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[Continued on next page]

(54) **Title**: HYBRID BIT WITH BLADES AND DISCS

(57) **Abstract**: A hybrid drill bit includes a bit body having a central bit body axis at a center of the bit body, a blade on the bit body extending from an end of the bit body, and a roller disc rotatably coupled to the bit body about the end of the bit body to rotate on a roller disc axis. The roller disc axis extends toward the central bit body axis, and the blade includes a plurality of fixed cutting elements.

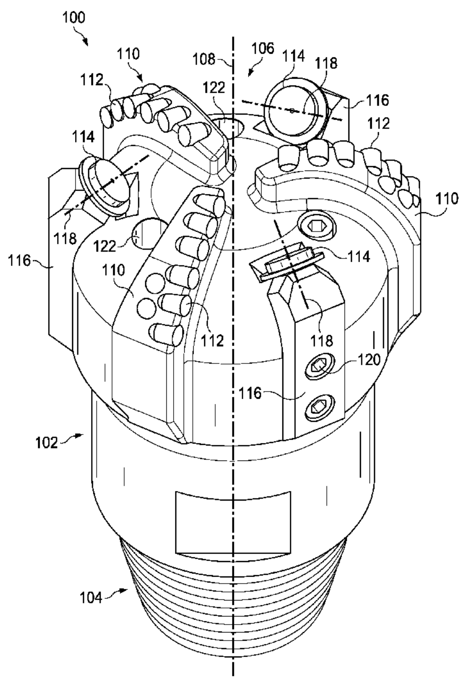

FIG. 2

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Hybrid Bit with Blades and Discs

BACKGROUND

[0001] The present disclosure relates to hybrid drill bits for drilling a wellbore in a formation, and more particularly to hybrid drill bits with blades and roller discs.

[0002] Hybrid drill bits can be used to drill a wellbore in a formation through rotation of the hybrid drill bits about a longitudinal axis. A drill bit generally includes cutting elements and cutting structures at a drill end of the drill bit. A hybrid drill bit generally includes more than one type of cutting structure or cutting element at a drill end of the hybrid drill bit. Cutting elements and cutting structures typically form a wellbore in a subterranean formation by shearing, crushing, cracking, or a combination of shearing, crushing, and cracking portions of the formation during rotation of the drill bit.

DESCRIPTION OF DRAWINGS

[0003] FIG. 1 is a schematic partially cross-sectional view of an example well system.

[0004] FIG. 2 is a schematic perspective view of an example hybrid drill bit.

[0005] FIG. 3A is a schematic end view of an example hybrid drill bit.

[0006] FIG. 3B is a schematic side view of an example hybrid drill bit profile.

[0007] FIG. 4A is a schematic end view of an example hybrid drill bit.

[0008] FIG. 4B is a schematic side view of an example hybrid drill bit profile.

[0009] FIG. 5A is a schematic end view of an example hybrid drill bit.

[0010] FIG. 5B is a schematic side view of an example hybrid drill bit profile.

[0011] FIG. 6 is a schematic partially cross-sectional side view of an example roller disc.

[0012] FIG. 7 is a schematic partially cross-sectional side view of an example roller disc.

[0013] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0014] Referring first to FIG. 1, a well system 10 generally includes a substantially cylindrical wellbore 12 that extends from a wellhead 14 at the surface 16 downward into the Earth into one or more subterranean zones of interest 18 (one shown). The subterranean zone 18 can correspond to a single formation, a portion of a formation, or more than one formation accessed by the well system 10, and a given well system 10 can access one, or more than one, subterranean zone 18. A portion of the wellbore 12 extending from the wellhead 14 to the subterranean zone 18 is lined with lengths of tubing, called casing 20. The depicted well system 10 is a vertical well, with the wellbore 12 extending substantially vertically from the surface 16 to the subterranean zone 18. The concepts herein, however, are applicable to many other different configurations of wells, including horizontal, slanted or otherwise deviated wells, and multilateral wells with legs deviating from an entry well.

[0015] A drill string 22 is shown as having been lowered from the surface 16 into the wellbore 12. In some instances, the drill string 22 is a series of jointed lengths of tubing coupled together end-to-end and/or a continuous (i.e., not jointed) coiled tubing. The drill string 22 includes one or more well tools, including a bottom hole assembly 24. The bottom hole assembly 24 can include, for example, a hybrid drill bit. In the example shown, the wellbore 12 is being drilled. The wellbore 12 can be drilled in stages, and the casing 20 may be installed between stages.

[0016] Referring to FIG. 2, an example hybrid drill bit 100 that can be used in the bottom hole assembly 24 of the well system 10 of FIG. 1 is shown in a perspective view. The example hybrid drill bit 100 includes a bit body 102 with a pin end 104 on one longitudinal end of the bit body 102, a drill end 106 on another longitudinal end of the bit body 102 opposite the pin end 104, and a center longitudinal axis through the center of the bit body 102 that defines a central bit body axis 108. In some instances, the pin end 104 is male and is threaded to mate with a female box at a tubing end of a drill string. The hybrid drill bit 100 includes blades 110 with fixed cutting elements 112, the blades 110 extending longitudinally from the drill end 106 of the bit body 102, and roller discs 114 rotatably coupled to arms 116 extending generally along the central bit body axis 108 and beyond the drill end 106 of the bit body 102. Each of the roller discs 114 rotate about a rotational axis that defines a roller disc axis 118 extending toward (directly or substantially) the central bit body axis 108. The hybrid drill bit 100 has more than one type of cutting structure and/or cutting element, for example, blades 110 with fixed cutting elements 112 and roller discs 114 configured to rotate, such that the example drill bit 100 is considered a hybrid drill bit.

[0017] Various types of cutting elements and cutting structures may be provided on a hybrid drill bit. In the example shown in FIG. 2, the hybrid drill bit 100 includes three blades 110 and three roller discs 114. The example hybrid drill bit 100 can include additional or different features and components. For example, the number of roller discs 114 and blades 110 can vary. In some instances, a hybrid drill bit can have one or more discs and one or more blades. For example, a hybrid drill bit can have one blade and one roller disc, one blade and a plurality of roller discs, a plurality of blades and one roller disc, or a plurality of blades and a plurality of roller discs.

[0018] The arms 116 attach to the bit body 102 with fasteners 120 such that the arms 116 are removable from the bit body 102. In some instances, the arms 116 are an extension of the bit body 102, are welded to the bit body 102, and/or the arms 116 are connected to the bit body 102 in another way. In other instances, the roller discs 114 are rotatably coupled to the bit body 102 about the drill end. For example, the roller discs 114 can attach to the bit body 102 about the drill end 106 without arms 116.

[0019] In some instances, the roller discs 114 rotate on spindles (not shown) extending from the bit body 102 or arms 116 along the roller disc axes 118. The roller discs 114 can attach to the spindles via a bearing system to allow rotation of the roller discs 114 about the roller disc axes 118. The bearing system can include, for example, a seal, ball bearings, a lubrication system, and/or a pressure compensation system.

[0020] The roller discs 114 can operate at a number of positions and configurations. In the example shown, the roller discs 114 are radially disposed near an outer lateral periphery of the drill end 106. In some instances, the roller discs 114 are disposed more inward toward the central bit body axis 108, more outward from the central bit body axis 108, or in a different position than shown in FIG. 2. In some instances, the roller disc axes 118 of the roller discs 114 intersect the central bit body axis 108, for example, to allow true rolling of the roller discs 114 against a rock formation as the example hybrid drill bit 100 rotates about its central bit body axis 108. True rolling occurs when the roller disc axes 118 intersect the central bit body axis 108, and a radial vector of each roller disc 114 points in the direction of rotation of the drill bit. In other instances, the roller disc axes 118 of the roller discs 114 do not intersect the central bit body axis 108, and the roller disc axes 118 are non-radial from the central bit body axis 108. The roller discs 114 can approximate true rolling, for example, near-true rolling with some shearing against a formation as the example hybrid drill bit 100 rotates about its central bit body axis 108. Near-true rolling occurs when the roller disc axes 118 do not intersect the central bit body axis 108, and a radial vector of each roller disc 114 points slightly offset the direction of rotation of the bit body 102, for example, when the roller disc axis 118 is slightly offset from the central bit body axis 108. The slight offset causes the roller disc 114 to rotate with some skidding (i.e. shearing) against the formation. In certain instances, a hybrid drill bit can have at least two roller discs, where a first roller disc has a roller disc axis that intersects a central bit body axis, and a second roller disc has a roller disc axis that does not intersect the central bit body axis.

[0021] In the example shown in FIG. 2, the blades 110 are disposed extending substantially linearly on the drill end 106 from the central bit body axis 108 toward the outer lateral periphery of the drill end 106. The outer lateral periphery of the drill end 106 has a radiused edge, and the blades 110 curve longitudinally along the radiused edge of the outer lateral periphery of the drill end 106. The fixed cutting elements 112 extend in a row along the blade, such that the fixed cutting elements form a line along each blade 110 from an end of the blade 110 closest to the central bit body axis 108 to an end of the blade 110 closest to the outer lateral periphery of the drill end 106. In some instances, the blades 110 and fixed cutting elements 112 are disposed in a different way. For example, the blades 110 can extend in a lateral curve from the central bit body axis 108 toward the outer lateral periphery, the fixed cutting elements 112 can extend in a curved row along the blades 110, and/or the fixed cutting elements 112 can be disposed in multiple rows along each of the blades 110. In the example shown, the three blades 110 are the same in shape and size. In other instances, one or more of the blades on a hybrid drill bit are a different shape or size from each other. The fixed cutting elements 112 are shown as being cylindrical polycrystalline diamond compact (PDC) cutters partially embedded into the blade 110. In some instances, the fixed cutting elements are different, for example, natural diamond inserts, thermally stable PDC cutters, tungsten carbide inserts, metal inserts, milled cutters or teeth, or another hard and abrasive material.

[0022] In some instances, the bit body 102 includes nozzles 122 at the drill end 106 to provide drilling fluid to the hybrid drill bit 100 during drilling.

[0023] Referring to FIG. 3A, the example hybrid drill bit 100 is shown in an end view, specifically, showing the drill end 106. The roller disc axes 118 of the roller discs 114 extend toward the central bit body axis 108. Each roller disc 114 is positioned with a pin angle defined by the angle between the roller disc axis 118 and a plane perpendicular to the central bit body axis 108.

[0024] In the example shown in FIG. 3A, the roller disc axes 118 are non-radial from the central bit body axis 108. If non-radial, an offset, S, between each roller disc axis 118 and the central bit body axis 108 is less than or equal to 0.5 inches in a 10.5 inch size or smaller hybrid bit. For example, the offset S can be 1/16 inch, 1/14 inch, 1/2 inch, or another dimension. The offset S is the shortest distance between the central bit body axis 108 and the roller disc axis 118. In other words, the offset S can be defined as a distance between the roller disc axis 118 and a plane through the central bit body axis 108, where the plane is parallel to the roller disc axis 118. In some instances, the offset S is the same for each roller disc 114. In other instances, the offset S is different for one or more or each roller discs 114.

[0025] In some instances, the offset S is small such that while the hybrid drill bit 100 rotates about the central bit body axis 108 and the drill end 106 is against a formation, the roller discs 114 rotate in near-true rolling with a small amount of shear or skidding relative to rolling. In instances with a small offset S, the near-true rolling with a small amount of shear or skid facilitates drilling into a formation, for example, in drilling into a soft formation. In other instances, the offset S is zero such that as the hybrid drill bit 100 rotates about a central bit body axis 108 and the drill end 106 is against a formation, the roller discs 114 rotate in true-rolling without shear against the formation. In instances with a zero offset S, the true-rolling of the roller discs 114 facilitates drilling into a formation, for example, in directional drilling and drilling into a hard formation.

[0026] Referring to FIG. 6, roller disc 114 is shown in a side view on arm 116. The roller disc 114 includes a disc body 602 and a generally ring-shaped cutting row 604 radially disposed about the disc body 602. The roller disc 114 includes one cutting row 604. The cutting row 604 defines a rotational plane 606 through the center of the cutting row, where the roller disc axis 118 is normal to the rotational plane 606. The center 608 of the roller disc 114 is the intersection of the roller disc axis 118 and the rotational plane 606.

[0027] The cutting row 604 can take many forms. In some instances, the cutting row 604 includes a continuous carbide disc radially disposed on the disc body 602. In the example shown in FIG. 6, a cross section of the cutting row 604 is a linear protrusion with a substantially circular outer tip. In some instances, the cross section of the cutting row is a triangular protrusion with a sharp tip, a trapezoidal protrusion with a straight tip, a rectangular protrusion with a straight tip, a domed protrusion with a blunt tip, a combination of these, or another configuration. For example, a configuration of the cross-section can be determined by a specific rock formation type. In other instances, the cutting row 604 includes a discontinuous disc configuration. For example, the cutting row can include a plurality of diamond inserts disposed about the disc body 602. The diamond inserts can be partially embedded into the disc body 602, coupled to the disc body 602 through welding, with fasteners, or bonded, and/or otherwise disposed about the disc body 602.

[0028] The pin angle of the roller disc 114 is defined by the angle between the roller disc axis 118 and a plane perpendicular to the central bit body axis 108. The pin angle is a complement to an angle β between the roller disc axis 118 and a longitudinal axis 109. The angle β is the smallest angle between the roller disc axis 118 and the longitudinal axis 109, where the longitudinal axis 109 is parallel to the central bit body axis 108 of the bit body 102 and intersects the center 608 of the roller disc 114. In the example shown in FIG. 6, the angle β is about 60 degrees. The angle β can be different, for example, β can be 0 degrees, 90 degrees, an angle between 0 and 90 degrees, or another angle.

[0029] Referring to FIG. 7, an example roller disc 114' is shown in a side view. The example roller disc 114' is like the roller disc 114 of FIG. 6, but the example roller disc 114' is oriented differently on the arm 116 than example roller disc 114. For example, roller disc 114' has an angle β of about 90 degrees.

[0030] Referring back to FIG. 3A, fixed placement of the roller discs 114 on the bit body 102 can vary between each of the roller discs 114. The roller discs 114 are at a distance L from the central bit body axis 108. The distance L is the shortest distance between the roller disc center 608 and the central bit body axis 108. In some instances, the distance L can be the same for each roller disc 114. In other instances, the distance L is different for one or more or each roller disc 114.

[0031] FIG. 3B shows an example hybrid drill bit profile 200 corresponding to the example hybrid drill bit 100 of FIG. 3A. The example hybrid drill bit profile 200 includes the shape cut by the hybrid drill bit 100 of FIG. 3A, showing each associated cutting element of the bit 100 transposed on a plane. In the example shown in FIG. 3B, the hybrid drill bit profile 200 is defined by three roller discs 114a, 114b, and 114c, and the fixed cutting elements 112 of the blades 110 projected onto a vertical plane passing through the central bit body axis 108 of the bit body 102. Each roller disc 114a, 114b, and 114c can include components and features of the roller disc 114 shown in FIG. 6, including a disc body 602, a cutting row 604, a rotational plane 606, a roller disc center 608, and a longitudinal axis 109 that intersects the center of the roller disc 114 and is parallel to the central bit body axis 108 of the bit body 102.

[0032] Each roller disc 114a, 114b, and 114c has a roller disc axis 118a, 118b, and 118c, respectively, that is offset from the central bit body axis 108 at distances Sa, Sb, and Sc, respectively. Distances Sa, Sb, and Sc are fixed, but can be different. For example, distances Sa, Sb, and Sc can all be the same, two or more can be the same, or each can be different. In some instances, the offset is the same for each roller disc 114a, 114b, and 114c, in that distances Sa, Sb, and Sc are equal.

[0033] Each roller disc 114a, 114b, and 114c is at a distance La, Lb, and Lc, respectively, from the central bit body axis 108. Distances La, Lb, and Lc are fixed, but can be different. For example, distances La, Lb, and Lc can all be the same, two or more can be the same, or each can be different.

[0034] Each roller disc axis 118a, 118b, 118c is at a respective pin angle from a plane perpendicular to the central bit body axis 108. Thus, each roller disc axis 118a, 118b, 118c is at an angle βa, βb, and βc, respectively, from a longitudinal axis 109a, 109b, 109c, respectively, that is parallel to the central bit body axis 108 and intersects the roller disc centers 608a, 608b, 608c, respectively. Angles βa, βb, and βc are fixed angles, but can be different. For example, angles βa, βb, and βc can all be the same, two or more angles can be the same, or each angle can be different.

[0035] In the example hybrid bit profile 200 shown in FIG. 3B, each respective rotational plane 606a, 606b, 606c through the roller discs 114a, 114b, 114c is perpendicular (precisely or substantially) to a periphery of the example hybrid bit profile 200. For example, each respective rotational plane 606a, 606b, 606c can be at an angle between 80 degrees and 100 degrees from the periphery of the example profile 200. In other instances, the rotational planes 606a, 606b, 606c are not generally perpendicular to the profile 200. The example profile 200 illustrates the cutting rows 604a, 604b, 604c of the roller discs 114a, 114b, 114c engaging a shoulder zone of the example profile 200. In some instances, the cutting rows 604a, 604b, 604c engage a cone zone, a nose zone, a gage zone, and/or the shoulder zone. The cutting rows 604a, 604b, 604c of the roller discs 114a, 114b, 114c do not engage a cone zone of the example profile 200. The gage zone is associated with the cylindrical sidewall of a wellbore, such that engaging the gage zone includes cutting only the cylindrical sidewall of the wellbore. The shoulder zone, nose zone, and cone zone are associated with a downhole end of the wellbore (i.e. bottom of hole). The nose zone extends farther beyond the drill end of a bit body than the cone and shoulder zones, and the shoulder zone bridges the nose zone and the gage zone. The cone zone is in the lateral center of the drill bit on the longitudinal drill end.

[0036] The cutting rows 604a, 604b, 604c extend further in the profile 200 than the fixed cutting elements 112 of the blades 110. The cutting rows 604a, 604b, 604c lead the fixed cutting elements 112 of the blades 110 in cutting a formation such that the cutting rows 604a, 604b, 604c prefracture the formation during drilling. The blades 110 can also support the roller discs 114a, 114b, 114c during drilling by limiting the contact stress between the cutting rows 604a, 604b, 604c and the formation. For example, the fixed cutting elements 112 contact the formation as the cutting rows 604a, 604b, 604c are partially engaged into the formation. In some instances, one or more of the fixed cutting elements 112 of the blades 110 extends further in the profile 200 than the cutting rows 604a, 604b, 604c. In other instances, the cutting rows 604a, 604b, 604c and the fixed cutting elements 112 extend into the profile 200 evenly. In other instances, one or more fixed cutting elements 112 can extend further than one or more of the cutting rows 604a, 604b, 604c, and another subset of cutting rows 604a, 604b, 604c can extend further than other fixed cutting elements 112. For example, a cutting row profile of a first roller disc can extend further than a fixed cutting element profile, and the fixed cutting element profile can extend further than a profile of a second roller disc.

[0037] Referring to FIG. 4A, an example hybrid drill bit 100’ is shown in an end view. The example hybrid drill bit 100’ is like the example hybrid drill bit 100 of FIG. 3A, except the hybrid drill bit 100’ includes four roller discs 114 and two blades 110.

[0038] FIG. 4B shows an example hybrid drill bit profile 200’ corresponding to the example hybrid drill bit 100’ of FIG. 4A. The example hybrid drill bit profile 200’ is like the example hybrid drill bit profile 200 of FIG. 3B, except the example hybrid drill bit profile 200’ includes four roller discs 114a, 114b, 114c, and 114d, and fixed cutting elements 112 from two blades 110.

[0039] Referring to FIG. 5A, an example hybrid drill bit 100’’ is shown in an end view. The example hybrid drill bit 100’’ is like the example hybrid drill bit 100 of FIG. 3A, except the hybrid drill bit 100’’ includes four roller discs 114 and three blades 110’. The blades 110’ of the example hybrid drill bit 100’’ radially extend from the central bit body axis 108 less than the roller discs 114. For example, the blades 110’ are more radially inward than the roller discs 114 with respect to the central bit body axis 108 of the bit body 102.

[0040] FIG. 5B shows an example hybrid drill bit profile 200'' corresponding to the example hybrid drill bit 100'' of FIG. 5A. The example hybrid drill bit profile 200'' is like the example hybrid drill bit profile 200 of FIG. 3B, except the example hybrid drill bit profile 200'' includes four roller discs 114a, 114b, 114c, 114d and fixed cutting elements 112 from the three blades 110 from FIG. 5A.

[0041] Hybrid drill bits, such as the example hybrid drill bits 100, 100', and 100'', can be configured to rotate about a central bit body axis with a drill end against a formation in a wellbore. Roller discs disposed about the drill end crush or crack a formation in a substantially or wholly rotating action, while fixed cutting elements on a blade scrape against the formation in a shearing action. The rotating action of the roller discs can include true rolling or near-true rolling with partial scraping or shearing of the formation. In some instances, the roller discs prefracture the formation such that the fixed cutting elements scrape the prefractured cuttings of formation.

[0042] In view of the discussion above, certain aspects encompass, a hybrid drill bit including a bit body having a central bit body axis at a center of the bit body, a blade on the bit body extending from an end of the bit body, and a roller disc rotatably coupled to the bit body about the end of the bit body to rotate on a roller disc axis. The roller disc axis extends toward the central bit body axis. The blade includes a plurality of fixed cutting elements.

[0043] Certain aspects encompass, a well drilling system including a well head, a drill string connected to the well head, and a hybrid drill bit connected to the drill string. The hybrid drill bit includes a bit body having a central bit body axis at a center of the bit body, a blade on the bit body extending from an end of the bit body, and a roller disc rotatably coupled to the bit body about the end of the bit body to rotate on a roller disc axis. The roller disc axis extends toward the central bit body axis. The blade includes a plurality of fixed cutting elements.

[0044] Certain aspects encompass, a method of cutting a formation in a wellbore. The method includes rotating a drill bit in a formation in a wellbore, crushing or cracking the formation in a rotating action using a roller disc on the drill bit, and scraping the formation in a shearing action using fixed cutting elements on a blade on the drill bit.

[0045] The aspects above can include some, none, or all of the following features. The hybrid drill bit includes an arm coupled to the bit body extending generally along the central bit body axis and beyond the end of the bit body. The roller disc is rotatably coupled to the arm. The roller disc axis of the roller disc intersects the central bit body axis. The roller disc axis of the roller disc is non-radial from the central bit body axis. The shortest distance S between the central bit body axis and the roller disc axis is less than 0.5 inches. The roller disc includes a disc body and a generally ring-shaped cutting row radially disposed about the disc body, and the roller disc includes only one cutting row. The cutting row defines a rotational plane through the center of the cutting row, and the rotational plane is normal to the roller disc axis. The rotational plane of the roller disc is generally perpendicular to a periphery of a corresponding bit profile, and a center of the roller disc is the intersection of the roller disc axis and the rotational plane. The roller disc is in a shoulder zone of the bit profile. The hybrid bit includes a plurality of discs and a plurality of blades. The plurality of discs is a different distance L from the central bit body axis, where the distance L is the shortest distance between a center of the respective roller disc and the central bit body axis. The plurality of roller discs may not be in the cone zone of a corresponding bit profile. Each roller disc axis of the plurality of discs is at a different angle β from the central bit body axis, where the angle β is the angle of the respective roller disc axis from the central bit body axis. The plurality of blades are more radially inward than the plurality of discs with respect to the central bit body axis of the bit body. The cutting row of the roller disc extends further from the end of the bit body than the fixed cutting elements of the blade. The hybrid drill bit includes an arm coupled to the bit body extending generally along the central bit body axis and beyond the end of the bit body, and the roller disc is rotatably coupled to the arm. The roller disc includes a disc body and a generally ring-shaped cutting row radially disposed about the disc body, and the roller disc comprises only one cutting row. Crushing or cracking the formation in a rotating action using a roller disc includes prefracturing the formation using the roller disc, where the roller disc is deeper into the formation than the fixed cutting elements of the blade. Scraping the formation in a shearing action using fixed cutting elements on a blade includes scraping prefractured cuttings of formation.

Crushing or cracking the formation in a rotating action using a roller disc on the drill bit includes a roller disc configured to roll against the formation with small shear.

[0046] A number of embodiments have been described. Nevertheless, it will be understood that various modifications may be made. Accordingly, other embodiments are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A hybrid drill bit, comprising:

   a bit body defining a central bit body axis;

   a blade on the bit body extending from an end of the bit body, the blade comprising a plurality of fixed cutting elements; and

   a roller disc rotatably coupled to the bit body about the end of the bit body to rotate on a roller disc axis, the roller disc axis extending toward the central bit body axis.

2. The hybrid drill bit of claim 1, comprising an arm coupled to the bit body extending generally along the central bit body axis and beyond the end of the bit body; and

   where the roller disc is rotatably coupled to the arm.

3. The hybrid drill bit of claim 1, where the roller disc axis of the roller disc intersects the central bit body axis.

4. The hybrid drill bit of claim 1, where the roller disc axis of the roller disc is non-radial from the central bit body axis.

5. The hybrid drill bit of claim 4, where a shortest distance S between the central bit body axis and the roller disc axis is less than 0.5 inches.

6. The hybrid drill bit of claim 1, where the roller disc comprises a disc body and a generally ring-shaped cutting row radially disposed about the disc body; and

   where the roller disc comprises only one cutting row.

7. The hybrid drill bit of claim 6, where the cutting row defines a rotational plane through the center of the cutting row, the rotational plane being normal to the roller disc axis;

where the rotational plane of the roller disc is generally perpendicular to a periphery of a corresponding bit profile; and

where a center of the roller disc is the intersection of the roller disc axis and the rotational plane.

8. The hybrid drill bit of claim 7, where the roller disc is in a shoulder zone of the bit profile.

9. The hybrid drill bit of claim 1, comprising a plurality of roller discs and a plurality of blades.

10. The hybrid drill bit of claim 9, where each disc of the plurality of roller discs is a different distance L from the central bit body axis, where the distance L is a shortest distance between a center of the respective roller disc and the central bit body axis.

11. The hybrid drill bit of claim 9, where the plurality of roller discs are not in a cone zone of a corresponding bit profile.

12. The hybrid drill bit of claim 9, where each roller disc axis of the plurality of discs is at a different angle β from the central bit body axis, where the angle β is the angle of the respective roller disc axis from the central bit body axis.

13. The hybrid drill bit of claim 9, where the plurality of blades are more radially inward than the plurality of discs with respect to the central bit body axis of the bit body.

14. The hybrid drill bit of claim 7, where the cutting row of the roller disc extends further from the end of the bit body than the fixed cutting elements of the blade.

15. A well drilling system, comprising:

a well head;

a drill string connected to the well head;

a hybrid drill bit connected to the drill string, the hybrid drill bit comprising:

a bit body having a central bit body axis at a center of the bit body;

a blade on the bit body extending from an end of the bit body, the blade comprising a plurality of fixed cutting elements; and

a roller disc rotatably coupled to the bit body about the end of the bit body to rotate on a roller disc axis, the roller disc axis extending toward the central bit body axis.

16. The well drilling system of claim 15, where the hybrid drill bit further comprises:

an arm coupled to the bit body extending generally along the central bit body axis and beyond the end of the bit body; and

where the roller disc is rotatably coupled to the arm.

17. The well drilling system of claim 15, where the roller disc comprises a disc body and a generally ring-shaped cutting row radially disposed about the disc body; and

where the roller disc comprises only one cutting row.

18. A method of cutting a formation in a wellbore, the method comprising:

rotating a drill bit in a formation in a wellbore;

crushing or cracking the formation in a rotating action using a roller disc on the drill bit; and

scraping the formation in a shearing action using fixed cutting elements on a blade on the drill bit.

19. The method of claim 18, where crushing or cracking the formation in a rotating action using a roller disc comprises prefracturing the formation using the roller disc, where the roller disc is deeper into the formation than the fixed cutting elements of the blade; and

where scraping the formation in a shearing action using fixed cutting elements on a blade comprises scraping prefractured cuttings of formation.

20. The method of claim 18, where crushing or cracking the formation in a rotating action using a roller disc on the drill bit comprises a roller disc configured to roll against the formation with small shear.

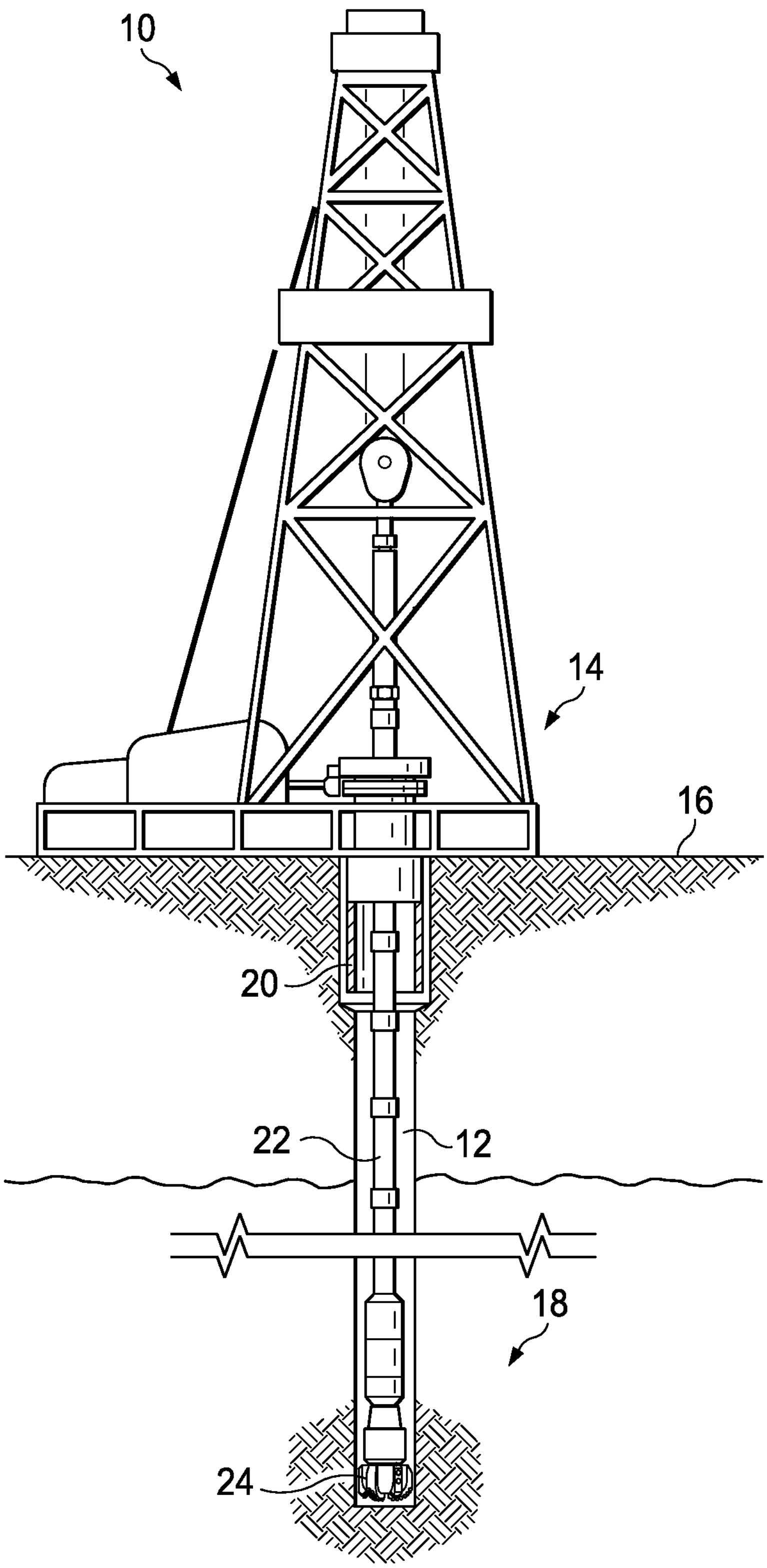
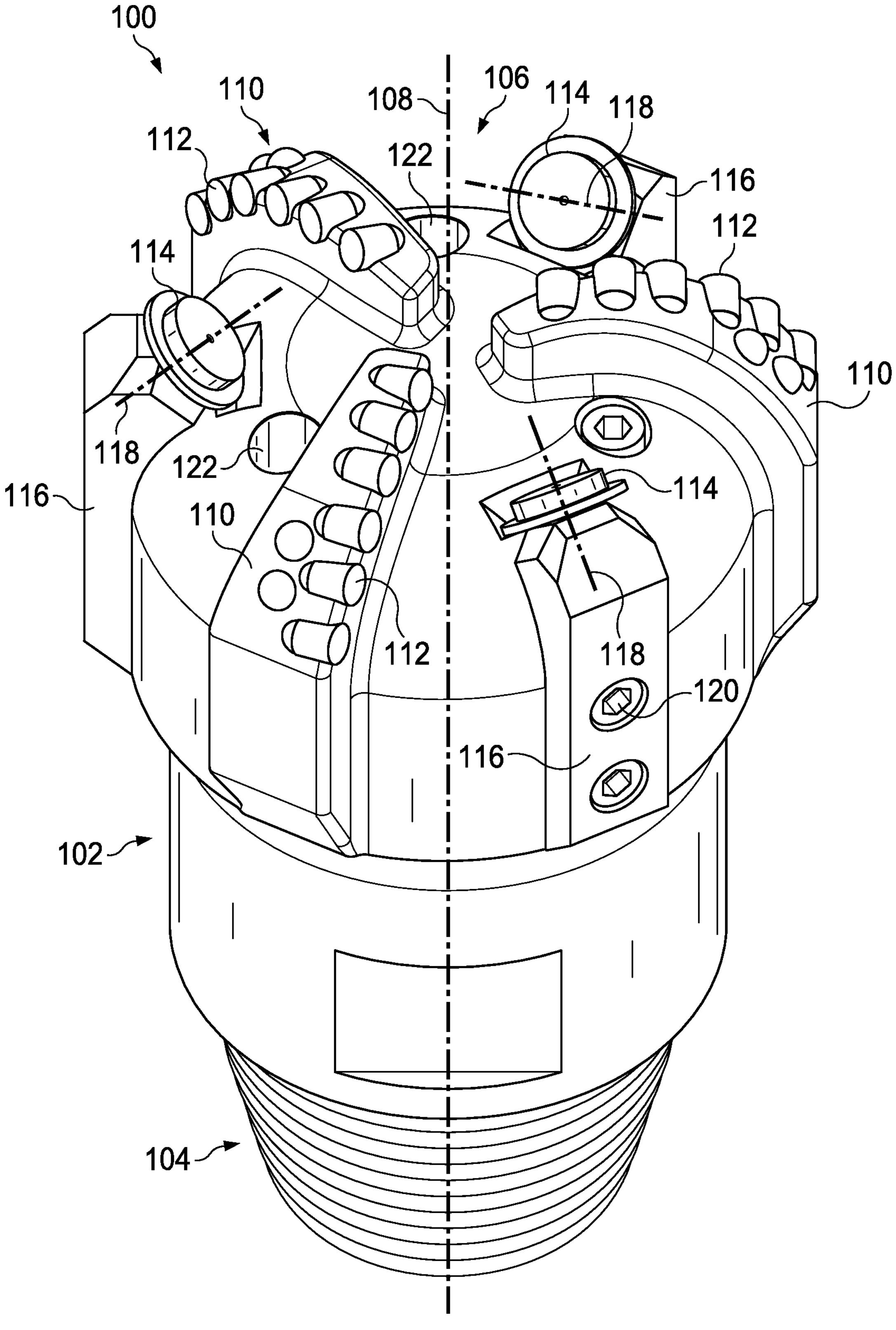


FIG. 1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102
104

FIG. 2

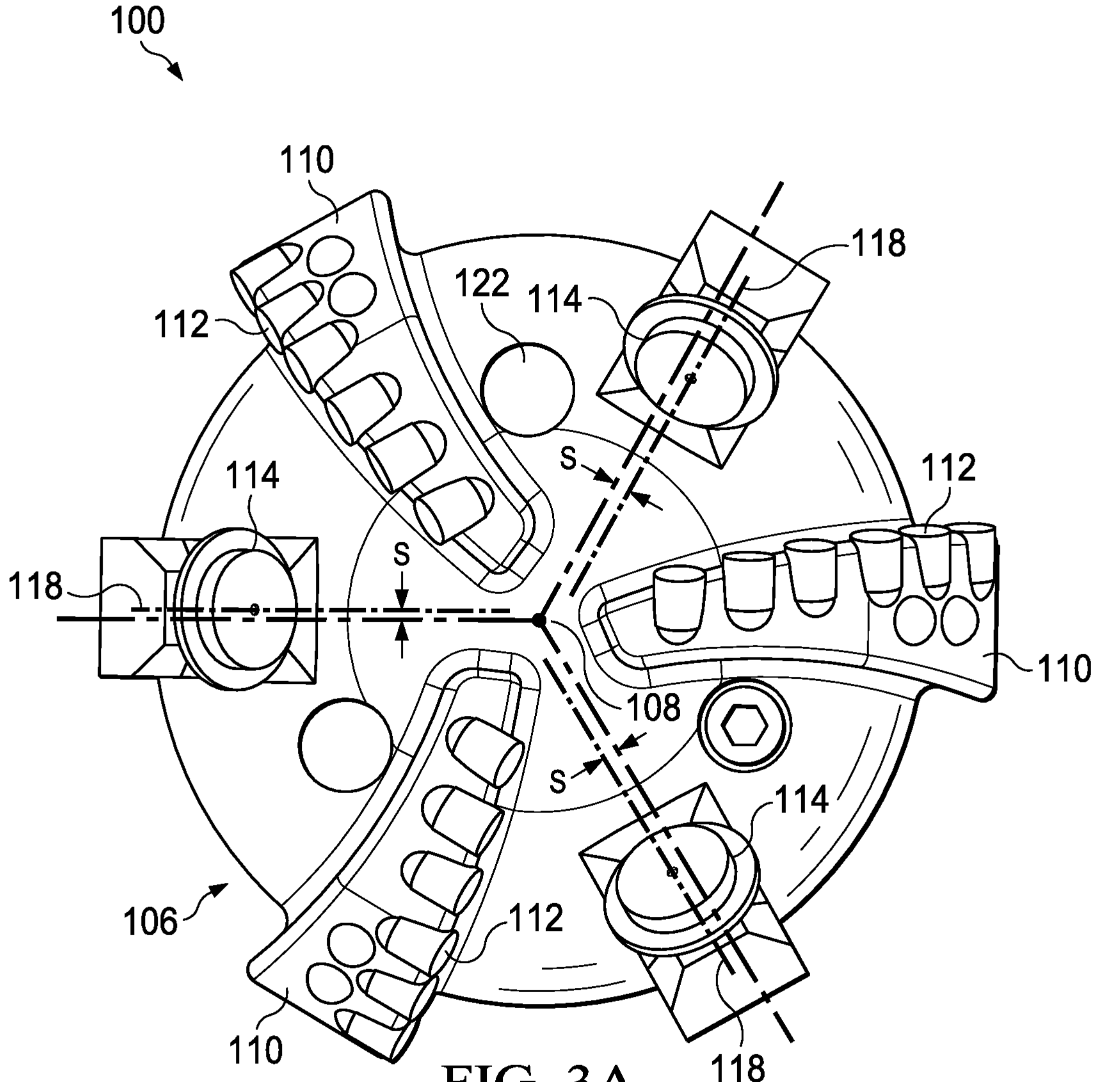
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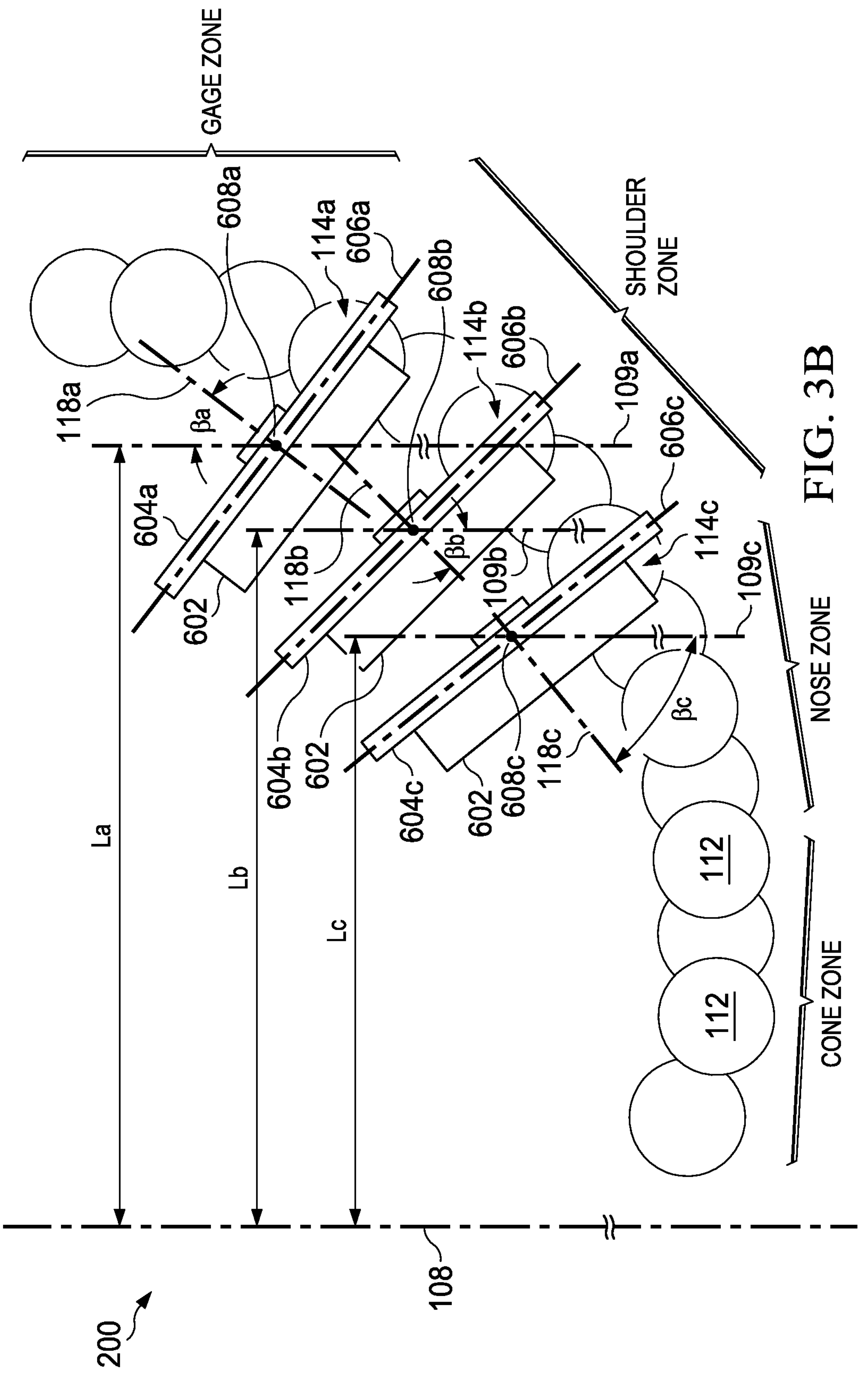
FIG. 3A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NOSE ZONE
CONE ZONE
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βa
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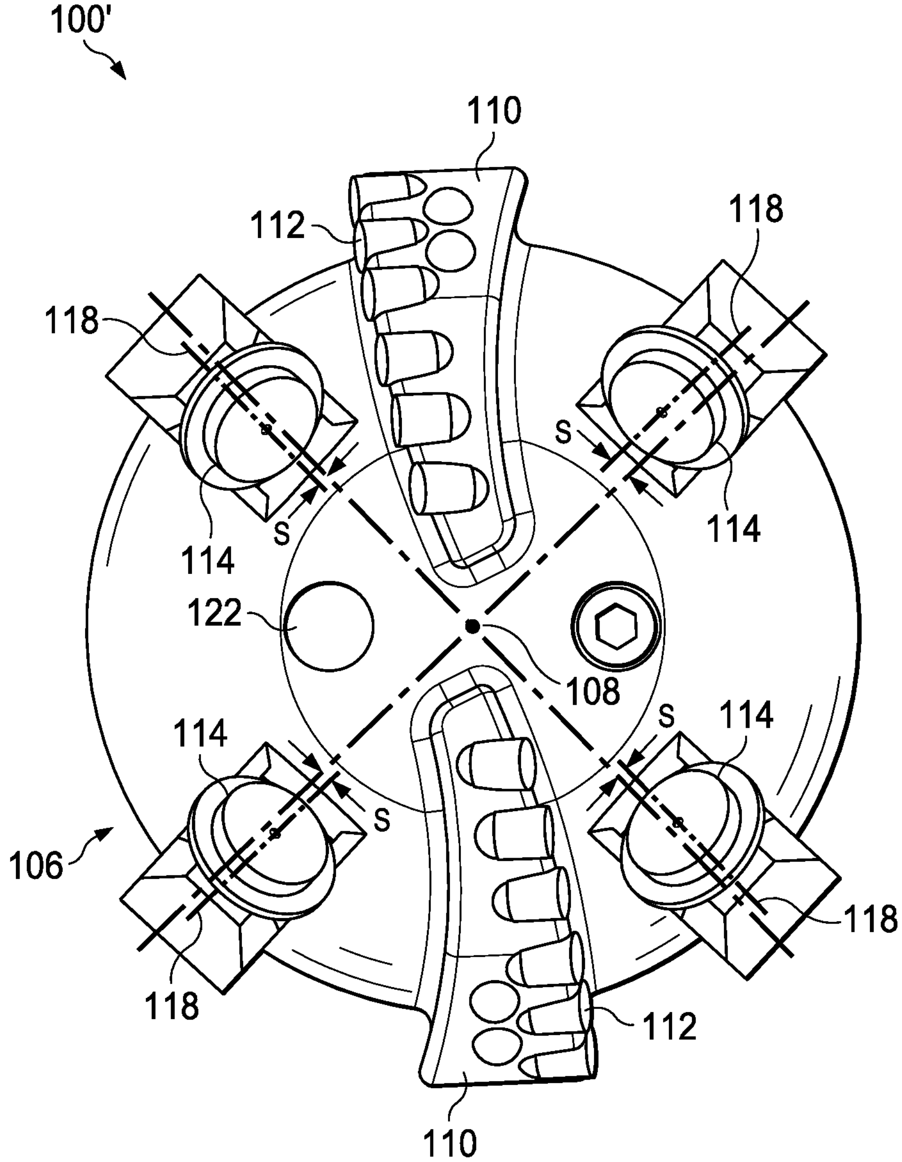
602
118b
βb
109b
606c
114c
109c
βc
118c
608c
604b
604c
112
112
La
Lb
Lc
108
200

FIG. 3B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S
114
114
S
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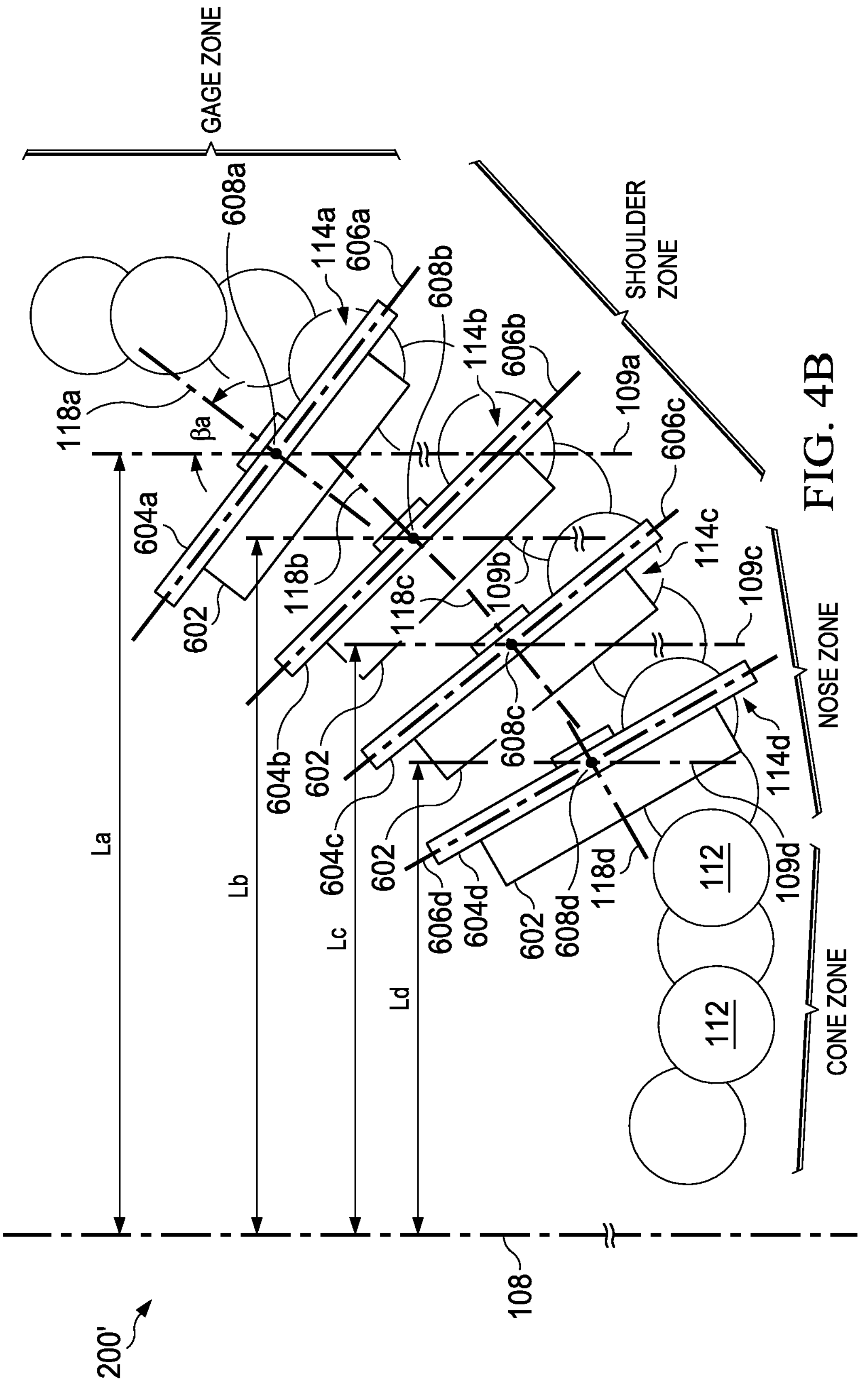
118
118
112
110

FIG. 4A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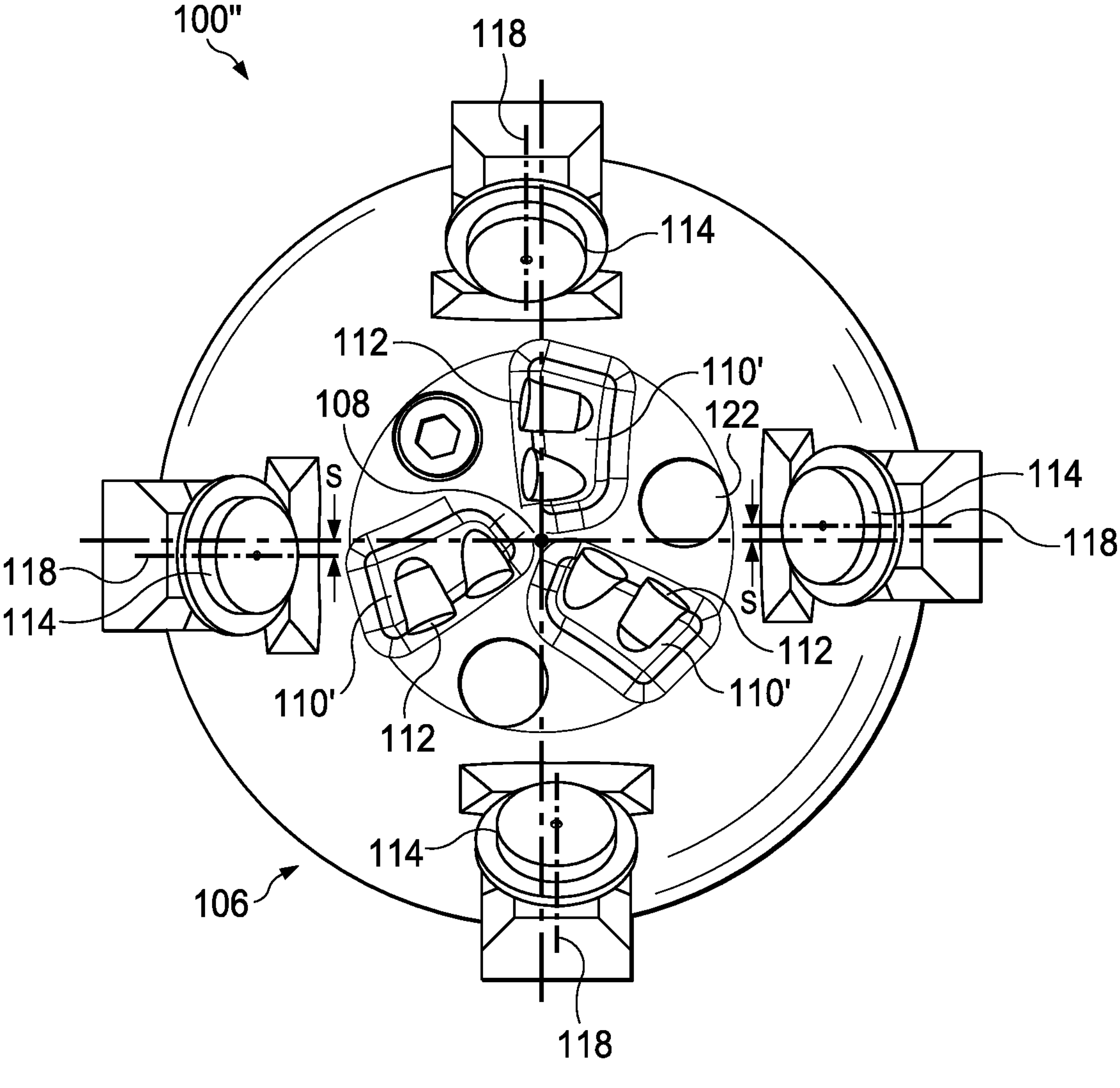
602
118b
118c
109b
114c
109c
604b
602
608c
114d
604c
602
606d
604d
602
608d
118d
109d
112
112
La
Lb
Lc
Ld
108
200'

FIG. 4B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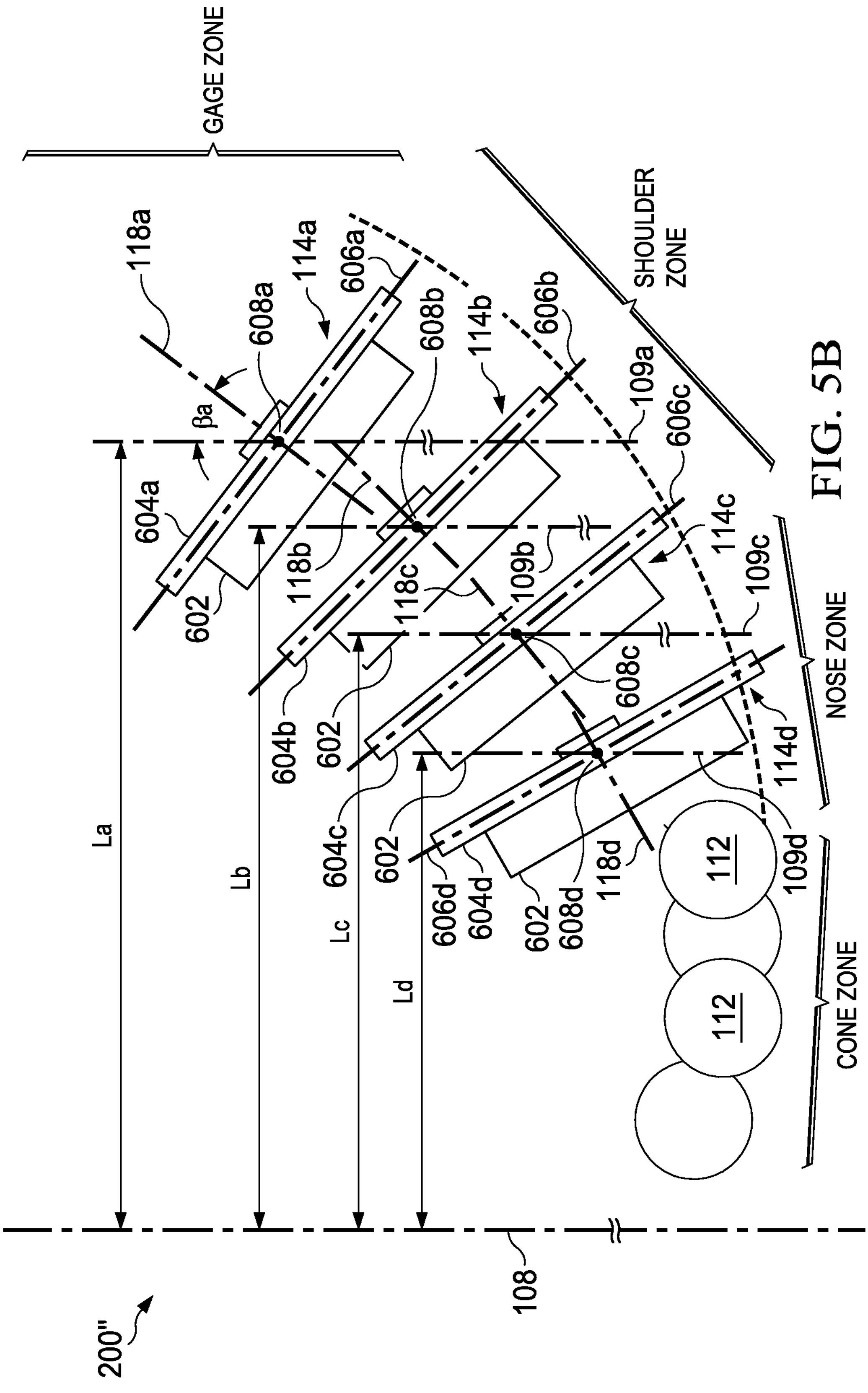
118
114
112
110'
108
122
114
S
118
118
114
S
112
110'
110'
112
114
106
118

FIG. 5A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608c
604c
602
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606d
604d
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Lb
Lc
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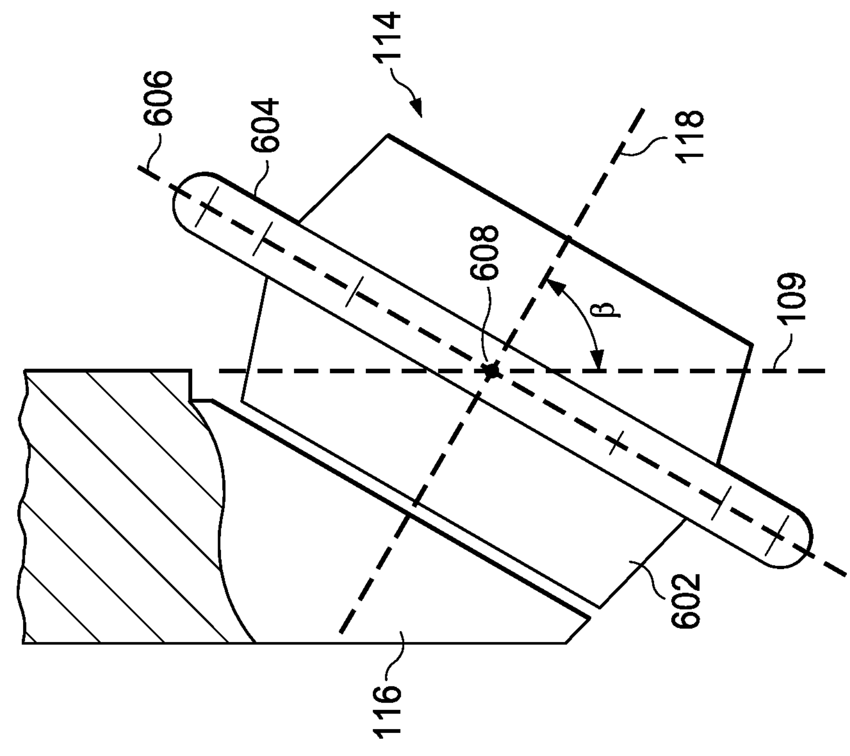
108
200"

FIG. 5B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β
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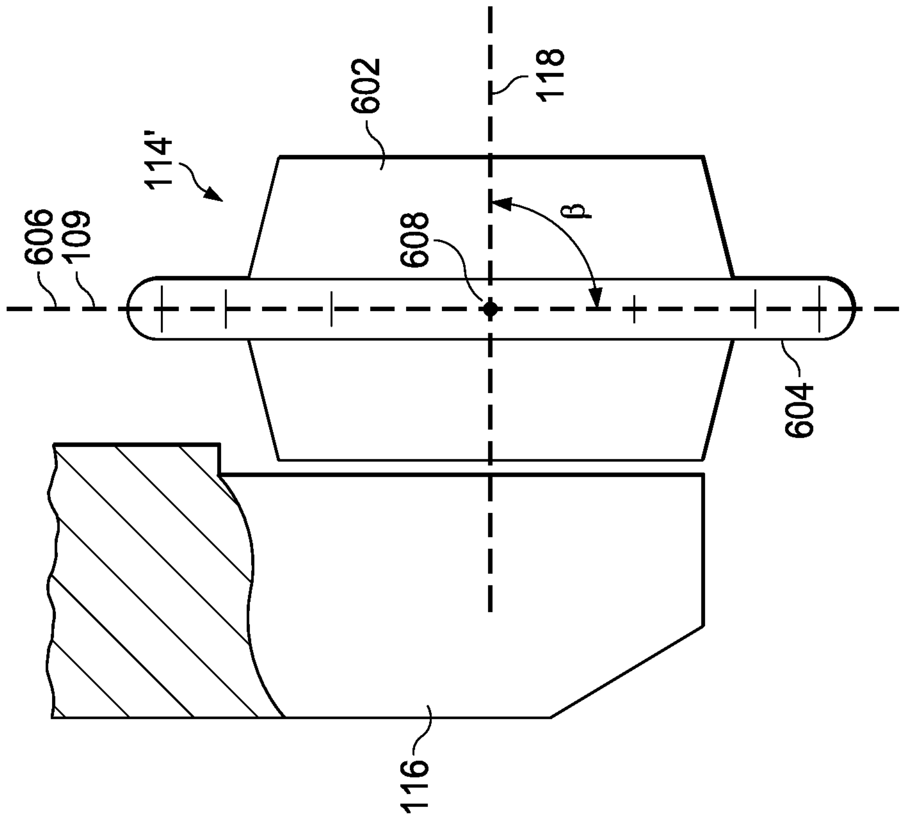
116

FIG. 6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114'
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β
604
116

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/039114

A. CLASSIFICATION OF SUBJECT MATTER

E21B 10/42(2006.01)i, E21B 10/12(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 10/14; E21B 10/36; B23P 15/28; E21B 10/06; E21B 10/00; E21B 10/12; E21B 10/28

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: hybrid bit, roller disk, cutting element, blade, axis, scrap, crack

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2011-0162893 A1 (ZHANG, ZHEHUA) 07 July 2011 See paragraphs [0048],[0062]-[0065],[0070], claims 1-5, and figures 4A-6.	1,3-5,9-13,15,18-20 2,6-8,14,16-17
Y	US 2008-0296068 A1 (ZAHRADNIK et al.) 04 December 2008 See paragraphs [0015]-[0016] and figures 1-2.	2,16
Y	WO 85-02223 A1 (ROCK BIT INDUSTRIES U.S.A., INC.) 23 May 1985 See page 5, lines 5-14 and figures 1-2.	6-8,14,17
A	US 2010-0155146 A1 (NGUYEN et al.) 24 June 2010 See paragraphs [0030]-[0031] and figures 3-4.	1-20
A	US 2011-0079440 A1 (BUSKE et al.) 07 April 2011 See paragraphs [0031]-[0032] and figures 1-2.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"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	Date of mailing of the international search report
11 February 2015 (11.02.2015)	**12 February 2015 (12.02.2015)**

Name and mailing address of the ISA/KR
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Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/039114

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