



(43) International Publication Date
19 February 2015 (19.02.2015)

- (51) International Patent Classification:
E21B 10/42 (2006.01) *E21B 12/00* (2006.01)
- (21) International Application Number:
PCT/US2014/051225
- (22) International Filing Date:
15 August 2014 (15.08.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/866,365 15 August 2013 (15.08.2013) US
14/459,936 14 August 2014 (14.08.2014) US
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- (81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM,
TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM,
ZW.

- (84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))

(54) Title: LOCKING RING WITH TAPERED RECESSES

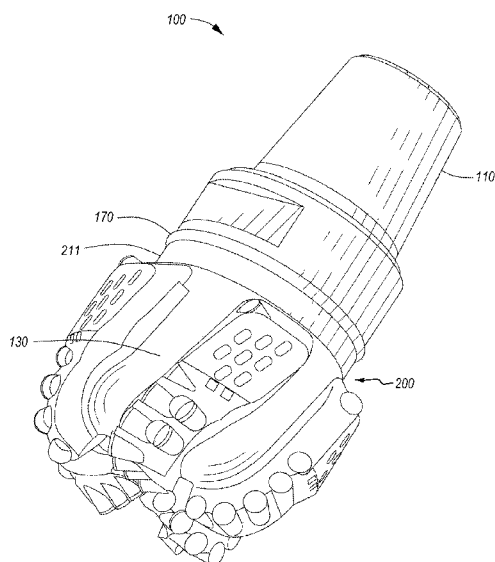


FIG. 1

(57) Abstract: A locking ring positioned between first and second components. The locking ring includes a body having first and second opposing axial surfaces and a bore formed axially therethrough. A recess is formed into the second axial surface. The recess is defined by an outer radial surface, first and second opposing circumferentially offset surfaces, and an inner axial surface disposed between the first and second axial surfaces. At least a portion of first circumferentially offset surface is oriented at an angle between 30° and 85° with respect to a plane that is perpendicular to a longitudinal centerline through the body.

TITLE

LOCKING RING WITH TAPERED RECESSES

CROSS-REFERENCE TO RELATED APPLICATIONS

5 **[0001]** The present application claims priority to and the benefit of United States Patent Application No. 14/459,936, entitled “LOCKING RING WITH TAPERED RECESSES,” and filed August 14, 2014, which claims priority to and the benefit of United States Provisional Patent Application No. 61/866,365, entitled “LOCKING RING WITH TAPERED RECESSES,” and filed August 15, 2013, the disclosures of which are
10 incorporated herein by reference in their entireties.

BACKGROUND

[0002] In downhole tools, two components that have a similar composition may be connected by the fusing or addition of material. For example, two components made of
15 steel may be connected to one another through welding and/or brazing. The two components may be positioned near or adjacent one another and heated metal or additional steel may be applied to an interface between the two components to bind the two components together. However, the application additional material may result in a poor connection between components made of or including dissimilar compositions.

20 **[0003]** A connection pin may be used to couple a bit to a drill string. In such bits, the connection pin has threads formed on the outer surface thereof, and the bit has corresponding threads formed on the inner surface thereof. The threaded engagement, by itself, may not be sufficient to hold the connection pin and the bit together downhole due to high loads and/or vibration while drilling. Further, it may be difficult to weld the
25 connection pin and the bit together to fortify the engagement if they are made from different materials with different melting points. For example, the connection pin may be made of steel, and the bit may be made of tungsten carbide matrix.

[0004] As such, a steel locking ring may be positioned between the connection pin and the bit. One axial surface of the locking ring is welded to the connection pin. The
30 other axial surface of the locking ring has several circumferentially-offset pockets or recesses that are adapted to receive corresponding circumferentially-offset axial protrusions or “castellations” formed on an axial surface of the drill bit. The pockets interlock with the castellations to fortify the engagement between the locking ring and the bit.

SUMMARY

[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 the claimed subject matter.

[0006] In accordance with some embodiments of the present disclosure, embodiments of a locking ring are described. One embodiment of a locking ring includes a body. The body may have first and second opposing axial surfaces and a bore formed axially therethrough. A recess may be formed into the second axial surface. The recess may at least partially be defined first and second opposing circumferentially offset surfaces. At least a portion of the first circumferentially offset surface may be oriented at an angle between 20° and 85° with respect to a plane that is perpendicular to a longitudinal centerline through the body.

[0007] Embodiments of a downhole tool are also described. In one embodiment, the downhole tool includes first and second components that are made of different materials. The first component may have a first engagement feature formed on an outer surface thereof. The second component may have a second engagement feature formed on an inner surface thereof. The second component may include an axial protrusion extending therefrom. A locking ring may be positioned between the first and second components. The locking ring may include an annular body having first and second opposing axial surfaces and a bore formed axially therethrough. A recess may be formed into the second axial surface for receiving the axial protrusion. The recess may at least partially be defined by an outer radial surface, first and second opposing circumferentially offset surfaces, and an inner axial surface disposed between the first and second axial surfaces. At least a portion of the first circumferentially offset surface may be oriented at an angle between 20° and 85° with respect to a plane that is perpendicular to a longitudinal centerline through the body.

[0008] In another embodiment, a downhole tool may include a non-weldable component. The non-weldable component may have an axial protrusion and/or a locking ring. The locking ring may include an annular body having first and second opposing axial surfaces. An axial recess may be formed into the second axial surface. The axial recess may be configured to receive the axial protrusion. The axial recess may at least be partially defined by an outer radial surface and opposing first and second

circumferentially offset surfaces. At least a portion of the first and second circumferentially offset surfaces may be oriented at an angle between 30° and 45° with respect to a plane that is perpendicular to a longitudinal centerline through the body. An inner axial surface may be disposed between the first and second axial surfaces.

- 5 [0009] An embodiment of a method of assembling a downhole tool is also disclosed. The method may include inserting a shaft of a first component through a bore formed axially through a locking ring. The locking ring may include an annular body having first and second opposing axial surfaces. An axial protrusion extending from a second component may be aligned in a recess formed in the second axial surface of the locking ring. Threads formed on an outer surface of the shaft may be engaged with threads
10 formed on an inner surface of the second component. The engagement of the threads may apply a force to a circumferentially offset surface of the axial recess to compress the circumferentially offset surface.

15 BRIEF DESCRIPTION OF THE DRAWINGS

- [0010] In order to describe the manner in which embodiments of the present disclosure may be used, a more particular description will be rendered by reference to specific embodiments as illustrated in the appended drawings. While some of the drawings are schematic representations of systems, assemblies, features, methods, or the like, at least some of the drawings may be drawn to scale. Understanding that these drawings depict example embodiments of the disclosure and are not therefore to be considered to be limiting of the scope of the present disclosure or to scale for each embodiment contemplated herein, the embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:
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- 25 [0011] FIG. 1 illustrates a perspective view of an embodiment of a downhole tool utilizing a locking ring, according to the present disclosure;

[0012] FIG. 2 illustrates an exploded perspective view of the embodiment of a downhole tool utilizing a locking ring depicted in FIG. 1;

- [0013] FIG. 3 illustrates another exploded perspective view of the embodiment of a downhole tool utilizing a locking ring depicted in FIG. 1;
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[0014] FIG. 4 illustrates a cross-sectional view of an embodiment of a downhole tool, according to the present disclosure;

[0015] FIG. 5 illustrates an enlarged cross-sectional view of an embodiment of a downhole tool to illustrate an axial protrusion of the second component disposed within a recess in the locking ring, according to the present disclosure;

5 [0016] FIG. 6 illustrates an enlarged cross-sectional view of an embodiment of a downhole tool having an inner radial surface of a locking ring, according to the present disclosure;

[0017] FIG. 7 illustrates a perspective view of an embodiment of a downhole tool showing a locking ring removed (for clarity), according to the present disclosure;

10 [0018] FIG. 8 illustrates a cross-sectional perspective view of the embodiment of a downhole tool shown in FIG. 7;

[0019] FIG. 9 illustrates an enlarged cross-sectional view of an embodiment of an axial protrusion of a second component disposed within a recess in the locking ring, according to the present disclosure;

15 [0020] FIG. 10 illustrates a perspective view of an embodiment of a locking ring, according to the present disclosure;

[0021] FIG. 11 illustrates a top view of a second axial surface of an embodiment of a locking ring, according to the present disclosure; and

[0022] FIG. 12 illustrates an embodiment of a method of assembly for a downhole tool according to the present disclosure.

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DETAILED DESCRIPTION

[0023] FIG. 1 illustrates a perspective view of an embodiment of a downhole tool 100 utilizing a locking ring 200 and FIGS. 2 and 3 show exploded perspective views of the downhole tool 100. The downhole tool 100 may include a first component 110, a second component 130, and a locking ring 200 disposed therebetween.

25 [0024] Referring to FIG. 1, the first and second components 110, 130 may be made of or include the same or different materials. The components 110, 130 may be made of or include one or more metals or metal alloys. For example, suitable metals may include steel, including carbon steel (e.g., AISI 10XX, AISI 11XX, AISI 12XX, or AISI 15XX), manganese steel (e.g., AISI 13XX), nickel steel (e.g., AISI 23XX, or AISI 25XX), nickel-chromium steel (e.g., AISI 31XX, AISI 32XX, AISI 33XX, or AISI 34XX), molybdenum steel (e.g., AISI 40XX, or AISI 44XX), chromium-molybdenum steel (e.g., AISI 41XX), nickel-chromium-molybdenum steel (e.g., AISI 43XX, or AISI 47XX), nickel-molybdenum steel (e.g., AISI 46XX, or AISI 48XX), chromium steel (e.g., AISI 50XX,

or AISI 51XX), combinations thereof, and the like, where “XX” may range from 1 to 99 and represents the carbon content.

[0025] The first component 110 and/or the second component 130 may also be made of or include one or more composite metal alloys and/or metal alloy matrices. For example, the first component 110 and/or the second component 130 may be or include a carbide, such as tungsten carbide, titanium carbide, calcium carbide, silicon carbide, aluminum carbide, chromium carbide, molybdenum carbide, combinations thereof, and the like. In some embodiments, the first component 110 may be made of a weldable material, and the second component 130 may be made of a non-weldable material. In at least one specific embodiment, the first component 110 may be made of steel (e.g., AISI 4340 steel), and the second component 130 may be made of a tungsten carbide matrix material.

[0026] The first component 110 is shown as a connection pin that may be configured to couple to a drill string (not shown). It may be appreciated, however, that although the first component 110 is shown as a connection pin, other components are also contemplated. For example, the first component 110 may be or include a drill pipe, a drill string, a coiled tubing, a wireline, a drill collar, a stabilizer sleeve, an internal in a larger tool, similar downhole tool components, or combinations thereof.

[0027] A locking ring 200 may be configured to mechanically rotationally lock to the second component 130 and to connect to the first component 110 with a weld 170, or braze, or other fixation material. In some embodiments, the weld 170 may not be necessary. The locking ring 200 may have a body 211 sized to have similar dimensions to dimensions of the first component and/or second component. For example, an outer diameter of the body 211 may be substantially similar to an outer diameter of the first component 110. In another example, the body 211 may be an annular body.

[0028] FIG. 2 illustrates an exploded perspective view of the embodiment of a downhole tool 100 of FIG. 1. The downhole tool 100 may include a first component 110 connected to a locking ring 200 with, for example, a weld 170. The locking ring 200 may be mechanically rotationally locked to a second component 130. The first component 110 may include a head 114 having a shaft 116 extending therefrom. The shaft 116 may include threads 120 about a circumference. As shown, the head 114 has a greater cross-sectional length (e.g., diameter) than the shaft 116. A bore 112 may extend through the head 114 and/or the shaft 116. The diameter of the bore 112 may vary along the length of the first component 110. The inner surface of the head 114 that defines the bore 112 may

include a plurality of threads formed thereon for connecting to another component, such as a drill string or other downhole tool.

5 [0029] The head 114 may have one or more grooves (two are shown 118-1, 118-2) formed in the outer surface thereof. At least one groove 118-1, 118-2 may be formed around a portion of the circumference of the head 114. In another embodiment, a single groove may be formed around the entire circumference of the head 114. The (radial) depth of the grooves 118-1, 118-2 may vary along the circumference of the head 114. In some embodiments, the grooves 118-1, 118-2 may facilitate mating of the downhole tool 100 to a drill string, other downhole tool, or other tubular.

10 [0030] The second component 130 is shown as a drill bit (e.g., a polycrystalline diamond compact drill bit) that may be used to drill a wellbore into a subterranean formation. It may be appreciated, however, that although the second component 130 is shown as a drill bit, other components are also contemplated. For example, the second component 130 may be or include other types of bits, such as a roller-cone bit; an underreamer; a stabilizer (e.g., a stabilizer sleeve); a logging-while-drilling (“LWD”) tool; a measuring-while-drilling (“MWD”) tool; a concentric hole opener; a housing on a motor; or the like.

15 [0031] The second component 130 may have a bore 133 formed at least partially (or completely) therethrough. The inner surface adjacent the bore 133 of the second component 130 has a plurality of threads 134 formed thereon that are adapted to engage corresponding threads 120 formed on the outer surface of the shaft 116 of the first component 110. The threaded shaft 116 may provide an axial preload or tension in the connection with the second component 130. However, in other embodiments, configurations other than threads may be used on the shaft 116 and/or inner surface adjacent the bore 133 of the second component 130 to, for instance, provide a similar preload. For example, a quick lock configuration may be used.

20 [0032] The second component 130 may have one or more radial protrusions (e.g., blades and/or gage pads) 136 formed on the outer (radial) surface thereof. Although 5 radial protrusions 136 are shown, it may be appreciated that the number of radial protrusions 136 may be within a range having lower and upper values of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, or more. The radial protrusions 136 may be circumferentially-offset from one another and extend radially-outward from the outer (radial) surface of the second component 130. For example, each of the radial protrusions 136, as shown, is

circumferentially offset from an adjacent radial protrusion 136 by 72 degrees. In another example, the radial protrusions 136 may not all be equally spaced.

[0033] The second component 130 may also have one or more axial protrusions or “castellations” 140 formed on an outer (axial) surface thereof. Although 10 axial protrusions 140 are shown, it may be appreciated that the number of axial protrusions 140 may be within a range having lower and upper values of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, or more.

[0034] The number of axial protrusions 140 may be correlated with the number of radial protrusions 136. For example, the number of axial protrusions 140 as shown are twice as many as the number of radial protrusions (e.g. ten axial protrusions 140 to five radial protrusions 136). In some embodiments, the number of axial protrusions 140 may not be correlated with the number of radial protrusions 136.

[0035] The axial protrusions 140 may be positioned in a variety of patterns on the second component 130. As shown, the axial protrusions 140 are circumferentially-offset from one another and extend axially-outward from the outer axial surface 115 of the second component 130. In at least one embodiment, if an even number of axial protrusions 140 are employed, each axial protrusion 140 can be directly across from another corresponding axial protrusion 140. In some embodiments, the axial protrusions 140 may be distributed equally about the circumference of the axial surface of the second component 130. In other embodiments, the axial protrusions 140 may be distributed at non-equal intervals about the circumference of the axial surface of the second component 130. In some embodiments, the axial protrusions 140 may axially extend equidistantly from the outer axial surface 115 of the second component 130. In other embodiments, the axial protrusions 140 may axially extend in non-uniform distances from the outer axial surface 115 of the second component 130.

[0036] The locking ring 200 may be disposed between the first and second components 110, 130. In at least one embodiment, the locking ring 200 may be or serve as a stabilizer. The locking ring 200 may have a body 211 that may be annular. The body 211 may have a cross-sectional dimension (e.g. a diameter) within a range having lower and upper values of 50 mm, 60 mm, 75 mm, 100 mm, 150 mm, 200 mm, 300 mm, 400 mm, 500 mm, 600 mm, more than 600 mm, or any value therebetween. For example, the diameter of the body 211 may be between 60 mm and 600 mm, between 60 mm and 200 mm, between 60 mm and 150 mm, or between 60 mm and 100 mm.

[0037] The body 211 may have an axial bore 212 formed therethrough. The bore 212 may be arranged and designed to have the shaft 116 of the first component 110 extend therethrough. The bore 212 may have a cross-sectional dimension (e.g. diameter) within a range having lower and upper values of 40 mm, 50 mm, 60 mm, 70 mm, 80 mm, 90 mm, 100 mm, 150 mm, 200 mm, 300 mm, 400 mm, more than 400 mm, or any value therebetween. For example, the diameter of the bore 212 may be between 40 mm and 400 mm, between 40 mm and 150 mm, or between 40 mm and 100 mm.

[0038] The locking ring 200 may be made of the same material as the first component 110 and/or the second component 130, or the locking ring 200 may include a different material. In at least one embodiment, the locking ring 200 may include steel or another weldable material. For example, the locking ring 200 may be made from a nickel-chromium-molybdenum alloy steel such as AISI 43XX steel (e.g., 4340 steel).

[0039] A first axial surface 221 of the locking ring 200 may be substantially planar, flat, smooth, or combinations thereof. The first axial surface 221 may be positioned adjacent to and abut an axial surface of the first component 110 (e.g., the steel connection pin) when the downhole tool 100 is assembled, as shown in FIG. 1. A second, opposing axial surface 231 of the locking ring 200 may have one or more indentations or axial recesses 232 formed into the annular body 211, as shown in FIG. 3. At least one axial recess 232 may be arranged and designed to receive a corresponding axial protrusion 140 of the second component 130 therein. As shown, each axial recess 232 is arranged and designed to receive its corresponding axial protrusion 140. The axial recesses 232 may be circumferentially-offset from one another around the second axial surface 231 of the locking ring 200. Although not shown, in another embodiment, the second axial surface 231 of the locking ring 200 may have the one or more axial protrusions extending therefrom, and the outer axial surface 115 of the second component 130 may have one or more corresponding indentations or recesses formed therein. In other words, the configuration of the axial protrusions and the recesses may be reversed and/or the second axial surface 231 of the locking ring and the outer axial surface 115 of the second component 130 may each have both axial protrusions and axial recesses. Although 10 axial recesses 232 are shown, it may be appreciated that the number of axial recesses 232 may be within a range having lower and upper values of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, or more depending, for example, at least in part, on the number of axial protrusions 140 on the second component 130.

[0040] In operation, the second axial surface 231 of the locking ring 200 may be placed in contact with the outer axial surface 115 of the second component 130. More particularly, the axial protrusions 140 (whether on the outer axial surface 115 of the second component 130, on the second axial surface 231 of the locking ring 200, or both) are aligned with and inserted into the corresponding axial recesses 232 (whether in the second axial surface 231 of the locking ring 200, on the outer axial surface 115 of the second component 130, or both). The contact between the angled surfaces of the axial protrusions 140 and the angled surfaces of the axial recesses 232 may prevent or limit circumferential movement between the locking ring 200 and the second component 130 as will be described in more detail in FIGS 5 through 8.

[0041] With the first axial surface 221 of the locking ring 200 (i.e., the flat surface) abutting the first component 110, the locking ring 200 and the first component 110 may be welded, brazed, or otherwise affixed together. In at least one embodiment, the locking ring 200 and the first component 110 may be welded together via electronic welding with CASTOLIN® 6868 HD weld material. It may be appreciated that the order of assembly described above is merely illustrative, and the first component, the second component 130, and the locking ring 200 may be assembled in a different order.

[0042] FIG. 4 illustrates a cross-sectional view of an embodiment of a downhole tool 300, according to the present disclosure. Once a first axial surface 421 of a locking ring 400 is in contact with an axial surface 313 of a first component 310, the first component 310 and the locking ring 400 may be welded, brazed, or otherwise affixed together to provide a more secure connection between the first component 310 and locking ring 400. For example, the first component 310 and the locking ring 400 may be welded together via electronic welding with CASTOLIN® 6868 HD weld material. The weld 370 may form an annular ring around the first component 310 and the locking ring 400 to secure them together. The weld 370 that assists in securing the locking ring 400 to the first component 310 also, in effect, secures the second component 330 to the first component 310 as the locking ring 400 and second component 330 are mechanically rotationally locked relative to one another. Furthermore, the mechanical lock between the locking ring 400 and second component 330 may be released by moving the locking ring 400 axially relative to the second component 330. The locking ring 400 may be moved axially relative to the second component 330 by rotating the first component 310 relative to the second component 330 on the second engagement features 320 (e.g. threads) on the outer surface of the shaft 316 that engage (e.g. threadably) with the second engagement

feature 334 (e.g. threads) on an inner surface 333 of the second component 330. When the locking ring 400 and first component 310 are welded, brazed, or otherwise affixed to one another, the connection (e.g. weld 370) limits or prevents the rotation of the first component 310 relative to the second component 330 and, hence, the locking ring 400.

5 [0043] FIG. 5 illustrates an enlarged cross-sectional view of an embodiment of a downhole tool to illustrate an axial protrusion 340 of a second component 330 disposed within an axial recess 432 in a locking ring 400. The outer radial surface 344 of each axial protrusion 140 may be oriented at an angle α with respect to a plane 362 that is perpendicular to the longitudinal axis or centerline 360 (an example of which is shown in
10 FIG. 4) through the second component 330 and/or the locking ring 400. In some embodiments, the angle α may be within a range having lower and upper values of 20°, 30°, 40°, 60°, 70°, 80°, 85°, 89°, more than 89°, or any value therebetween. For example, the angle α may be between 30° and 60°, between 40° and 70°, between 50° and 80°, or between 30° and 85°. More particularly, the angle α may be between 20° and 80°,
15 between 25° and 60°, between 30° and 50°, between 30° and 45°, or between 30° and 40°. In other embodiments, the angle α may have a single value within the aforementioned ranges. For example, the angle α may be 20°, 30°, 40°, 60°, 70°, or 80°. In at least one example, the angle α may be 45°. In at least another example, the angle α may be 30°.

20 [0044] The axial recesses 432 may be tapered to receive the axial protrusions 340. More particularly, the outer radial surface 444 defining each axial recess 432 may be arranged and designed to mate with the outer radial surface 344 of the corresponding axial protrusion 340. As such, the outer radial surface 444 of each axial recess 432 may be oriented at an angle β with respect to the plane 362 that is perpendicular to the
25 longitudinal centerline 360 through the locking ring 400 and/or the second component 330. The angle β may be within a range having lower and upper values of 20°, 30°, 40°, 50°, 60°, 70°, 80°, 85°, 89°, or more than 89°, or any value therebetween. For example, the angle β may be between 30° and 60°, between 40° and 70°, between 50° and 80°, or between 30° and 85°. More particularly, the angle β may be between 20° and 80°,
30 between 25° and 60°, between 30° and 50°, between 30° and 45°, or between 30° and 40°. In other embodiments, the angle β may have a single value within the aforementioned ranges. For example, the angle β may be 20°, 30°, 40°, 60°, 70°, or 80°. In at least one example, the angle β may be 45°. In at least another example, the angle β may be 30°. In at least one embodiment, the angles α and β may be the same.

[0045] The outer axial surface 350 of each axial protrusion 340 may be substantially parallel to the plane 362 that is perpendicular to the longitudinal centerline 360 (an example of which is shown in FIG. 4) through the second component 330. As used herein, “substantially parallel” means within 10° of parallel, and “substantially perpendicular” means within 10° of perpendicular. The outer axial surface 350 and inner axial surface 450 may abut one another or may be spaced apart from one another. Upon application of a force to urge the locking ring 400 against the second component 330, a space between the outer axial surface 350 and inner axial surface 450 may allow for compression of the material surrounding the axial protrusion 340 and/or the axial recess 432. Compression of the material surrounding the axial protrusion 340 and/or the axial recess 432 may provide tighter seal between the axial protrusion 340 and the axial recess 432 in the event of slight differences in sizing. Compression of the material surrounding the axial protrusion 340 and/or the axial recess 432 may provide an axial preload upon the first and second engagement features (examples of which are labeled as 320, 334 in FIG. 4) of the downhole tool 300.

[0046] In at least one embodiment, a tip portion 352 may be formed on each outer axial surface 350 and extend axially therefrom. A tip recess 453 may be formed on each inner axial surface 450. The tip recess 453 may be configured to accommodate the tip portion 352. The tip portion 352 may include a cylindrical base portion 354 and a conical or frustoconical portion 356. The tip portion 352 may be or include remains from the material used to make the second component 330 (or first component). For example, the tip portion 352 may be remaining material from a casting process. The tip recess 453 may be shaped to compliment the tip portion 352. For example, the tip recess 453 may include a cylindrical base portion 455 and a conical and/or frustoconical portion 457. In another embodiment, the tip portion 352 may be omitted, and the outer axial surface 350 of each axial protrusion 340 may be substantially flat, such as shown in FIG. 6. In such an embodiment, the tip recess 453 may be omitted. For example, the tip portion 352 may be ground down such that it is substantially parallel with or within the same plane as (e.g. removed from) the outer axial surface 350.

[0047] An outer radial surface 344 may be a planar surface oriented at the angle α with respect to the plane 362, as depicted in FIG. 5. As shown in FIG. 6, an outer radial surface 544 may be a curved or otherwise non-planar surface that includes at least a portion of the outer radial surface 544 oriented at an angle α with respect to a plane 562. For example, for an outer radial surface 544 that is completely curved, a tangent line (not

shown) through the outer radial surface 544 may be oriented at an angle α . In some embodiments, the outer radial surface 544 may be a curved surface that includes a portion having a tangent line (not shown) through the outer radial surface 544 at an angle α with the plane 562.

5 [0048] In other embodiments, the outer radial surface 544 may include a portion of the outer radial surface 544, whether planar or curved, that is oriented at an angle α and another portion, whether planar or curved, that is angled at a second angle that may be greater than or less than the angle α . For example, a first portion of the outer radial surface 544 may be planar and have an angle α or may be curved such that a tangent line
10 (not shown) through the outer radial surface 544 is angled at an angle α and a second portion of the outer radial surface 544 may be planar and have a second angle or may be curved such that a tangent line (not shown) through the outer radial surface 544 is angled at a second angle. Furthermore, the outer radial surface 544 may include more or fewer portions that are oriented at varying angles and/or the same angles (whether all portions
15 include planar surfaces and/or or a tangent lines of curved surfaces) with respect to each other.

[0049] The outer radial surface 644 of the axial recess 640 may be configured to mate complementarily with substantially all of the outer radial surface 544 of the axial protrusion 540. The outer radial surface 644 of the axial recess 640 may be configured
20 such that a portion of the outer radial surface 644 mates complementarily with the outer radial surface 544 of the axial protrusion 540. For example, the outer radial surface 544 depicted in FIG. 6 includes a portion at an angle α that mates complementarily with the outer radial surface 644 of the axial recess 640. Other portions of the outer radial surface 544 of the axial protrusion 540 may not complementarily mate with the outer radial
25 surface 644.

[0050] FIG. 6 depicts an embodiment of downhole tool 500 including a locking ring 600 that may have one or more axial recesses 632 partially defined by an inner radial surface 642. The inner radial surface 642 defining each recess 632 is arranged and designed to mate with an inner radial surface 542 of a corresponding axial protrusion 540
30 on a second component 530. As shown, the inner radial surface 642 defining each recess 632 may be generally perpendicular to plane 562 through the locking ring 600 and/or the second component 530. In another embodiment, the inner radial surface 642 defining each recess 632 may be oriented at an angle γ with respect to the plane 562 that is perpendicular to the longitudinal centerline through the locking ring 600 and/or the

second component 530. The angle γ may be within a range having lower and upper values of 20°, 30°, 40°, 50°, 60°, 70°, 80°, 85°, 89°, more than 89°, or any value therebetween. For example, in some embodiments, the angle γ may be between 20° and 70°. In another example, the angle γ may be between 30° and 50°.

5 [0051] As shown in FIGS. 7 and 8, a downhole tool 700 may include a first component 710 and a second component 730. The first component 710 and second component 730 may be held relative to one another by a locking ring with axial recesses connected to the first component 710 with a weld 770. While visible in FIG. 8, the locking ring 800 is not depicted in FIG. 7 in order to show axial protrusions 740 and axial
10 surfaces 750 thereof. The axial protrusions 740 on the second component 730 each may include opposing inner and outer radial surfaces 742, 744, opposing circumferentially offset surfaces 746, 748, and an outer axial surface 750. The radial length of each axial protrusion 140 may be greater than, less than, or equal to the circumferential length of the axial protrusion 140.

15 [0052] The axial protrusions 740 of the second component 730 may include interfaces 758 between the outer radial surface 744 and the opposing circumferentially offset surfaces 746, 748 of the axial protrusions 740 may be sharp (e.g., about 90°) or curved. In at least one embodiment, the interfaces 758 may have a radius of curvature between the outer radial surface 744 and the opposing circumferentially offset surfaces 746, 748
20 within a range having lower and upper values of 1 mm, 2 mm, 3 mm, 4 mm, 5 mm, 6 mm, 7 mm, 8 mm, 9 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, more than 30 mm, or any value therebetween. For example, the radius of curvature may be between 1 mm and 5 mm, between 3 mm and 7 mm, between 5 mm and 10 mm, between 8 mm and 12 mm, between 10 mm and 15 mm, or between 15 mm and 25 mm.

25 [0053] FIG. 8 depicts a tangential cross-sectional perspective view of the downhole tool 700 including a first component 710 that may be connected to a locking ring 800 ring by a weld 770. The locking ring 800 may be mechanically rotationally locked to a second component 730. An axial protrusion 740 may be received by an axial recess 832 in the locking ring 800.

30 [0054] FIG. 9 illustrates an enlarged view of a cross-sectional view similar to that in FIG. 8 to illustrate an embodiment of an axial protrusion (e.g. of the second component) disposed within a recess (e.g. in the locking ring), according to the present disclosure. As shown in FIG. 9, the opposing circumferentially offset surfaces 946, 948 of each axial protrusion 940 may be oriented at angles Γ , Δ , respectively, with respect to a plane 962

(which may be similar to plane 362 depicted in FIG. 5 that is perpendicular to the longitudinal centerline 360) through the second component 930. The angles Γ and/or Δ may be individually selected within a range having lower and upper values of 20°, 30°, 40°, 50°, 60°, 70°, 80°, 85°, 89°, more than 89°, or any value therebetween. For example, the angles Γ and/or Δ may be between 30° and 60°, between 40° and 70°, between 50° and 80°, or between 30° and 85°. More particularly, the angles Γ and/or Δ may be between 30° and 40°, between 35° and 45°, between 40° and 50°, between 45° and 55°, between 50° and 60°, between 55° and 65°, between 60° and 70°, between 65° and 75°, between 70° and 80°, or between 75° and 85°. Although the angles Γ and Δ are shown as being the same in FIG. 9, it may be appreciated that in other embodiments, the angles Γ and Δ may be different. In at least one embodiment, lower values for the angles Γ and/or Δ may increase the ability of the opposing circumferentially offset surfaces 946, 948 to engage with circumferentially offset surfaces 1046, 1048 of an axial recess 1032 in a locking ring 1000. In at least one embodiment, higher values for the angles the angles Γ and/or Δ may increase the ability of the opposing circumferentially offset surfaces 946, 948 to apply a rotational force to the circumferentially offset surfaces 1046, 1048 of the axial recess 1032 without the second component 930 slipping rotationally relative to the locking ring 1000.

[0055] The opposing circumferentially offset surfaces 1046, 1048 defining each axial recess 1032 may be arranged and designed to mate with the opposing circumferentially offset surfaces 946, 948 of the corresponding axial protrusion 940. As such, the opposing circumferentially offset surfaces 1046, 1048 may be oriented at angles E, Z, respectively, with respect to the plane 962. The angles E and/or Z may be individually selected within a range having lower and upper values of 20°, 30°, 40°, 50°, 60°, 70°, 80°, 85°, 89°, more than 89°, or any value therebetween. For example, the angles E and/or Z may be between 30° and 60°, between 40° and 70°, between 50° and 80°, or between 30° and 85°. More particularly, the angles E and/or Z may be between 30° and 40°, between 35° and 45°, between 40° and 50°, between 45° and 55°, between 50° and 60°, between 55° and 65°, between 60° and 70°, between 65° and 75°, between 70° and 80°, or between 75° and 85°. Although the angles E and Z are shown as being the same in FIG. 9, it may be appreciated that in other embodiments, the angles E and Z may be different. In at least one embodiment, the angles Γ and E may be the same, and the angles Δ and Z may be the same. The inner axial surface 1050 defining each axial recess 1032 is arranged and designed to mate with the outer axial surface 950 of the corresponding axial protrusion

940. As such, the inner axial surface 1050 of each axial recess 1032 may be substantially parallel to the plane 962.

[0056] The opposing circumferentially offset surfaces 946, 948 may be a planar surface oriented at the angles Γ and Δ with respect to the plane 962, such as the
5 circumferentially offset surface 948 depicted in FIG. 9. As depicted by the opposing circumferentially offset surface 946, one or more of the circumferentially offset surfaces 946, 948 may be a curved or otherwise non-planar surface that includes at least a portion of the circumferentially offset surface 946 oriented at an angle Γ or Δ with respect to a plane 962. In some embodiments, one or more of the circumferentially offset surfaces
10 946, 948 may be a curved surface that includes a portion having an angle Γ or Δ with respect to a plane 962. In other embodiments, one or more of the circumferentially offset surfaces 946, 948 may include a portion of the outer radial surface that is oriented at an angle Γ or Δ and another portion that is angled at a second angle that may be greater than or less than the angle Γ or Δ . One or more of the circumferentially offset surfaces 1046,
15 1048 may be configured to mate complementarily with substantially all of one or more of the circumferentially offset surfaces 946, 948 of the axial protrusion 940. One or more of the circumferentially offset surfaces 1046, 1048 may be configured such that a portion of one or more of the circumferentially offset surfaces 1046, 1048 may mate complementarily with one or more of the circumferentially offset surfaces 946, 948 of the
20 axial protrusion 940. For example, the circumferentially offset surface 946 depicted in FIG. 9 includes a portion at an angle Δ that mates complementarily with a portion of the circumferentially offset surface 1046 at an angle Z . Other portions of one or more of the circumferentially offset surfaces 1046, 1048 may not complementarily mate with one or more of the circumferentially offset surfaces 946, 948.

[0057] As shown in FIGS. 10 and 11, interfaces 1258 between an outer radial surface 1244 and opposing circumferentially offset surfaces 1246, 1248 of a locking ring 1200 may be sharp (e.g., about 90°) or curved, in some embodiments. In at least one embodiment, there may be a radius of curvature between the outer radial surface 1244 and the opposing circumferentially offset surfaces 1246, 1248 within a range having
30 upper and lower values including any of 1 mm, 2 mm, 3 mm, 4 mm, 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, 30 mm, more than 30 mm, or any value therebetween. For example, the radius of curvature may be between about 1 mm and about 5 mm, between about 3 mm and about 7 mm, between about 5 mm and about 10 mm, between about 8 mm and about 12 mm.

[0058] FIG. 10 depicts a perspective view of an embodiment of a locking ring 1200, and FIG. 11 depicts a top view of the second axial surface 1231 of the locking ring 1200 shown in FIG. 10, according to the present disclosure. Each axial recess 1232 formed in the second axial surface 1231 of the locking ring 1200 may be arranged and designed to receive a corresponding axial protrusion of a second component.

[0059] Although the present disclosure generally describes the axial protrusions on the second component and recesses on the first component, as described above. For example, the second axial surface of the locking ring may have one or more axial protrusions extending therefrom, the outer axial surface of the second component may have one or more corresponding indentations or recesses formed therein. In other words, the configuration of the axial protrusions and the recesses may be reversed and/or the second axial surface of the locking ring and the outer axial surface of the second component may each have both axial protrusions and axial recesses.

[0060] An embodiment of a method of assembling a downhole tool according to the present disclosure is depicted in FIG. 12. The method 1300 may include inserting 1372 a shaft of a first component through a bore formed axially through a locking ring. The locking ring may include a body having first and second opposing axial surfaces. An axial protrusion extending from a second component may be aligned 1374 in an axial recess formed in the second axial surface of the locking ring. One or more engagement features (e.g. threads) formed on an outer surface of the shaft may be engaged 1376 with one or more engagement features (e.g. threads) formed on an inner surface of the second component. A force may be applied 1378 to a circumferentially offset surface of the axial recess to compress the circumferentially offset surface. The method 1300 may also include welding 1380 the locking ring to the first component.

[0061] As used herein, the terms “inner” and “outer”; “up” and “down”; “upper” and “lower”; and other like terms as used herein refer to relative positions to one another and are not intended to denote a particular direction or spatial orientation. The terms “couple,” “coupled,” “connect,” “connection,” “connected,” “in connection with,” and “connecting” refer to “in direct connection with” or “in connection with via another element or member.”

[0062] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from “Locking Ring with Tapered Recesses.” Accordingly, all such modifications are intended to be included

within the scope of this disclosure. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. § 120, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words 'means for' together with an associated function.

10 [0063] Certain embodiments and features have been described using a set of values with may form an upper and/or lower limit of a range. Certain lower limits, upper limits and ranges appear in one or more claims below. All numbers, percentages, ratios, or other values stated herein are intended to include not only that value, but also other values that are about or approximately the stated value, as would be appreciated by one of ordinary skill in the art encompassed by embodiments of the present disclosure. A stated value should therefore be interpreted broadly enough to encompass values that are at least close enough to the stated value to perform a desired function or achieve a desired result. The stated values include at least the variation to be expected in a suitable manufacturing or production process, and may include values that are within 5%, within 1%, within 20 0.1%, or within 0.01% of a stated value.

[0064] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are 25 fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

[0065] The present disclosure may be embodied in other specific forms without departing from its spirit or characteristics. The described embodiments are to be considered as illustrative and not restrictive. The scope of the disclosure is, therefore, 30 indicated by the appended claims rather than by the foregoing description. Changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

What is claimed is:

- 5 1. A locking ring adapted to be positioned between first and second components, comprising:
- a body having opposing first and second axial surfaces and a bore formed axially therethrough, wherein a recess is formed into the second axial surface, the recess at least partially defined by:
- 10 opposing first and second circumferentially offset surfaces, wherein at least a portion of the first circumferentially offset surface is oriented at an angle between 20° and 85° with respect to a plane that is perpendicular to a longitudinal centerline through the body.
- 15 2. The locking ring of claim 1, wherein at least a portion of the first circumferentially offset surface is oriented at an angle between 30° and 60° with respect to the plane that is perpendicular to the longitudinal centerline through the body.
3. The locking ring of claim 1, wherein at least a portion of the second
- 20 circumferentially offset surface is oriented at an angle between 30° and 60° with respect to the plane that is perpendicular to the longitudinal centerline through the body.
4. The locking ring of claim 1, wherein the recess is further defined by an outer radial surface, wherein at least a portion of the outer radial surface is oriented at an angle
- 25 between about 30° and about 85° with respect to the plane that is perpendicular to the longitudinal centerline through the body.
5. The locking ring of claim 1, wherein the recess is further defined by an inner axial surface, wherein the inner axial surface has a notch formed therein toward the first axial
- 30 surface, and wherein the notch is shaped to receive a conical or frustoconical portion of the second component.

6. The locking ring of claim 1, wherein the recess is further defined by an outer radial surface and an interface between the outer radial surface and the first circumferentially offset surface, wherein the interface has a radius of curvature between 1 mm and 25 mm.

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7. The locking ring of claim 1, wherein the body has a diameter between 60 mm and 600 mm.

8. The locking ring of claim 1, wherein the body is made of steel.

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9. The locking ring of claim 1, wherein the first axial surface of the body is substantially flat and parallel to the plane that is perpendicular to the longitudinal centerline through the body.

15 10. The locking ring of claim 1, wherein the recess comprises a plurality of recesses that are circumferentially-offset from one another.

11. A downhole tool, comprising:

20 a first component having a first engagement feature formed on an outer surface thereof;

a second component having a second engagement feature formed on an inner surface thereof, wherein the second component includes an axial protrusion extending therefrom; and

25 a locking ring positioned between the first and second components, the locking ring including a body having first and second opposing axial surfaces and an axial bore formed therethrough, wherein an axial recess is formed into the second axial surface, and the axial recess is configured to receive the axial protrusion, the axial recess at least partially defined by:

30 an outer radial surface;
opposing first and second circumferentially offset surfaces, wherein at least a portion of the first circumferentially offset surface is oriented at an angle between 20° and 85° with respect to a plane that is perpendicular to a longitudinal centerline through the body; and

an inner axial surface disposed between the first and second axial surfaces.

12. The downhole tool of claim 11, wherein the first component is made of steel, and the second component is made of tungsten carbide.

5 13. The downhole tool of claim 12, wherein the locking ring is made of steel, and wherein the first component is welded to the locking ring.

14. The downhole tool of claim 13, wherein the first component is a connector pin, and the second component is a drill bit.

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15. The downhole tool of claim 11, wherein at least a portion of the second circumferentially offset surface is oriented at an angle between 20° and 60° with respect to the plane that is perpendicular to the longitudinal centerline through the body.

15 16. The downhole tool of claim 11, wherein at least a portion of the outer radial surface is oriented at an angle between 30° and 85° with respect to the plane that is perpendicular to the longitudinal centerline through the body.

17. The downhole tool of claim 11, wherein the axial protrusion has a conical or
20 frustoconical tip portion extending therefrom.

18. A downhole tool, comprising:

a non-weldable component having an axial protrusion extending therefrom; and

a locking ring positioned adjacent to and abutting the non-weldable component,

25 the locking ring including a body having first and second opposing axial surfaces and an axial bore formed therethrough, wherein an axial recess is formed into the second axial surface, and the axial recess is configured to receive the axial protrusion, the axial recess at least partially defined by:

an outer radial surface;

30 opposing first and second circumferentially offset surfaces, wherein at least a portion of the first and second circumferentially offset surfaces are oriented at an angle between 30° and 60° with respect to a plane that is perpendicular to a longitudinal centerline through the body; and

an inner axial surface disposed between the first and second axial surfaces.

19. The downhole tool of claim 18, further comprising a weldable component positioned adjacent the locking ring and opposite the non-weldable component.

5 20. The downhole tool of claim 19, wherein the locking ring is welded or brazed to the weldable component.

21. The downhole tool of claim 18, wherein the first and second circumferentially offset surface are oriented at the same angle with respect to the plane that is perpendicular
10 to the longitudinal centerline through the body.

22. The downhole tool of claim 18, wherein the axial protrusion comprises an outer axial surface, the outer axial surface of the axial protrusion and the inner axial surface of the axial recess not contacting when the locking ring and the non-weldable component
15 abut one another.

23. A method of assembling a downhole tool, comprising:
inserting a shaft of a first component through a bore formed axially through a locking ring, wherein the locking ring includes a body having first and second opposing
20 axial surfaces;

aligning an axial protrusion extending from a second component in an axial recess formed in the second axial surface of the locking ring,

engaging one or more threads formed on an outer surface of the shaft with one or more threads formed on an inner surface of the second component; and

25 applying a force to a circumferentially offset surface of the axial recess to compress the circumferentially offset surface.

24. The method of claim 23, wherein the first component and the locking ring are made of steel, and wherein the second component is made of tungsten carbide.
30

25. The method of claim 24, further comprising welding the first component and the locking ring together.

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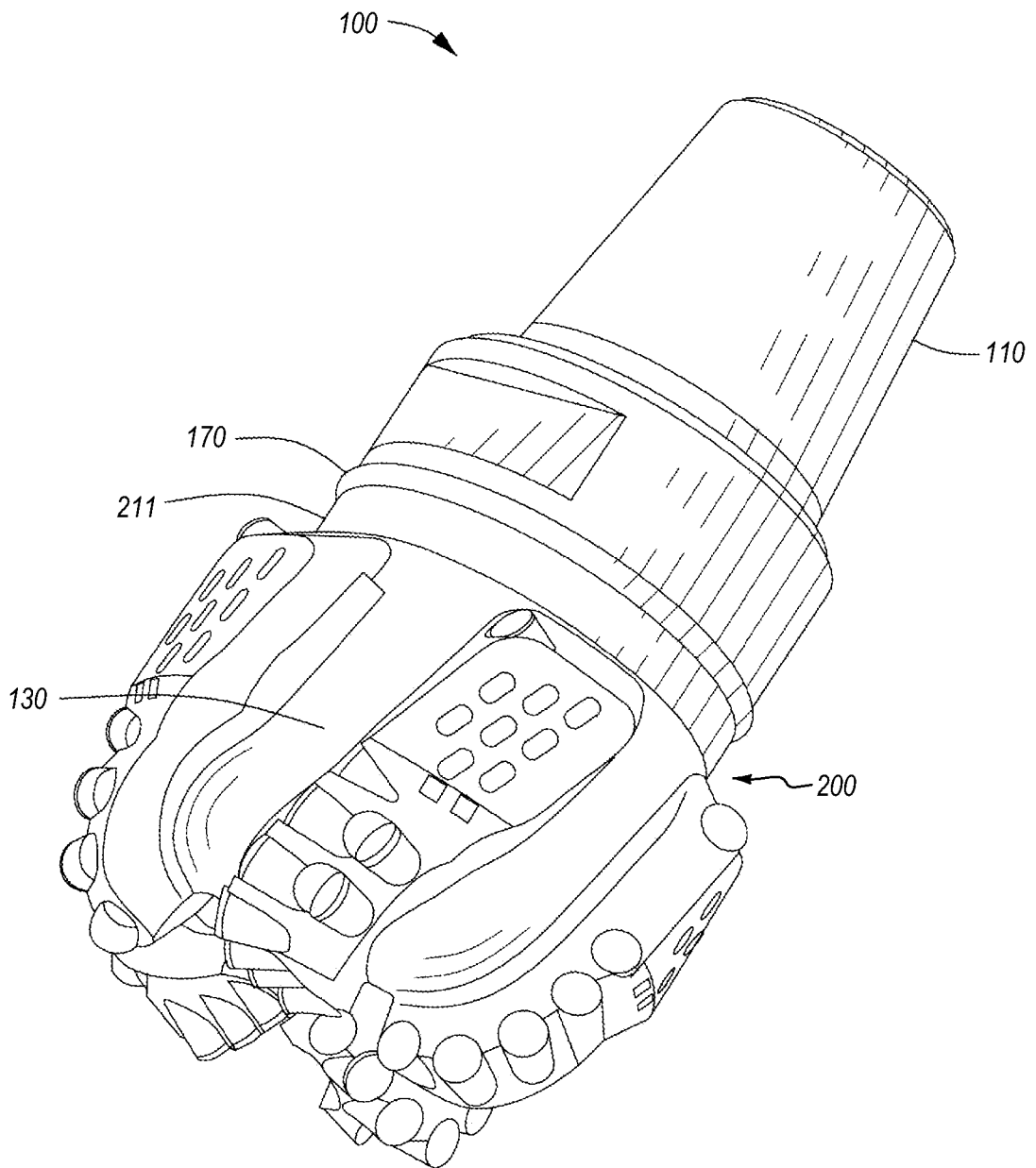


FIG. 1

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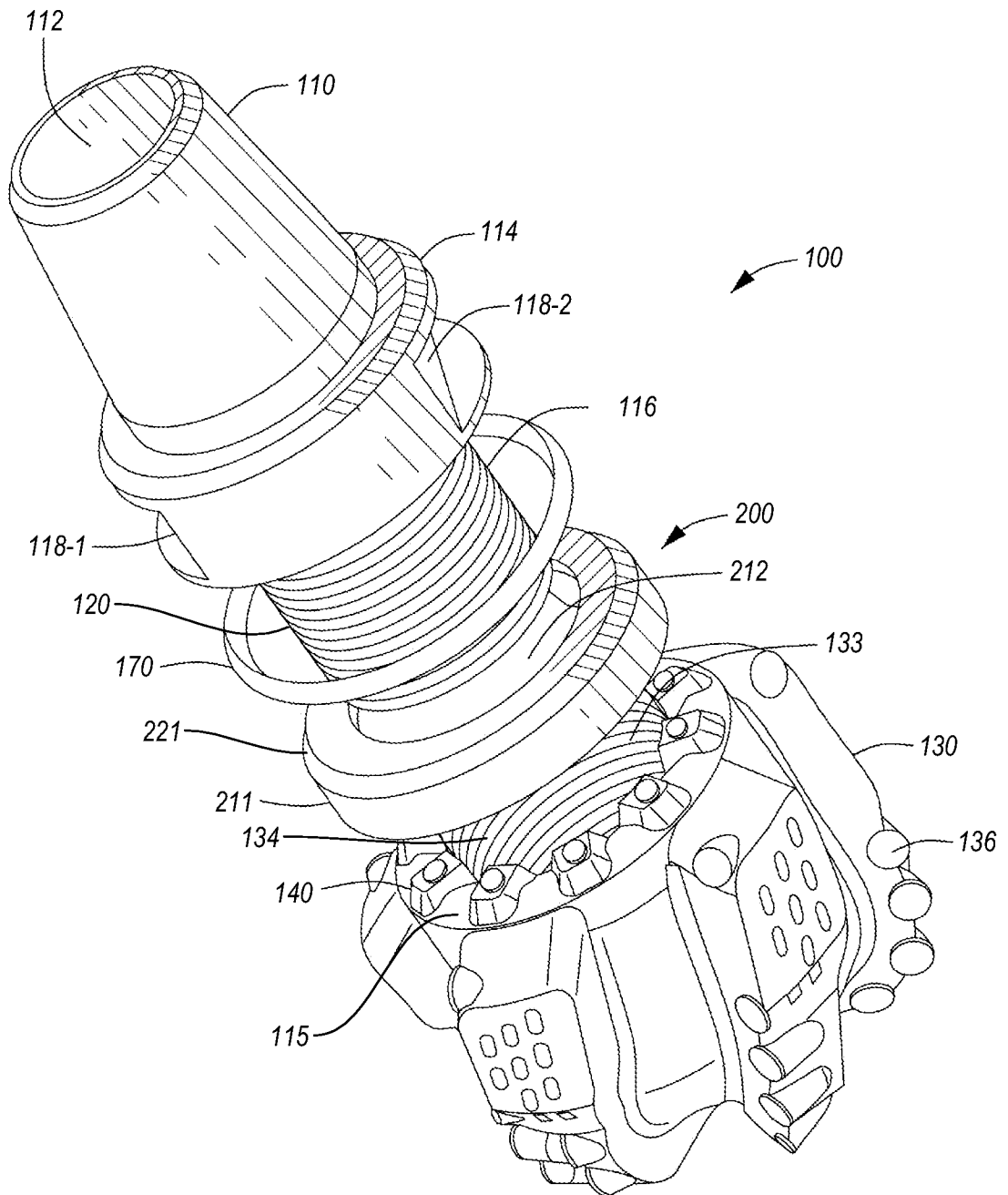


FIG. 2

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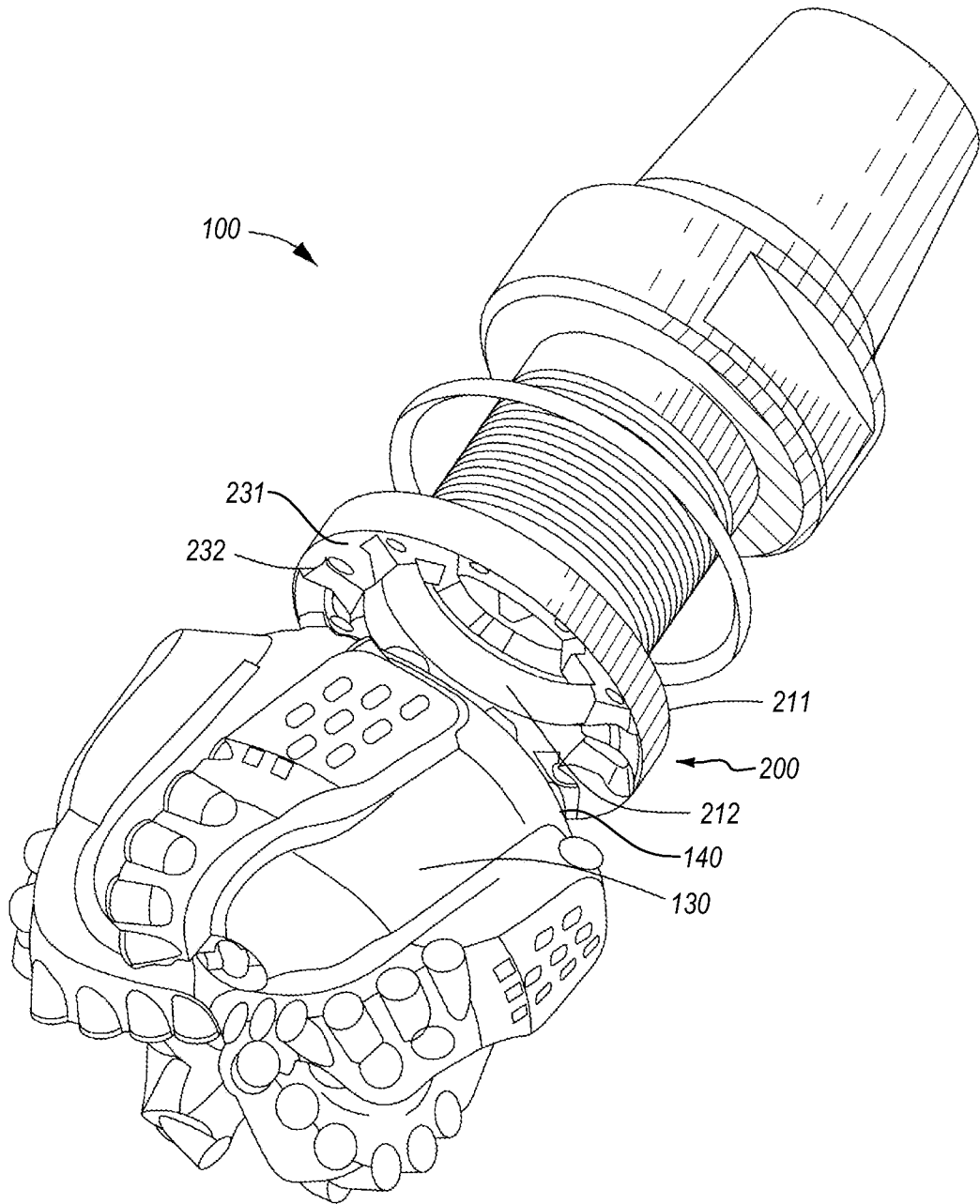


FIG. 3

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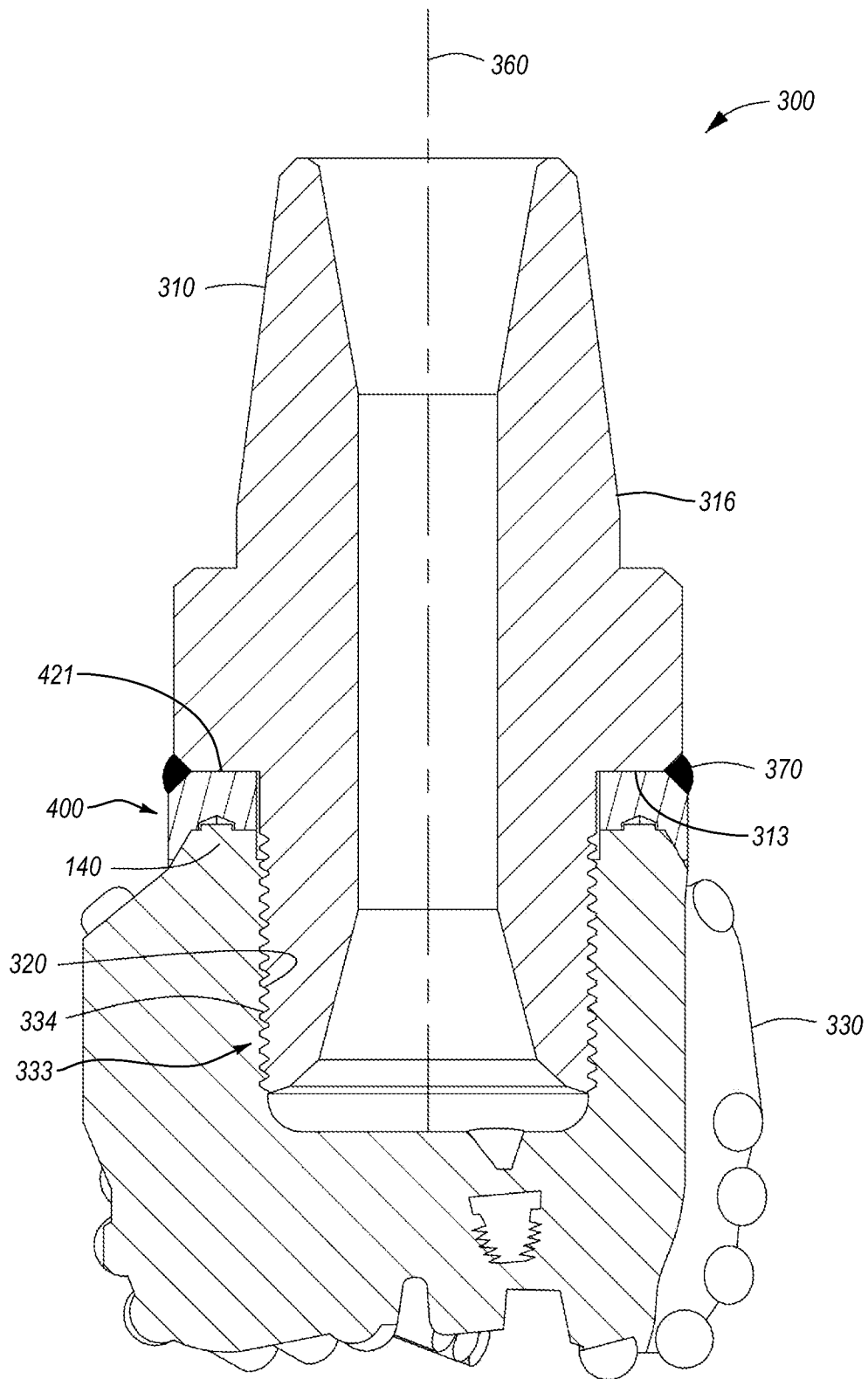


FIG. 4

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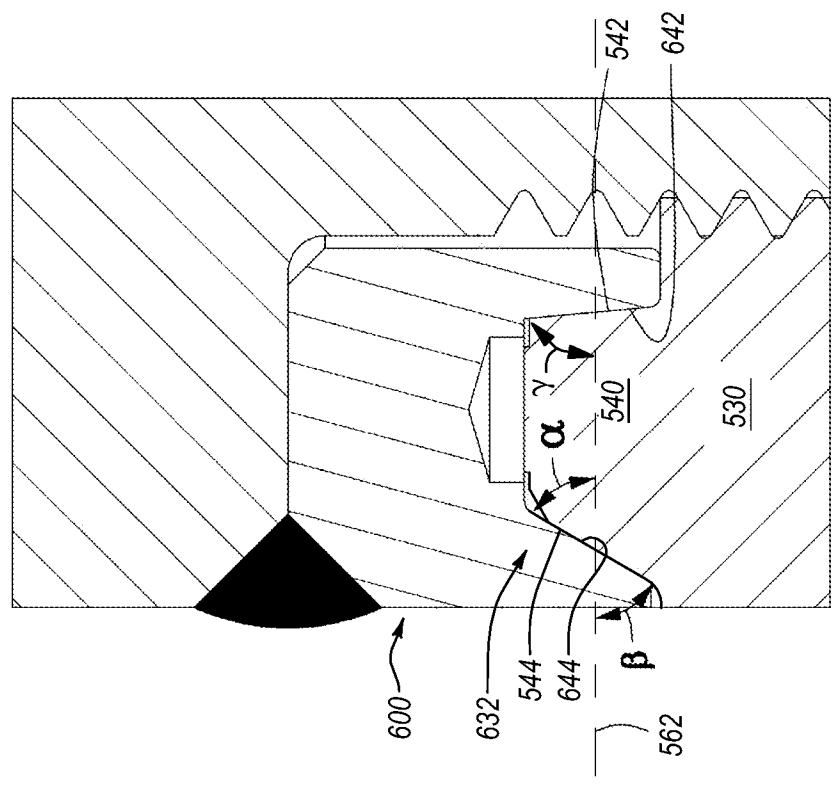


FIG. 6

300

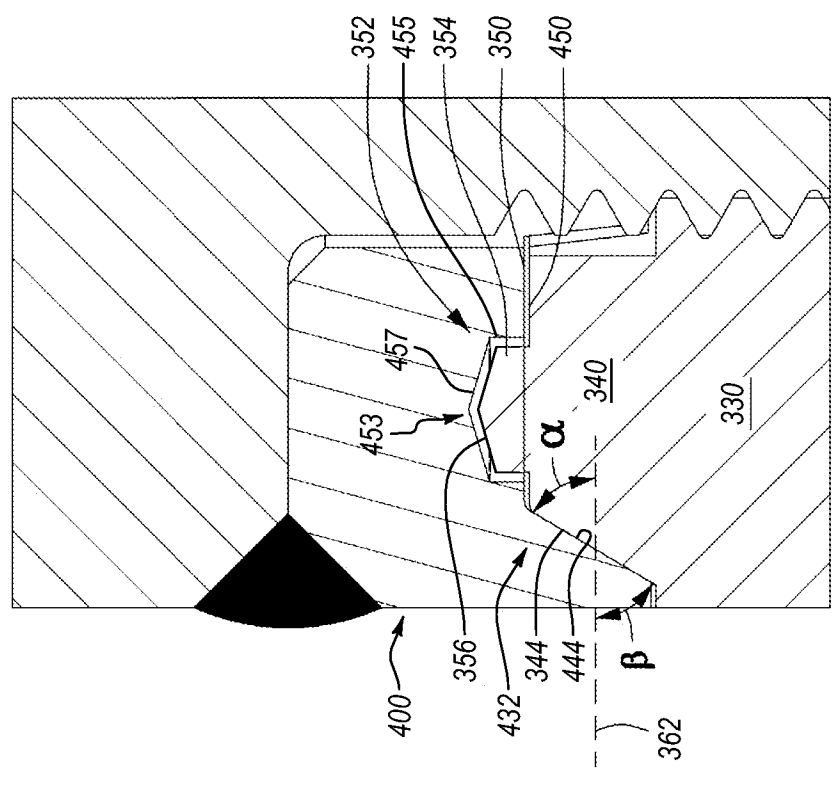


FIG. 5

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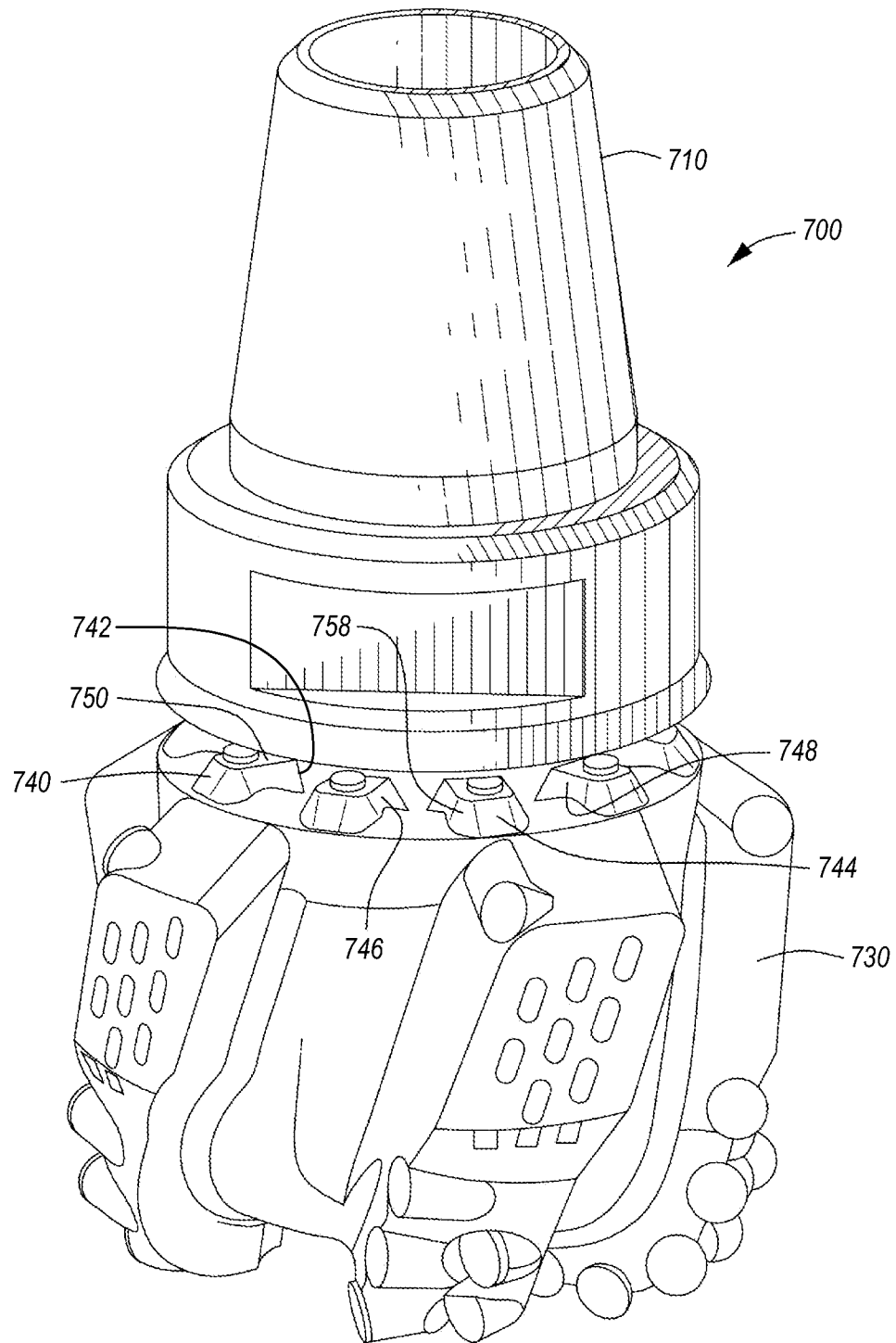


FIG. 7

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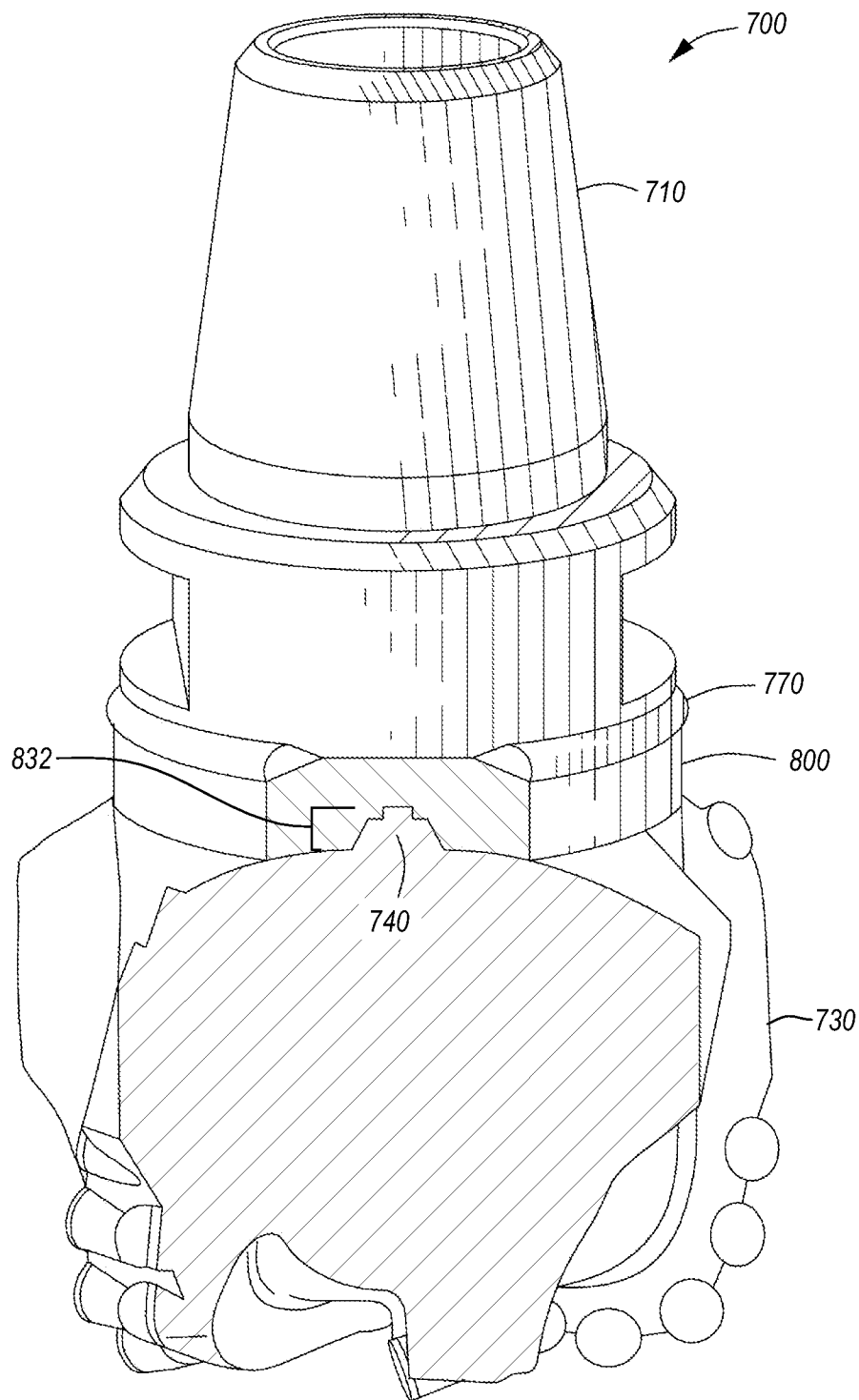


FIG. 8

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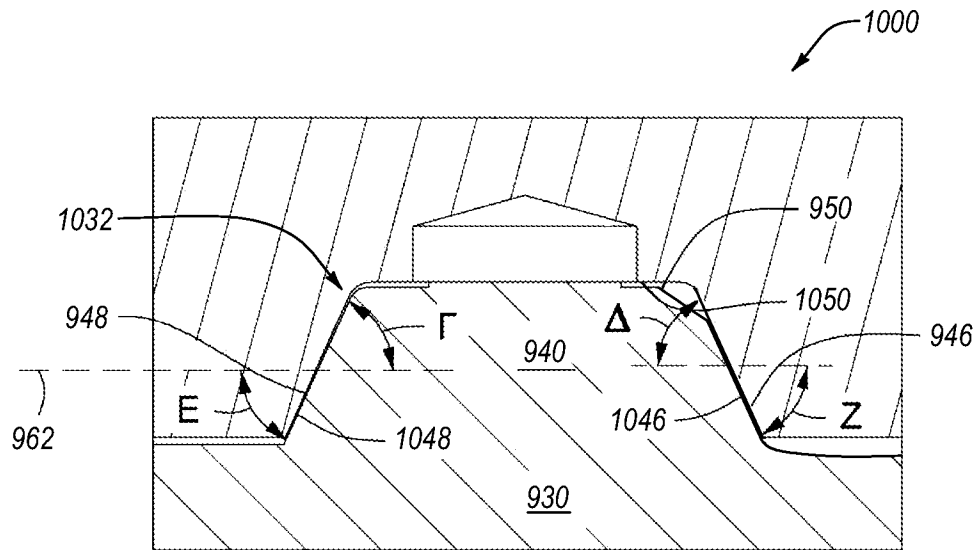


FIG. 9

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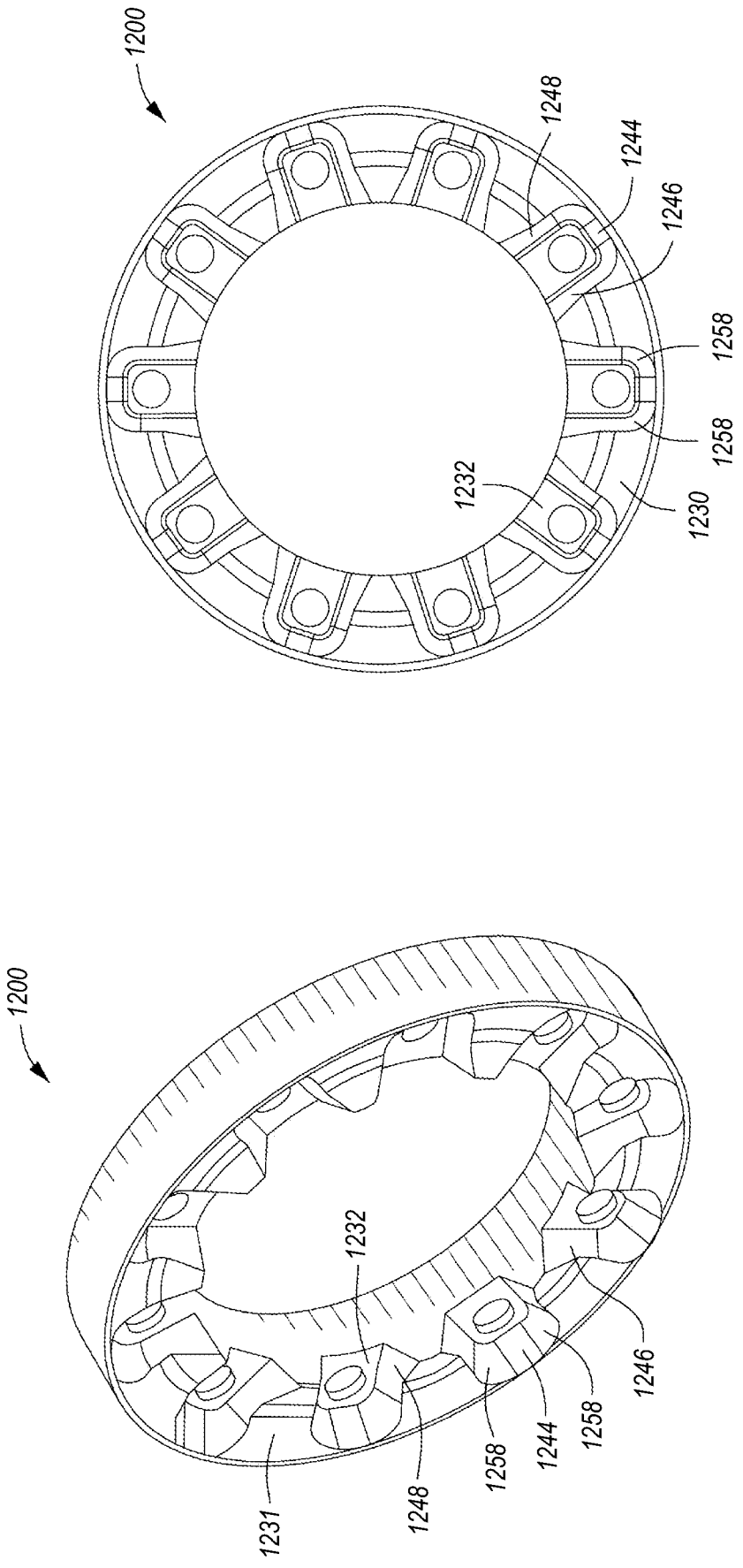


FIG. 11

FIG. 10

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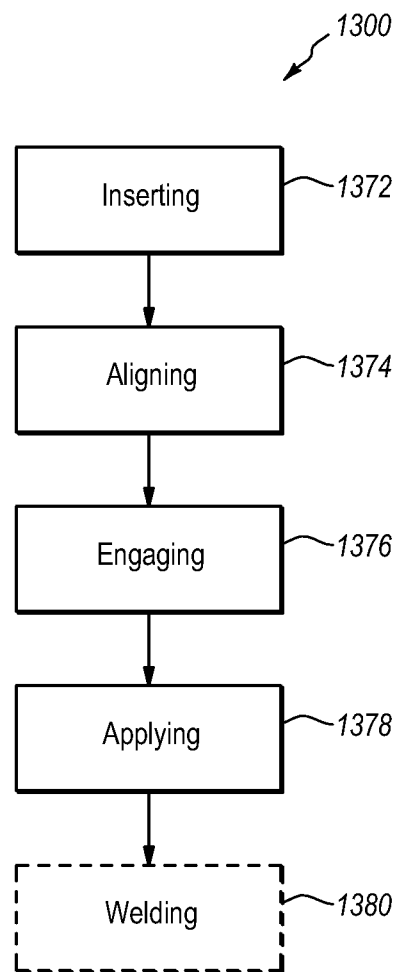


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/051225**A. CLASSIFICATION OF SUBJECT MATTER****E21B 10/42(2006.01)i, E21B 12/00(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 10/42; E21B 7/00; B23K 35/38; E21B 10/00; E21B 10/61; B32B 37/12; G01V 3/06; B23K 31/02; E21B 12/00

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: drill bit, tapered recess, angle, protrusion, connector pin, weld

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013-0043874 A1 (CLARK et al.) 21 February 2013 See paragraphs [0054]–[0059] and figures 3(a)–3(b).	1–25
Y	US 2011-0186354 A1 (SMITH et al.) 04 August 2011 See paragraphs [0072]–[0075] and figures 13–14.	1–25
A	US 2010-0270086 A1 (MATTHEWS, III et al.) 28 October 2010 See paragraphs [0037]–[0038] and figures 4–5.	1–25
A	US 2013-0032412 A1 (HAUGVALDSTAD et al.) 07 February 2013 See paragraphs [0041]–[0042] and figures 14(a)–14(c).	1–25
A	US 2006-0169752 A1 (DEN BOER et al.) 03 August 2006 See paragraph [0047] and figure 1.	1–25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

09 December 2014 (09.12.2014)

Date of mailing of the international search report

10 December 2014 (10.12.2014)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/051225

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