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(54) **HIGH SPEED DRILLING SYSTEM AND METHODS OF USING SAME**

HOCHGESCHWINDIGKEITSBOHRSYSTEM UND VERWENDUNGSVERFAHREN DAFÜR

SYSTÈME DE FORAGE À GRANDE VITESSE ET SES PROCÉDÉS D'UTILISATION

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Description

FIELD

[0001] The present application is directed to high speed drilling systems and methods, and in particular, to high speed drilling systems and methods that are used in underground and/or wireline drilling or mining applications.

BACKGROUND

[0002] Conventional drill strings commonly implement percussive drilling methods such as top-hammer and down-the-hole (DTH) hammer full face drilling systems. However, such percussive drilling methods are costly, environmentally unfriendly, and energy inefficient. Rotary-only drill bits have low penetration rates due to limitations of traditional drilling equipment and drill strings. US 2010/243331 discloses a helical drilling apparatus, systems and methods according to the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003]

Figure 1 illustrates a drilling system according to embodiments disclosed herein;

Figure 2 illustrates a first drill bit for use in the drilling system as in Figure 1;

Figure 3A illustrates an isometric view of a second drill bit for use in the drilling system as in Figure 1;

Figure 3B illustrates a top view of the second drill bit for use in the drilling system as in Figure 1;

Figure 3C illustrates a front view of the second drill bit for use in the drilling system as in Figure 1;

Figure 3D illustrates a rear view of the second drill bit for use in the drilling system as in Figure 1;

Figure 3E illustrates a side view of the second drill bit for use in the drilling system as in Figure 1;

Figure 3F illustrates a first sectional view of the second drill bit for use in the drilling system as in Figure 1;

Figure 3G illustrates a second sectional view of the second drill bit for use in the drilling system as in Figure 1;

Figure 4 illustrates a split collar that can be adapted to be a quick attach/detach coupling between a gearbox and a drill string in the drilling system as in Figure 1; and

Figure 5A illustrates a slip sub that can be adapted for use with the drilling system as in Figure 1.

Figure 5B illustrates another slip sub that can be adapted for use with the drilling system as in Figure 1.

Figure 6 is an exploded view of a grooved roller bearing for use with the drilling system as in Figure 1.

Figure 7 is an exploded view of another grooved roller bearing for use with the drilling system as in Figure 1.

Figure 8 is a schematic view of a drill string assembly having deployable skates in a deployed position.

Figure 9 is a schematic view of the drill string assembly of Figure 8 having the deployable skates in a retracted position.

Figure 10 is a sectional view of a drill string component having a variable wall thickness in accordance with embodiments disclosed herein.

DETAILED DESCRIPTION

[0004] The present disclosure can be understood more readily by reference to the following detailed description, which includes examples, drawings, and claims. However, before the present devices, systems, and/or methods are disclosed and described, it is to be understood that this disclosure is not limited to the specific devices, systems, and/or methods disclosed unless otherwise specified, as such can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting. The scope of the invention is recited in claims 1 and 6; other aspects of the invention are recited in the dependent claims.

[0005] The following description is provided as an enabling teaching of the disclosed invention in its best, currently known embodiment. To this end, those skilled in the relevant art will recognize and appreciate that many changes can be made to the various aspects of the disclosure, while still obtaining the beneficial results of the disclosure. It will also be apparent that some of the desired benefits of the disclosure can be obtained by selecting some of the features of the disclosure without utilizing other features. Accordingly, those who work in the art will recognize that many modifications and adaptations to the present disclosure are possible and can even be desirable in certain circumstances and are a part of the present disclosure. Thus, the following description is provided as illustrative of the principles of the present disclosure and not in limitation thereof.

[0006] As used throughout, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a drill rod" can include two or more such drill rods unless the context indicates otherwise.

[0007] Ranges can be expressed herein as from "about" one particular value, and/or to "about" another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently

of the other endpoint.

[0008] Optionally, in some aspects, when values are approximated by use of the antecedents "about," "substantially," or "generally," it is contemplated that values within up to 15%, up to 10%, up to 5%, or up to 1% (above or below) of the particularly stated value or characteristic can be included within the scope of those aspects.

[0009] As used herein, the terms "optional" or "optionally" mean that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0010] Disclosed herein, in various aspects and with reference to the Figures, is a high speed drilling system. In exemplary applications, the disclosed high speed drilling system can be used underground. Optionally, the high speed drilling system can be used to perform wireline drilling and mining operations.

[0011] Figure 1 illustrates a drilling system 100 that includes a sled assembly 105 and a drill head 110. The sled assembly 105 can be coupled to a drill feed 120 (e.g., a slide frame) as part of an underground drill rig 130. The drill head 110 is configured to have one or more threaded member(s) 140 coupled thereto. Threaded members can include, without limitation, drill rods and casings. For ease of reference, the tubular threaded member 140 will be described as a drill rod. The drill rod 140 can in turn be coupled to additional drill rods to form a drill string 150. In turn, the drill string 150 can be coupled to a drill bit 160 that includes or is coupled to a core barrel assembly or other in-hole tool configured to interface with the material to be drilled, such as a formation 165. As is known in the art, the use of a wireline drilling system (that allows for deployment or retrieval of in-hole components using a wireline cable) can allow for retrieval of a core barrel assembly (or other in-hole tool) without the need for retrieving the drill string 150. Although not described herein, it is contemplated that the drilling system 100 can further comprise an overshot, a head assembly, and other conventional components of wireline drilling systems.

[0012] In the illustrated example, the drill feed 120 can be oriented such that the drill string 150 is generally horizontal or oriented upwardly relative to the horizontal. Further, the drill head 110 can be configured to rotate the drill string 150 during a drilling process. In particular, the drill head 110 may vary the speed at which the drill head 110 rotates as well as the direction of rotation. The rotational rate of the drill head and/or the torque the drill head 110 transmits to the drill string 150 may be selected as desired according to the drilling process.

[0013] The sled assembly 105 can be configured to translate relative to the drill feed 120 to apply an axial force to the drill head 110 to urge the drill bit 160 into the formation 165 as the drill head 110 rotates. In the illustrated example, the drilling system 100 includes a drive assembly 170 that is configured to move the sled assembly 105 relative to the drill feed 120 to apply the axial force

to the drill bit 160 as described above. As will be discussed in more detail below, the drill head 110 can be configured in a number of ways to suit various drilling conditions. Further aspects of a drilling system 100 in accordance with the present invention are disclosed in U.S. Patent No. 8,051,925 to Drenth, filed April 26, 2011.

[0014] As illustrated in Figure 2, the drill bit 200 can include a shank 20 and a crown 30. The crown 30 can comprise a first and a second crown portions 34A, 34B. With reference to Figures 2-3F, each of the first and second crown portions 34A, 34B can have a cutting face 60A, 60B having a plurality of projections 66A, 66B extending therefrom. In another aspect, each of the first and second crown portions 34A, 34B can define a plurality of bores 64A, 64B extending from the cutting faces 60A, 60B to an interior space 110 (Figures 3F and 3G). In this aspect, it is contemplated that the plurality of bores 64A, 64B can be configured to direct water (or other drilling fluid) substantially directly to the cutting faces 60A, 60B from the interior space. In one aspect, a first crown portion 34A and a second crown portion 34B can be spaced apart relative to a first transverse axis that is perpendicular to the longitudinal axis. In a further aspect, each of the first and second crown portions 34A, 34B can comprise a first longitudinal edge, a second longitudinal edge, an outer surface 40A, 40B, and at least one inner surface 42A, 42B. Optionally, as shown in Figures 3A-3B, it is contemplated that each of the first and second crown portions 34A, 34B can define a respective channel 65A, 65B that extends away from the cutting faces 60A, 60B in a proximal direction. In these aspects, the channels 65A, 65B can divide the first and second crown portions into respective central sections 67A, 67B and peripheral sections 69A, 69B. Each central section 67A, 67B and each peripheral section 69A, 69B can define a respective portion of the cutting faces 60A, 60B. Optionally, the channels 65A, 65B can intersect at least one bore (e.g., bore 64A, 64B) defined within a respective crown portion. Optionally, the channels can have symmetrical profiles measured relative to a midpoint (or midplane) of the bit. For example, the channels 65A, 65B can optionally have equal or substantially equal radii of curvature. In exemplary aspects, the crown 30 of the drill bit 200 disclosed herein can have a base surface 80 that is spaced from the cutting faces 60A, 60B of each of the crown portions 34A, 34B relative to the longitudinal axis 12 of the drill bit. As shown in Figure 2, the base surface 80 and the inner surfaces 42A, 42B of the first and second crown portions 34A, 34B can cooperate to define a slot 90 that extends across the drill bit, dividing the first and second crown portions.

[0015] The drill bit can optionally be a self-sharpening full-face rotary bit. In exemplary aspects, the drill bit 200 disclosed herein can be a diamond-impregnated bit, with the diamonds (including natural or synthetic diamonds) impregnated within a matrix. In these aspects, it is contemplated that the matrix can be configured to wear and/or erode to thereby expose the diamond material

impregnated within the matrix. It is further contemplated that drill bit 200 can comprise a plurality of selected materials, with each material being provided as a selected weight percentage of the drill bit. It is contemplated that drill bit 200 can comprise carbon (not including diamond) in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 7.00% by weight of the drill bit. In exemplary aspects, the carbon of the drill bit 200 can be provided as at least one of carbon powder and carbon fibers. It is further contemplated that the drill bit 200 can comprise chromium in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 1.00% by weight of the drill bit. It is further contemplated that the drill bit 10 can comprise cobalt in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 1.00% by weight of the drill bit. Optionally, it is further contemplated that the drill bit 200 can comprise copper in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 30.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise iron in any desired amount, such as, for example and without limitation, an amount ranging from about 50.00% to about 90.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise manganese in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 8.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise molybdenum in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 0.20% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise nickel in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 6.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise silicon in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 0.50% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise silicon carbide in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 2.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise silver in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 12.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise tin in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 6.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise tungsten in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 41.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise tungsten carbide in any desired

amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 35.00% by weight of the drill bit. It is further contemplated that the drill bit 200 can comprise zinc in any desired amount, such as, for example and without limitation, an amount ranging from about 0.00% to about 24.00% by weight of the drill bit. The weight percentages referred to herein relate to the weight of the solidified, fully infiltrated drill bit. In exemplary aspects, the drill bit can comprise a matrix of diamonds and hard particulate material that is infiltrated with a binder using conventional methods, with the fully infiltrated drill bit comprising materials with the above-disclosed weight percentages. Although the cutting media of the drill bit are generally referred to herein as "diamonds," it is contemplated that the bit can comprise other cutting media (e.g., tungsten carbide) as are known in the art.

[0016] Optionally, in exemplary aspects, to form the drill bit, the powdered hard particulate material can be placed in a mold of suitable shape. The binder is typically placed on top of the powdered hard particulate material. The binder and the powdered hard particulate material are then heated in a furnace to a flow or infiltration temperature of the binder so that the binder alloy can bond to the grains of powdered hard particulate material. Infiltration can occur when the molten binder alloy flows through the spaces between the powdered hard particulate material grains by means of capillary action. When cooled, the powdered hard particulate material matrix, the diamonds, and the binder form a hard, durable, strong body. Typically, natural or synthetic diamonds (or other cutting media) are inserted into the mold prior to heating the matrix/binder mixture.

[0017] Referring to Figure 3B, it is contemplated that the crown can comprise multiple matrices that can have different binder hardnesses. According to some embodiments, a crown can comprise a first matrix 402 comprising a first binder of a first hardness and a second matrix 404 can comprise a second binder of a second hardness. (An exemplary boundary between the binders is illustrated with a dashed line 400). In these aspects, the first hardness (of the first binder) can be greater than the second hardness (of the second binder). The first matrix can extend from a central axis of the bit to a first radial distance, and the second matrix can extend from the first matrix to the outer surface 40A, 40B. In further embodiments, the crown can comprise three matrices having binders with three different hardnesses. Optionally, in exemplary aspects, the matrices can be arranged to have increasing hardness from or proximate the bit's central axis moving radially outwardly to the radial edges of the bit.

[0018] It is further contemplated that the matrix of the drill bits disclosed herein can be configured to form supporting structures behind the diamonds within the drill bits, thereby preventing the polishing of the impregnated diamonds during operation.

[0019] In exemplary aspects, the drill bit 200 disclosed

herein can further optionally comprise a plurality of wear-resistant members that are embedded therein portions of at least one of the base surface and/or the at least one inner surface of the crown portions of the drill bit. It is contemplated, optionally and without limitation, that the plurality of wear-resistant members can be embedded therein portions of the base surface adjacent to the at least one inner surface that serves as the impact wall (e.g., the trailing wall) as a result of the rotation of the drill bit in use. In this aspect, it is contemplated that the plurality of wear-resistant members can be embedded in an area of the base surface proximate to the juncture of the base surface and the respective inner surfaces. In a further aspect, the plurality of wear-resistant members in the base surface can be positioned in a desired, predetermined array. In one example, the array of the plurality of wear-resistant members can comprise a series of rows of wear-resistant members. In this aspect, it is contemplated that each row can comprise a plurality of the wear-resistant members positioned substantially along a common axis. Optionally, the common axis can be substantially parallel to the adjacent at least one inner surface. Thus, it is contemplated that the array of the plurality of wear-resistant members can comprise a series of rows of wear-resistant members in which each of the rows are substantially parallel to each other and to the adjacent at least one inner surface.

[0020] In a further aspect, optionally and without limitation, the plurality of wear-resistant members can be embedded therein portions of the inner surface that serves as the impact wall (e.g., the trailing wall) as a result of the rotation of the drill bit in use. In this aspect, it is contemplated that the plurality of wear-resistant members can be embedded in an area of the at least one inner surface proximate to the juncture of the base surface and the at least one inner surface. In a further aspect, the plurality of wear-resistant members in the base surface can be positioned in a desired, predetermined array. In one example, the array of the plurality of wear-resistant members can comprise a series of rows of wear-resistant members. In this aspect, it is contemplated that each row can comprise a plurality of the wear-resistant members positioned substantially along a common axis. Optionally, the common axis can be substantially parallel to the adjacent base surface. Thus, it is contemplated that the array of the plurality of wear-resistant members can comprise a series of rows of wear-resistant members in which each of the rows are substantially parallel to each other and to the adjacent base surface. In a further aspect, the array of the plurality of wear-resistant members positioned on the at least one inner surface can be spaced away from the cutting faces of the drill bit 200 at a desired distance.

[0021] In another aspect, at least a portion of the plurality of wear resistant members can extend proudly from the respective base surface and/or at least one inner surface in which it is embedded. In one aspect, it is further contemplated that the array can comprise additional rows

of wear resistant members that are encapsulated within the drill bit 200 in an underlying relationship with the exposed rows of the wear-resistant members that are positioned in one of the base surface and/or the at least one inner surface of the drill bit 200. In this fashion, the additional wear-resistant members can be exposed upon the normal wear of the drill bit 200 during operation.

[0022] In one aspect, each wear-resistant member can be an elongated member, for example and without limitation, the elongate member can have a generally rectangular shape having a longitudinal axis. It is contemplated that the elongate members can be positioned such that the longitudinal axis of each elongate member is substantially parallel to the adjacent base surface and/or at least one inner surface. Without limitation, it is contemplated that each wear-resistant member can comprise at least one of Tungsten Carbide, TSD (thermally stable diamond), PDC (polycrystalline diamond compact), CBN (cubic boron nitride), single crystal Aluminum Oxide, Silicon Carbide, wear resistant ceramic materials, synthetic diamond materials, natural diamond, and polycrystalline diamond materials.

[0023] Various embodiments of diamond impregnated, self-sharpening rotary bits can be implemented with drilling system 100. Further exemplary bits are disclosed in U.S. Patent Application No. 14/085218 to Pearce et al., filed November 20, 2013 and U.S. Patent No. 10,077,609 to Pearce et al., filed March 3, 2016. It should be further understood, particularly with reference to Figures 3A-3G, that except as specifically disclosed herein, the particular appearance of the drill bit features depicted in the Figures is not required to achieve the functionality disclosed herein. Indeed, it is understood that individual features of the disclosed bits, as well as combinations of features of the disclosed bits, can serve an ornamental purpose.

[0024] The drill string 150 can be an open tubular drill string. In this way, the drill string can accommodate deployment of survey instrumentation into the drill string. For example, the open tubular drill string can enable real time measure while drilling (MWD) surveying or post-drilling verification pump-in instrumentation surveying.

[0025] The drill head assembly 110 can be configured to rotate the drill bit at a speed of at least 1000 rpm, or 1000-2000 rpm, or 2000-4000 rpm, or 4000-5000 rpm or greater. Accordingly, it is contemplated that the bit can rotate at least 50% faster than conventional technology and preferably three to four times faster than typical rotary drilling equipment. According to some aspects, although not essential for all purposes, the axial thrust applied at the cutting face of the drill bit can be reduced as compared to lower drill rotation speeds. The reduced axial force can reduce hole deviation, thereby enabling drill operators to hit drilling targets with greater accuracy.

[0026] According to one embodiment, a high-speed electric drive motor can be disposed at the drill head assembly 110. In a further embodiment, a drive motor can comprise an integral multiplying gearbox so that the gearbox output provides the desired drill bit speed. In

another embodiment, a gearbox can be coupled to a conventional drive motor of the drill head assembly 110. In yet a further embodiment, a quick attach/detach gearbox can be mounted between the drill string and the drill rig. Conventional drill strings couple to the drill head via threaded coupling that can be difficult to disengage. According to at least one embodiment, a quick attach/-detach gearbox can include a split collar coupling 300 at its output, which couples to the drill string. Each of the drill head's gearbox and the drill string can comprise a flange 302A, 302B. The drill head gearbox's flange 302A can abut the drill string's flange 302B, and a split collar 304 can receive the pair of abutting flanges in an annular groove 306. Respective ends 308 of the split collar 304 can be joined via known means, such as, for example, fasteners 310, thereby retaining the abutting flanges 302A, 302B. In this way, the drill head can be coupled to the drill string in a releasable fashion. According to at least one aspect, the split collar coupling can comprise an EPIROC V-LOK clamp system or equivalent system as is known in the art. In a further embodiment, a quick pin coupling can releasably couple the drill head to the drill string. In yet further embodiments, other quick attach/-detach couplings can be used to couple the gearbox to the drill string. In this way, the gearbox can be removed to allow easy and productive access to the open drill string.

[0027] In yet a further embodiment, a gearbox 220 can be disposed within the drill string. The gearbox can be in communication between the drill string and the drill bit and can be configured to step up the rotation rate between the drill string and the drill bit so that rotation of the drill string at a first rate causes rotation of the drill bit at a second rate that is greater than the first rate. The gearbox 220 can be disposed adjacent the drill bit to enable survey instrumentation to extend to a bottom of the borehole-if the gearbox 220 were positioned closer to the surface, then the presence of the gearbox would prevent survey instrumentation from advancing to the bottom of the borehole. The gearbox 220 can use various gearing implementations including a planetary gear train, strain wave gearing, or a traction roller/traction drive in order to step up the rotation speed from the drill head assembly 110 to the drill bit 200. The drill string 140 can further comprise skates 600 that are disposed at radial edges of the drill string. The skates can bias against the walls of the borehole in order to provide a fixed (i.e., nonrotating) surface so that a portion of the gearbox can be non-rotary. In this way, the gearbox can use the ground as a fixed surface in order to enable the gearbox to step the rotary speed up from a first speed to a second speed. (As should be understood, the gearbox can use a fixed surface in order to step up the rotational speed between its input and its output.) In some embodiments, the skates can be deployable so that they can extend radially from the drill string's longitudinal axis. The skates can be mechanically deployed upon application of force against the drill bit, for example, when the bit engages the distal end of the borehole. Optionally, in some aspects, the skates can

be deployable via an inflatable bladder that biases against an interior surface of each skate, thereby forcing each skate radially outward and against walls of the borehole. For example, as the drill bit applies pressure against the foundation at the distal end of the borehole, the reaction force can apply a compressive force to a bladder, causing the bladder to expand radially outward from the longitudinal drilling axis. The radial expansion of the bladder can move the skates radially outward to bias against the walls of the borehole. As the drill bit removes the foundation, the pressure that the distal end of the borehole applies to the drill bit can decrease, releasing the applied pressure to the bladder, allowing the skates to retract, thereby allowing the drill bit to advance until it again applies sufficient pressure to the distal end of the borehole at the advanced position in order to again deploy the skates. In another aspect, referring to Figures 8 and 9, force against the drill bit can cause wedge surfaces 602 to slide against skates 600, thereby deploying the skates outwards. In yet further embodiments, the skates can be deployed via centrifugal force as the bit rotates. In still further embodiments, instead of skates, rollers can be deployed to engage walls of the hole to provide a reactionary force. Such rollers and skates can comprise wear-resistant tungsten carbide and/or other wear resistant material.

[0028] Referring to FIGs. 6-10, in some aspects, grooved roller bearings 500, such as those provided by Creative Motion Control, can be configured to function both as thrust bearing members and as gearing members for stepping up the rotation rate of the drill bit. For example, it is contemplated that such grooved roller bearings can act as a planetary gear. In some aspects, for example, the outer race 502 can couple to the drill string, and the inner race 504 can couple to the drill bit. Grooved rollers 508 can act as planets gears to couple the outer race 502 to the inner race 504. The grooved rollers 508 can pivotably couple to support rings 510 at respective ends. The support rings 510 can couple to the skates 600 so that when the skates 600 engage the outer surface of the borehole and stop relative movement between the skates 600 and borehole, the grooved rollers 508 can be held in fixed positions about the drilling axis. In this way, the rotation of the drill string at a first rotational rate can cause a stepped up, faster second rotational rate at the drill bit. Figure 7 illustrates another grooved roller bearing 500' for use as a planetary gearbox.

[0029] A drill slip sub 400 can be implemented in various embodiments, in particular for embodiments that do not employ a down-the-hole gearbox. One or more slip subs can be used on long drill strings and can provide anti-bucking, torque-reducing drill string high-speed-bearing stabilizers. Examples of slip subs include high-impact strength, low-friction centralizers (such as the MAXR EXTREME) and self-lubricating, ultralow friction centralizers (such as the MAXR REVOLUTION) as are known in the oil and gas industry. Representative images of such slip subs are provided in Figure 5. It is contemplated

plated that such oil and gas slip subs can be re-sized and otherwise modified for use with wireline applications. Unlike oil and gas boreholes, which typically have boreholes that are much larger than the drill string, wireline boreholes can have very tight annuli (i.e. space between the borehole walls and the drill string). This can be, in part, due to the need for a sufficient outer diameter and wall thickness to maximize stiffness to withstand high rotary speed drilling while providing a bore sufficient to pass instrumentation therethrough. Accordingly, the slip subs can be configured for thin-wall drill strings having tight annuli. In one embodiment, the drill string tubing can be $\frac{1}{4}$ to $\frac{3}{16}$ of an inch thick. In further embodiments, the thickness can be $\frac{1}{2}$ inch thick or less. It is contemplated that the drill string-to-hole annulus radius differential can be equal to or less than the tubing thickness. Accordingly, the slip sub can be configured to fit within such an annulus. The slip sub can be made of a high strength material so that the walls can be thin enough to be used in wireline applications. Such centralizers can engage side-walls of the bore to prevent the drill string from bowing. Optionally, the outer surface of the slip sub can comprise spiral or helical protrusions. In some aspects, a slip sub 400' can receive the drill string so that the outer wall of the drill string engages an inner bore in the slip sub. In further aspects, a slip sub 400 can be a component within the drill string.

[0030] Referring to Figure 10, the drill string can comprise drill rods 140 having varying wall thicknesses. The variable wall thickness drill rods can optimize strength to weight ratios. Examples of drill rods having variable wall thicknesses are disclosed in U.S. Patent No. 10,024,117, to Drenth et al., filed July 18, 2014.

[0031] In one aspect the threaded drill string component or drill rod 600 comprises a hollow elongate body 610 having a box end portion 620, an opposing pin end portion 630 and a cylindrical mid-body portion 640 that extends longitudinally between the respective box and pin end portions. A central longitudinal axis LA extends through the hollow body 610 between the respective box and pin end portions 620, 630. Each of the respective box and pin end portions 620, 630 have an end portion inner wall 622, 632 having a first inner diameter D1. In one aspect, the end portion inner wall 622, 632 can have a substantially cylindrical shape that is positioned uniformly about the central longitudinal axis. In a further aspect, the cylindrical mid-body portion 640 has a mid-body inner wall 642 having a variable wall diameter and a mid-body outer wall 643 having a substantially constant outer diameter. Although described herein as having the same inner diameter D1, it is contemplated that the inner walls 622, 632 of the box and pin end portions 620, 630 can optionally have different inner diameters.

[0032] In another aspect, the mid-body inner wall 642 of the mid-body portion can have at least one projecting portion having at least one male projection 644 or upset that is spaced from both the box and pin end portions 620, 630 and extends inwardly toward the central longitudinal

axis LA of the hollow body 610 and a plurality of troughs 660 defined in the mid-body inner wall 642 of the mid-body portion 640. In one aspect, it is contemplated that each projection of the at least one male projection 644 has a male projection inner wall face 46 that can have a second inner diameter D2 that can be equal to or greater than the first inner diameter D1. In one aspect, the male projection inner wall face 646 can have a substantially cylindrical shape that is positioned uniformly about the central longitudinal axis LA. In this aspect, each male projection 644 can have, in a perpendicular plane bisecting the central longitudinal axis LA, a substantially torodial shape.

[0033] In another exemplary aspect, a first trough 660' of the plurality of troughs 660 can extend from a distal end 624 of the box end portion 620 to a proximal end 650 of the at least one male projection 644 and a second trough 660" of the plurality of troughs 660 can extend from a distal end 652 of the at least one male projection to a proximal end 634 of the pin end portion 630. In this aspect, each trough 660 can comprise a substantially cylindrical portion 662 having a first trough diameter that is greater than the respective first and second inner diameters. Each trough can also have a first frustoconical portion 664 that is sloped outwardly from the central longitudinal axis LA and extends between the respective distal end 624 of the box end portion 620 and proximal end 634 of the pin end portion 30 to the substantially cylindrical portion 62 and has a variable inner diameter that is greater than the first inner wall diameter D1. In an optional aspect, not shown, at least a portion of the substantially cylindrical portion of each trough 660 can further comprise a plurality of longitudinally extending ridges that extend inwardly toward the central longitudinal axis LA.

[0034] In a further aspect, a portion of each trough 660 adjacent to the at least one male projection 644 can comprise a second frustoconical portion 666 that is sloped inwardly from the central longitudinal axis LA and extends between the substantially cylindrical portion 62 of the mid-body portion and an edge 647 of the male projection inner wall face 46. It is contemplated that the first and second frustoconical portions 664, 666 can have any desired longitudinal cross sectional shape. In one example, and not meant to be limiting, at least a portion of each second frustoconical portion 666 can be linear in longitudinal cross-section and can be positioned at an acute angle β with respect to a perpendicular plane bisecting the central longitudinal axis LA. In one aspect, the acute angle β can be between about 0.01 to about 10 degrees; preferably less than about 8 degrees; and, more preferred, less than about 6 degrees. In exemplary aspects, the acute angle β can range from about 0.5 to about 8 degrees, from about 0.5 to about 6 degrees, from about 0.5 to about 5 degrees, from about 1 to about 7 degrees, from about 1 to about 6 degrees, from about 1 degrees to about 5 degrees, or from about 2 degrees to about 6 degrees.

[0035] In one aspect, it is contemplated that at least a portion of each second frustoconical portion 666 can be curvilinear in longitudinal cross-section. Similarly, it is contemplated that at least a portion of each first frustoconical portion 664 can be linear and/or curvilinear in longitudinal cross-section. In another aspect, at least a portion of each first frustoconical portion 664 can have a quarter sine wave shape in longitudinal cross-section with an amplitude equal to one-half of the first trough diameter.

[0036] In another aspect, at each first frustoconical portion 664, the inner diameter of the hollow body 10 can transition from the second inner diameter D2 of the male projection inner wall face 646 to the first trough diameter along a first longitudinal transition length L1. Similarly, at each second frustoconical portion 66, the inner diameter of the hollow body 610 can transition from the first inner diameter D1 of the respective box and pin end portions 620, 630 to the first trough diameter along a second longitudinal transition length L2. The total of the respective first and second transition lengths L1, L2 is less than about 15%, preferably less than about 12.5% and, more preferred, less than about 10% of the overall length of the drill rod.

[0037] In various exemplary aspects, the elongate length of the plurality of troughs can comprise greater than 60% of the elongate length of the mid-body portion; preferably greater than 70% of the elongate length of the mid-body portion, and more preferred, greater than 80% of the elongate length of the mid-body portion.

[0038] In a further aspect, it is contemplated that the transition from the second frustoconical portion 666 to the male projection inner wall face 646 can be chamfered. Similarly, it is contemplated that the transition from the second frustoconical portion 666 to the adjoining cylindrical portion of the mid-body portion 640 of the trough 660 can be chamfered.

[0039] In another aspect, it is contemplated that the at least one male projection 644 of each projecting portion can comprise a single male projection, which can optionally extend circumferentially about the central longitudinal axis LA. Alternatively, it is contemplated that the at least one male projection 644 of each projecting portion can comprise a plurality of circumferentially spaced male projections. Optionally, in exemplary aspects, the at least one projecting portion can comprise a single projecting portion (i.e., a single axial location with at least one male projection) that is positioned at a desired axial location in the mid-body portion. As one will appreciate from the above disclosure, it is contemplated that the respective end portion inner walls 622, 632 of the box and pin end portions 620, 630 can effectively act as an additional internal male projection or upset 644' that is located at the respective outer end portions of the hollow body 610 of the drill rod 600.

[0040] In one aspect, the axial spacing between sequential projecting portions (e.g., sequential axial locations with at least one male projection 644) and/or the

axial spacing between the pin and box end portions 620, 630, 644' and a sequential projecting portion (e.g., at least one male projection 644), which effectively corresponds to the spacing between the internal upsets in the drill string component, can reflect a selected separation distance. For example and without limitation, when the drill string components disclosed herein are used as casings for other drill string components to be passed therethrough, the selected separation distance (e.g., the spacing between sequential male projections 644 and/or the spacing between a male projection and the pin and box end portions 620, 630, 644') can be made relative to and as a percentage of the elongate length of the individual respective drill string components being passed therethrough. For example, if a drill string component being passed through the drill rod is 10 feet in length, then the selected separation distance would be less than 100% of the elongate length of the drill string component passing through the drill rod. In this aspect, it is contemplated that the selected separation distance can correspond to a distance that is less than about 90%, less than about 80%, less than about 70%, less than about 60%, less than about 50%, less than about 40%, or less than about 30% of the elongate length of the individual drill string components that are passed therethrough the hollow body 10 of the drill rod 100 (or other drill string component). In exemplary aspects, it is contemplated that the selected separation distance can range from about 0.30m to about 1.83m (1 foot to about 6 feet) and more preferably, from about 0.61m to about 1.52m (2 feet to about 5 feet) and, most preferably, from about 0.91m to about 1.52m (3 feet to about 5 feet). In further exemplary aspects, it is contemplated that the selected separation distance can be less than about 1.52m (5 feet).

[0041] The drilling system 100 can be electrically powered. This can provide an advantage over conventional diesel-powered drilling systems that require costly ventilation in mines. Moreover, electrically powered drilling systems can have lower maintenance costs than diesel-powered drilling rigs. The drilling system 100 can further be automated to eliminate the need for an operator, which can further reduce ventilation requirements in a mine where the drilling system is disposed.

[0042] As should be understood, the drilling system 100 as disclosed herein can provide various improvements over prior drilling systems. For example, the drilling system 100 can be less environmentally and economically costly than percussive drilling systems. The penetration rates can be improved over traditional rotary drilling equipment. For example, it is contemplated that the drilling system 100 disclosed herein can produce penetration rates ranging from 0.5 to 1.0 meters per minute. The drilling system 100 can provide an open drill string in order to deploy survey instrumentation. The drilling system 100 can maintain minimum hole deviation throughout drilling in order to accurately hit drill targets. And the drilling system 100 can implement bits that stay

sharp and, therefore, have a longer life, than surface-set diamond or PCD insert drag rotary bits.

[0043] According to one embodiment, a method of drilling can include drilling at a first, high angular drill speed to a first depth, and subsequently drilling at a second, lower angular drill speed to a second depth. In some embodiments, the first depth can be 10 meters, or preferably 5 meters or less. In this way, buckling of the drill string due to drilling with a high angular drill speed in deep bores can be avoided while still taking advantage of higher penetration rates of high angular speed drilling.

[0044] Although several embodiments of the disclosure have been disclosed in the foregoing specification, it is understood by those skilled in the art that many modifications and other embodiments of the disclosure will come to mind one of ordinary skill in the art to which the disclosure pertains, having the benefit of the teaching presented in the foregoing description and associated drawings. It is thus understood that the disclosure is not limited to the specific embodiments disclosed herein, and that many modifications and other embodiments are intended to be included within the scope of the appended claims. Moreover, although specific terms are employed herein, as well as in the claims which follow, they are used only in a generic and descriptive sense, and not for the purposes of limiting the disclosure, nor the claims which follow.

Claims

1. A system (100) comprising:

a drill feed (120);
a drill head (110) comprising a motor and coupled to the drill feed;
a drill string (150) having a proximal end, wherein the drill string comprises at least one drill rod (140) operatively coupled to the drill head so that the drill head is configured to axially and rotationally drive the drill string; and
a drill bit (160) coupled to the bottom end of the drill string,

characterized in that the drill head is configured to rotate the drill bit at at least 1000 rpm, and the system further comprises a gearbox (220) that is disposed adjacent the output of the motor and is configured to step up a rotation rate between an output of the motor and the proximal end of the drill string.

2. The system of claim 1, wherein the gearbox is removably attached between the drill string and the drill head.

3. The system of any preceding claim, wherein the drilling system further comprises a drill string slip sub (400).

4. The system of any of the preceding claims, wherein the drill bit comprises a first matrix (402) having a first binder hardness and a second matrix (404) having a second binder hardness, wherein the first matrix is disposed within a first radius from a longitudinal axis of the bit, and the second matrix is disposed outside the first radius from the longitudinal axis of the drill bit.

5. The system of any preceding claim, wherein the at least one drill rod has a varying wall thickness.

6. A method comprising:
rotating the drill bit of the drilling system of any one of the preceding claims, wherein the drill bit is rotated at at least 1000 rpm.

7. The method of claim 6, wherein rotating the drill bit of the drill system at at least 1000 rpm comprises rotating the drill bit at at least 4000 rpm.

8. The method of claim 6, wherein the drill string of the drilling system is an open drill string.

9. The method of claim 6, further comprising rotating the drill bit at a speed below 1000 rpm after a select depth.

10. The method of claim 9, wherein the select depth is 10 meters or less.

11. The method of claim 6, wherein the drilling system is positioned underground, and wherein the drill bit is advanced within a formation (165).

Patentansprüche

1. Ein System (100), das Folgendes umfasst:

einen Bohrvorschub (120);
einen Bohrkopf (110), der einen Motor umfasst und mit dem Bohrvorschub gekoppelt ist;
einen Bohrstrang (150) mit einem proximalen Ende, wobei der Bohrstrang mindestens eine Bohrstange (140) umfasst, die operativ mit dem Bohrkopf gekoppelt ist, so dass der Bohrkopf so konfiguriert ist, dass er den Bohrstrang axial und rotierend antreibt, und
einen Bohrmeißel (160), der mit dem unteren Ende des Bohrstrangs gekoppelt ist,
dadurch gekennzeichnet, dass der Bohrkopf so konfiguriert ist, dass er den Bohrmeißel mit mindestens 1000 U/min dreht, und
das System zudem ein Getriebe (220) umfasst, das neben dem Ausgang des Motors angeordnet ist und so konfiguriert ist, dass es eine Rotationsrate zwischen einem Ausgang des Motors und dem proximalen Ende des Bohrstrangs

erhöht.

2. Das System nach Anspruch 1, wobei das Getriebe abnehmbar zwischen dem Bohrstrang und dem Bohrkopf angebracht ist. 5
3. Das System nach einem der vorhergehenden Ansprüche, wobei das Bohrsystem zudem ein Bohrstrang-Gleitstück (400) umfasst. 10
4. Das System nach einem der vorhergehenden Ansprüche, wobei der Bohrmeißel eine erste Matrix (402) mit einer ersten Bindemittelhärte und eine zweite Matrix (404) mit einer zweiten Bindemittelhärte umfasst, wobei die erste Matrix innerhalb eines ersten Radius von einer Längsachse des Meißels angeordnet ist und die zweite Matrix außerhalb des ersten Radius von der Längsachse des Bohrmeißels angeordnet ist. 15
5. Das System nach einem der vorhergehenden Ansprüche, wobei die mindestens eine Bohrstange eine variierende Wandstärke aufweist. 20
6. Ein Verfahren, das Folgendes umfasst:
Drehen des Bohrmeißels des Bohrsystems nach einem der vorhergehenden Ansprüche, wobei der Bohrmeißel mit mindestens 1000 U/min gedreht wird. 25
7. Das Verfahren nach Anspruch 6, wobei das Drehen des Bohrmeißels des Bohrsystems mit mindestens 1000 U/min das Drehen des Bohrmeißels mit mindestens 4000 U/min umfasst. 30
8. Das Verfahren nach Anspruch 6, wobei der Bohrstrang des Bohrsystems ein offener Bohrstrang ist. 35
9. Das Verfahren nach Anspruch 6, das zudem das Drehen des Bohrmeißels nach einer ausgewählten Tiefe mit einer Geschwindigkeit unter 1000 U/min umfasst. 40
10. Das Verfahren nach Anspruch 9, wobei die ausgewählte Tiefe 10 Meter oder weniger beträgt. 45
11. Das Verfahren nach Anspruch 6, wobei das Bohrsystem unterirdisch positioniert ist und wobei der Bohrmeißel innerhalb einer Formation (165) vorge-schoben wird. 50

Revendications

1. Un système (100) comprenant : 55
 - une avance de forage (120) ;
 - une tête de forage (110) comprenant un moteur

et couplée à l'avance de forage ;

un train de tiges (150) présentant une extrémité proximale, dans lequel le train de tiges comprend au moins une tige de forage (140) couplée à la tête de forage de sorte que la tête de forage est configurée pour entraîner axialement et par rotation le train de tiges ; et un trépan (160) couplé à l'extrémité inférieure du train de tiges,

caractérisé par le fait que la tête de forage est configurée pour faire tourner le trépan à au moins 1 000 tr/min, et

le système comprend en outre une boîte d'engrenage (220) disposée à côté de la sortie du moteur et configurée pour augmenter la vitesse de rotation entre la sortie du moteur et l'extrémité proximale du train de tiges.

2. Le système de la revendication 1, dans lequel la boîte d'engrenage est fixée de manière amovible entre le train de tiges et la tête de forage.
3. Le système de l'une des revendications précédentes, dans lequel le système de forage comprend en outre un dispositif de glissement de train de tiges (400).
4. Le système de l'une des revendications précédentes, dans lequel le trépan comprend une première matrice (402) présentant une première dureté de liant et une deuxième matrice (404) présentant une deuxième dureté de liant, dans lequel la première matrice est disposée dans un premier rayon par rapport à un axe longitudinal du trépan et la deuxième matrice est disposée hors du premier rayon par rapport à l'axe longitudinal du trépan.
5. Le système de l'une des revendications précédentes, dans lequel au moins une tige de forage présente une épaisseur de paroi variable.
6. Un procédé consistant à :
faire tourner le trépan du système de forage de l'une des revendications précédentes, dans lequel le trépan tourne à au moins 1 000 tr/min.
7. Le procédé de la revendication 6, dans lequel la rotation du trépan du système de forage à au moins 1 000 tr/min est en fait une rotation du trépan à au moins 4 000 tr/min.
8. Le procédé de la revendication 6, dans lequel le train de tiges du système de forage est un train de tiges ouvert.
9. Le procédé de la revendication 6, consistant en outre à faire tourner le trépan à une vitesse inférieure à 1 000 tr/min après une profondeur déterminée.

10. Le procédé de la revendication 9, dans lequel la profondeur déterminée est égale à 10 mètres ou moins.

11. Le procédé de la revendication 6, dans lequel le système de forage est positionné sous terre et dans lequel le trépan avance dans une formation (165).

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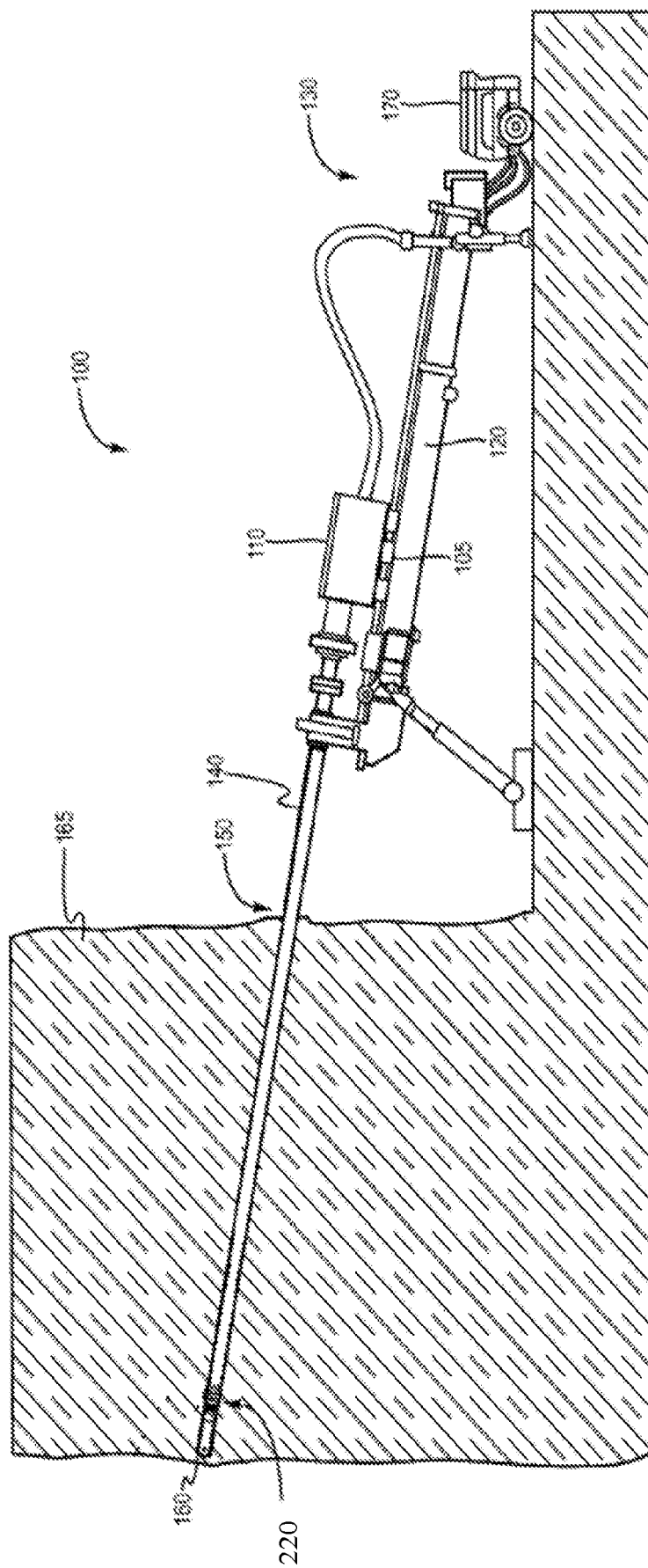


Figure 1

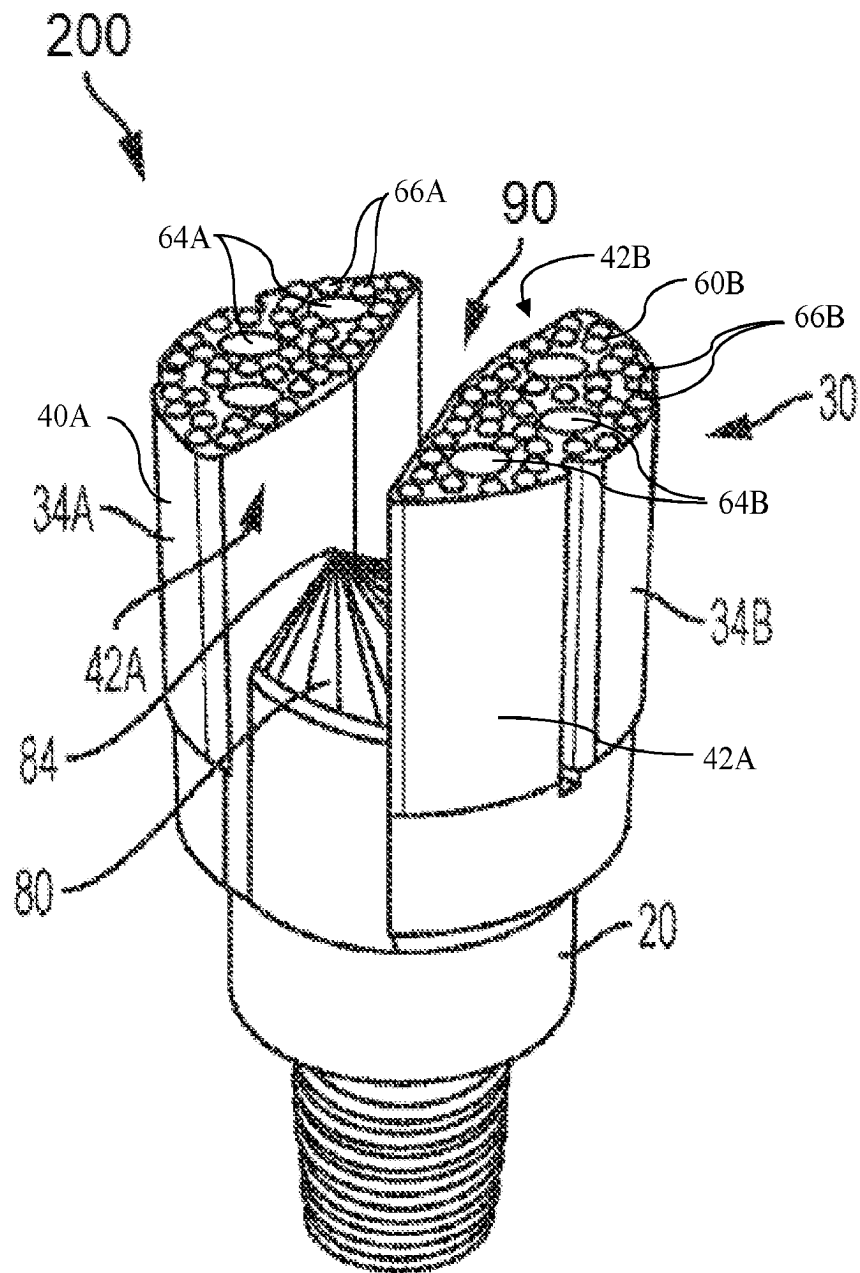


Figure 2

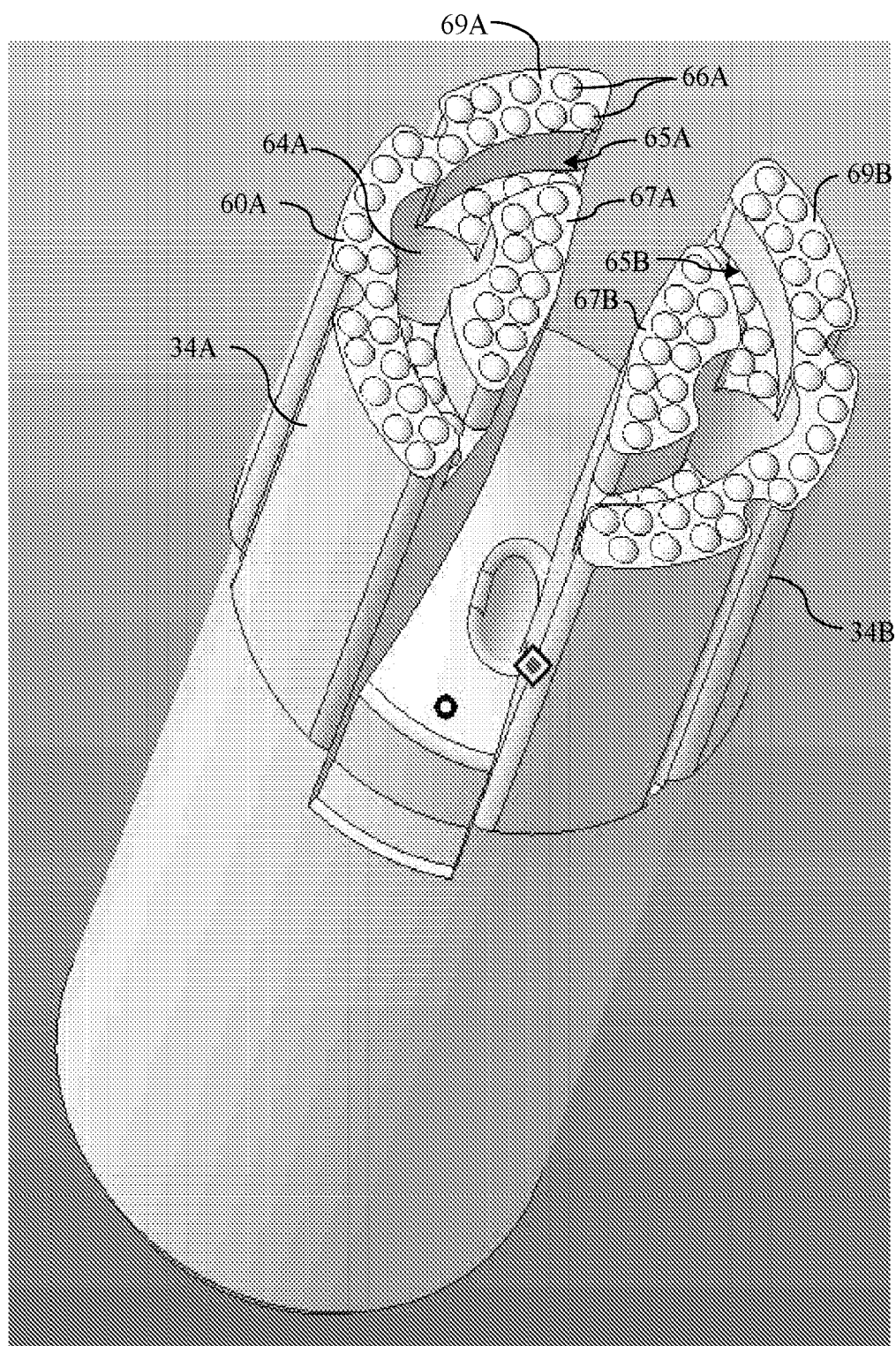


Figure 3A

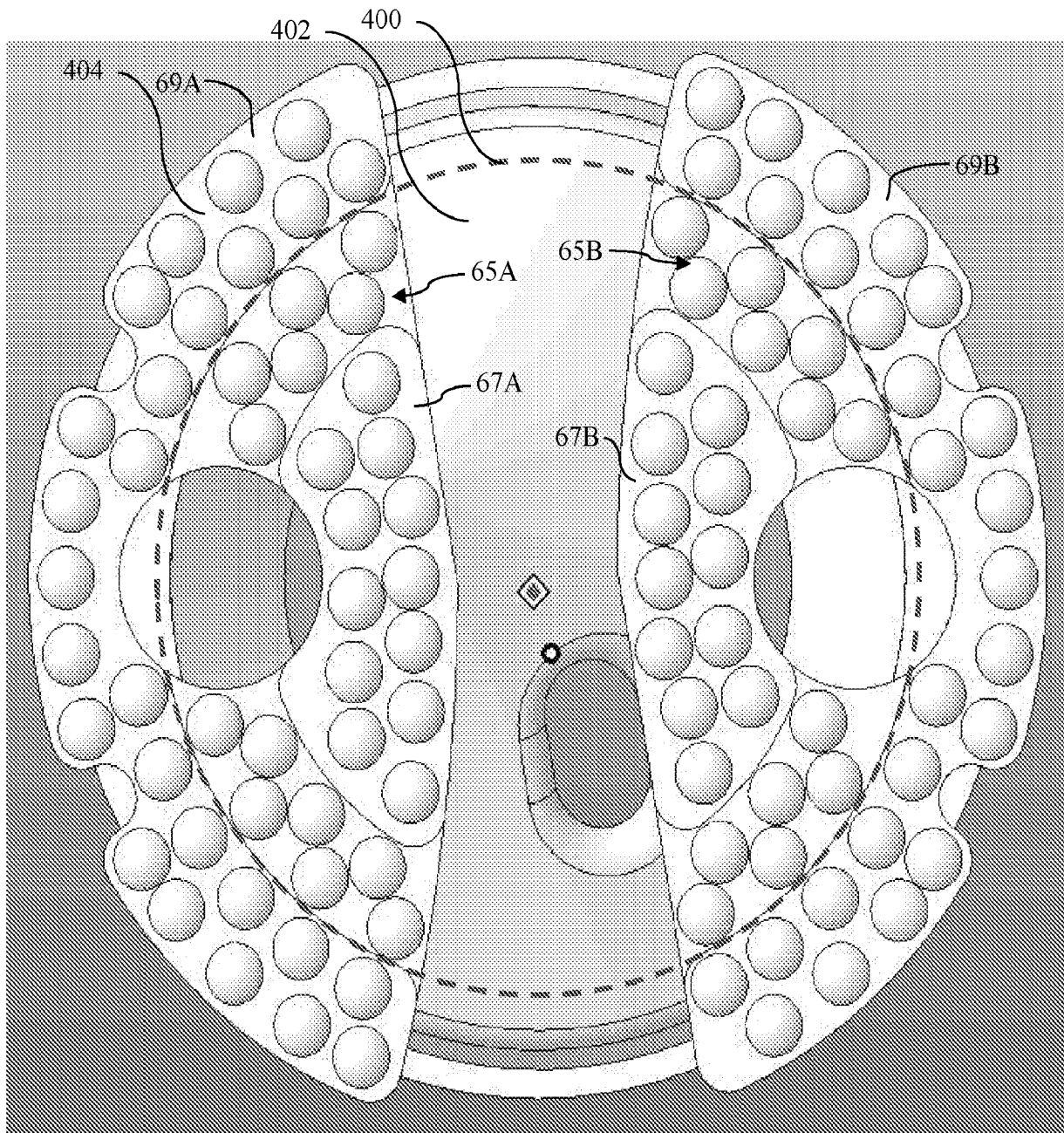


Figure 3B

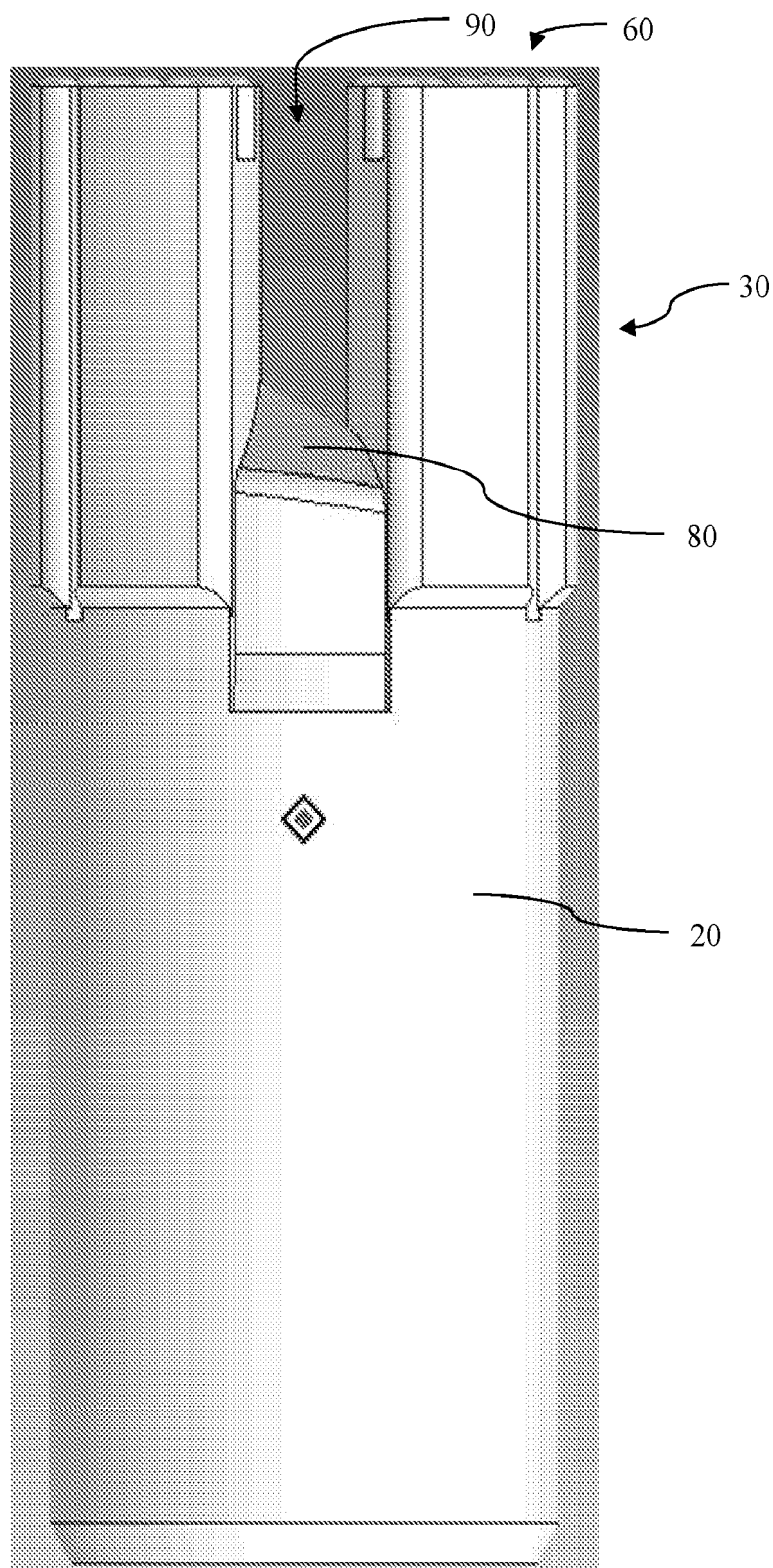


Figure 3C

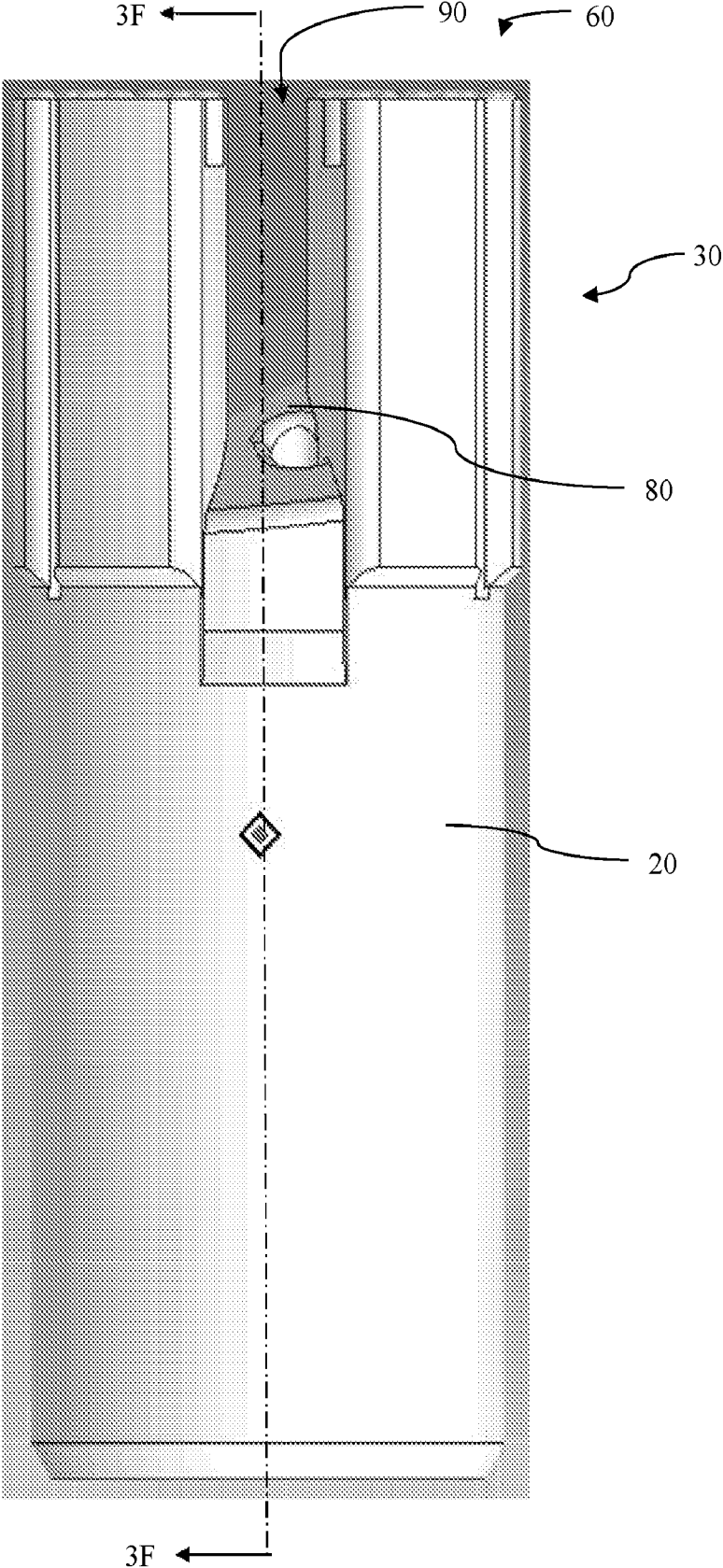


Figure 3D

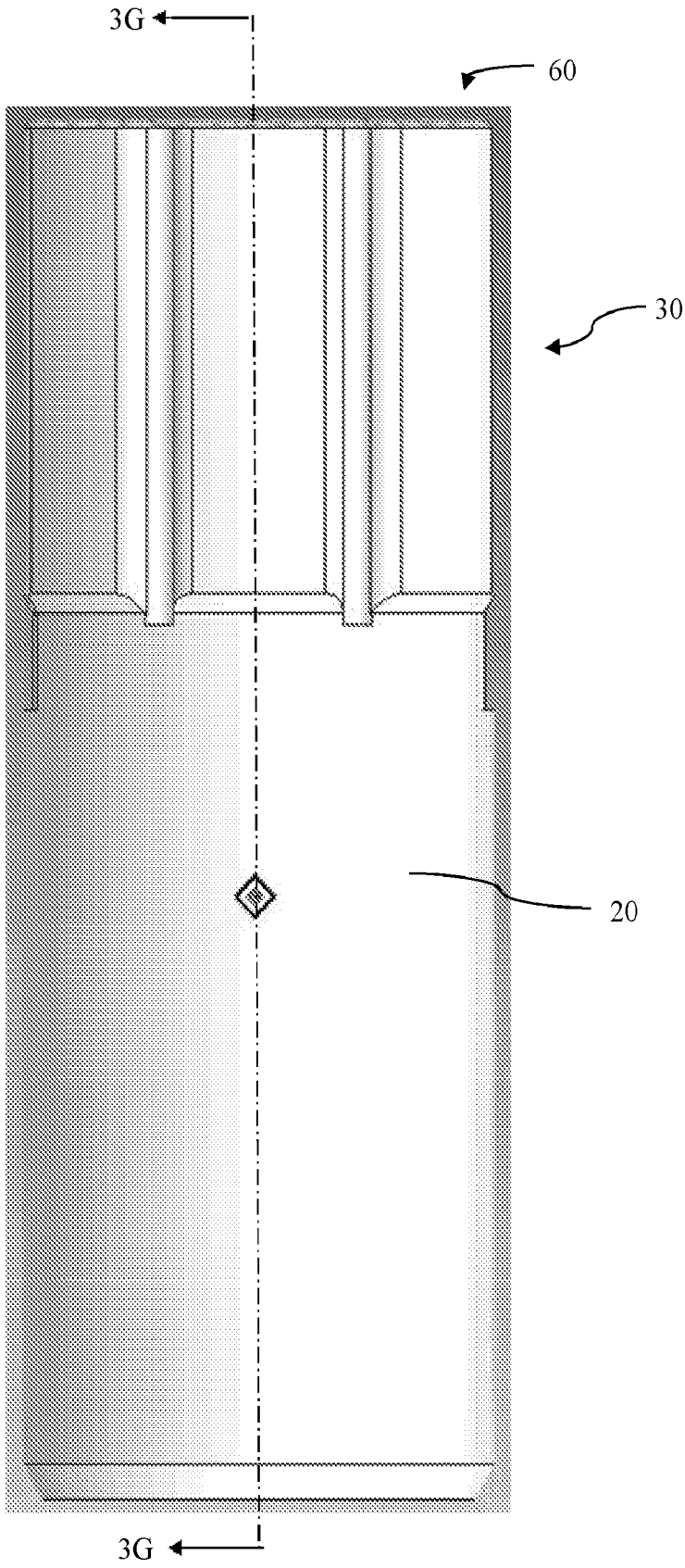


Figure 3E

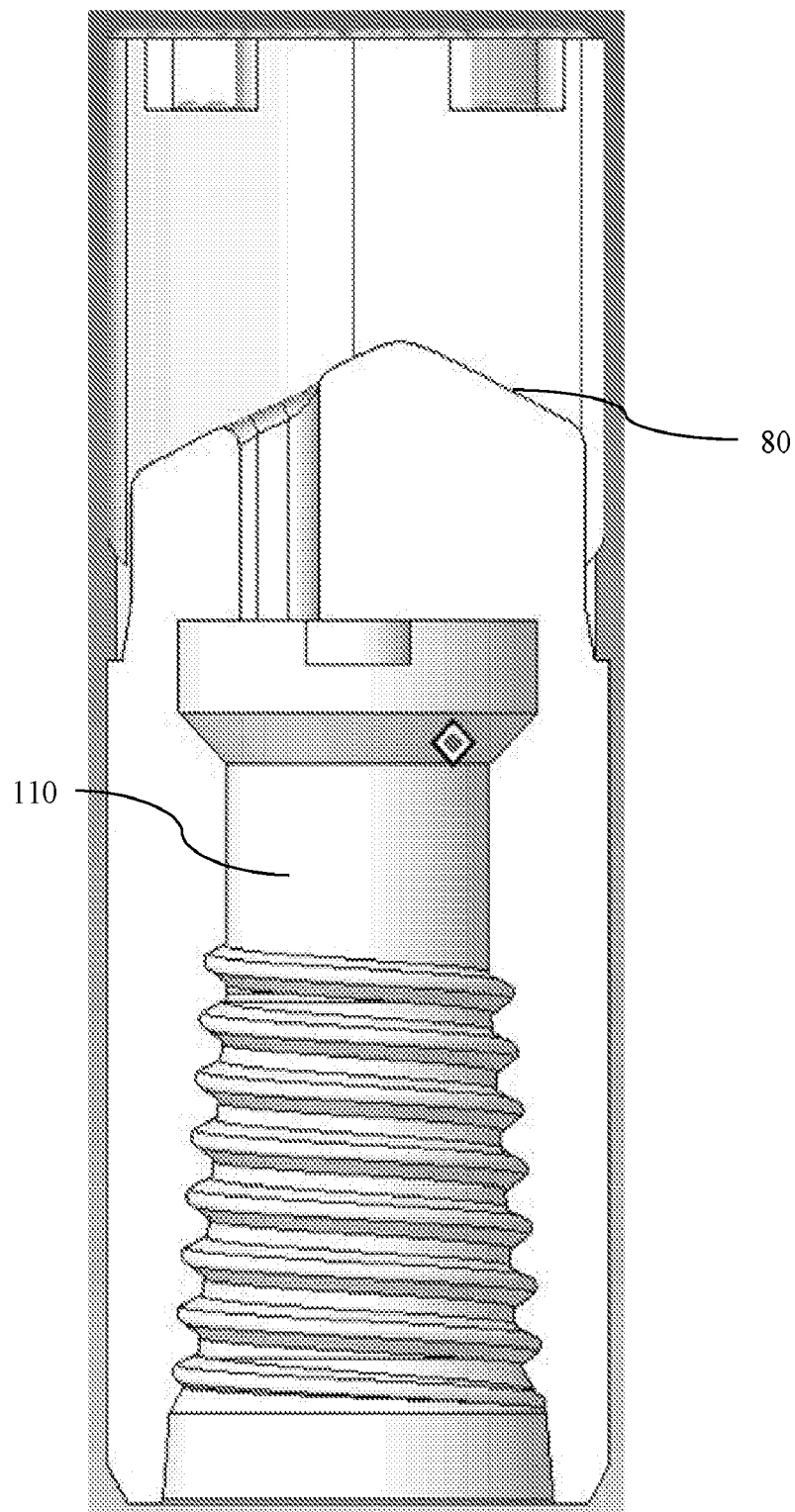


Figure 3F

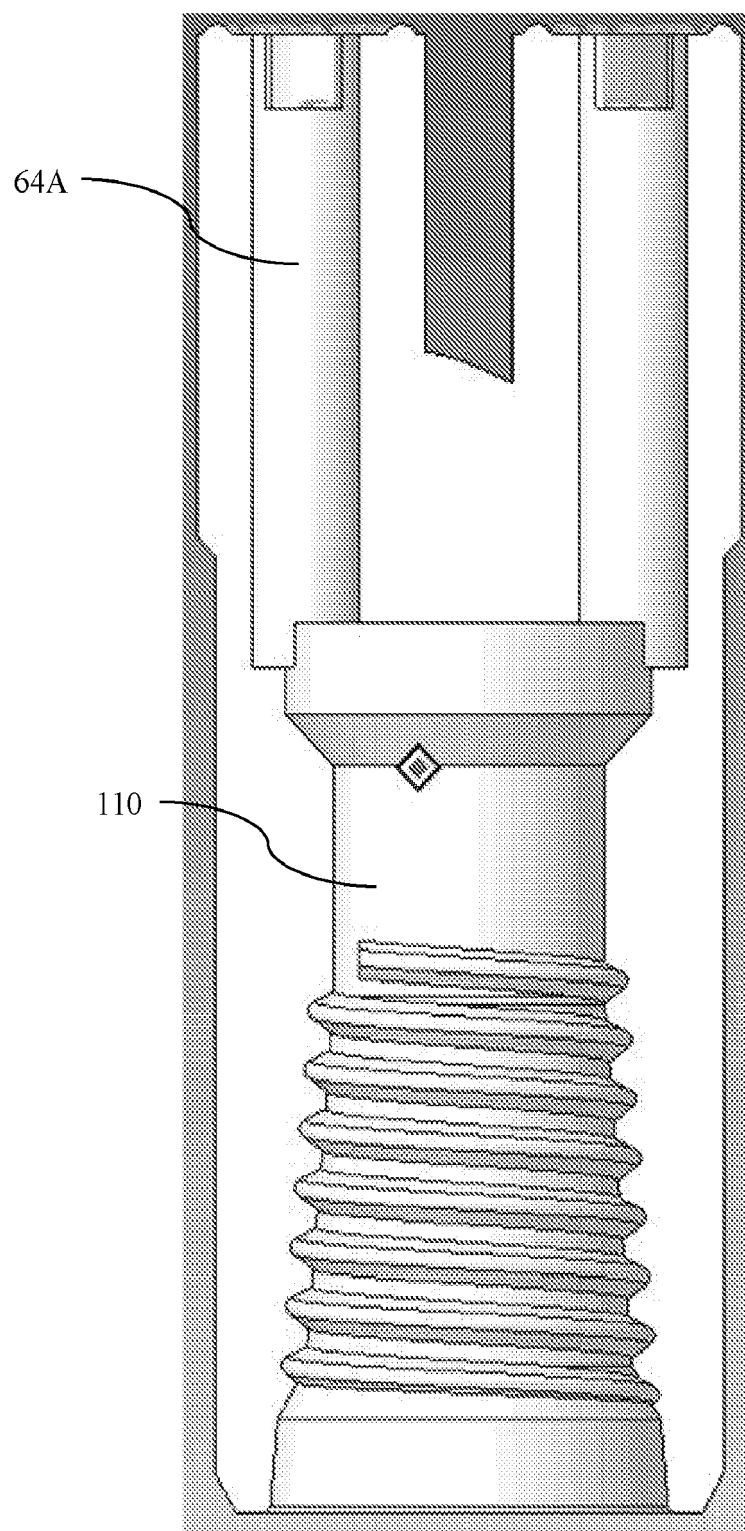


Figure 3G

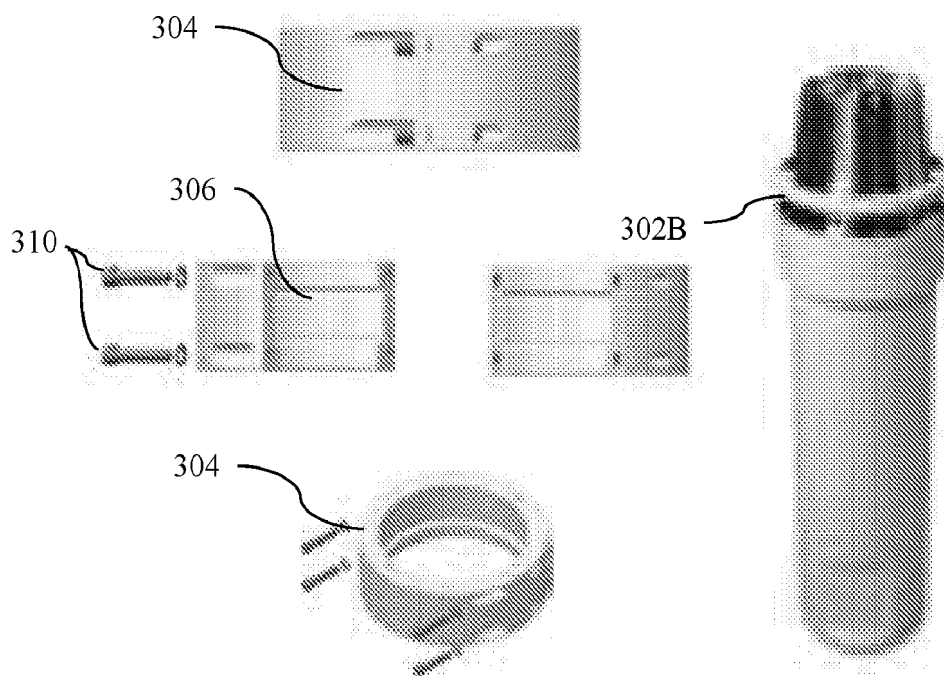
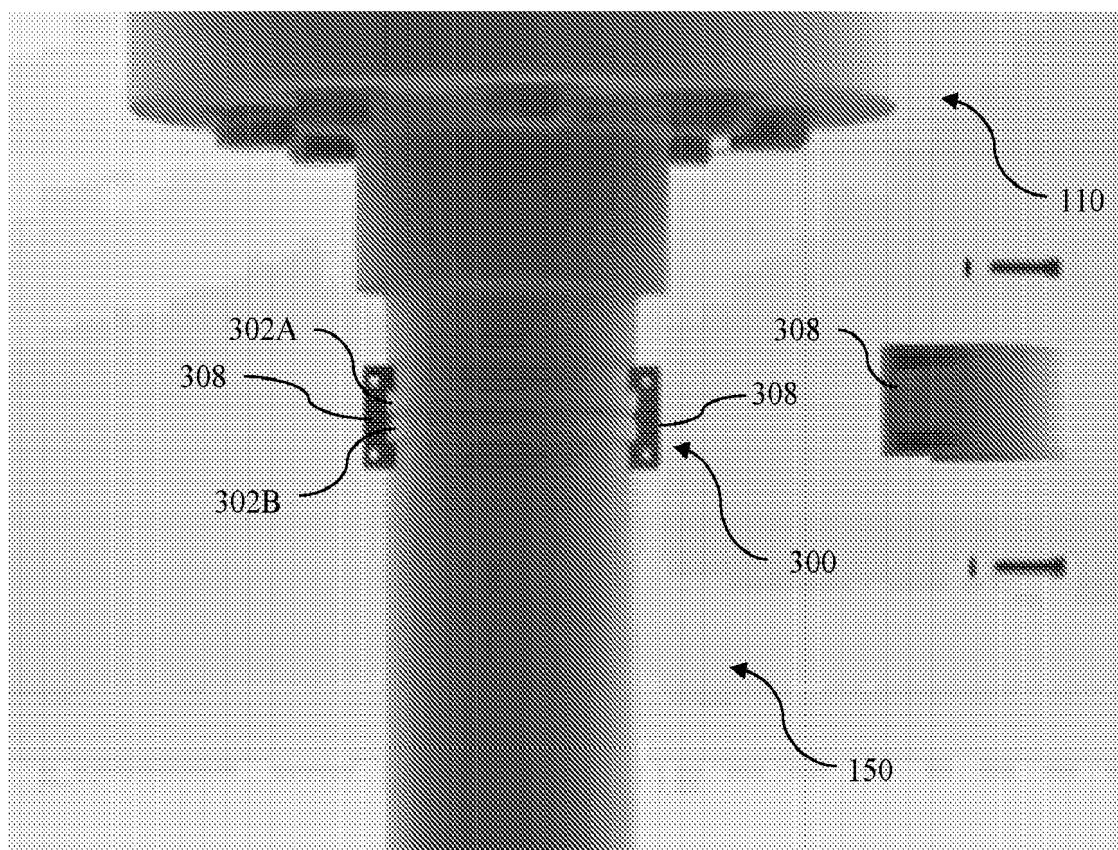


Figure 4

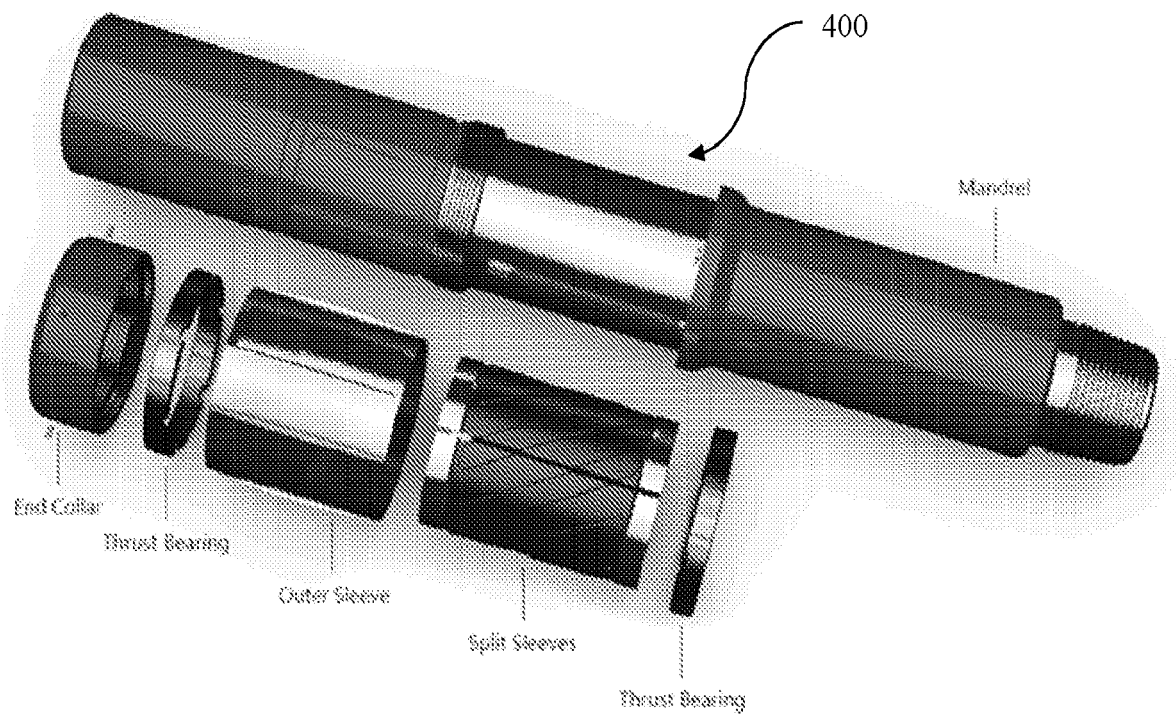


Figure 5A

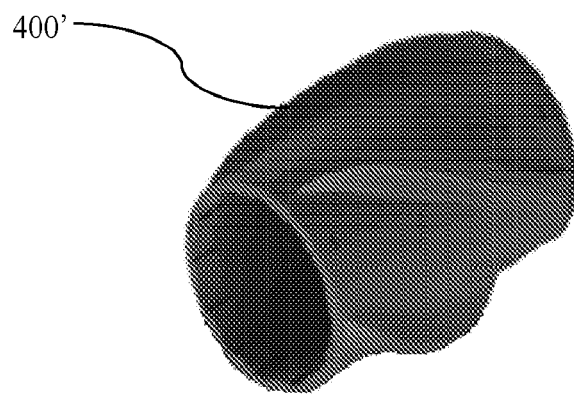


Figure 5B

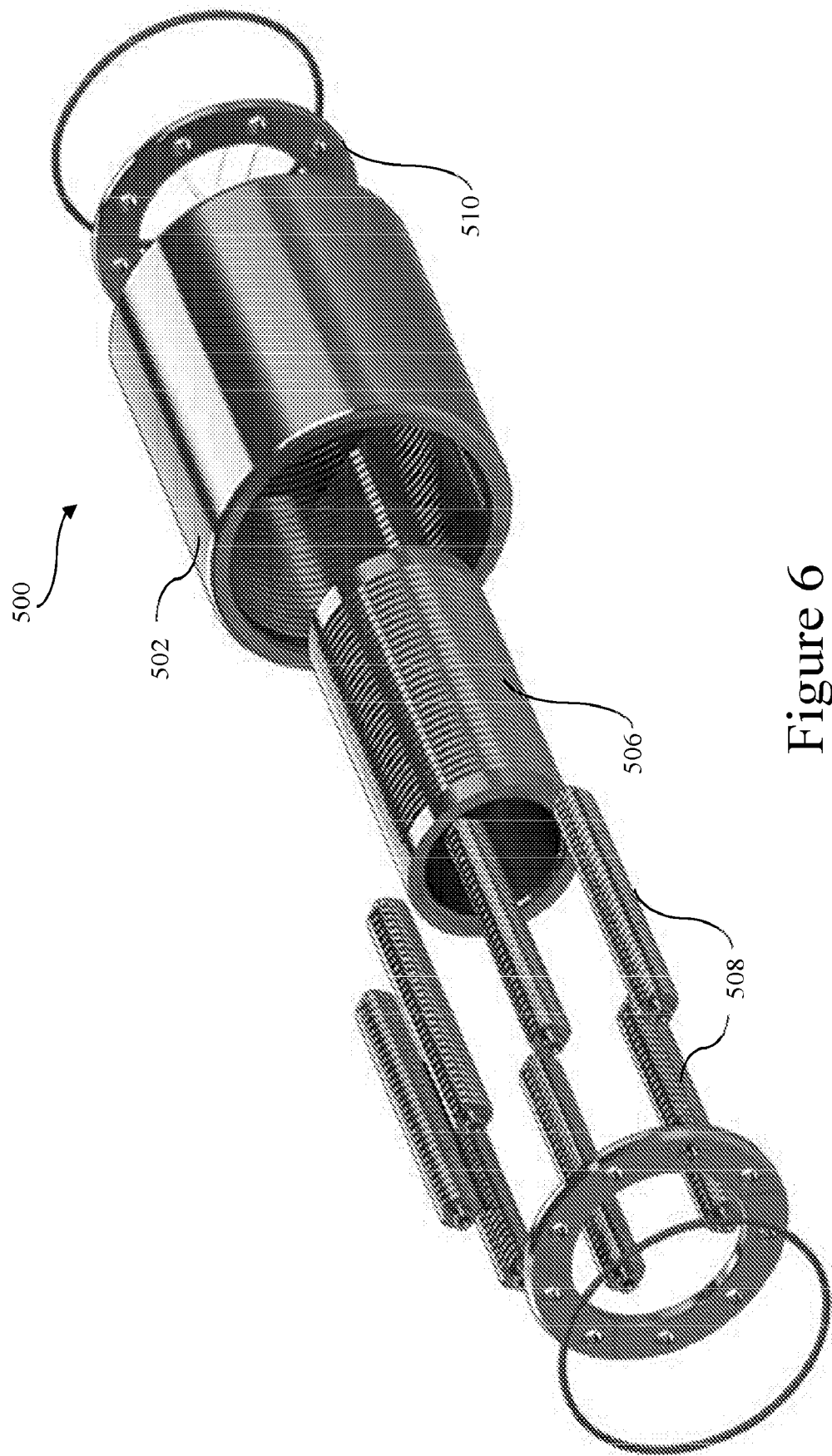


Figure 6

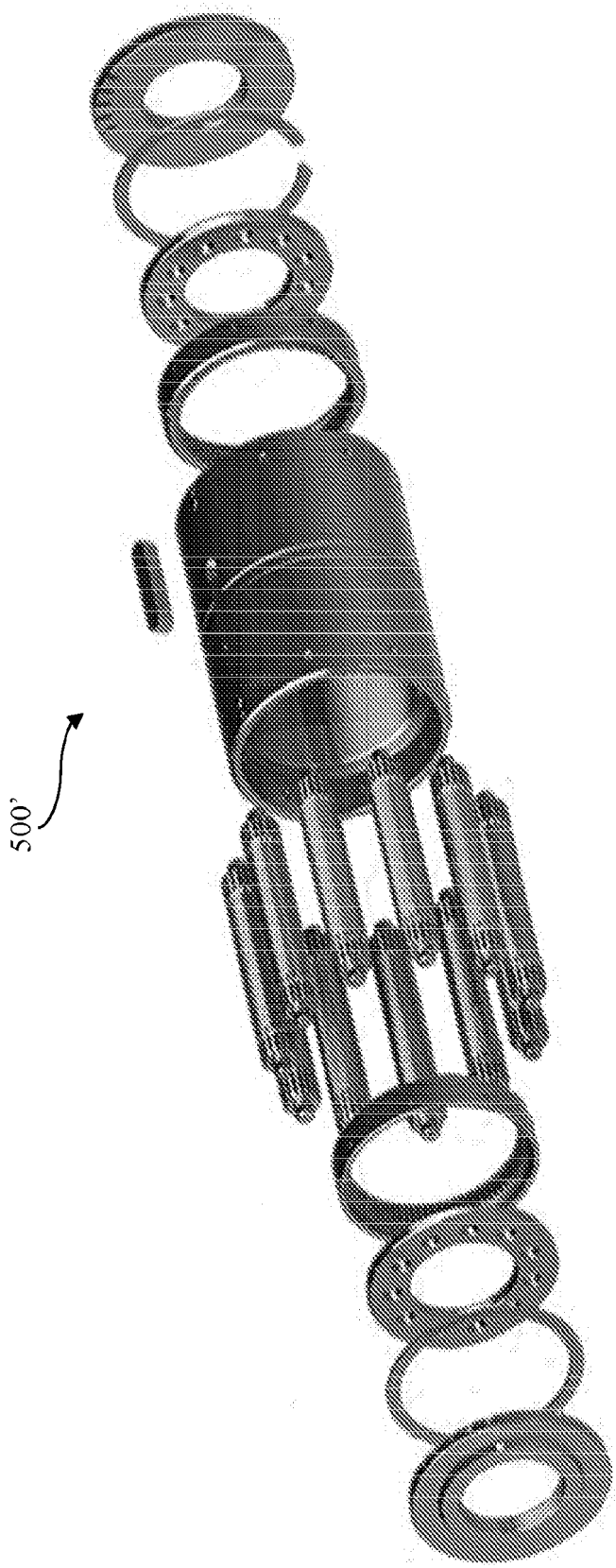


Figure 7

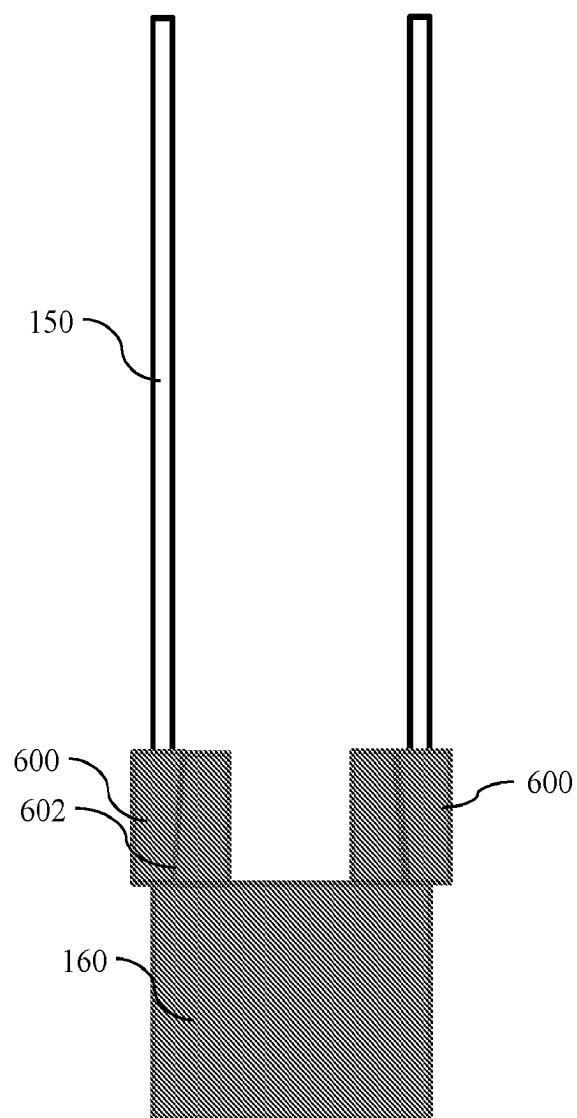


Figure 8

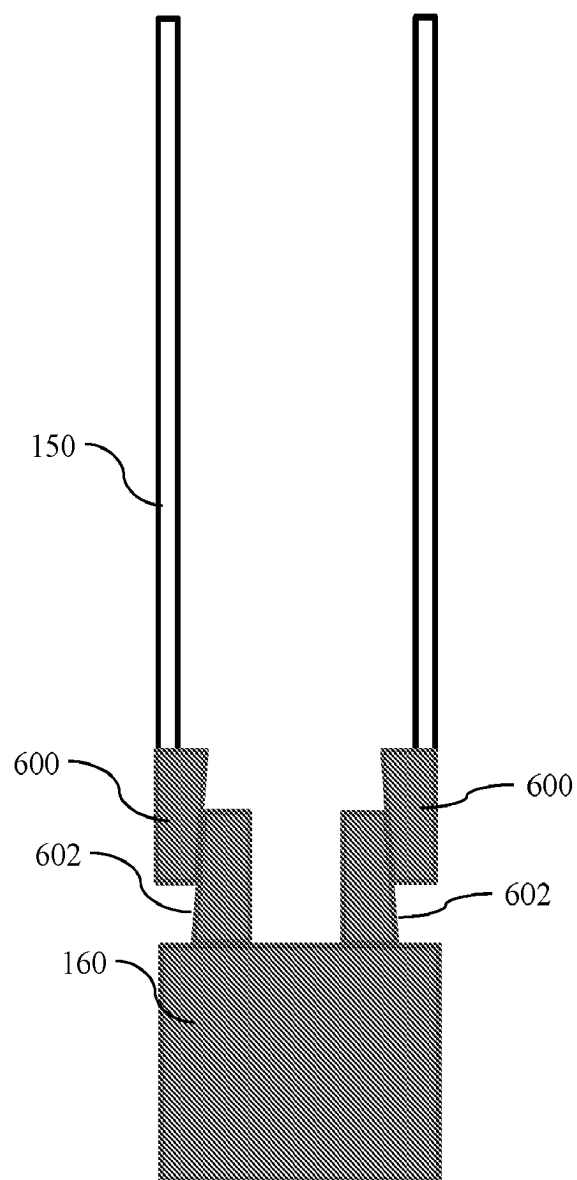


Figure 9

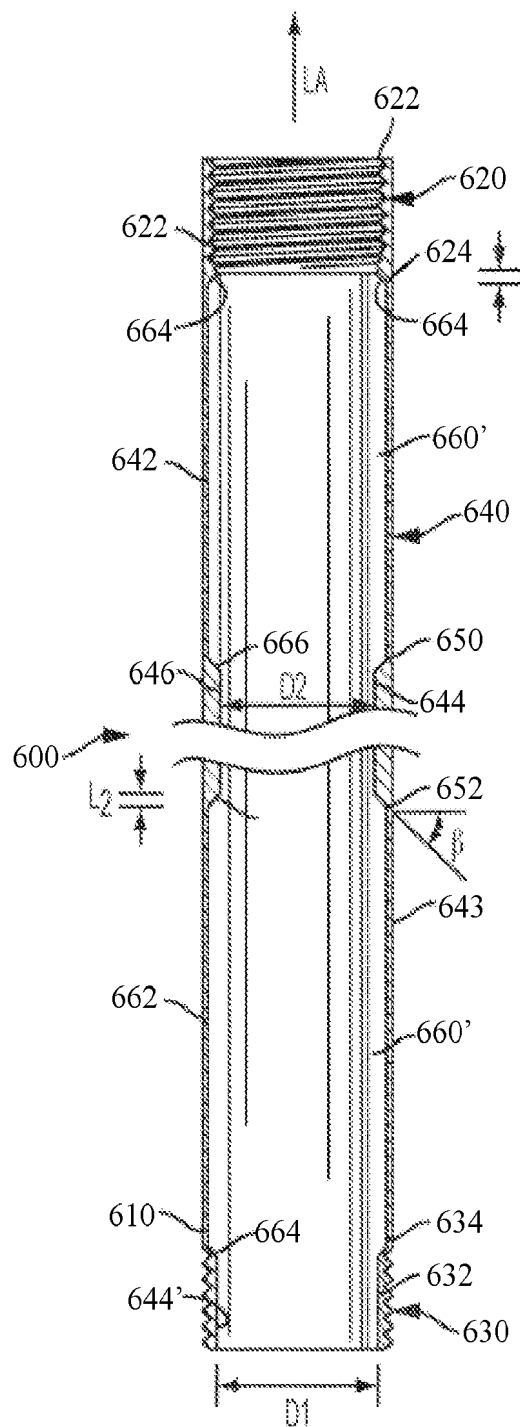


Figure 10

REFERENCES CITED IN THE DESCRIPTION

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