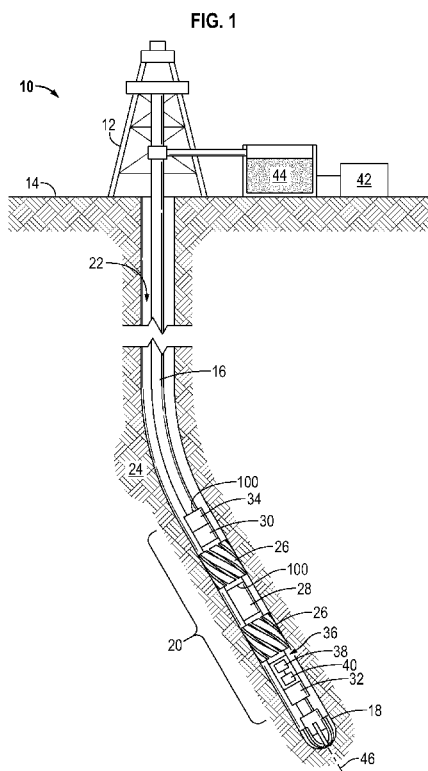




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[Continued on next page]

(54) Title: ROTARY SHOULDERS AND THREAD DESIGN



(57) Abstract: A thread structure in accordance to one or more embodiments includes a thread extending helically along the cylindrical member in spaced thread turns, the thread having a crest extending between a first flank and a second flank and a root extending between the thread turns, the root having a curvature defined by a portion of an ellipse tangentially adjoining the first and second flank at respective flank transition points, the ellipse having a major axis extending parallel to the axis and a minor axis extending perpendicular to the major axis and through a root bottom.



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ROTARY SHOULDERED CONNECTIONS AND THREAD DESIGN**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of priority to U.S. provisional patent application number 62/012232, filed on June 13, 2014, and U.S. Non-Provisional patent application number 14/737,443, filed on June 11, 2015, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] This section provides background information to facilitate a better understanding of the various aspects of the disclosure. It should be understood that the statements in this section of this document are to be read in this light, and not as admissions of prior art.

[0003] In downhole drilling, the drilling elements comprising a drilling tool are frequently coupled together by threaded structures. In these coupled drilling elements, the thread design is critical since failure often occurs in the thread structure. Whenever fatigue induced failure in the thread structure does occur, the initial crack starts at the thread root. This is due to the high stress concentrations located at the root of the threads when the thread structure is subject to severe loading.

SUMMARY

[0004] A thread structure in accordance to one or more embodiments includes a thread extending helically along the cylindrical member in spaced thread turns, the thread having a crest extending between a first flank and a second flank and a root extending between the thread turns, the root having a curvature defined by a portion of an ellipse tangentially adjoining the first and

second flank at respective flank transition points, the ellipse having a major axis extending parallel to the axis and a minor axis extending perpendicular to the major axis and through a root bottom. In some embodiments the major axis intersects the flank transition points. The thread structure may be incorporated in a rotary shouldered connection. In accordance to some embodiments, the rotary shouldered connection is utilized in a drill string, for example in the bottom hole assembly.

[0005] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The disclosure is best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of various features may be arbitrarily increased or reduced for clarity of discussion.

[0007] Figure 1 illustrates a drilling system incorporating a rotary shouldered connection in accordance to one or more aspects for drilling a wellbore, for example, a high dog-leg severity wellbore.

[0008] Figure 2 illustrates a rotary shouldered connection according to one or more aspects of the disclosure.

[0009] Figure 3 illustrates a thread structure and a thread root according to one or more aspects of the disclosure.

[0010] Figures 4 and 5 graphically illustrate stress characteristics of a thread root according to one or more aspects of the disclosure.

DETAILED DESCRIPTION

[0011] It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0012] As used herein, the terms connect, connection, connected, in connection with, and connecting may be used to mean in direct connection with or in connection with via one or more elements. Similarly, the terms couple, coupling, coupled, coupled together, and coupled with may be used to mean directly coupled together or coupled together via one or more elements. Terms such as up, down, top and bottom and other like terms indicating relative positions to a given point or element may be utilized to more clearly describe some elements. Commonly, these terms relate to a reference point such as the surface from which drilling operations are initiated.

[0013] Figure 1 is a schematic illustration of an embodiment of a directional drilling system, generally denoted by the numeral 10, in which embodiments of rotary shouldered connections 100 may be incorporated. Directional drilling system 10 includes a rig 12 located at surface 14 and a drill string 16 suspended from rig 12. A drill bit 18 is disposed with a bottom hole assembly ("BHA") 20 and deployed on drill string 16 to drill (i.e., propagate) borehole 22 into formation 24.

[0014] The depicted BHA 20 includes one or more stabilizers 26, a measurement-while-drilling ("MWD") module or sub 28, a logging-while-drilling ("LWD") module or sub 30, and a steering device 32 (e.g., bias unit, RSS device, steering actuator, pistons, pads), and a power generation module or sub 34. The illustrated directional drilling system 10 includes a downhole steering control system 36, e.g. control unit or attitude hold controller, disposed with BHA 20 and operationally connected with steering device 32 to maintain drill bit 18 and BHA 20 on a desired drill attitude to propagate borehole 22 along the desired path (i.e., target attitude). Depicted downhole steering control system 36 includes a downhole processor 38 and direction and inclination ("D&I") sensors 40, for example, accelerometers and magnetometers. Downhole steering control system 36 may be a closed-loop system that interfaces directly with BHA 20 sensors, i.e., D&I sensors 40, MWD sub 28 sensors, and steering device 32 to control the drill attitude. Downhole steering control system 36 may be, for example, a unit configured as a roll stabilized or a strap down control unit. Although embodiments are described primarily with reference to rotary steerable systems, it is recognized that embodiments may be utilized with non-RSS directional drilling tools. Directional drilling system 10 includes drilling fluid or mud 44 that can be circulated from surface 14 through the axial bore of drill string 16 and returned to surface 14 through the annulus between drill string 16 and formation 24.

[0015] The tool's attitude (e.g., drill attitude) is generally identified as the axis 46 of BHA 20. Attitude commands may be inputted (i.e., transmitted) from a directional driller or trajectory controller generally identified as the surface controller 42 (e.g., processor) in the illustrated embodiment. Signals, such as the demand attitude commands, may be transmitted for example via mud pulse telemetry, wired pipe, acoustic telemetry, and wireless transmissions. Accordingly, upon directional inputs from surface controller 42, downhole steering control

system 36 controls the propagation of borehole 22 for example by operating steering device 32 to steer the drill bit and to create a deviation, dogleg or curve in the borehole along the desired path. In particular, steering device 32 is actuated to drive the drill bit to a set point. The steering device or bias unit may be referred to as the main actuation portion of the directional drilling tool and may be categorized as a push-the-bit, point-the-bit, or hybrid device.

[0016] In point-the-bit devices, the axis of rotation of the drill bit 18 is deviated from the local axis of bottom hole assembly 20 in the general direction of the desired path (target attitude). The borehole is propagated in accordance with the customary three-point geometry defined by upper and lower stabilizer 26 touch points and the drill bit 18 touch point. The angle of deviation of the drill bit axis coupled with a finite distance between the drill bit and lower stabilizer results in the non-collinear condition required for a curve to be generated. There are many ways in which this may be achieved including a fixed bend at a point in the bottom hole assembly close to the lower stabilizer or a flexure of the drill bit drive shaft distributed between the upper and lower stabilizer.

[0017] In the push-the-bit rotary steerable system there is usually no specially identified mechanism to deviate the drill bit axis from the local bottom hole assembly axis; instead, the requisite non-collinear condition is achieved by causing either or both of the upper or lower stabilizers to apply an eccentric force or displacement in a direction that is preferentially orientated with respect to the direction of the borehole propagation. Again, there are many ways in which this may be achieved, including non-rotating (with respect to the hole) eccentric stabilizers (displacement based approaches) and eccentric actuators that apply force to the drill bit in the desired steering direction, e.g. by extending steering actuators into contact with the

surface of the borehole. Again, steering is achieved by creating non co-linearity between the drill bit and at least two other touch points.

[0018] The drilling system may be of a hybrid type, for example having a rotatable collar, a sleeve mounted on the collar so as to rotate with the collar, and a universal joint permitting angular movement of the sleeve relative to the collar to allow tilting of the axis of the sleeve relative to that of the collar. Actuators control the relative angles of the axes of the sleeve and the collar. By appropriate control of the actuators, the sleeve can be held in a substantially desired orientation while the collar rotates. Non-limiting examples of hybrid systems are disclosed for example in U.S. Pat. Nos. 8,763,725 and 7,188,685.

[0019] The development of rotary steerable systems such as available under the POWERDRIVE™, e.g. the POWERDRIVE ARCHER®, trademark from Schlumberger Technology Corporation, has enabled the execution of high dog leg severity (DLS) drilling. As a result of the elevated degree of DLS, the bottom hole assembly (BHA) 20 components in the drill string 16 are subjected to higher bending cyclical loads. In turn, the increase in dynamic bending loads shortens the fatigue life of the components and failures occur, e.g., twist-off failures. Abundant field experience and theoretical analysis have shown that most fatigue failures occur at the rotary shouldered connections (RSCs) located at each end of the BHA components. Traditionally, the RSCs used have been standard API tapered threaded connections. While standard API threaded joints are widely used in the drilling industry, their fatigue strength is too low to meet the requirements imposed by the high DLS market.

[0020] When fatigue failure occurs in the threaded connection, the crack tends to initiate at the thread root of the weaker member (pin or box). An optimized root design is critical to reducing

stress concentration in the root, thereby enhancing fatigue strength. Figure 2 illustrates a rotary shouldered connection (RSC) 100 in accordance to one or more embodiments having a thread structure 110 design for high-DLS (dog-leg severity) field joints, i.e. connections. Rotary shouldered connection 100 includes a pin end 103 of a member 112 having external thread structures 110 and a box end 105 of another member 112 having internal thread structures 110. Members 112 are cylindrical or tubular support members, e.g., pipe, collars. The RSC 100 is illustrated in Figure 2 made-up with the pin end shoulder 119 and the box end shoulder 121, e.g., contact surfaces, contacting one another. The threaded connection is subject to a tensile load 48 along the longitudinal axis 2-2 of the connection. With reference to Figure 1, rotary shouldered connection 100 is described in particular with reference to the bottom hole assembly 20, however, rotary shouldered connections 100 may be utilized throughout the drill string 16.

[0021] Figure 3 illustrates a thread structure 110 in accordance to one or more embodiments. With continued reference in particular to Figures 2 and 3, RSC 100 has a tangential elliptical thread root portion 116 design with an optimized root depth 62 and thread parameters such as pitch 50, equivalent root radius 52, and flank angle 54 which corresponds to flank 118-1 in Figure 3. The flank angle of the flank 118-2 on the opposite side of root portion 116 is identified with the reference number 54-2. As will be understood by those skilled in the art with benefit of the disclosure flank angles 54 and 54-2 may be the same or different. Analytical and numerical results indicate that the rotary shouldered connection 100 thread designs significantly increase the BHA connection life under high-DLS conditions compared to commonly used standard API threads. For example, at 15 deg./100 ft DLS, a minimum factor 4 enhancement in fatigue life is predicted compared to NC38 thread, which is the most commonly used API connection for example for 4.75 inch tools.

[0022] At least one thread 114 extends helically along the cylindrical support member 112 in spaced thread turns. Thread 114 may be a single start helix or a double start helix. The thread structure may have a taper described for example as a uniform change in the diameter of a work piece measured along its axis and measured for example in taper per foot, taper per inch, in degrees, and for example in the metric system as a ratio of diameter change over length. With reference to Figure 2 a taper may be defined in terms of the change in diameter between first diameter 3 and second diameter 5 along the length 7. The thread structure may have a pitch 50, shown from crest to crest in Figure 2, identified in terms of threads per length or distance between crests. For example, a rotary shouldered connection having three threads per inch (TPI) may also be referred to as having a pitch of $1\frac{1}{3}$ or 0.3336 inches.

[0023] Wall surface 111 represents the external cylindrical surface of a box end 105 thread structure 110 or the central bore surface of a pin end 103 thread structure 110. A thread root portion 116 is located between adjacent threads 114, i.e. adjacent thread turns. The root portion 116 has a root bottom 115 and a curved surface extending between flank transition points 117. Thread structure 110 includes flanks, generally identified with reference number 118 and specifically as 118-1 and 118-2, on opposing sides of crest 120. One of flank 118-1 and 118-2 may be load bearing, e.g., 118-1, and the other of flank 118-1 and 118-2 a non-load bearing, or stab, flank, e.g., 118-2. When the thread structure is subject to loading the forces will be transmitted between coupled pin end 103 and box end 105 thread structures via contiguous mating load bearing flanks 118-1 of the respective pin and box threads, see e.g., Figure 2.

[0024] Figure 3 depicts a thread structure 110 having a tangential elliptical root portion 116 design. The depicted root portion 116 has a curvature defined by a portion of an ellipse 66, tangentially adjoining the two flanks 118, a load bearing flank 118-1 and a non-load bearing

flank 118-2, of the adjacent threads 114, i.e. thread turns, at flank transition points 117. The ellipse 66 has a major axis 122 and a shorter minor axis 124 extending perpendicularly from the major axis. The major axis 122 extends parallel with the longitudinal axis 2-2 of the support member 112. Minor axis 124 extends radially outward and perpendicular from the support member 112, e.g., perpendicular to the axis 2-2. For example, minor axis 124 may extend radially outward from root bottom 115. The root depth 62 extends from the flank transition point 117 to the root bottom 115. In Figure 3, the major axis 122 is illustrated vertically offset from intersecting the transition points 117 and positioned vertically above the transition point 117 relative to the root bottom 115.

[0025] The transition points 117 are points of tangency of the extending flanks 118 with the ellipse 66. The flank angles 54 of the adjacent flanks 118 separated by root portion 116 or the flanks separated by crest 120 may be equal or different. In Figure 3, the flank angle 54 of adjacent load bearing and non-load bearing flanks are equal and the surface area of the load flank bearing and non-load bearing flank are equal. In some embodiments, the flank angles of the adjacent load and non-load flanks may be different. The depicted root portion 116 curvature is symmetric, however the root curvature may be asymmetric.

[0026] With reference to Figures 2 and 3, thread structure 110 includes the thread parameters described in Table 1 below.

TABLE 1

<u>Name</u>	<u>Symbol</u>	<u>Reference No.</u>
Pitch		50 (FIG. 2)
Equivalent Root Radius	R	52 (FIG. 3)
Flank Angle	FA	54 (FIG. 3)
Root Semi-Width at Flank Transition Point	SW ($SW = R\cos(FA)$)	56 (FIG. 3)
Root Width at Crest	RW ($RW = \text{Pitch} - (\text{Crest Width})$)	58 (FIG. 3)
Truncated Thread Height	TH ($TH = [RW/2 - R\cos(FA)]/\tan(FA) + RD$)	60 (FIG. 3)
Root Depth between Flank Transition Points 117 and Root Bottom 115	RD	62 (FIG. 3)
Crest Width		64 (FIG. 3)

[0027] The thread structure 110 of RSC 100 has larger pitch 50 and larger equivalent root radius 52, and smaller flank angle 54, relative to a round root configuration for example of a standard API NC38 thread, to reduce stress concentration in the root portion 116 and maintain shear resistance and galling resistance of the thread. Various root designs such as circular, tangential ellipse, non-tangential ellipse, and cubic spline are contemplated, and finite element analysis (FEA) of a notched specimen indicates that using a tangential elliptical shape is most effective in reducing stress concentration in the root portion.

[0028] In accordance to some aspects, the root portion 116 in the thread structure 110 has an equivalent root radius 52 defined by a portion of an ellipse 66, tangentially adjoining the two flanks 118 of the adjacent threads 114, see e.g. Figure 3. The "equivalent radius" or "equivalent root radius" is the local radius of the ellipse at the transition point where the flank 118 is tangent to the ellipse 66, i.e., transition point 117. With reference to Figure 3, the equivalent radius 52 extends at a right angle to the flank at the tangent point 117 to the ellipse center which

corresponds to minor axis 124 in Figure 3. The thread structure 110 with an equivalent root radius 52 that is longer than a circular or round radius provides a greater relief in stress concentration in the root. For a given root semi-width 56, the root depth 62 can be optimized such that the peak stress is maintained in the middle of the root portion 116, with the manufacturing tolerance considered (e.g. machined or cold rolled). For example, the nominal dimensions in the proximity of a root depth 62 of about 0.014 inches (RD = 0.014 inches) if machined, or about 0.015 inches if cold rolled, and a root semi-width 56 of about 0.53 inches (SW = 0.053 inches) are illustrated in Figures 4 and 5. Figure 4 illustrates the root depth 62 plotted against a stress concentration factor (SCF). Stress concentration factor (SCF) may for example be a local peak alternating stress in a component divided by the nominal alternating stress in the pipe wall at the location of the component. Figure 5 illustrates a normalized position against the axial normal stress in kilopounds per square inch (ksi) for various dimensions of root depth 62 in inches.

[0029] FEA results demonstrate that thread structure 110 has the similar tensile/shear capacity as standard API NC38 thread. A summary of non-limiting examples of primary thread parameters of thread structures 110 in accordance to one or more embodiments are listed in in Table 2.

TABLE 2

Root Semi-Width 56	~ 0.050 to ~ 0.061 inches
Equivalent Root Radius 52	~ 0.057 to ~ 0.061 inches
Flank Angle 54	~ 20° to ~ 30°
Crest Width 64	~ 0.1 to ~0.2 inches
Root Depth 62	~ 0.012 to ~ 0.020 inches
Semi-Major Axis 122	~0.050 to ~0.055 inches
Semi-Minor Axis 124	~0.013 to ~0.020 inches
Taper (T.P.F.)	~ 1.0 to ~1.5 taper per foot
Pitch (T.P.I.) 50	~ 3 threads per inch

[0030] In accordance to one or more aspects, the characteristics of a rotary shouldered connection 100 includes a thread structure 110 having a tangential elliptical root portion 116 design with one or more of an equivalent root radius 52 of approximately 0.059 inches and a root depth 62 of approximately 0.014 inches, a single-start helix thread 114, pitch 50 of about 3 threads per inch, taper of about 1.25 taper per foot, and a flank angle 54 of about 25 degrees, for example the flank angle 54 of flank 118-1 in Figure 3, a semi-major axis length of about 0.053 inches and a semi-minor axis length of about 0.016 inches. The flank angles 54 and 54-2 may be the same or different. In accordance to some embodiments a life enhancement minimum factor of 2 to 4 based on connection FEA. The average contact pressure on the load bearing flank 118-1 induced by makeup torque (MUT) may increase by about 6 to 15 percent. The average contact pressure on a shoulder 119, 121, e.g., induced by MUT, may increase by about 8 to 10 percent. Sealing may improve relative to the API standard NC38 thread. The thread structure 110 may have similar tensile capacity and shear capacity to the API standard NC38 thread. In accordance

to some aspects, compressive treatments such as shot-peening and cold-rolling may be applied to the thread structure to further improve fatigue life of the threads.

[0031] In accordance to one or more aspects, the thread structure 110 may have an equivalent root radius 52 of about 0.057 inches to about 0.061 inches, a flank angle 54 of about 20 to about 30 degrees, a crest width 64 of about 0.1 to about 0.2 inches, and a root depth 62 of about 0.012 to about 0.020 inches. The thread structure 110 may have a root semi-width 56 at flank transitions points of about 0.050 to about 0.060, a pitch 50 of about three threads per inch, and a taper of about 1.0 to about 1.5 taper per foot. The major axis 122 may have a semi-major axis length for example of about 0.050 inches to about 0.055 inches and a semi-minor axis 124 length of about 0.013 to about 0.020 inches.

[0032] In accordance to one or more embodiments, a thread structure 110 has a tangential elliptical root portion 116 geometry with an equivalent root radius of about 0.057 inches to about 0.061 inches, a flank angle of about 25 to about 27.5 degrees, and a root depth of about 0.014 to about 0.016 inches.

[0033] The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the disclosure. Those skilled in the art should appreciate that they may readily use the disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the disclosure. The scope of the invention should be determined only by the language of the

claims that follow. The term "comprising" within the claims is intended to mean "including at least" such that the recited listing of elements in a claim are an open group. The terms "a," "an" and other singular terms are intended to include the plural forms thereof unless specifically excluded.

WHAT IS CLAIMED IS:

1. A thread structure, comprising:
 - a cylindrical member extending along an axis;
 - a thread extending helically along the cylindrical member in spaced thread turns, the thread comprising:
 - a crest extending between a first flank and a second flank; and
 - a root extending between the thread turns, the root having a curvature defined by a portion of an ellipse tangentially adjoining the first and second flank at respective flank transition points, the ellipse having a major axis extending parallel to the axis and a minor axis extending perpendicular to the major axis and through a root bottom.
2. The thread structure of claim 1, further comprising:
 - a root semi-width at the flank transition points of about 0.050 to about 0.061 inches;
 - an equivalent root radius of about 0.057 to about 0.061 inches; and
 - a root depth of about 0.012 to about 0.020 inches.
3. The thread structure of claim 2, wherein the root depth is about 0.013 to about 0.016 inches.
4. The thread structure of claim 1, further comprising:
 - a root semi-width at the flank transition points of about 0.050 to about 0.055 inches;
 - an equivalent root radius of about 0.057 to about 0.061 inches; and

- a root depth of about 0.012 to about 0.016 inches.
5. The thread structure of claim 4, wherein the root depth is about 0.014 to about 0.015 inches.
 6. The structure of claim 1, further comprising:
a root depth of about 0.012 to about 0.020 inches;
a root semi-width at the flank transition points of about 0.050 to about 0.060 inches; and
a pitch of about three threads per inch.
 7. The structure of claim 1, further comprising:
a root depth of about 0.013 to about 0.016 inches;
a root semi-width at the flank transition points of about 0.050 to about 0.055 inches; and
a pitch of about three threads per inch.
 8. The structure of claim 1, further comprising:
a root semi-width at the flank transition points of about 0.050 to about 0.061 inches;
an equivalent root radius of about 0.057 to about 0.061 inches;
a first flank angle relative to the minor axis of about 20 to about 30 degrees;
a root depth of about 0.012 to about 0.020 inches;
a pitch of about three threads per inch; and
a taper of about 1.0 to about 1.5 tapers per foot.
 9. The structure of claim 1, further comprising:

a root semi-width at the flank transition points of about 0.052 inches to about 0.055 inches;

an equivalent root radius of about 0.057 to about 0.059 inches;

a first flank angle relative to the minor axis of about 24 to about 28.5 degrees;

a root depth of about 0.013 to about 0.016 inches;

a pitch of about three threads per inch; and

a taper of about 1.0 to about 1.5 tapers per foot.

10. The structure of claim 1, further comprising:

an equivalent root radius of about 0.057 to about 0.059 inches;

a first flank angle relative to the minor axis of about 24 to about 28.5 degrees;

a crest width of about 0.1 to about 0.2 inches; and

a pitch of about three threads per inch.

11. A rotary shouldered connection (RSC), the RSC comprising:

a first tubular having a longitudinal axis and a pin end carrying a thread structure;

a second tubular having a box end carrying a thread structure, wherein the pin end and the box end are threadedly connected;

the thread structure including a thread extending helically in spaced thread turns, the thread comprising:

a crest extending between a first flank and a second flank; and

a root extending between the thread turns, the root having a curvature defined by

a portion of an ellipse tangentially adjoining the first and second flank at

respective flank transition points, the ellipse having a major axis extending

parallel to the longitudinal axis and a minor axis extending perpendicular to the major axis and through a root bottom.

12. The RSC of claim 11, wherein the thread comprises:
 - a root semi-width at the flank transition points of about 0.050 to about 0.061 inches;
 - an equivalent root radius of about 0.057 to about 0.061 inches; and
 - a root depth of about 0.012 to about 0.020 inches.
13. The RSC of claim 11, wherein the thread comprises:
 - an equivalent root radius of about 0.057 to about 0.059 inches;
 - a first flank angle relative to the minor axis of about 24 to about 28.5 degrees;
 - a crest width of about 0.1 to about 0.2 inches; and
 - a pitch of about three threads per inch.
14. The RSC of claim 11, wherein the thread comprises:
 - a root semi-width at the flank transition points of about 0.050 to about 0.061 inches;
 - an equivalent root radius of about 0.057 to about 0.061 inches;
 - a first flank angle relative to the minor axis of about 20 to about 30 degrees;
 - a root depth of about 0.012 to about 0.020 inches;
 - a pitch of about three threads per inch; and
 - a taper of about 1.0 to about 1.5 tapers per foot.
15. The RSC of claim 11, wherein the thread comprises:
 - a root semi-width at the flank transition points of about 0.052 to about 0.055 inches;

an equivalent root radius of about 0.057 to about 0.059 inches;
a first flank angle relative to the minor axis of about 24 to about 28.5 degrees;
a root depth of about 0.013 to about 0.016 inches;
a pitch of about three threads per inch; and
a taper of about 1.0 to about 1.5 tapers per foot.

16. A drilling system, comprising:

a drilling string comprising a rotary shouldered connection (RSC) having a thread

structure on a tubular support member having a longitudinal axis, the thread

structure including a thread extending helically in spaced thread turns, the thread comprising:

a crest extending between a first flank and a second flank; and

a root extending between the thread turns, the root having a curvature defined by

a portion of an ellipse tangentially adjoining the first and second flank at

respective flank transition points, the ellipse having a major axis extending

parallel to the longitudinal axis and a minor axis extending perpendicular

to the major axis and through a root bottom.

17. The system of claim 16, wherein the thread comprises:

a root semi-width at the flank transition points of about 0.050 to about 0.061 inches;

an equivalent root radius of about 0.057 to about 0.061 inches; and

a root depth of about 0.012 to about 0.020 inches.

18. The system of claim 16, wherein the thread comprises:

an equivalent root radius of about 0.057 to about 0.059 inches;
a first flank angle relative to the minor axis of about 24 to about 28.5 degrees;
a crest width of about 0.1 to about 0.2 inches; and
a pitch of about three threads per inch.

19. The system of claim 16, wherein the thread comprises:

a root semi-width at the flank transition points of about 0.050 to about 0.061 inches;
an equivalent root radius of about 0.057 to about 0.061 inches;
a first flank angle relative to the minor axis of about 20 to about 30 degrees;
a root depth of about 0.012 to about 0.020 inches;
a pitch of about three threads per inch; and
a taper of about 1.0 to about 1.5 tapers per foot.

20. The system of claim 16, wherein the thread comprises:

a root semi-width at the flank transition points of about 0.052 to about 0.055 inches;
an equivalent root radius of about 0.057 to about 0.059 inches;
a first flank angle relative to the minor axis of about 24 to about 28.5 degrees;
a root depth of about 0.013 to about 0.016 inches;
a pitch of about three threads per inch; and
a taper of about 1.0 to about 1.5 tapers per foot.

FIG. 1

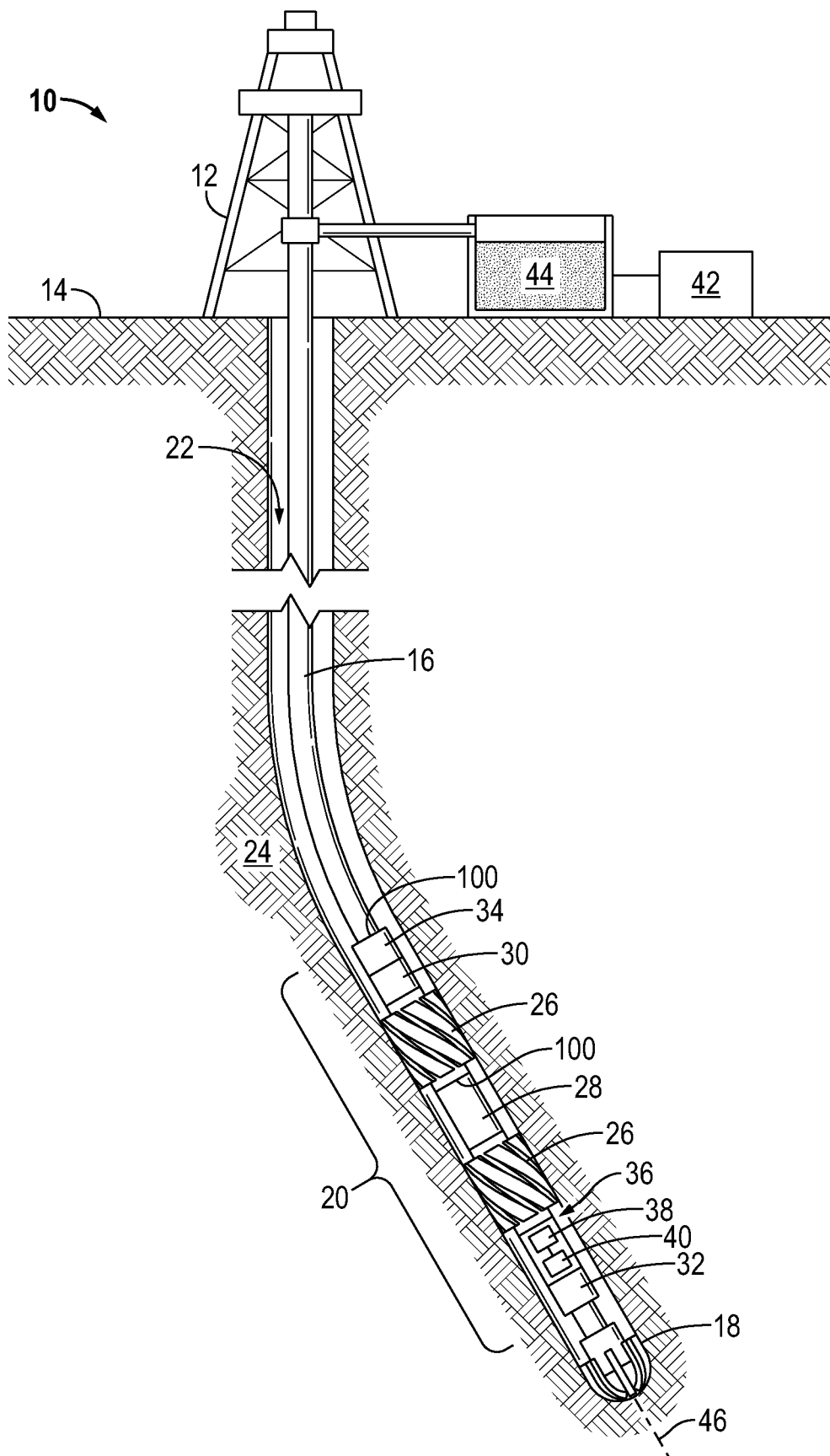


FIG. 2

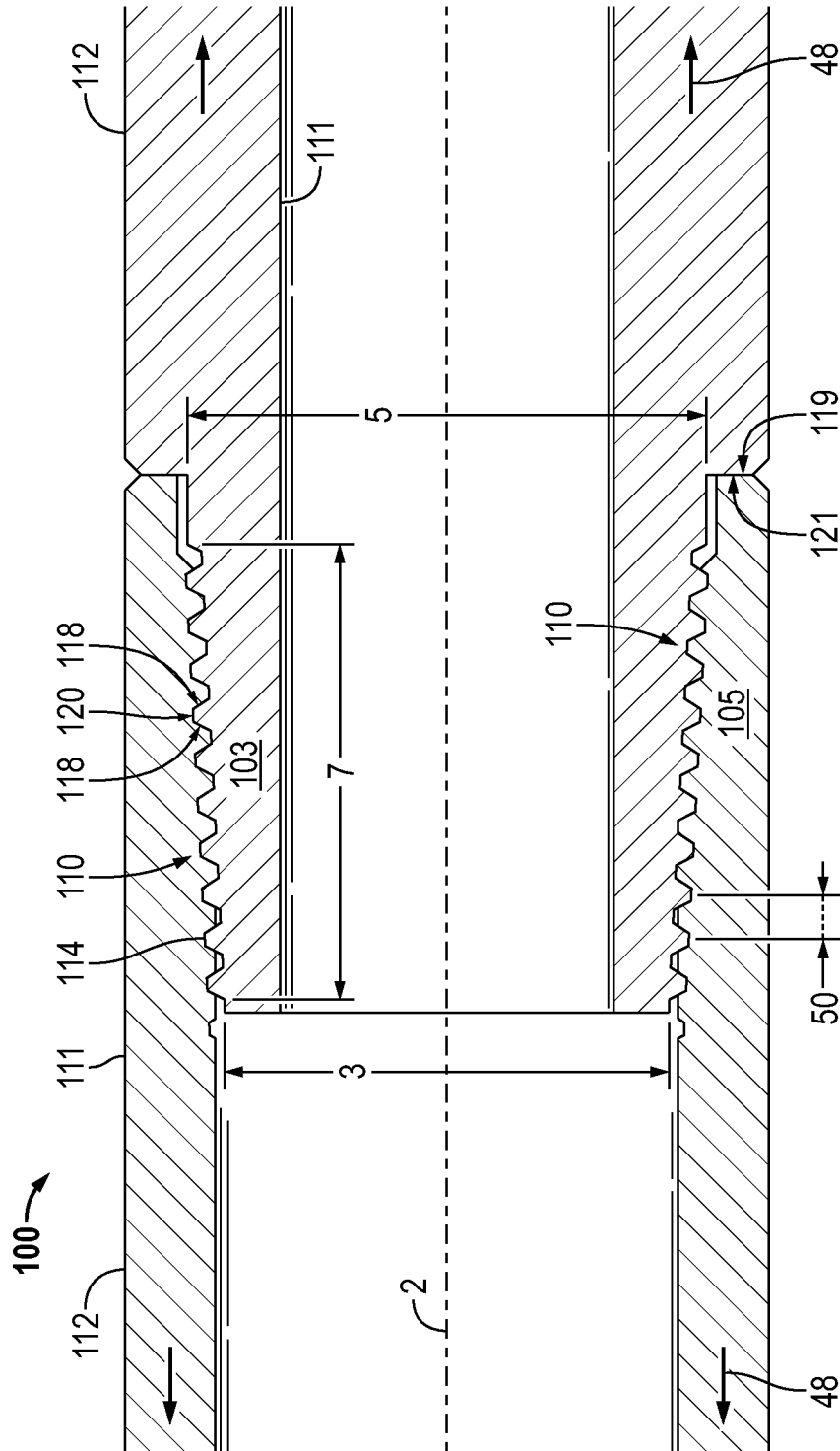


FIG. 3

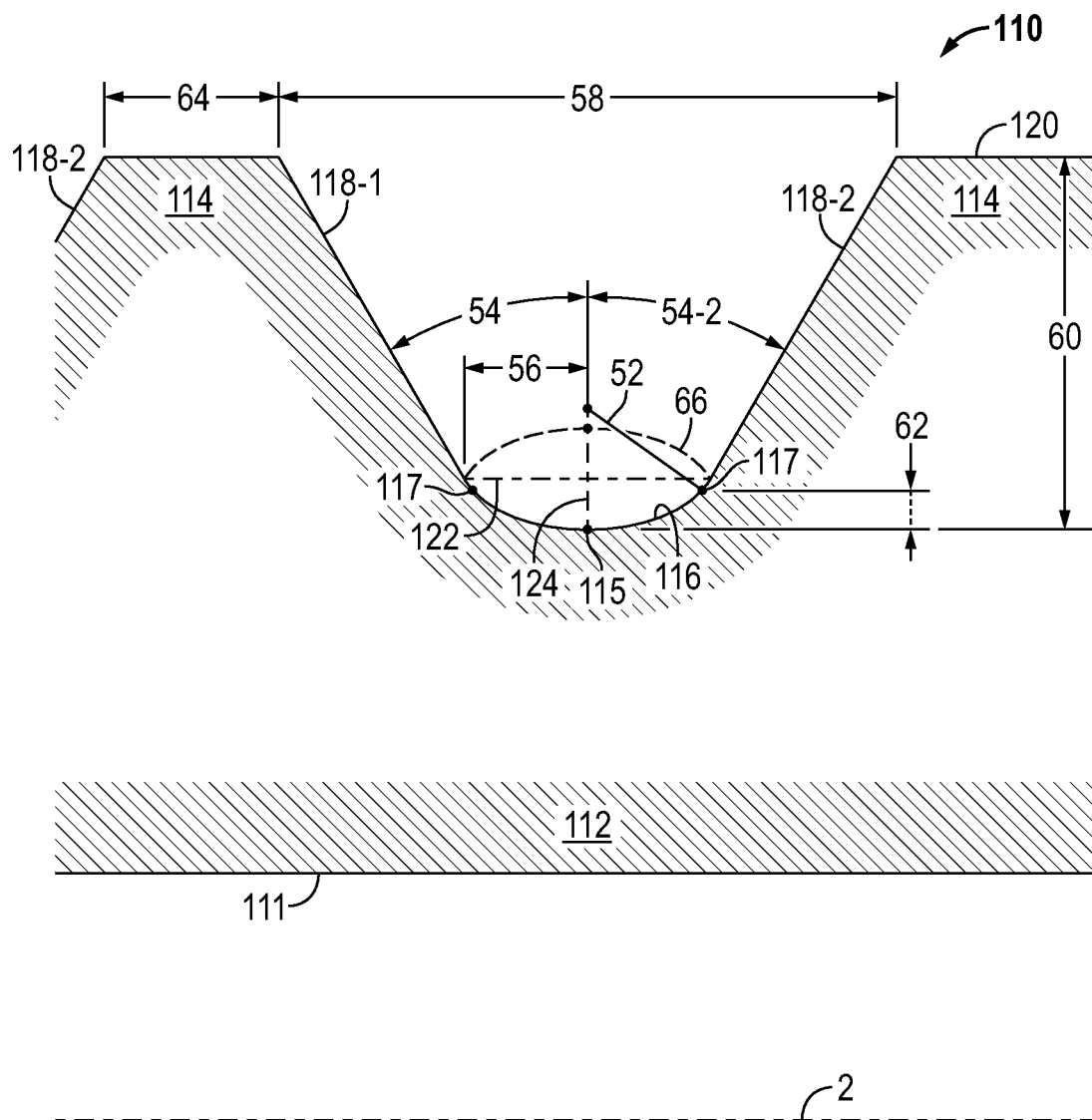


FIG. 4

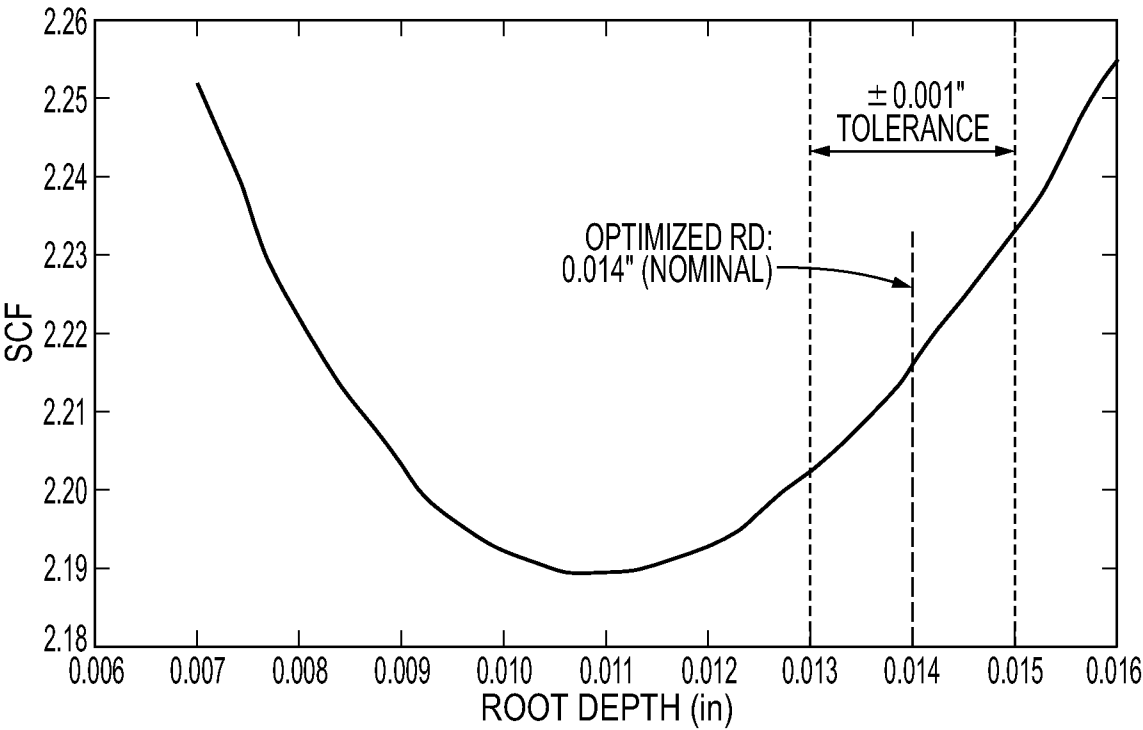
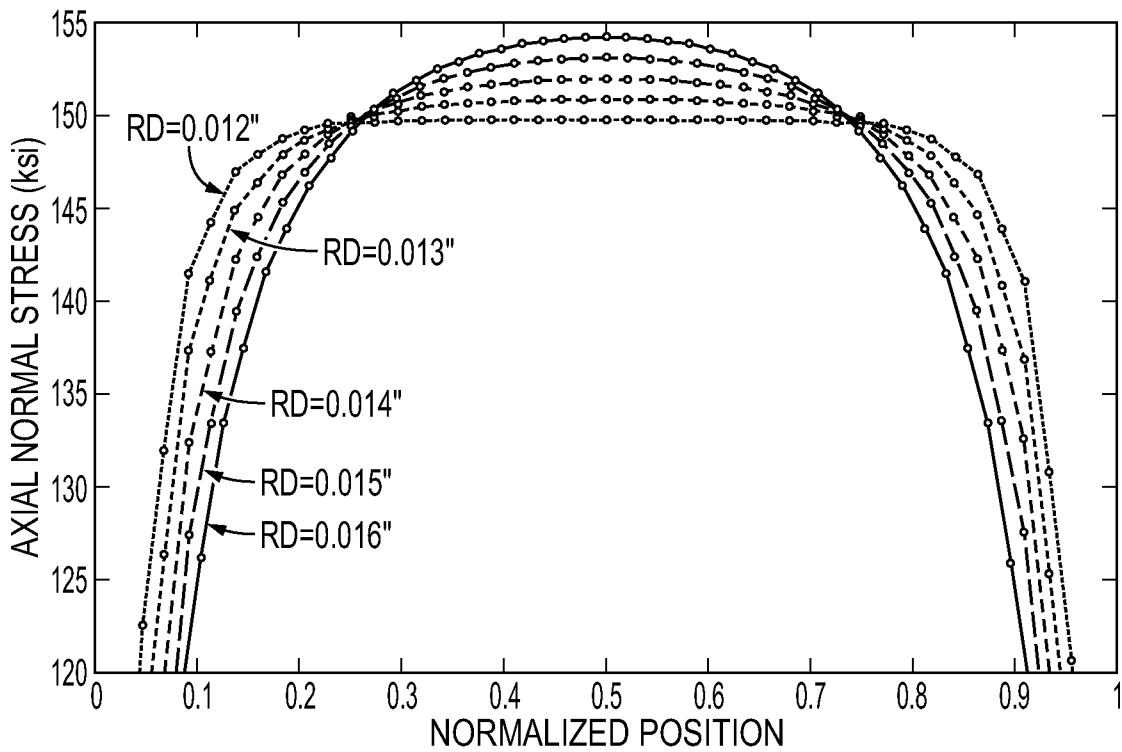


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/035451**A. CLASSIFICATION OF SUBJECT MATTER****E21B 17/02(2006.01)i, E21B 17/042(2006.01)i, E21B 17/20(2006.01)i, F16L 15/06(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 17/02; F16L 25/00; F16D 1/00; B23C 3/32; H02G 3/06; E21B 29/02; E21B 17/042; E21B 17/20; F16L 15/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: thread, root, flank, cylindrical, crest, curvature, axis, connection and ellipse

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002-0113436 A1 (VERDILLON, LIONEL) 22 August 2002 See paragraphs [0013]-[0081], [0122]-[0162], [0219]-[0275], and figures 1-7E.	1-20
A	US 7078623 B1 (SHEEHAN, ROBERT K.) 18 July 2006 See column 7, lines 40-43 and figure 3.	1-20
A	US 2010-0123311 A1 (CHURCH, KRIS L.) 20 May 2010 See paragraphs [0043]-[0045] and figure 1.	1-20
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A	US 2007-0131412 A1 (FINCI, BULENT et al.) 14 June 2007 See paragraphs [0014]-[0018] and figure 1.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

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