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(54) **A DIRECTIONAL CORE DRILL ASSEMBLY**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to directional core drilling operations in bedrock, and in particular an assembly for steering a core barrel along a pre-defined path and at same time collect core samples of the bedrock, using said core barrel.

BACKGROUND

[0002] In mining and engineering operations, a core barrel mounted in front of a drill string is used to obtain core samples from the bedrock. The core barrel is tubular in shape and terminated with a tubular drill bit in front. Inside the core barrel, there is a retractable core sampling arrangement including a core tube holding the core sample, and a core catcher mounted at the lower end of the core tube. Furthermore the core sampling arrangement includes a rotational joint followed by a latching unit. The latching unit is arranged to ensure that the core sampling arrangement is fixed at a specific distance from the drill bit, preventing the core sampling arrangement from moving forward from its designated position inside the core barrel as well as being pushed upward as the core sample enters the core tube. When a core sample is to be retrieved, the rotation of the drill string is ceased and the drill string lifted until the core catcher clamps the core and breaks it loose from the subsurface. Then, a fishing unit attached to a wire line is lowered into the interior of the drill string until it connects to the latching unit located at the rear end of the core sampling arrangement. In horizontal or climbing holes the fishing unit is pumped into the drill string by the drill fluid. By pulling the wire line, the latching unit will disconnect from the core barrel, allowing the whole core sampling arrangement to be hoisted to the surface.

[0003] A conventional core barrel should ideally follow a straight line as it penetrated the bedrock. The borehole trajectory may however deviate from the planned straight trajectory due to natural drift caused by the bedrock or the drill plan involves a curved trajectory. In such occasions a steerable core barrel may be used to guide the bore hole back to the planned trajectory or to obtain a specific curved trajectory.

[0004] It is known from prior art several steerable rock drills that can controllably change the path of a bore hole, although most of them are not able to collect core as they penetrate the bed rock. A common feature in the said drills are the use of a packer element to rotationally fixate an eccentric bearing or stabilizer to the borehole wall in order to accomplish a deflection of the drill bit facing relative to the longitudinal axis of the well bore. The deflection is usually accomplished by using an outer body, comprising a front bearing, a rear bearing and an eccentric bearing or stabilizer placed between at the lower end of the drill, which forces an internal rotating shaft towards the opposite wall of the bore hole therewith achieving a directional deviation of the drill bit. In another embodiment not being part of the current invention, the packer itself is used to accomplish a deflection of the drill bit facing.

[0005] US2005/0109542 and US6516900 describe methods used for non-coring steerable drilling with a packer assembly. US2005/0109542 uses a quite complex system including sensors, actuators, valves mounted inside the drill body and an electrical cable to the topside to enable the individual pads to be activated and thus enable the packer element to be moved eccentrically to the borehole and thereby accomplish a deflection of the drill bit facing.

[0006] US6516900 uses only one set of pads to be activated by the drill fluid in order to accomplish a deflection of the drill bit facing .The direction of the bit deflection, denoted as toolface angle by those skilled in the art, are adjusted by setting the packer in a rotational position that provide the desired direction of deflection. The system depends on a pressure activated mechanical locking coupling arrangement between the outer housing and the rotating shaft to accommodate said setting of the rotational position. Activation/de-activation of the packer pads and the mechanical locking coupling are pre-set at two different pressure settings by use of dedicated valves. The patent also explains a third pressure setting that deactivates the packer to enable straight forward drilling. The valves are mounted as an integral part of the drill body. Based on the flow diagram shown in Fig. 6 where the main supply line for drilling fluid is shown to be open, one can assume that the pressure build-up is obtained by a fixed restriction in the supply line arranged downstream the control valves. By changing the flow rate, the pressure increases with increased flow rate and *visa versa* known according to known physics of fluid dynamics. Downstream the flow restriction the drill fluid flush the drill bit and then flow back to surface in the annulus formed by the drill string and the borehole wall. In order to change the pressure settings of the valves or pressure versus flow rates one need to pull the drill topside to replace the flow restriction.

[0007] More relevant to this invention is the patents US5758732 and NO316286B1 that concerns steerable drilling system able to collect core samples as it penetrates the bedrock. The deflection is accomplished by using an eccentric bearing (NO316286B1) or stabilizer (US5758732) placed at the lower end of the drill. In order to drill in a predefined direction the rotational position of the eccentric bearing or stabilizer has to be fixed relative to the bore hole by use of a packer arrangement that is fixed to the same outer body that supports the eccentric bearing or stabilizer. The packer comprises pads that are forced towards the borehole wall by pressurized drilling fluid, preventing the outer body to rotate during drilling, but allowing the outer body to slide in the borehole longitudinal direction while drilling. The packer has thus no direct function with respect to the deflection mechanism as being the case for US2005/0109542 and US6516900. The pads is activated by arranging a constriction (fig. 3, detail 34) that the drilling fluid has to pass thought on its way to the drill bit, thus creating necessary pressure build up to the packer and locking mechanism. The drill fluid pressure is varied from topside by varying the drill fluid flow rate. Change in direction of the drill bit facing, denoted as the toolface angle, relay in patent NO316286B1 on a mechanical locking coupling fixed to the drill rods. By reducing the flow rate, and thus the pressure, the coupling will engage with the outer body and allow the operator to change the toolface angle by rotating the drill string at topside. Downstream the flow restriction the drill fluid flows out of the bit front facing, back to surface in the annulus formed by the drill string and the borehole wall. NO316286B1 also describes use of a measuring instrument attached to a mule shoe shed to facilitate for the operator to measure the position of the outer body.

[0008] For drills pressurized by the drilling fluid using a fixed constriction one would thus need to operate above a minimum flow rate otherwise the locking coupling between the drill string and outer body might engage during drilling and/or the packer will loosen its grip towards the borehole. In such cases the consequence would be that the entire outer body assembly may rotate causing loss of toolface orientation and potentially damage the locking coupling and other connected systems in the drill.

[0009] In patent US2712434 a toolface adjustment device is described. The patent shows a detent bolt fixed to the eccentric housing, and a notch placed on a spiral shaped surface attached to an internal rotating shaft. When said shaft is rotated counter clockwise the detent bolt will engage said notch, thus allowing the operator to rotate the outer body including the eccentric bearing in desired position.

[0010] CA2749316C discusses an adjustable eccentric bushing assembly for a wireline-operated directional core barrel drill as shown in NO316286B1. The eccentric bearing comprises an outer housing with an eccentric bore and an eccentric inner sleeve carrying a bushing. By rotating the eccentric inner sleeve relative to the outer housing, the degree of deflection of the shaft can be adjusted, thus the degree of deflection of the drill bit facing.

[0011] WO2013028074 describes a trust bearing assembly for a steerable drilling system able to collect core samples as it penetrates the bedrock. The trust bearing assembly comprises a stator bearing plate with a convex or concave side opposite to the bearing elements that engages a matching support plate attached to the stationary outer body. Furthermore the trust bearing assembly comprises a rotor bearing plate that engages the drill string. The trust bearing assembly is located inside the tubular structure that is a part of the outer body. The tubular structure has multiple transverse holes close to the said bearing plates. Said transverse holes provide a fluid passage between the bearing compartment to the annulus between the outer body and the borehole wall thus provide cooling for the bearing elements.

[0012] A significant disadvantage of the existing directional drills pressurized by the drilling fluid is the dependency on a steady and pre-determined flow rate to achieve correct pressurization for the drill control functions, with- or without valves, because the pressure build up is established by a constriction of the drill fluid passage at the drill bit. This is highly problematic as the flow rate is one of the main parameters for the drilling operator to ensure good working conditions for the drill bit. The drill fluid prime function is to provide cooling of the drill bit and transport of rock debris out of the hole, but it is common to adjust the flow rate to maintain bit sharpness or even reduce the flow rate close to zero in short periods to sharpen the drill bit. Limitation on flow rate is also problematic for the high volume flow rates required for pumping instruments or core tubes in horizontal or climbing holes.

[0013] Another disadvantage with the prior art described is that if the pressure and flow characteristics needs to be changed one would need to pull the drill to surface and change the size of the constriction, alternatively use communication telemetry between surface and hole bottom where the drill is located.

[0014] Another disadvantage of the prior art described in CA2749316C is that the toolface orientation change every time the degree of deflection of the shaft is adjusted, since the adjustment involves rotating the eccentric inner sleeve relative to the outer housing.

[0015] Another disadvantage with the prior art described in US2712434 and NO316286B1 is that the toolface angle adjustment device has only one locking position. As a consequence changing the toolface angle would need to involve several complicated steps involving that the drill string is turned at topside, to ensure that the pin or detent plug has engaged the notch, followed by the actual setting of toolface angle. To accurately rotate the rods from top side in order to engage the coupling may be very difficult due to high torque caused by friction between the drill string and bore hole wall something that is specially apparent in holes where a steerable drill is used due to the curved trajectory or in deep holes thus said torque may cause the operator to make mistakes due to twist in the drill rods.

[0016] Another disadvantage with the prior art described in patent WO2013028074 is that the trust bearing plates are placed inside the outer body, thus limiting the exposure to cooling liquid in form of drilling fluid that pass on its way to the surface. Trust bearings in general and especially roller and sliding type trust bearings are due to the geometry and concept, dependent on extensive cooling to avoid overheating and premature wear.

[0017] Yet another disadvantage by arranging the bearing plates inside the outer body is that the configuration limits the diameter of the core sample. Since the bearing plates need a given minimum contact area to carry the axial trust force, the bearing inner diameter must be reduced accordingly to maintain the same contact area while reducing the bearing outer diameter.

OBJECTS OF THE INVENTION

[0018] The main object of the invention is to provide a device and method for the pressurization of a directional core drill packer assembly that ensure the packer pads are exposed to a predefined pressure regardless of flow rate.

[0019] Another object of the invention is to enable adjustment of the predefined packer pressure without pulling the drill to the surface.

[0020] Another object of the invention is to enable unrestricted adjustment of flow rate to the drill bit during drilling thus facilitate for the operator to freely adjust the flow rate without effecting the pressure to the said packer pads.

[0021] Another object of the invention is to enable high volume flow for pumping core tubes and survey instruments, without significantly increasing the system pressure.

[0022] Another object of the invention is to provide a safety feature to avoid uncontrolled pressure spikes when using high volume flow rates for the pumping the core tube thought the drill string and a reliable landing indicator at the same time.

[0023] Another object of the invention is to enable easier and more reliable adjustment of the toolface angle in steerable core barrels by use of an instantly engaged coupling between the shaft and outer housing that is not dependent on the drill fluid pressure.

[0024] Another object of the invention is to enable adjustment of the of drill bit deflection in steerable core barrels without changing the toolface angle.

[0025] Another object of the invention is to provide a trust bearing assembly for steerable core barrels that maximize the cooling of the bearing elements and maximize the diameter of the core samples.

SUMMARY OF THE INVENTION

[0026] The aforesaid main object of the invention is achieved with an assembly having the characteristic features as set forth in claim 1.

[0027] Further solutions to the objects of the invention and further characteristics thereof are set forth in the remaining claims.

[0028] According to the present inventions several inventive steps are taken to develop a steerable core barrel drill with improved overall performance and reliability compared to existing technology. These are as follows: An assembly for controlling the pressure to a packer in a steerable core barrel assembly is disclosed. According to the present invention a pressure controlled valve is integrated into the retrievable core tube assembly to ensure the packer is always correctly pressurized. The system functionality is monitored topside by reading the drill fluid pressure and flow rate; no or limited flow rate should be monitored prior to reaching the pre-set packer pressure.

[0029] According to the present invention the pre-set packer pressure can be adjusted at a suitable time when the core tube assembly is retrieved to surface, typically every 3rd meter of drilling to empty the rock sample from the core tube.

[0030] According to the present invention the pre-set packer pressure will act as a maximum pressure that can be obtained by the system, thus working as a safety feature for the system and a landing indicator for the core tube when pumped into the drill string.

[0031] It is also disclosed an assembly for adjustment of the toolface angle in steerable core barrels that minimize need for rotation of the drill string and do not depend on system fluid pressure. According to the present invention an instant counter clockwise engaged coupling is arranged between the outer body and the rotational shaft, said coupling has a hollow inner diameter that facilitate a core tube to pass through. The engagement takes place independent of the rotational position of the shaft relative to the outer stationary body, thus facilitate instant correction of toolface if needed.

[0032] Further, is disclosed an assembly for adjustment of drill bit deviation in steerable core barrels without affecting the toolface angle. According to the present invention the eccentric bearing is supported by a 3-point support arrangement where the bearing is allowed to tilt in the drill longitudinal direction, thus aligning with the deflected shaft.

[0033] Lastly, it is disclosed an assembly for improving the cooling of trust bearings in steerable core barrels as well as facilitate maximum diameter of the core samples. According to the present invention an arrangement for direct exposure of the bearing element to the drilling fluid and maximization of bearing inner diameter is accomplished.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] For detailed understanding of the disclosure, references should be made to the following detailed description taken in conjunction with the accompanying drawings in which like elements are generally designated by like numerals, and wherein;

FIG. 1 shows a schematic illustration of a steerable drilling system able to collect core samples as it penetrates the bedrock, which assembly includes according to prior art technology; a deflection mechanism to accomplish deviation of the drill bit, a packer, a retrievable core tube assembly, a trust bearing and according to the present invention, a packer pressure control device integrated into the core tube assembly.

FIG. 2 shows a schematic illustration of a retrievable core tube assembly for a steerable drilling system comprising a packer pressure control device according to the present invention.

FIG. 3 shows a schematic illustration of the detailed assembly of a packer for a steerable drilling system able to collect core samples as it penetrates the bedrock, comprising a pressure control device according to the present invention.

FIG. 4 shows a preferred embodiment of the invention including a device equalizing the pressure across the core tube assembly prior to retrieval in case the return drill fluid leaks in to the underground structure.

FIG. 5 shows according to the invention a schematic illustration of a preferred embodiment of the retrievable tube section comprising the adjustable pressure control valve as well as the adjusting mechanism.

FIG. 6 shows according to the invention a cross sectional view A-A shown in FIG. 1 of a preferred embodiment of the coupling mechanism between the shaft and outer housing to enable adjustment of the toolface angle.

FIG. 7 shows according to the invention a schematic illustration of a preferred adjustment mechanism for drill bit deflection in a steerable drilling system able to collect core samples as it penetrates the bedrock.

FIG. 8 shows according to the invention a cross sectional view B-B shown in FIG. 7 of a preferred adjustment mechanism for drill bit deflection in a steerable drilling system able to collect core samples as it penetrates the bedrock.

FIG. 9 shows according to the invention a schematic illustration of a preferred trust bearing assembly for a steerable drilling system able to collect core samples as it penetrates the bedrock.

FIG. 10 shows according to the invention the exterior of a preferred trust bearing assembly as shown in FIG. 8.

DETAILED DESCRIPTION

[0035] Referring to FIG. 1 and FIG. 2, a directional core drill assembly (1) includes as a minimum the following prior art embodiments;

- a drill string (2) that is connected to a shaft (5) running thought an outer body (3) with a drill bit (14) at an end thereof
- a core tube assembly (4) comprising a core tube (10) and a releasable locking mechanism (not shown) mounted inside a drive coupling attached at the upper end of the shaft (5), said core tube assembly (4) can be retrieved to surface by a wire line operated tool (8). The core tube has a swivel element (7) that enables the upper section of the core tube assembly to rotate due to the coupling to the shaft and the lower core tube (10) section to be stationary due to the frictional coupling to the rock sample during drilling.
- a non-rotating outer body (3) that houses a packer with packer pads (15) and a shaft deflection mechanism comprising an eccentric bearing (12), a front bearing (13) and a rear bearing (11).
- an axial trust bearing (6) to enable the non-rotating outer body (3) to be pushed downwards while drilling.
- an electronic orientation unit (not shown) attached to the core tube assembly (4) to measure the rotational position of the eccentric bearing (12) in order to monitor the toolface angle of the drill bit (14).
- an embodiment not being part of the current invention, (not shown) to engage- and disengage the rotating shaft (5) to the outer body (3) to enable adjustment of the rotational position of the outer body (3) thus also the eccentric bearing (12).

The packer assembly with a retrievable pressure control device according to the invention is denoted (9) in FIG 1 and further detailed in FIG 2 and FIG 3. A detailed explanation of the invention follows;
Drill fluid is pumped down through the drill string (2) comprising a hollow inner flow passage (20). When the drilling fluid reaches the core drill assembly (1) the drilling fluid will enter the annulus (21) between the outer diameter of the core tube assembly (4) and the inner diameter of the shaft (5). The seal (18) mounted on the core tube assembly (4) is blocking for further passage of drilling fluid along the annulus (21). The seal (18) and a traverse opening (24) lead the drilling fluid into cavity (25) located inside the core tube assembly (4). The cavity (25) is confined by the wall (17) and a spring loaded valve (29). The feed drilling fluid further communicate directly to the packer cavity (23) via the annulus (21) thought the traverse opening (22) in the shaft (5). The packer cavity (23) is confined by seals (16) in both ends and a packer bladder not shown said seals (16) are sealing between shaft (5) and the outer body (3). The packer bladder could be made out of a flexible, but robust material such as reinforced rubber, and are sealing the full length and circumference of the packer cavity (23). Said packer bladder may be equipped with a protection pad to avoid the packer pads (15) to wear the packer bladder. The spring loaded valve (29) can be adjusted to allow drilling fluid to pass at a defined pressure (P1). The spring load can be adjusted when the core tube is retrieved to surface. By feeding drilling fluid from surface the pressure (P1) will rise until the valve (29) opens, thus pressurize all components prior to the valve (29) including the packer assembly (9) thought traverse passage (22). The packer bladder will consequently expand and thus work on the diametrically placed packer pads (15), pushing them outwards until they engage with the bore hole wall, creating a rotational fixation of the outer body (3), but allowing the

outer body (3) to slide in the borehole longitudinal direction while drilling. Drilling fluid passing thought valve (29) will then enter the cavity (26) that is confined by the wall (30). The traverse opening (27) further lead the drilling fluid out of the cavity (26) and thus the interior of core tube assembly (4). The drilling fluid is now free to flow down to the drill bit along annulus (28). The drill fluid is returned to surface via the annulus formed between the borehole and the outer body (3)/drill string (2), respectively. The bottom hole pressure (P2) downstream the spring loaded valve (2) is determined by the static liquid column plus the frictional losses in all flow passages downstream the valve and to the surface.

[0036] Provided one can measure the drill fluid pressure as well as flow rate at surface, the functionality of the packer pressure control device can conveniently be checked while the drill tool is down hole by the following procedure while the drill tool is not rotating;

- Start the pump and provide sufficient pressure to generate a flow rate.
- While the return flow is visualized at the surface the pump should be stopped. The static pressure inside the drill is thus equalized with the static pressure outside the drill.
- Start the pump gradually to build up pressure. No flow rate should be measured until pressure control valve opens. The pressure reading when flow is registered represents the shut-in pressure opening the packer pressure control valve.

[0037] The same procedure can be performed while the drill is at surface.

[0038] There might be situations where the return flow leaks into the underground structure and thus does not completely fill the return annulus up to surface. When the drill is stopped to retrieve the core assembly tube (4), this unbalanced static pressure might impose a significant extra force to overcome when pulling the core tube assembly (4) by wire line (8). The feed pressure P1, determined by the static head within the drill string to surface would be higher than P2 due to the leakage to underground. The extra weight to be pulled would thus equal the differential pressure between P1 and P2 multiplied with the cross sectional area of the inner tube assembly (4).

[0039] Such a situation might imply a significant extra weight to pull when retrieving the core. FIG 4 shows how this problem is solved according to a preferred embodiment the invention. A detailed explanation of the invention follows;

Cavity (25) is confined by the wall (17) and a spring loaded hollow valve (29) resting against a hollow longitudinal valve seat (31). The valve seat (31) is connected to an annulus (32) leading thought wall (17) and ending in a second valve (33). The valve (33) is connected to the core barrel assembly hoisting hook in such manner that when the core tube assembly locking means (not shown) is being retracted by the wire line tool (8) in order to free the core tube assembly from its seat, valve (33) will be lifted from its seat as well. This will open for passage of drill fluid though annulus (34) and as a consequence equalize pressures P1 and P2. By implementing this feature any imbalance between P1 and P2 will be equalized before start of the hoisting operation and said extra weight to be pulled due to the prior imbalance eliminated.

[0040] In FIG. 4 the adjustable valve (29) is shown closed that implies the drill fluid has been shut off. Valve (33) is shown in an open position that implies the core tube assembly (4) is being retrieved by pulling the wire line tool (8).

[0041] FIG. 5 shows according to the invention a detailed section in FIG. 2 of a preferred embodiment of the adjustment principle of the packer control valve (29). A detailed explanation follows.

[0042] The spring seat (35) slides along the inner wall of the core tube assembly (3). A cylindrical sleeve with threads (36) is located at the inner wall of the core tube assembly (3), just beyond the spring seat (35). Another centrally arranged cylindrical adjustment sleeve (39) with threads is arranged inside the sleeve (36). The threads on sleeve (36) intersect with the threads in adjustment sleeve (39). When rotating the adjustment sleeve (39) it will thus move upwards or downwards dependent of the direction of rotation and hence also move the spring seat (35) and hereby the valve (29) spring load. In order to access adjustment sleeve (39) there is arranged an open section (38) in the core tube assembly (4) enabling to screw the adjustment sleeve (39) by a special tool key.

[0043] In relation to embodiments shown in FIG 1,2,3,4 it should also be mentioned that the pre-set packer pressure (P1) will be the maximum pressure that can be obtained in the system, thus acting like a safety feature for the drill. Such pressure limitation would eliminate the danger of system failure due overpressure that could damage to components such as extruding or bursting packer bladder and seals (16,18). Furthermore the pre-set packer pressure (P1) would work as a landing indicator for the core tube (4). When the core tube (4) is pumped in into the drill string in order to be seated inside the steerable core barrel the pressure will rise equal to pressure (P1), thus provide an easy recognizable indication of that the said core tube assembly (4) is correctly seated and the drill ready for use.

[0044] In relation to the embodiments shown in FIG 1,2,3,4 it should also be mentioned the packer assembly (9) can be configured with different numbers of packer pads (15), both in longitudinal direction and around the circumference. The said pads could have any shape and surface area suitable, as well as having a very hard outer layer to avoid premature wear, or spikes or longitudinal placed knifes cutting into the bore hole wall.

[0045] The shown specific schematic configurations of valves (29) and (33) and adjustment device shown in FIG 1,2,3,4 and 5 are only meant for illustration. For those skilled in the art it is obvious that the seal (18), valves

(29)/(33) and valve adjustment device can be arranged at any suitable physical location above the swirl element (7) on the retrievable core tube assembly and arranged in many configurations, although providing the same adjustable packer pressure control function according to the invention. Furthermore the seals (16) can be located at any suitable place along the shaft (4) and its couplings.

[0046] In another embodiment not being part of the current invention, the adjustment sleeve (39) is placed to work on the valve seat instead (60) of the valve spring (61).

[0047] In another embodiment not being part of the current invention, the valve (29) is arranged with a small leakage fluid passage to facilitate a moderate flow thought the bit (14) without building up significant pressure in the system or for de-pressurization without hoisting the core tube assembly. Said leakage may be located at any suitable place on the core tube assembly (4) or outer body (5).

[0048] In another embodiment not being part of the current invention, the packer pads (15) is replaced with one or more pistons, said pistons sealing against the outer body (5), thus no packer bladder is needed.

[0049] In another embodiment not being part of the current invention, the packer bladder is replaced with a pressure operated wedge. In this case the packer pads (15) would rest on the said wedge, and the wedge is able to slide along the interior of the packer assembly (9) in order to provide a radially movement of the packer pads (15).

[0050] In another embodiment not being part of the current invention, the packer assembly is divided into two separate sections with some distance between each in order to provide better grip towards the bore hole wall when drilling in soft or very broken rock formations.

[0051] FIG. 6 shows according to the invention a cross sectional view A-A in FIG. 1 of a preferred embodiment of the coupling mechanism between the shaft and outer housing to enable adjustment of the toolface angle.

[0052] A cylindrical locking housing (40) is fixed to the outer body (3). Inside the cylindrical locking housing (40) a number of non-revolving asymmetric figure-eight shaped sprags (41) are placed. The sprags (41) are resting against shaft (5). When the shaft (5) rotates in one direction the sprags (41) slip or free-wheel, but when a torque is applied in the opposite direction, the sprags (41) tilt slightly, producing a wedging action that rotationally locks the cylindrical housing (40) and shaft (5) to each other because of friction. The engagement thus takes place independent of the rotational position of the shaft relative to the outer stationary body. The sprags (41) are spring-loaded so that they lock with very little backlash. The system is arranged so that the shaft (5) can rotate freely clock wise ie. equal to drill bit (14) rotational direction and locks counter clockwise. When a change in toolface angle is needed, both rotational movement of the drill string (2) and flow of drilling fluid are ceased thus unloading the packer pads (15). By rotating the drill string top side counter clockwise the drill shaft (5) will rotate equally, causing the sprags (41) to lock the cylindrical housing (40) to the shaft (5). The outer body (3) will consequently follows and thus a change in toolface angle is obtained.

[0053] The specific schematic configurations of a system for adjusting the toolface angle shown in FIG 6 are only meant for illustration. The spring loaded sprags (41) can have any shape or made of any material as long as they provide the same wedging action that rotationally locks the cylindrical housing (40) and shaft (5) to each other because of friction. For those skilled in the art it is known many types of one-way and free-wheel clutches and similar devices that can be used to accomplish the instant engagement between shaft (5) and outer body (3) independent of the rotational position of the shaft (5) relative to the outer stationary body (3). Such other embodiments not being part of the current invention could be, but not limited to sprags engaging a cogwheel or different sprag configuration, shaped inserts or rolling elements that wedges or engages when the said shaft is turned counter clock wise. Furthermore, the physical location of the said system for adjusting the toolface angle can be located at any place along the shaft (5) as well as in connection with any shaft coupling to provide the same instant one-way locking function according to the invention.

[0054] FIG. 7 and FIG. 8 shows according to the invention a system for adjusting the drill bit deflection leaving the toolface angle unaffected. FIG. 8 shows the cross sectional view B-B in FIG: 7. A detailed explanation follows:

Referring to FIG. 1, FIG. 7 and FIG. 8 an outer body (3), comprising a front bearing (13), a rear bearing (11) and an adjustable eccentric bearing (12) placed between, forces an internal rotating shaft (5) towards the opposite wall of the bore hole therewith achieving a directional deviation of the drill bit. The eccentric bearing assembly comprises an eccentric bearing housing (42) with a slot shaped inner bore with two tracks (50) going longitudinally along the bore. The housing (42) has a centrally arranged threaded traverse hole (43) to accommodate an adjustment screw (44) and an adjustment pad (45). Said adjustment screw (44) has a concave inner diameter and the adjustment pad (45) a convex end that match each other.

[0055] A deflection bearing element (46) with two radially protruding side pads or bolts (47) is arranged inside the eccentric bearing housing (42). Said side bolts or pads (47) are mounted in fixed seats in such way that they cannot move out of the seat, but still able to rotate freely and thereby allowing the bearing element (46) to tilt around the axis of the said bolts or pad (47). The bolt seats are preferably placed at the middle of the bearing element (46), when seen from a side view, in such way that the bearing has equal distance to each end as well as equal distance between top and bottom, measured from the centre of the bolt seat. Said side pads or bolts (47) are further engaging a wedge (48) that may slide along the bearing housing (42) tracks (50) and a stop bar or edge (49). The wedge position is adjusted by the position of a threaded flange ring (51). Said flange ring (51) can be adjusted from outside thought a slot (52) in the eccentric bearing housing (42) by a special key tool.

[0056] The degree of shaft (5) deflection can be adjusted by changing the height of the adjustment screw (44) and the adjustment pad (45) working on the deflection bearing element (46). In combination the two elements can cover a large number of deflection settings. As an example 5 different screw heights and 5 pad heights will provide 25 different deflection settings. After adjustment of the deflection setting, the flange ring (51) is tighten up in order for the wedges (48) to engage the side pads or bolts (47), thus locking the deflection bearing element (46) in a fixed position axially and radially. Due to the said convex and concave shape of the screw (44) and pad (45) connection surfaces and the centrally placed side pads or bolts (47) the deflection bearing element (46) is yet able to tilt allowing the deflection bearing element (46) to align with the shaft (5) at any deflection degree. The bearing element (46) may be made of the same material thought just have a layer with material matching the shaft properties.

[0057] The specific schematic configuration of a device for adjusting the degree of drill bit deflection shown in FIG. 7 and FIG. 8 is only meant for illustration. For those skilled in the art it is known many similar configurations to achieve the same 3-point support functionality according to the invention which is;

- locking the deflection bearing element (46) in a fixed position axially and radially and simultaneously
- enable the deflection bearing element (46) to tilt in the shaft (5) longitudinal direction and
- enable adjustment of drill bit (14) deflection without changing toolface orientation

[0058] The adjustment screw (44) and the adjustment pad (45) can be replaced by for instance an adjustable wedge or can have many different shapes and still provide the same functionality regarding deflection and axially alignment of the bearing element (46). The side pads or bolts (47) can have any shape that enables the bearing element (46) to align with axis of the shaft (5). Furthermore the bolts or pads (47) can be fixed to the bearing element or be machined as a part of the bearing element or be placed away from the centre of the bearing side, although this not ideally for the tilting movement. The side tracks (50), the stop bar (49) and wedge (48) can have many shapes and still provide the same functionality to lock the side pads or bolt (47). It is also possible, but not necessary, to arrange a 4^{th} support point diametrically opposite to the traverse hole (43) by arranging a similar threaded traverse hole in the bearing housing (42). A set screw can then be attached after the other 3 off support point have been tightening up. The set screw should preferably have a convex end to enable the bearing element to tilt in the shaft (5) longitudinal direction.

[0059] FIG. 9 and FIG. 10 shows according to the invention a preferred embodiment of a trust bearing assembly that facilitate direct cooling of the bearing elements as well as maximize the diameter of the core sample within the physically limitation set forth by the outer body (3) diameter and the drill bit (14) outer diameter.

[0060] Referring to FIG. 1, FIG. 8 and FIG. 9 a trust bearing (6) comprises a stator element (6A) and a rotor element (6B), said stator element (6A) having a convex or concave side (55) opposite to the bearing contact surfaces (53). Next to the axial trust bearing stator element (6A) there is arranged a radial bearing (57). The outer body (3) has a convex or concave shaped end (58) engaging with the stator element (6B) in such way that the stator element (6B) and rotor element (6A) is always aligned. The stator element (6A) is thus not fixed to the radial bearing housing (56), but a stop bar (59) fixed to the outer body (3) prevents the stator element (6A) from rotation. Said trust bearing (6) having an outer diameter similar or close to the outer body (3), thus having the maximum size possible within the physically limitation set forth by the diameter of the outer body (3) and the drill bit (14). By having the trust bearing (6) fully exposed to the annulus between the outer body and the borehole wall the trust bearing elements (6) are directly exposed to the return drilling fluid, thus maximizing the cooling of said trust bearing (6). Furthermore, the design facilitates extraction of core samples thought the centre of the trust bearing (6) with a maximum diameter to what is physically possible. Since the trust bearing (6) need a given minimum contact area to carry the trust force, the bearing inner diameter, and thus the core sample diameter, is determined by the bearing outer diameter. The trust bearing (6) further comprise diamond or similar very hard contact surfaces in order to allow the bearing to be exposed to the drilling fluid without extensive wear.

[0061] The specific schematic configurations of a trust bearing assembly shown in FIG. 9 and FIG. 10 are only meant for illustration. For those skilled in the art it is known many configurations to provide similar functionality according to the invention.

[0062] In another embodiment not being part of the current invention, the convex and concave shape is replaced with one or more tilt compensation spring washers or other flexible structure, such as but not limited to rubber seat, springs or flexible metal ring with or without radial compression slots or similar.

[0063] In another embodiment not being part of the current invention, the stop bar (59) is fixed to the stator element (6B), engaging the outer body (3).

[0064] In another embodiment not being part of the current invention, the bearing elements (6) is covered by a mesh of similar thin wall structure to avoid foreign objects to enter the space between the bearing elements (6).

Claims

1. A directional core drill assembly comprising;

    • a rotatable shaft (5) running thought a non-rotating outer body (3), the shaft being connected to a drill string (2) at the rear end, and a drill bit (14) at the other end thereof,
    • the non-rotating outer body (3) that houses a packer assembly (9) and a shaft deflection mechanism comprising an eccentric bearing or stabiliser (12), a front bearing (13) and a rear bearing (11),
    • the non-rotating outer body (3) further comprise an axial trust bearing (6) engaging at one side of the non-rotating body (3), and at the other side the drill string (2) or a coupling thereof to enable drill string (2) to push the non-rotating outer body (3) downwards while drilling,
    • an arrangement to engage- and disengage the rotating shaft (5) to/from the outer body (3) to enable adjustment of the rotational position of the outer body (3) and thus also the eccentric bearing (12),
    • a core assembly (4) arranged inside the shaft, comprising a core tube (10) and a releasable locking mechanism, said core tube assembly thus can be retrieved to surface by a wire line operated retrieving tool (8),
    • an electronic orientation unit attached to the core tube assembly (4) to measure the rotational position of the eccentric bearing (12) in order to monitor the toolface angle of the drill bit (14),

    wherein, the core tube assembly (4) includes an adjustable control valve (29) that pressurizes the drill fluid when said drill fluid is being pumped thru the valve, wherein the pressurized drill fluid communicates with the packer assembly.

2. A directional core drill assembly according to Claim 1, wherein the pressure control valve (29) is set to open at a specific pre-defined pressure.

3. A directional core drill assembly according to claim 1, wherein the pressure control valve (29) is adapted to maintain the specific pre-defined pressure independently of flow rate.

4. A directional core drill assembly according to claim 1, wherein the pressure control valve (29) can be adjusted or serviced when the retrievable core tube assembly (4) is brought to surface.

5. A core drilling system according to claim 4, wherein the pressure control valve (29) is pre-tensioned by a spring (61).

6. A directional core drill assembly according to claim 1, wherein said arrangement to engage- and disengage the rotating shaft (5) to/from the outer body (3) is facilitated by a one-way locking coupling, said coupling run freely during drilling operation, but adapted to lock the rotating shaft (5) to the outer body (3) when the shaft (5) is rotated in the opposite direction.

7. A directional core drill assembly according to claim 6, wherein the one-way locking coupling comprises a cylindrical locking housing (40) fixed to the outer body (3) where a number spring loaded embodiments are arranged inside the cylindrical locking housing (40) providing a wedging action that rotationally locks the cylindrical housing (40) and shaft (5) to each other due to friction when the shaft (5) is rotated in the opposite direction relative to the drilling rotational direction.

8. A directional core drill assembly according to claim 1, wherein said deflection bearing element (46) has a 3-point support structure wherein the first support point is arranged rotationally 180 degrees relative to the toolface orientation angle and the second and third support points are arranged rotationally approximately +90 and -90 degrees, respectively, relative to the first support point, said support structure enabling;

    • the bearing element (46) to be locked in an axial- and radial position,
    • the bearing element (46) to tilt the shaft (5) in a longitudinal direction.

9. A directional core drill assembly according to claim 8, wherein the drill bit (14) deflection can be adjusted without changing the toolface orientation.

10. A directional core drill assembly according to claim 1, wherein said axial trust bearing (6) has an outer diameter similar to the outer body (3) and hereby being fully exposed to the annulus between the outer body (3) and bore hole wall, wherein the stator element (6B) is rotationally locked to the outer body (3) by studs or bars (59) and seated on an alignment seat located at end of radial bearing housing (56) to facilitate said bearing to always align with the rotor element (6A).

Patentansprüche

1. Gerichtete Kernbohranordnung, die Folgendes umfasst:

    • eine drehbare Welle (5), die durch einen nicht drehenden Außenkörper (3) verläuft, wobei die Welle am hinteren Ende mit einem Bohrstrang

(2) verbunden ist, und eine Bohrkrone (14) am anderen Ende davon,

• den nicht drehenden Außenkörper (3), der eine Packeranordnung (9) und einen Wellenumlenkungsmechanismus aufnimmt, der ein exzentrisches Lager oder einen Stabilisator (12), ein vorderes Lager (13) und ein hinteres Lager (11) umfasst,

• den nicht drehenden Außenkörper (3), der ferner ein Axiallager (6) aufweist, das an einer Seite des nicht drehenden Körpers (3) und an der anderen Seite des Bohrstrangs (2) oder dessen Kupplung angreift, um es dem Bohrstrang (2) zu ermöglichen, den nicht drehenden Außenkörper (3) während des Bohrens nach unten zu drücken,

• eine Anordnung zum Ein- und Auskuppeln der drehbaren Welle (5) an/von dem Außenkörper (3), um die Einstellung der Drehposition des Außenkörpers (3) und damit auch des Exzenterlagers (12) zu ermöglichen,

• eine im Inneren der Welle angeordnete Kernbaugruppe (4), die ein Kernrohr (10) und einen lösbaren Verriegelungsmechanismus umfasst, wobei die Kernrohrbaugruppe somit durch ein drahtleitungsbetriebenes Bergungswerkzeug (8) an die Oberfläche zurückgeholt werden kann,

• eine elektronische Ausrichtungseinheit, die an der Kernrohrbaugruppe (4) angebracht ist, um die Drehposition des exzentrischen Lagers (12) zu messen, um den Werkzeugflächenwinkel der Bohrkrone (14) zu überwachen,

wobei die Kernrohranordnung (4) ein einstellbares Steuerventil (29) enthält, das die Bohrflüssigkeit unter Druck setzt, wenn die Bohrflüssigkeit durch das Ventil gepumpt wird, wobei die unter Druck stehende Bohrflüssigkeit mit der Packeranordnung in Verbindung steht.

2. Gerichtete Kernbohranordnung nach Anspruch 1, wobei das Druckregelventil (29) so eingestellt ist, dass es bei einem bestimmten vordefinierten Druck öffnet.

3. Gerichtete Kernbohranordnung nach Anspruch 1, wobei das Druckregelventil (29) so ausgebildet ist, dass es den spezifischen, vordefinierten Druck unabhängig von der Durchflussrate aufrechterhält.

4. Gerichtete Kernbohranordnung nach Anspruch 1, wobei das Druckregelventil (29) eingestellt oder gewartet werden kann, wenn die zurückholbare Kernrohranordnung (4) an die Oberfläche gebracht wird.

5. Gerichtete Kernbohranordnung nach Anspruch 4, wobei das Druckregelventil (29) durch eine Feder (61) vorgespannt ist.

6. Gerichtete Kernbohranordnung nach Anspruch 1, wobei die Anordnung zum Ein- und Auskuppeln der drehbaren Welle (5) mit/von dem Außenkörper (3) durch eine Einweg-Verriegelungskupplung erleichtert wird, wobei die Kupplung während des Bohrbetriebs frei läuft, jedoch so angepasst ist, dass sie die drehbare Welle (5) mit dem Außenkörper (3) verriegelt, wenn die Welle (5) in der entgegengesetzten Richtung gedreht wird.

7. Gerichtete Kernbohranordnung nach Anspruch 6, wobei die Einweg-Verriegelungskupplung ein zylindrisches Verriegelungsgehäuse (40) umfasst, das an dem Außenkörper (3) befestigt ist, wobei eine Anzahl von federbelasteten Körpern innerhalb des zylindrischen Verriegelungsgehäuses (40) angeordnet ist, die eine Keilwirkung erzeugen, die das zylindrische Gehäuse (40) und die Welle (5) aufgrund von Reibung drehbar miteinander verriegelt, wenn die Welle (5) in die entgegengesetzte Richtung relativ zu der Bohrdrehrichtung gedreht wird.

8. Gerichtete Kernbohranordnung nach Anspruch 1, wobei das Umlenklagerelement (46) eine 3-Punkt-Abstützstruktur aufweist, bei der der erste Abstützpunkt um 180 Grad relativ zum Ausrichtungswinkel der Werkzeugoberfläche drehbar angeordnet ist und der zweite und dritte Abstützpunkt um etwa +90 bzw. -90 Grad relativ zum ersten Abstützpunkt drehbar angeordnet sind, wobei die Abstützstruktur ermöglicht, dass

• das Lagerelement (46) in einer Axial- und Radialposition arretiert wird,

• das Lagerelement (46) die Welle (5) in einer Längsrichtung kippt.

9. Gerichtete Kernbohranordnung nach Anspruch 8, wobei die Auslenkung der Bohrkrone (14) ohne Änderung der Werkzeugausrichtung eingestellt werden kann.

10. Gerichtete Kernbohranordnung nach Anspruch 1, wobei das Axiallager (6) einen Außendurchmesser ähnlich dem des Außenkörpers (3) hat und dadurch vollständig dem Ringraum zwischen dem Außenkörper (3) und der Bohrlochwandung ausgesetzt ist, wobei das Statorelement (6B) durch Bolzen oder Stangen (59) drehfest mit dem Außenkörper (3) verbunden ist und auf einem Ausrichtungssitz sitzt, der sich am Ende eines Radiallagergehäuses (56) befindet, um zu erleichtern, dass das Lager immer mit dem Rotorelement (6A) ausgerichtet ist.

Revendications

1. Ensemble carottier directionnel comprenant :

• un arbre rotatif (5) s'étendant à travers un corps externe non rotatif (3), l'arbre étant relié à un train de tiges de forage (2) à l'extrémité arrière, et un trépan de forage (14) à l'autre extrémité de celui-ci,
• le corps extérieur non rotatif (3) qui loge un ensemble de garniture d'étanchéité (9) et un mécanisme de déflexion d'arbre comprenant un palier excentrique ou un stabilisateur (12), un palier avant (13) et un palier arrière (11),
• le corps extérieur non rotatif (3) comprend en outre un palier de poussée axial (6) venant en prise au niveau d'un côté du corps non rotatif (3), et au niveau de l'autre côté le train de tiges de forage (2) ou un couplage de celui-ci pour permettre au train de tiges de forage (2) de pousser le corps extérieur non rotatif (3) vers le bas pendant le forage,
• un agencement pour mettre en prise et libérer l'arbre rotatif (5) avec/depuis le corps extérieur (3) pour permettre un ajustement de la position de rotation du corps extérieur (3) et donc également du palier excentrique (12),
• un ensemble de noyau (4) disposé à l'intérieur de l'arbre, comprenant un tube de noyau (10) et un mécanisme de verrouillage libérable, ledit ensemble de tube de noyau pouvant ainsi être récupéré à la surface par un outil de récupération actionné par ligne de fil (8),
• une unité d'orientation électronique fixée à l'ensemble de tube de noyau (4) pour mesurer la position de rotation du palier excentrique (12) afin de surveiller l'angle de face d'outil du trépan de forage (14),

dans lequel l'ensemble de tube de noyau (4) comprend une vanne de commande ajustable (29) qui met sous pression le fluide de forage lorsque ledit fluide de forage est pompé à travers la vanne, dans lequel le fluide de forage sous pression communique avec l'ensemble de garniture d'étanchéité.

2. Ensemble carottier directionnel selon la revendication 1, dans lequel la soupape de commande de pression (29) est réglée pour s'ouvrir à une pression prédéfinie spécifique.

3. Ensemble carottier directionnel selon la revendication 1, dans lequel la vanne de commande de pression (29) est adaptée pour maintenir la pression prédéfinie spécifique indépendamment du débit d'écoulement.

4. Ensemble carottier directionnel selon la revendication 1, dans lequel la soupape de commande de pression (29) peut être ajustée ou entretenue lorsque l'ensemble de tube de noyau récupérable (4) est amené à la surface.

5. Système carottier selon la revendication 4, dans lequel la vanne de commande de pression (29) est précontrainte par un ressort (61).

6. Ensemble carottier directionnel selon la revendication 1, dans lequel ledit agencement pour mettre et libérer l'arbre rotatif (5) avec/depuis le corps extérieur (3) est facilité par un couplage de verrouillage unidirectionnel, ledit couplage fonctionnant librement pendant l'opération de forage, mais adapté pour verrouiller l'arbre rotatif (5) sur le corps extérieur (3) lorsque l'arbre (5) est mis en rotation dans la direction opposée.

7. Ensemble carottier directionnel selon la revendication 6, dans lequel le couplage de verrouillage unidirectionnel comprend un logement de verrouillage cylindrique (40) fixé au corps extérieur (3) où un certain nombre de réalisations chargés par ressort sont agencées à l'intérieur du logement de verrouillage cylindrique (40) fournissant une action de calage qui verrouille en rotation le logement cylindrique (40) et l'arbre (5) l'un par rapport à l'autre en raison du frottement lorsque l'arbre (5) est mis en rotation dans la direction opposée par rapport à la direction de rotation de forage.

8. Ensemble carottier directionnel selon la revendication 1, dans lequel ledit élément de palier de déflexion (46) a une structure de support à 3 points où le premier point de support est agencé de manière rotative à 180 degrés par rapport à l'angle d'orientation de face d'outil et les deuxième et troisième points de support sont agencés de manière rotative à environ +90 et -90 degrés, respectivement, par rapport au premier point de support, ladite structure de support permettant ;

• à l'élément de palier (46) d'être verrouillée dans une position axiale et radiale,
• à l'élément de palier (46) d'incliner l'arbre (5) dans une direction longitudinale.

9. Ensemble carottier directionnel selon la revendication 8, dans lequel la déflexion du trépan de forage (14) peut être ajustée sans changer l'orientation de face d'outil.

10. Ensemble carottier directionnel selon la revendication 1, dans lequel ledit palier de poussée axial (6) a un diamètre extérieur similaire au corps extérieur (3) et étant ainsi entièrement exposé au niveau de l'espace annulaire entre le corps extérieur (3) et la paroi de trou de forage, dans lequel l'élément de stator (6B) est verrouillé en rotation au corps extérieur (3) par des goujons ou des barres (59) et repose sur un siège d'alignement situé à l'extrémité du logement de palier radial (56) pour aider ledit palier à toujours s'aligner avec l'élément de rotor (6A).

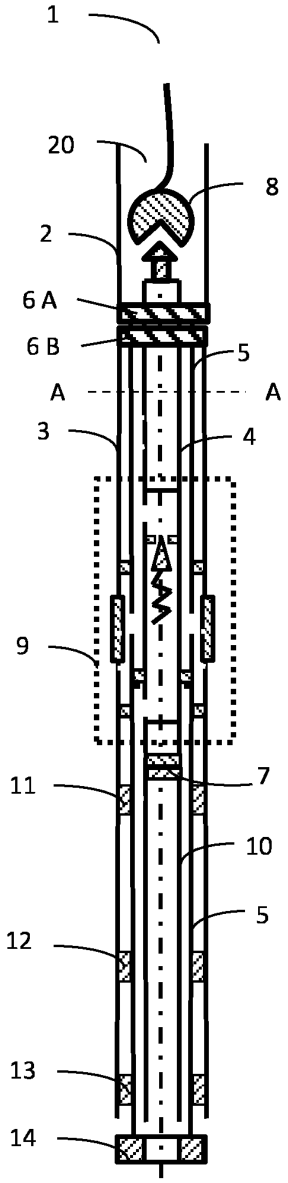

Figure 1

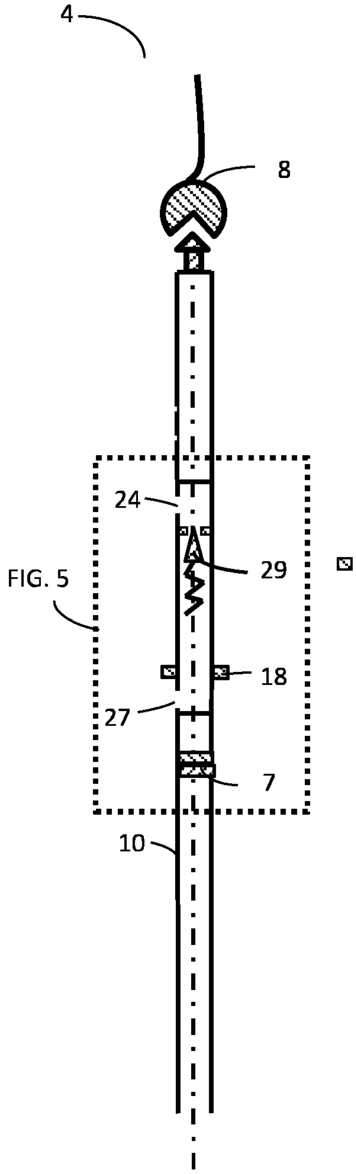

Figure 2

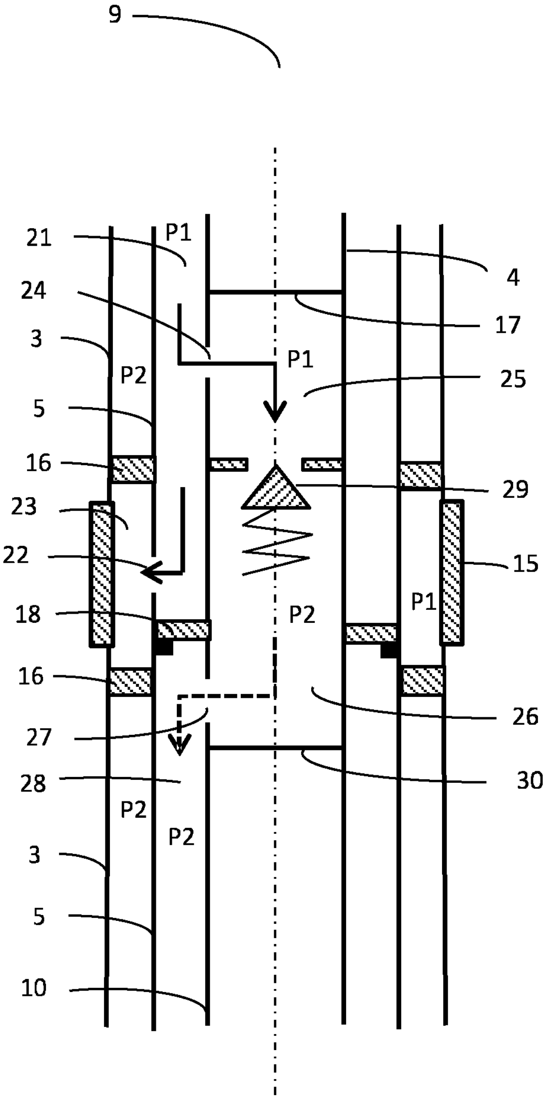

Figure 3

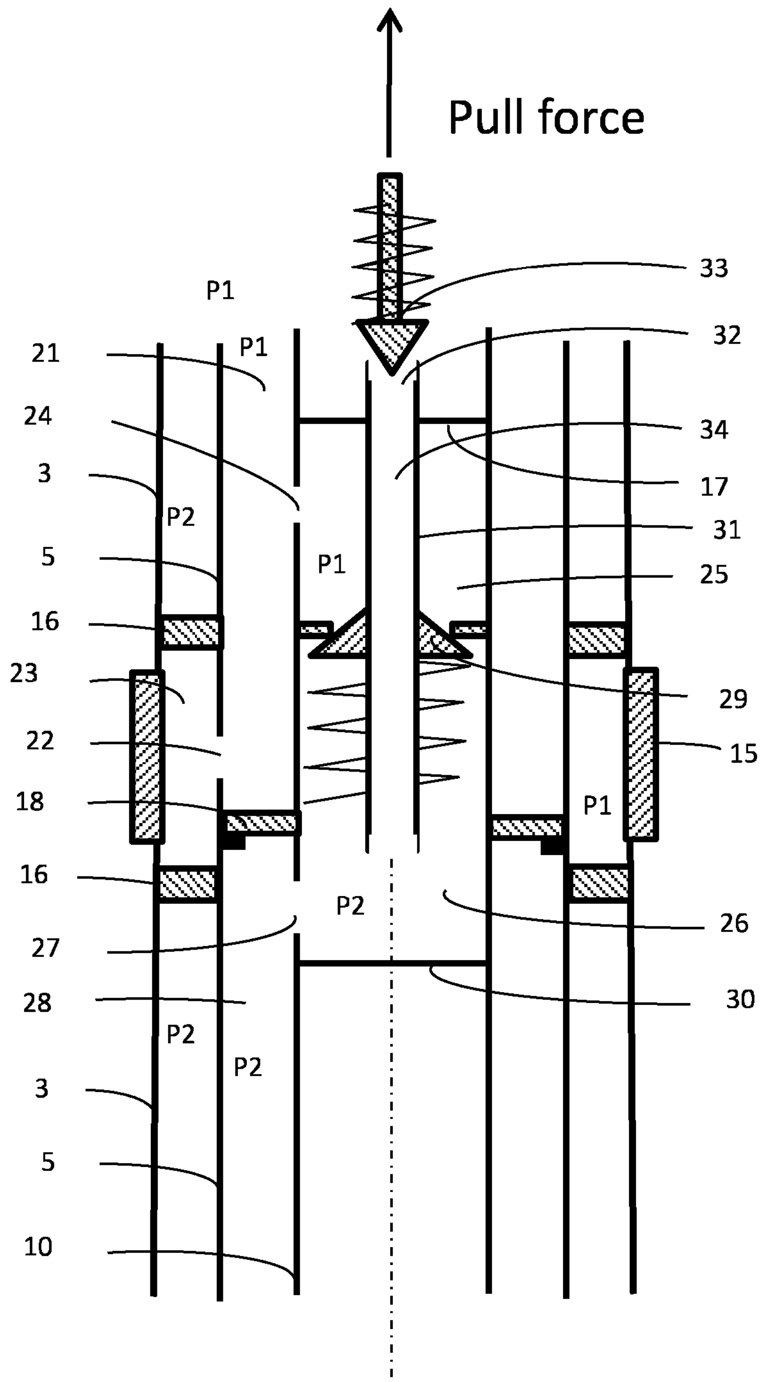
Pull force
P1
P1
21
24
3
P2
5
P1
16
23
22
18
16
P2
27
28
P2
P2
3
5
10
33
32
34
17
31
25
29
15
P1
26
30

Figure 4

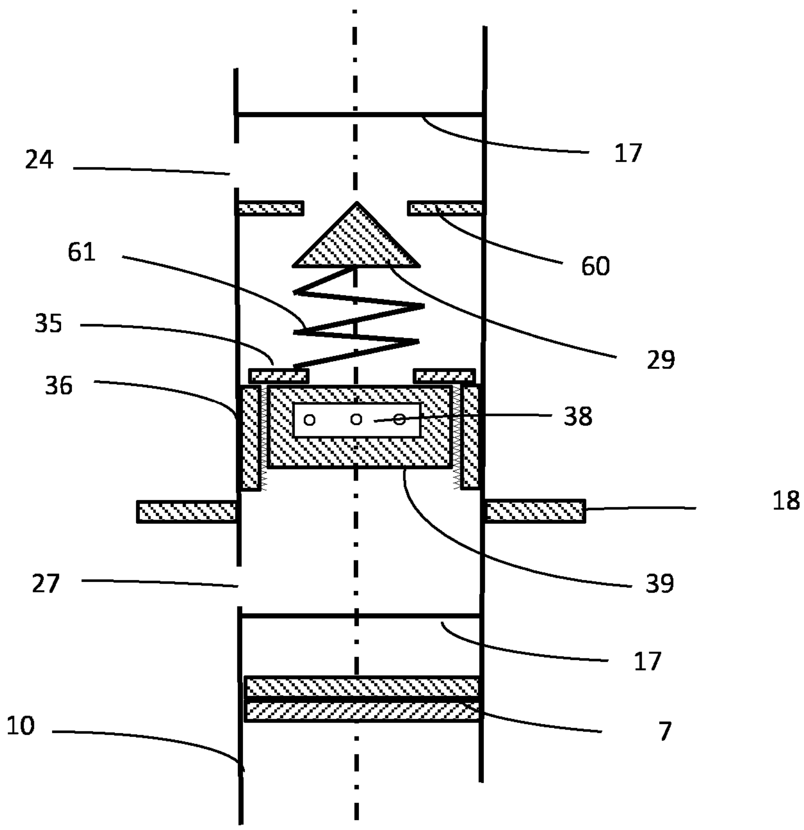

Figure 5

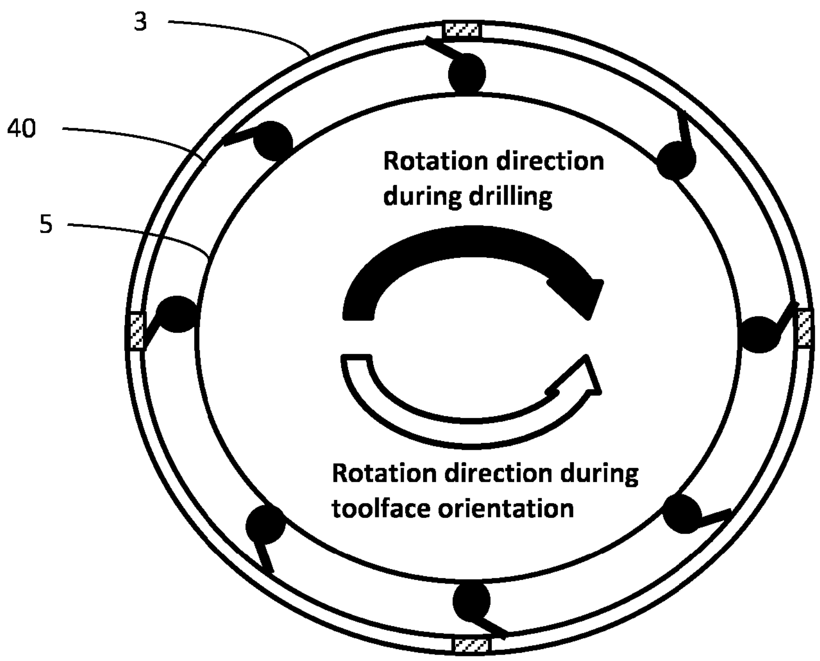

Figure 6

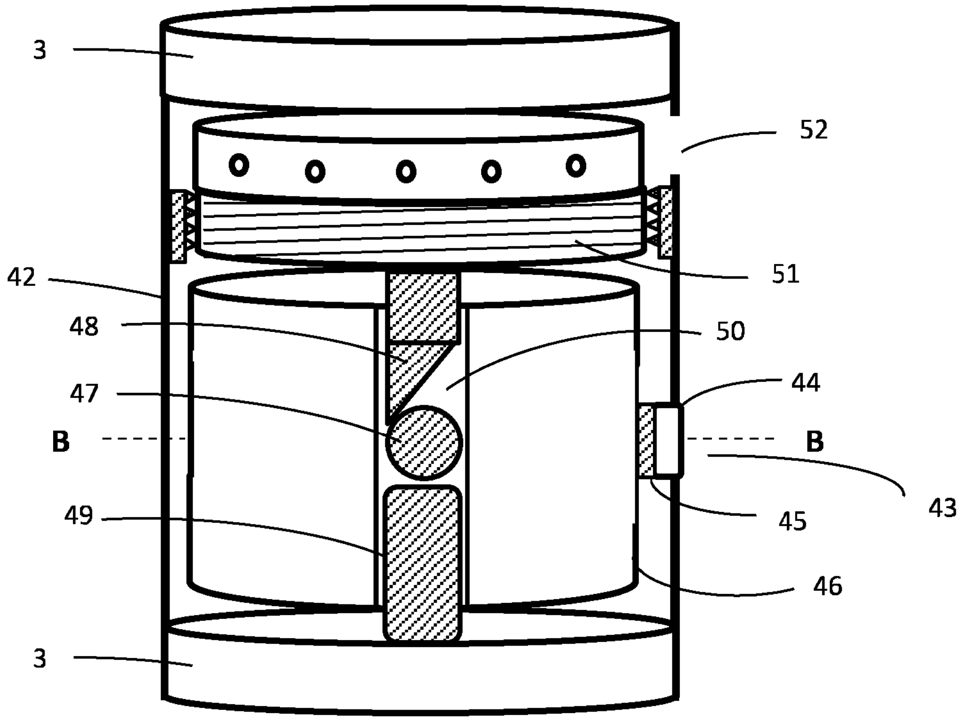

Figure 7

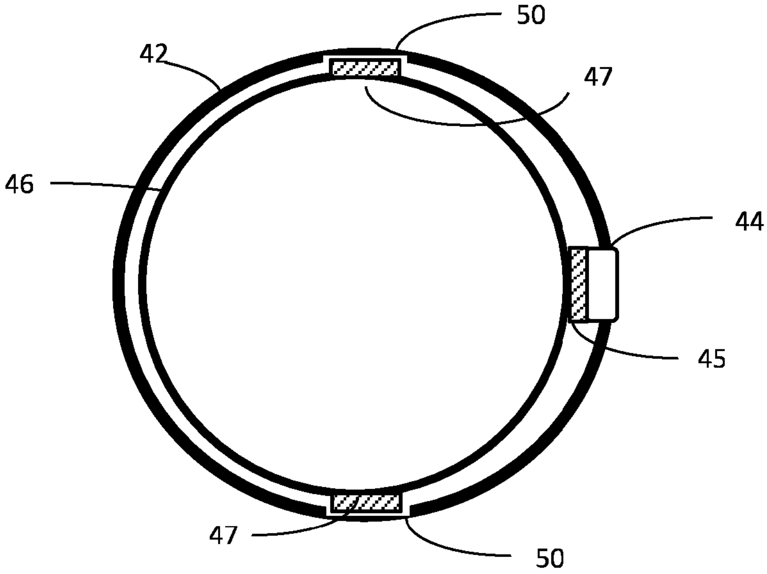

Figure 8

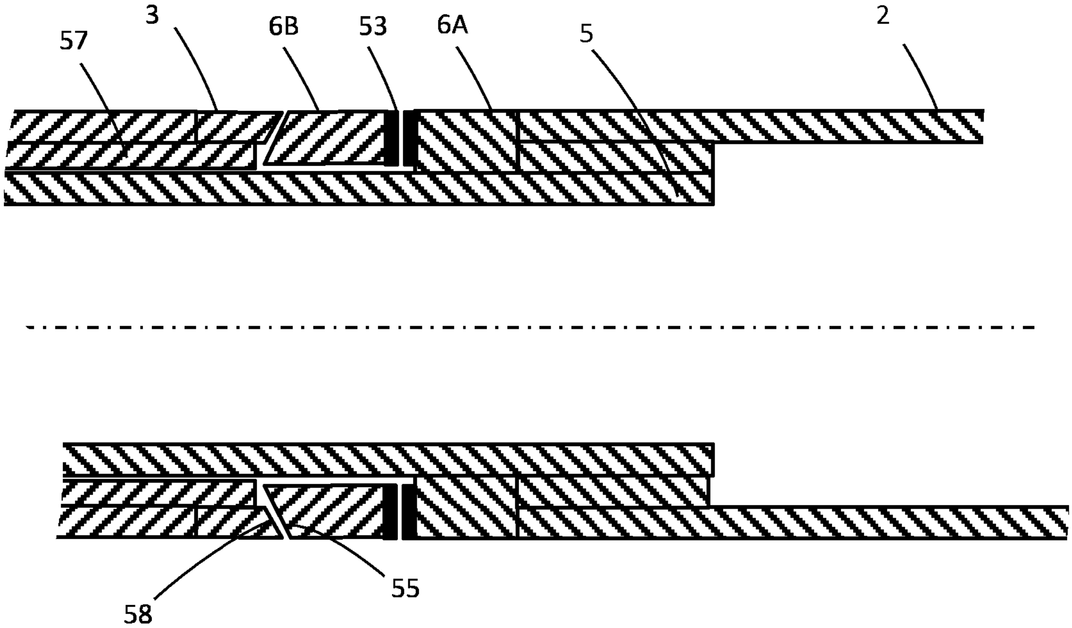

Figure 9

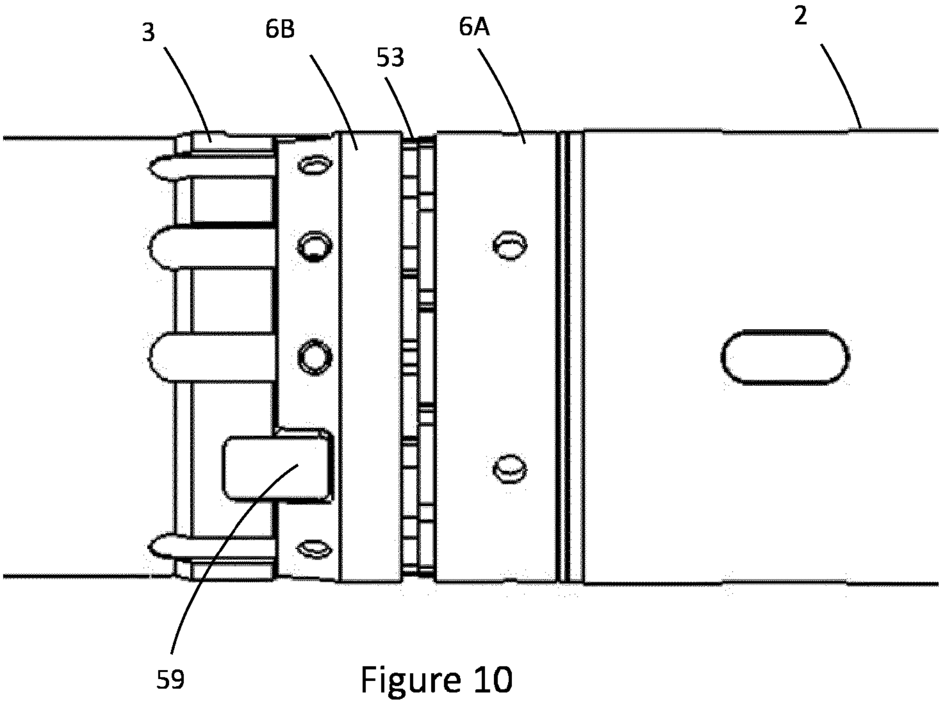

Figure 10

REFERENCES CITED IN THE DESCRIPTION

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