a third fluid passage in fluid communication with the second fluid passage.
   - 5. The apparatus of claim 4, further comprising a valve disposed in the rotor configured for selectively controlling the flow of fluid through a rotatable portion for controlling rotation of the rotatable portion and thereby controlling the position of the at least one blade.
   - 6. The apparatus of claim 5, further comprising a measurement while drilling device in communication with the drill string, wherein the valve is controllable in response to data from said measurement while drilling device.
   - 7. The apparatus of claim 1 further comprising a measurement while drilling device to control the rotational position of at least one blade so that the blade remains stationary relative to a bore hole during rotary drilling operations.
   - 8. The apparatus of claim 1, wherein the force is asymmetrical.
   - 9. The apparatus of claim 1, wherein during rotary steering the fluid flow maintains the at least one blade in a stationary position relative to a bore hole while applying the force to the drill string.
   - 10. The apparatus of claim 1, wherein rotary steering is achieved by controlling the at least one blade positioning, thereby enabling reorientation of a drill bit.
   - 11. An apparatus for steering a drill string, the apparatus comprising:
     - a drilling motor comprising a rotor, a stator, a first fluid passage disposed through the rotor for flowing drilling fluid from the rotor to a drill bit, and a second fluid passage disposed between the rotor and the stator and in
fluid communication with at least a portion of the first fluid passage, wherein the stator is rotatably disposed at least partially concentrically about the rotor; and a valve configured for selectively controlling the flow of drilling fluid from the first fluid passage to the second fluid passage for controlling the rotation of the stator.

12. The apparatus of claim 11, wherein the stator is configured for counter rotation relative to the rotor in response to fluid flow through the second fluid passage.

13. The apparatus of claim 12, wherein the rotation of the stator is controllable by the flow of drilling fluid through the second fluid passage.

14. The apparatus of claim 10, the apparatus further comprising:

- at least one blade fixedly disposed on an exterior surface of the stator, wherein rotation of the stator controls placement of said at least one blade to provide a force to the drill string and achieve a desired orientation of the drill bit for steering the drill string.

15. The apparatus of claim 14, wherein rotary steering is achieved by controlling the at least one blade orientation.

16. The apparatus of claim 11, wherein rotary steering is achieved by controlling the rotation of the stator.

17. A method for steering a drill string, the method comprising the steps of:

- connecting a drilling motor to a portion of the drill string;
- flowing fluid through a first fluid passage disposed within the drilling motor;
- operating the drilling motor to cause an asymmetrical moment about the drill string, wherein the asymmetrical moment offsets at least a portion of the drill string from a rotational center axis to achieve a desired change in orientation of a drill bit connected to the drill string; and controlling the operation of the drilling motor with a flow of fluid through a fluid passage disposed within the drilling motor.

18. The method of claim 17, wherein the asymmetrical moment is rotatably moveable in response to the flow of fluid through the fluid passage.

19. The method of claim 17, wherein the step of controlling the operation of the drilling motor further comprises a measurement while drilling-controlled valve disposed in the drilling motor, wherein the valve is configured to control the asymmetrical moment so that the asymmetrical moment acts upon a borehole for steering the drill string.