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Abstract

According to one embodiment of the invention, a rotary steerable tool includes a drive shaft having an upper portion configured to be coupled to a drill string and a lower portion configured to be coupled to a drilling tool. The drive shaft has a middle portion disposed between the upper and lower portions, the middle portion having a smaller diameter than each of the upper and lower portions. The tool further includes a housing rotatably coupled externally to the drive shaft at an axial location corresponding to the middle portion of the drive shaft, the housing formed from at least two housing segments configured to be coupled to each other substantially parallel to a longitudinal axis of the housing.
FIG. 2

FIG. 3
SPLIT HOUSING FOR ROTARY STEERABLE TOOL

RELATED APPLICATION

[0001] This application claims the benefit of U.S. provisional application Ser. No. 60/479,608, filed Jun. 17, 2003, entitled SPLIT HOUSING FOR ROTARY STEERABLE TOOL.

TECHNICAL FIELD OF THE INVENTION

[0002] This invention relates generally to the field of drilling systems and, more particularly, to a split housing for a rotary steerable tool.

BACKGROUND OF THE INVENTION

[0003] Drilling well bores in the earth, such as well bores for oil and gas wells, is an expensive undertaking. One type of drilling system used is rotary drilling, which consists of a rotary-type rig that uses a sharp drill bit at the end of a drill string to drill deep into the earth. At the earth’s surface, a rotary drilling rig often includes a complex system of cables, engines, support mechanisms, tanks, lubricating devices, and pulleys to control the position and rotation of the bit below the surface. Underneath the surface, the drill bit is attached to a long drill string that transports drilling fluid to the drill bit. The drilling fluid lubricates and cools the drill bit and also functions to remove cuttings and debris from the well bore as it is being drilled.

[0004] Directional drilling involves drilling in a direction that is not necessarily precisely vertical to access reserves. Directional drilling involves turning of the drill bit while within the well bore. Offshore drilling often involves directional drilling because of the limited space beneath the offshore platform, although directional drilling is also vastly used onshore.

[0005] Various types of directional drilling tools exist. One type of directional drilling involves rotary steerable directional drilling, in which the drill string continues to rotate while steering takes place. Typically, a plurality of steering ribs are associated with the rotary steerable directional drilling tool to facilitate the steering. The ribs are disposed outwardly from a sleeve, inside of which is disposed a rotating shaft associated with the drill string. In one type of rotary steerable directional drilling tool, the outer sleeve rotates and in another the outer sleeve does not rotate. In the type in which the outer sleeve does not rotate, bearings allow relative movement between the outer sleeve and the rotating shaft. High axial and torsional forces are often encountered during this type of drilling.

SUMMARY OF THE INVENTION

[0006] According to one embodiment of the invention, a rotary steerable tool includes a drive shaft having an upper portion configured to be coupled to a drill string and a lower portion configured to be coupled to a drilling tool. The drive shaft has a middle portion disposed between the upper and lower portions, the middle portion having a smaller diameter than each of the upper and lower portions. The tool further includes a housing rotatably coupled externally to the drive shaft at an axial location corresponding to the middle portion of the drive shaft, the housing formed from at least two housing segments configured to be coupled to each other substantially parallel to a longitudinal axis of the housing.

[0007] Some embodiments of the invention provide numerous technical advantages. Other embodiments may realize some, none, or all of these advantages. For example, according to one embodiment, a smaller diameter rotary steerable tool may be utilized without having to worry about breakage of the rotary steerable tool due to torsional forces during drilling operations. A smaller diameter rotary steerable tool, with its associated small diameter drill string, may not only be used to drill small diameter bore holes, but may be easily insertable into existing larger diameter bore holes so that new large diameter bore holes do not have to be drilled. In one embodiment, the smaller diameter rotary steerable tool is facilitated by a split housing (i.e., a housing formed from more than one segment) that allows the driveshaft to have a smaller diameter at an intermediate portion as well as to be formed from one piece, which aids in reducing the torsional stress on the driveshaft.

[0008] Other advantages may be readily ascertainable by those skilled in the art from the following figures, description, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a schematic diagram of a drilling rig in accordance with one embodiment of the present invention;

[0010] FIG. 2 is a functional block diagram of a rotary steerable tool associated with a drill string of the drilling rig of FIG. 1 in accordance with one embodiment of the present invention;

[0011] FIG. 3 is a partially exploded perspective view of an example rotary steerable tool in accordance with one embodiment of the present invention; and

[0012] FIG. 4 is a partial cross-sectional view of the rotary steerable tool of FIG. 3 illustrating an example steering system according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0013] The following description is directed to a rotary steerable tool associated with a drill string. In one embodiment, such a rotary steerable tool facilitates, among other things, more efficient and cost-effective drilling of well bores, especially small diameter well bores. In one embodiment of the invention, as described below, a smaller diameter rotary steerable tool may be utilized without having to worry about drilling problems, such as breakage of the rotary steerable tool, due to torsional forces encountered when drilling. This is facilitated, in one embodiment, by cylindrical housing formed from multiple arcuate housing segments that allow the drive shaft of the rotary steerable tool to have a smaller diameter at an intermediate portion compared to the end portions of the drive shaft.

[0014] FIG. 1 illustrates a drilling rig 10 in accordance with one embodiment of the present invention. In this embodiment, rig 10 is a conventional rotary table/kelly drive; however, the present invention contemplates other suitable drive devices for drilling rigs, such as top drive, power swivel, and down hole motor. Non-land rigs, such as jack up rigs, semi-submersibles, drill ships, mobile offshore
drilling units (MODUs), and other suitable drilling systems that are operable to bore through the earth to resource-bearing or other geologic formations are also useful with the invention.

[0015] In the illustrated embodiment, rig 10 includes a mast 12 supported above a rig floor 14. A lifting gear associated with rig 10 includes a crown block 16 mounted to mast 12 and a travelling block 18. Crown block 16 and travelling block 18 are coupled by a cable 20 that is driven by draw works 22 to control the upward and downward movement of travelling block 18.

[0016] Travelling block 18 carries a hook 24 from which is suspended a swivel 26. Swivel 26 supports a kelley 28, which in turn supports a drill string, designated generally by the numeral 30, in a well bore 32. A blow out preventor (BOP) 35 is positioned at the top of well bore 32. Drill string 30 may be held by slips 58 during connections and rig-idle situations or at other appropriate times.

[0017] Drill string 30 includes a plurality of interconnected sections of drill pipe 34, one or more stabilizers 37, a rotary steerable tool 36, and a rotary drilling tool 40, which may be a drill bit. Drill pipe 34 may be any suitable drill pipe having any suitable diameter and formed from any suitable material. Rotary steerable tool 36, which is described in greater detail below in conjunction with FIGS. 2 through 4, generally functions to control the direction of drilling tool 40. Rotary drilling tool 40 functions to bore through the earth when drill string 30 is rotated and weight is applied thereeto. Drill string 30 may include different elements or more or fewer elements than those illustrated depending on the type of drilling system. For example, drill string 30 may also include drill collars, measurement while drilling (MWD) instruments, and other suitable elements and/or systems.

[0018] Mud pumps 44 draw drilling fluid, such as mud 46, from mud tanks 48 through suction line 50. A “mud tank” may include any tank, pit, vessel, or other suitable structure in which mud may be stored, pumped from, returned to, and/or recirculated. Mud 46 may include any suitable drilling fluids, solids or mixtures thereof. Mud 46 is delivered to drill string 30 through a mud hose 52 connecting mud pumps 44 to swivel 26. From swivel 26, mud 46 travels through drill string 30 and rotary steerable tool 36, where it exits drilling tool 40 to scour the formation and lift the resultant cuttings through the annulus to the surface. At the surface, mud tanks 48 receive mud 46 from well bore 32 through a flow line 54. Mud tanks 48 and/or flow line 54 include a shaker or other suitable device to remove the cuttings.

[0019] Mud tanks 48 and mud pumps 44 may include trip tanks and pumps for maintaining drilling fluid levels in well bore 32 during tripping out of hole operations and for receiving displaced drilling fluid from the well bore 32 during tripping-in-hole operations. In a particular embodiment, the trip tank is connected between well bore 32 and the shakers. A valve is operable to divert fluid away from the shakers and into the trip tank, which is equipped with a level sensor. Fluid from the trip tank may then be directly pumped back to well bore 32 via a dedicated pump instead of through the standpipe.

[0020] Drilling is accomplished by applying weight to drilling tool 40 and rotating drill string 30, which in turn rotates drilling tool 40. Drill string 30 is rotated within well bore 32 by the action of a rotary table 56 rotatably supported on the rig floor 14. Alternatively, or in addition, a down hole motor may rotate drilling tool 40 independently of drill string 30 and the rotary table 56. As previously described, the cuttings produced as drilling tool 40 drills into the earth are carried out of well bore 32 by mud 46 supplied by pumps 44. To direct or “steer” drilling tool 40 in a desired direction, drill string 30 includes rotary steerable tool 36 adjacent to drilling tool 40.

[0021] FIG. 2 is a functional block diagram of rotary steerable tool 36 illustrating some of the components of rotary steerable tool 36 in accordance with one embodiment of the present invention. As illustrated, rotary steerable tool 36 includes an electrical system 202, a hydraulic system 210, a steering system 212, solenoid valves 214, and a data pulser 216.

[0022] Electrical system 202 includes a generator 204, a plurality of sensors 206, and a controller 208. Generally, generator 204 provides the electrical power for rotary steerable tool 36. A separate power source (not shown) may also be provided in addition to generator 204 to provide additional power or to provide backup power to rotary steerable tool 36. Generator 204 may also be used to provide power to other elements, components, or systems associated with either rotary steerable tool 36 or drill string 30.

[0023] Sensors 206 may include any suitable sensors or sensing systems that are operable to monitor, sense, and/or report characteristics, parameters, and/or other suitable data associated with rotary steerable tool 36, drilling tool 40, or the conditions within well bore 32. For example, sensors 206 may include conventional industry standard triaxial magnetometers and accelerometers for measuring inclination, azimuth, and tool face parameters. The sensed characteristics, parameters, and/or data is typically automatically sent to controller 208; however, sensors 206 may send the characteristics, parameters, and/or data to controller 208 in response to queries by controller 208.

[0024] Generally, controller 208 provides the “brains” for rotary steerable tool 36. Controller 208 is any suitable down hole computer or computing system that is operable to receive sensed characteristics or parameters from sensors 206 and to communicate the sensed characteristics or parameters to the surface so that drilling personnel may monitor the drilling process on a substantially real-time basis, if so desired. The data communicated to the surface may be processed by controller 208 before communication to the surface or may be communicated to the surface in an unprocessed state. Controller 208 communicates data to the surface using any suitable communication method, such as controlling data pulser 216.

[0025] Data pulser 216 may be any suitable transmission system operable to generate a series of mud pulses in order to transmit the data to the surface. Typically, mud pulses are created by controlling the opening and closing of a valve associated with data pulser 216, thereby allowing a small volume of mud to divert from inside drill string 30 into an annulus of well bore 32, bypassing drilling tool 40. This creates a small pressure loss, known as a “negative pulse” inside drill string 30, which is detected at the surface as a slight drop in pressure. The controlling of the valve associated with data pulser 216 is controlled by controller 208. In this manner, data may be transmitted to the surface as a
coded sequence of pressure pulses. Alternate types of pulses that may be used momentarily restrict mud flow inside the pipe. This type is referred to as a "positive pulse."

[0026] Hydraulic system 210 generally functions to provide hydraulic pressure to steering system 212 so that arched spring members associated with steering system 212 may be actuated in a predetermined manner to facilitate the steering of drilling tool 40. The arched spring members, which are described in greater detail below in conjunction with FIG. 4, are part of steering system 212 along with associated pistons that function to "push out" a respective arched spring member when a respective solenoid valve 214 is opened by electrical system 202. Solenoid valves 214 may be any suitable solenoid valves that are operable to allow hydraulic fluid to pass through hydraulic passages for the purpose of actuating arched spring members via pistons. Controller 206 may function to control the opening and closing of solenoid valves 214.

[0027] FIG. 3 is a partially exploded perspective view of an example rotary steerable tool 36 in accordance with one embodiment of the present invention. In the illustrated embodiment, rotary steerable tool 36 includes a rotating shaft 300, generally referred to as the "drive shaft," rotatably coupled within a non-rotating housing 302, a head end 304, a box end 306, and a saver sub 308.

[0028] Rotating shaft 300 is a hollow shaft having any suitable diameter and formed from any suitable material that is coupled to drill pipe 34 via head end 304 and coupled to drilling tool 40 (not explicitly shown) via saver sub 308. In one embodiment, rotating shaft 300 is formed from non-magnetic alloy, such as Monel or Inconel, so that magnetometers used with rotary steerable tool 36 operate properly. Rotating shaft 300 may be formed integral or may be formed from any number of separate pieces. If formed integral, as illustrated, then rotating shaft 300 does not utilize a cross-over sub.

[0029] According to one embodiment of the invention, rotating shaft 300 has a variable diameter along its length with its smallest diameter being associated with an intermediate portion of rotating shaft 300. In other words, a middle portion 320 of rotating shaft 300 has a smaller diameter than end portions 321, 322 of rotating shaft 300. This facilitates a smaller diameter rotary steerable tool 36 because, as described in more detail below, housing 302 may have a smaller diameter if middle portion 320 of rotating shaft 300 has a smaller diameter. One reason end portions 321, 322 of rotating shaft 300 may have a larger diameter than middle portion 320 is so that drilling problems, such as breakage of rotary steerable tool 36, due to torsional forces encountered during drilling may be avoided.

[0030] Housing 302 houses many of the components of electrical system 202, hydraulic system 210, solenoid valves 214, and other suitable components that allow rotary steerable tool 36 to be utilized for directional drilling. For example, the directional sensing electronics may be disposed within one of the housing segments 310, while the hydraulic system and related components may be disposed within another of the housing segments 310. In one embodiment, electromagnetically inductive coupling is utilized to get power to the electronic components housed within any of the housing segments 310. However, other coupling techniques, such as the use of slip rings, may be utilized.

[0031] As described above, a smaller diameter housing 302 may result by providing middle portion 320 of rotating shaft 300 with a smaller diameter than end portions 321, 322 of rotating shaft 300. Solely as examples, housing 302 may have an outside diameter of approximately 4 1/4 inches or approximately 3 1/2 inches.

[0032] As illustrated in FIG. 3, housing 302 is formed from multiple arcuate housing segments 310. The present invention contemplates any number of housing segments; however, based on the relatively small diameter of housing 302, two or three housing segments are preferred. Use of the term "arcuate" means that housing segments 310 are curved in such a manner that, when coupled together, they form a generally cylindrical housing. One technical advantage of having housing 302 formed from multiple arcuate housing segments 310 is that this allows driveshaft 300 to be formed from one piece of material, which aids in reducing the torsional stress on driveshaft 300, and to have a diameter of middle portion 320 smaller than end portions 321, 322.

[0033] Housing segments may be coupled to one another in any suitable manner. In the illustrated embodiment, housing segments are coupled together with fasteners 350, which may be any suitable fasteners, such as bolts, screws, rivets, and the like. In this embodiment, each housing segment 310 includes one or more protrusions 352 on one longitudinal side and one or more notches 354 on the opposite longitudinal side. Protrusions 352 on one housing segment 310 match up with a particular notch 354 on an adjacent housing segment 310 such that a fastener 350 may be inserted into appropriate fastening holes 356 in order to couple housing segments together.

[0034] Housing segments 310 may, in one embodiment, function to house the components of electrical system 202, hydraulic system 210, solenoid valves 214, and other suitable components that allow rotary steerable tool 36 to be utilized for directional drilling. For example, the directional sensing electronics may be disposed within one of the housing segments 310, while the hydraulic system and related components may be disposed within another of the housing segments 310. In one embodiment, electromagnetically inductive coupling is utilized to get power to the electronic components housed within any of the housing segments 310. However, other coupling techniques, such as the use of slip rings, may be utilized.

[0035] Head end 304 may be coupled to drill pipe 34 in any suitable manner, such as by a screwed connection.

[0036] Box end 306 couples to rotating shaft 300 in any suitable manner. In a particular embodiment, box end 306 is formed integral with rotating shaft 300. With reference to FIG. 4, box end 306 has internal threads 316 that function to accept external threads 317 of saver sub 308 in order to couple saver sub 308 to box end 306. Saver sub 308 functions to couple drilling tool 40 thereto and protects box end 306 from damage arising from repeated threading/unthreading of drilling tool 40.

[0037] Although any suitable steering system may be utilized in conjunction with rotary steerable tool 36, FIG. 4 is a partial cross-sectional view of rotary steerable tool 36 illustrating an example steering system 212 according to an embodiment of the present invention.

[0038] Steering system 212, according to one embodiment, includes a spring member 402 having a bearing surface 401, a pair of mounting pins 406 coupling spring
Spring member 402 is coupled to housing 302 via pins 406. In one embodiment, either one or both pins 406 are disposed within slots formed within the wall of housing 302 to allow for axial movement when piston 404 is actuated. However, spring member 402 may be coupled to housing 302 in other suitable manners.

In one embodiment, there are four steering systems 212 spaced approximately an equal circumferential distance apart around housing 302; however, any number of steering systems 212 may be used.

To drill well bore 32, weight is applied to drilling tool 40 and drilling commences by rotating drill pipe 34, which rotates head end 304, rotating shaft 306, box end 306, saver sub 308, and drilling tool 40 (not explicitly shown). Concurrently, drilling fluid, such as mud 46, is circulated down through drill pipe 34, rotating shaft 306, and saver sub 308 before exiting drilling tool 40 and returning to the surface in the annulus formed between the wall of well bore 32 and the outside surfaces of rotary steerable tool 36 and drill pipe 34. Rotating shaft 306 is able to rotate within housing 302 by utilizing one or more bearings 310. Any suitable bearings 310 may be utilized, such as roller bearings, journal bearings, and the like.

Although embodiments of the invention and their advantages are described in detail, a person of ordinary skill in the art could make various alterations, additions, and omissions without departing from the spirit and scope of the present invention as defined by the appended claims.

What is claimed is:

1. A rotary steerable tool, comprising:

- a drive shaft having an upper portion configured to be coupled to a drill string, the drive shaft having a lower portion configured to be coupled to a drilling tool, the drive shaft having a middle portion disposed between the upper and lower portions, the middle portion having a smaller diameter than each of the upper and lower portions; and

- a housing rotatably coupled externally to the drive shaft at an axial location corresponding to the middle portion of the drive shaft, the housing formed from at least two housing segments configured to be coupled to each other substantially parallel to a longitudinal axis of the housing.

2. The rotary steerable tool of claim 1, further comprising a plurality of biasing mechanisms coupled to the housing, each biasing mechanism configured to steer the steering tool when actuated by a piston.

3. The rotary steerable tool of claim 3, wherein each biasing mechanism comprises an arched spring member coupled to the housing by a pinned connection and wherein the piston engages an underside of the arched spring member.

4. The rotary steerable tool of claim 1, wherein an outside diameter of the housing is approximately 4½ inches.

5. The rotary steerable tool of claim 1, wherein an outside diameter of the housing is approximately 3½ inches.

6. The rotary steerable tool of claim 1, wherein the housing segments are coupled to one another with fasteners.

7. The rotary steerable tool of claim 6, wherein the fasteners are selected from the group consisting of bolts, screws, and rivets.

8. The rotary steerable tool of claim 1, wherein the housing comprises three arcuate housing segments, each arcuate housing segment forming approximately ⅔ of the circumference of the housing.

9. The rotary steerable tool of claim 1, wherein the housing comprises two arcuate housing segments, each arcuate housing segment forming approximately ⅔ of the circumference of the housing.

10. The rotary steerable system of claim 1, wherein the housing segments are coupled to each other by longitudinally extending pins.

11. A system for housing a drive shaft of a rotary steerable tool, comprising:

- a generally cylindrical housing rotatably coupled externally to the drive shaft at an axial location corresponding to an intermediate portion of the drive shaft, the generally cylindrical housing formed from a plurality of generally arcuate housing segments, each generally arcuate housing segment comprising at least one protrusion on a first side and a notch on a second side, the protrusions of each arcuate housing segment coupled to respective notches of adjacent arcuate housing segments, the protrusions and notches adapted to couple the housing segments to each other.

12. The system of claim 11, wherein the intermediate portion of the drive shaft has a smaller diameter than end portions of the drive shaft.

13. The system of claim 11, further comprising a plurality of biasing mechanisms coupled to the cylindrical housing, each biasing mechanism configured to steer the steering tool when actuated by a piston.

14. The system of claim 13, wherein each biasing mechanism comprises an arched spring coupled to the housing by a pinned connection and wherein the piston engages an underside of the arched spring.

15. The system of claim 11, wherein an outside diameter of the cylindrical housing is approximately 4½ inches.

16. The system of claim 11, wherein an outside diameter of the cylindrical housing is approximately 3½ inches.

17. The system of claim 11, wherein the arcuate housing segments are coupled to one another with fasteners.

18. The system of claim 17, wherein the fasteners are selected from the group consisting of bolts, screws, and rivets.

19. The system of claim 11, wherein the housing comprises three arcuate housing segments, each arcuate housing segment forming approximately ⅔ of the circumference of the cylindrical housing.
20. The system of claim 11, wherein the housing comprises two arcuate housing segments, each arcuate housing segment forming approximately ½ of the circumference of the cylindrical housing.

21. A rotary steerable tool, comprising:

- a variable diameter drive shaft having its smallest diameter located along an intermediate portion of the drive shaft, the drive shaft having an upper portion configured to be coupled to a drill string and a lower portion configured to be coupled to a drilling tool; and
- a housing rotatably coupled externally to the intermediate portion of the drive shaft, the cylindrical housing formed from two or more housing segments that, when coupled together along their longitudinal edges, form the circumference of the cylindrical housing.

22. The rotary steerable tool of claim 21, further comprising a plurality of biasing mechanisms coupled to the housing, each biasing mechanism configured to steer the steering tool when actuated by a piston.

23. The rotary steerable tool of claim 21, wherein each biasing mechanism comprises an arched spring coupled to the housing by a pinned connection and wherein the piston engages an underside of the arched spring.

24. The rotary steerable tool of claim 21, wherein an outside diameter of the cylindrical housing is approximately 4⅛ inches.

25. The rotary steerable tool of claim 21, wherein an outside diameter of the housing is approximately 3⅛ inches.

26. The rotary steerable tool of claim 21, wherein the housing segments are coupled to one another with bolts.

27. The rotary steerable tool of claim 21, wherein the housing comprises three arcuate housing segments, each arcuate housing segment forming approximately ½ of the circumference of the housing.

28. The rotary steerable tool of claim 21, wherein the housing comprises two arcuate housing segments, each arcuate housing segment forming approximately ½ of the circumference of the housing.

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