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Slaughter, JR. et al.

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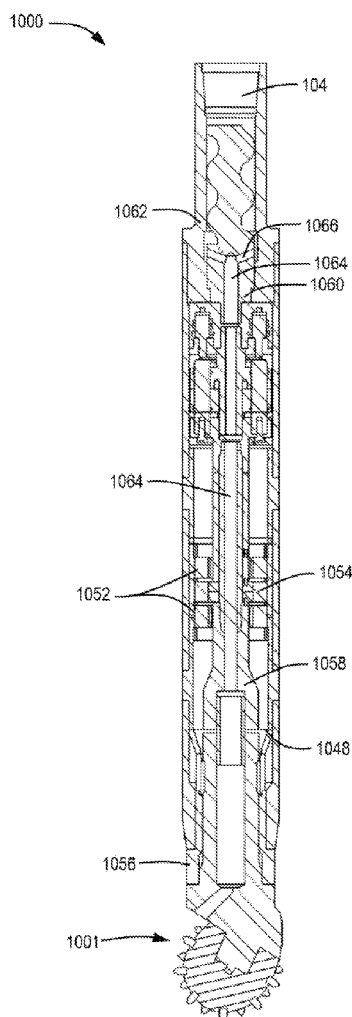
(57) **ABSTRACT**

A roller cone drill bit having a bit body. The bit body has a journal bearing coupled to an end portion thereof. A roller cone is coupled to the journal bearing. A first cutting element is coupled to the roller cone. A ratio of a radius of curvature of a crest portion of the first cutting element to a diameter of the first cutting element is between about 0.3:1 and about 0.8:1. A second cutting element is coupled to the roller cone. A ratio of a radius of curvature of a crest portion of the second cutting element to a diameter of the second cutting element is between about 0.05:1 and about 0.3:1. A height of the second cutting element is greater than the height of the first cutting element h between about 0.1 mm and about 6 mm.

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Related U.S. Application Data

(60) Provisional application No. 61/746,771, filed on Dec. 28, 2012.



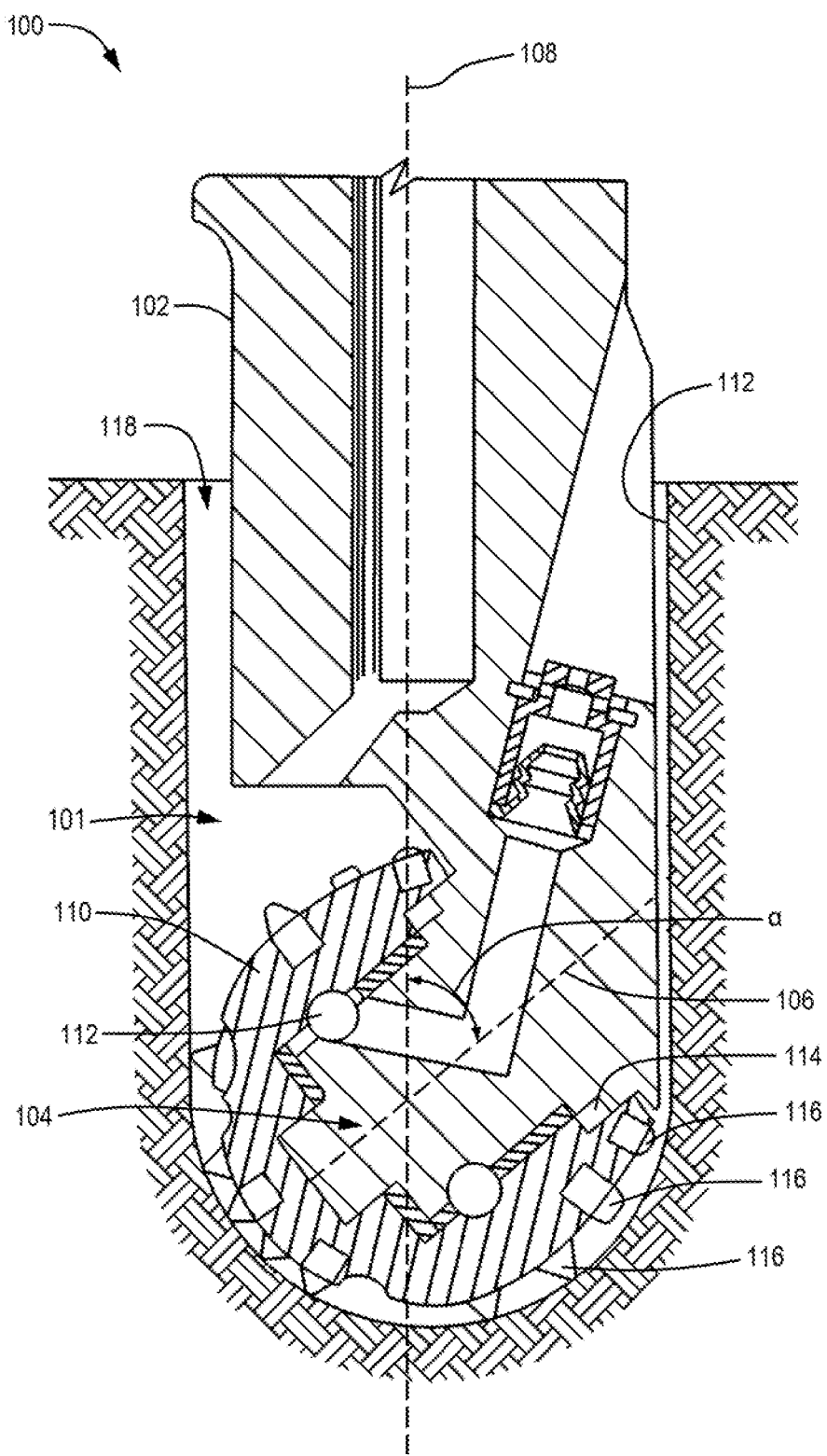


FIG. 1

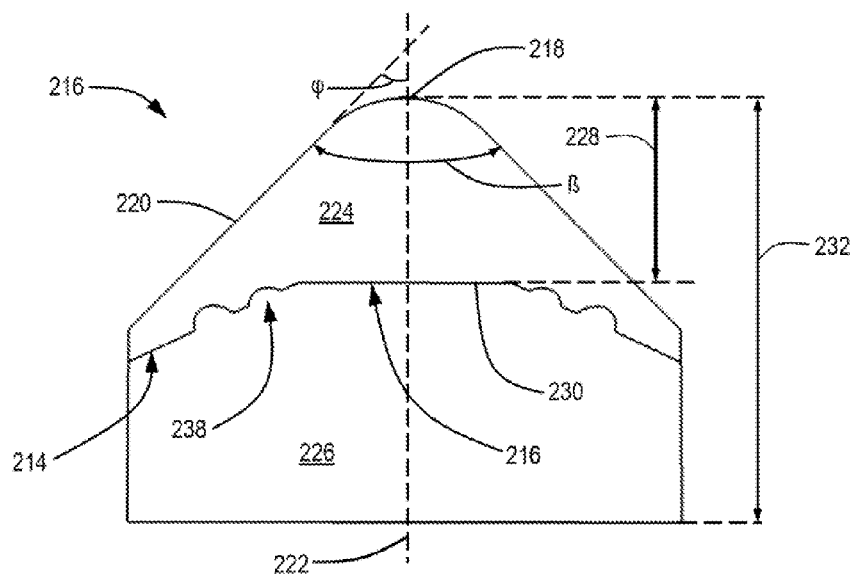


FIG. 2

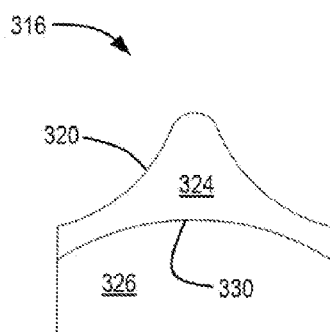


FIG. 3

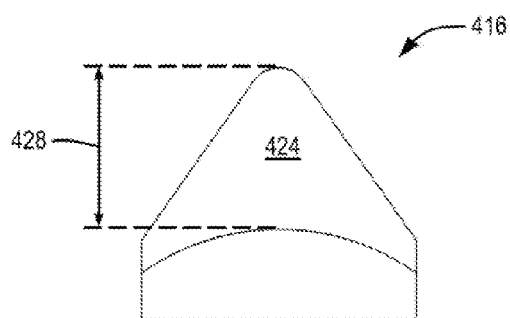


FIG. 4

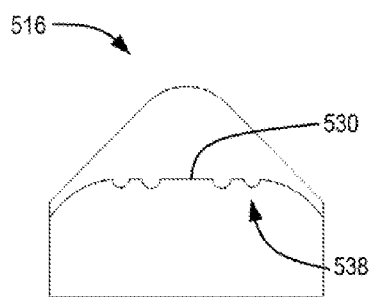


FIG. 5

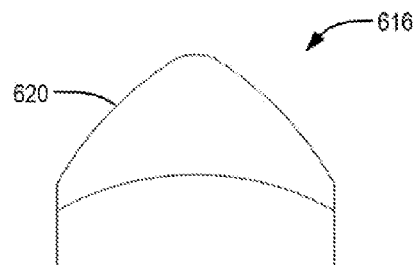


FIG. 6

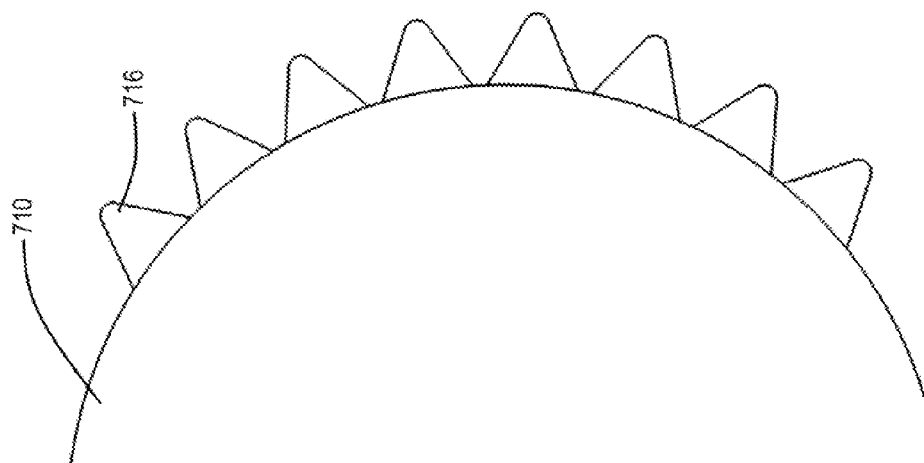


FIG. 7

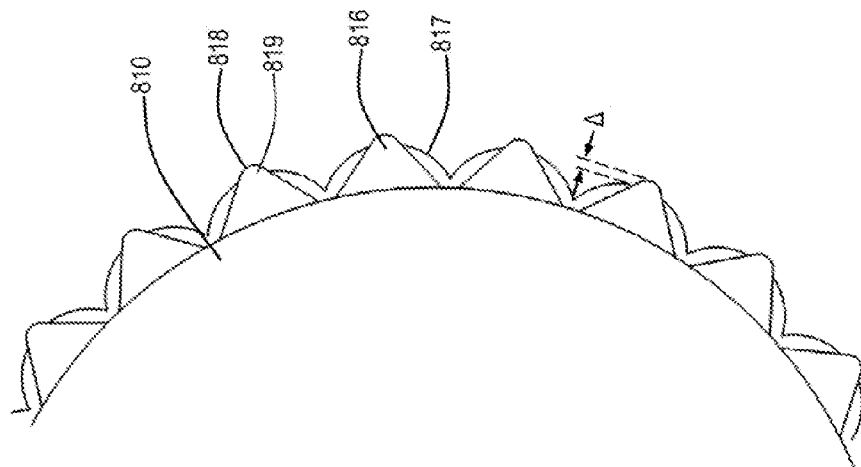


FIG. 8

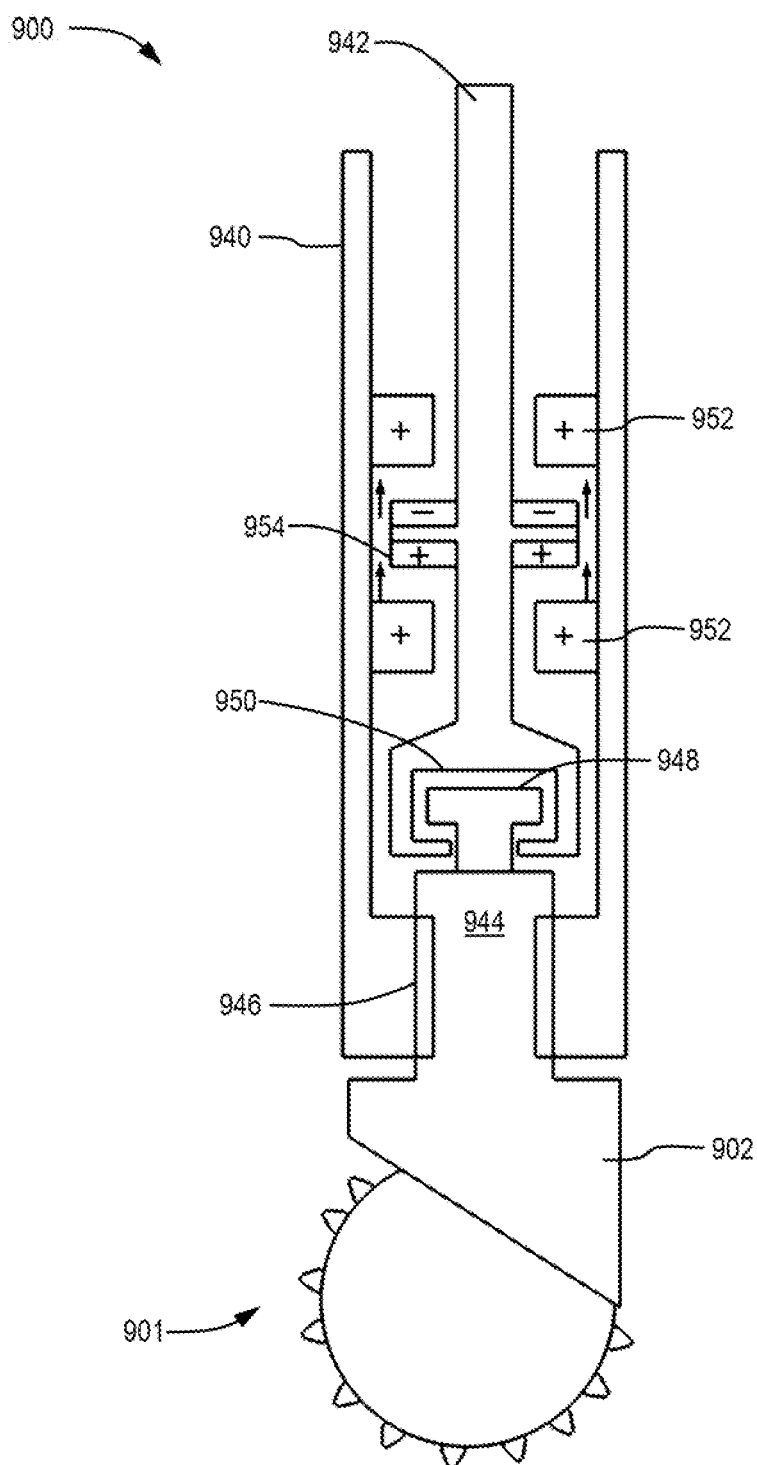


FIG. 9

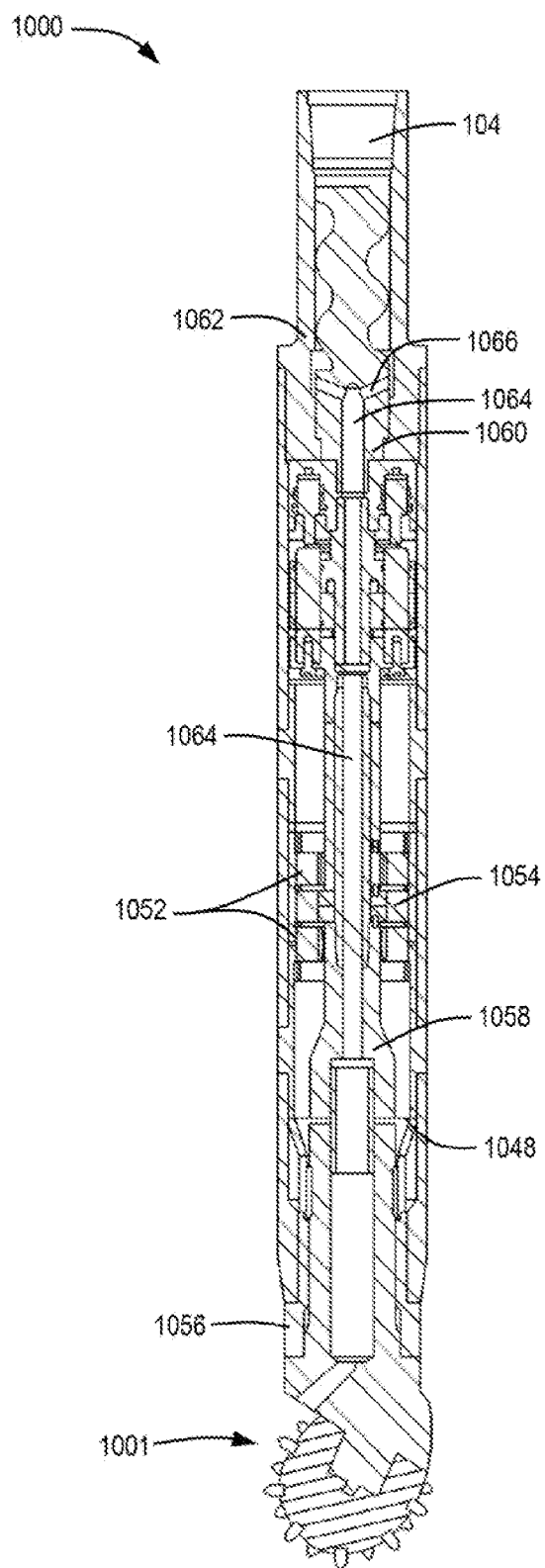


FIG. 10

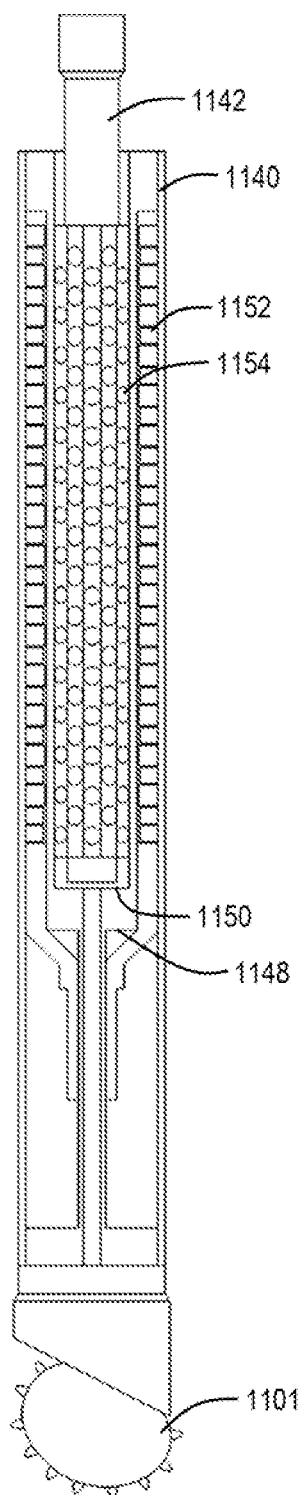


FIG. 11

ROLLER CONE DRILL BIT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of, and priority to, United States Patent Application No. 61/746,771, filed on Dec. 28, 2012 and entitled “ROLLER CONE DRILL BIT,” which application is incorporated herein by this reference in its entirety,

BACKGROUND

[0002] Conventional drilling systems used in the oil, gas, and mining industries to drill boreholes through subterranean formations include a drilling rig used to turn a drill string which extends downward into the well. A drill bit is coupled to the distal end portion of the drill string and is used to drill through the formation when rotated under an applied load. Drilling fluid or air is pumped through the drill string and drill bit to move cuttings away from the bit during drilling.

[0003] Drill bits fall within multiple categories, including fixed cutter bits, percussion hammer bits, and roller cone bits. Roller cone bits include a bit body formed from steel or another high strength material and have one or more roller cones rotatably coupled to the bit body. The roller cones are also formed from steel or other high strength material and include cutting elements on the cones. Drill bits that have integrally formed cutting elements are referred to as milled tooth bits, while, other roller cone bits may include cutting elements that are press fit into holes formed and/or machined into the roller cones.

[0004] The speed at which a borehole is drilled depends on a number of factors. These factors include, among others, the mechanical properties of the rocks that are drilled, the type of drill bit used, the materials of the drill bit cutting elements, the flow rate and type of circulating fluid, and the rotary speed and axial force applied to the drill bit. It is generally the case that for any particular mechanical property of a formation, a rate of penetration (“ROP”) of the drill bit corresponds to the amount of axial force on, and the rotary speed of, the drill bit. The rate at which the drill bit wears out is generally related to the ROP.

SUMMARY

[0005] Embodiments of a roller cone drill bit are disclosed. The drill bit may include a bit body with a roller cone coupled to an end portion of the bit body. First and second cutting elements may be coupled to the roller cone. A ratio of a radius of curvature of a crest portion of the first cutting element to a diameter of the first cutting element may be between about 0.3:1 and about 0.8:1, and a ratio of a radius of curvature of a crest portion of the second cutting element to a diameter of the second cutting element may be between about 0.05:1 and about 0.3:1. The height of each cutting element may be measured from an outer surface of the roller cone to the crest portion of the cutting element, and the height of the second cutting element may be greater than the height of the first cutting element by between about 0.1 mm and about 6 mm.

[0006] Some embodiments disclosed herein relate to a hammer assembly including a housing with a bore therein. A hammer arm may be disposed at least partially within the bore of the housing, and a bit body may be movably coupled to the hammer arm to allow the bit body to move axially relative to the hammer arm. A journal bearing may also be coupled to an

end portion of the bit body, and a roller cone may be coupled to the journal bearing. The roller cone may have cutting elements coupled thereto. A ratio of a radius of curvature of a crest portion of a first cutting element to a diameter of the first cutting element may be between about 0.3:1 and about 0.8:1, and a ratio of a radius of curvature of a crest portion of a second cutting element to a diameter of the second cutting element may be between about 0.05:1 and about 0.3:1. The height of the cutting elements may be measured from an outer surface of the roller cone to the crest portion of the cutting element, and the height of the second cutting element may be greater than the height of the first cutting element by between about 0.1 mm and about 6 mm.

[0007] A method for drilling, a borehole may include running a hammer drill assembly into the borehole, the assembly including: a housing and a hammer arm is disposed at least partially within a bore of the housing. A bit body may be coupled to the hammer arm and may be axially movable with respect to the hammer arm. A journal bearing may be coupled to an end portion of the bit body with a roller cone coupled to the journal bearing. At least two cutting elements may be coupled to the roller cone. A ratio of a radius of curvature of a crest portion of a first cutting element to a diameter of the first cutting element may be between about 0.3:1 and about 0.8:1. A ratio of a radius of curvature of a crest portion of a second cutting element to a diameter of the second cutting element may be between about 0.05:1 and about 0.3:1. The height of each cutting element may be measured from an outer surface of the roller cone to the crest portion of the cutting element, and the height of the second cutting element may be greater than the height of the first cutting element by between about 0.1 mm and about 6 mm. The first and second cutting elements of the drill bit may be contacted with a subterranean formation to form the borehole.

[0008] 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.

BRIEF DESCRIPTION OF DRAWINGS

[0009] One or more embodiments of a roller cone bit and/or hammer drilling assembly are described with reference to the following figures. The figures are drawn to scale for certain embodiments; however, a person of ordinary skill in the art should appreciate in view of the disclosure herein that the illustrated embodiments are not to scale for each embodiment contemplated herein or within the scope of the appended claims. The drawings may therefore also represent schematic or exaggerated illustrations of other embodiments within the scope of the present disclosure.

[0010] FIG. 1 depicts an illustrative roller cone bit, according to one or more embodiments of the present disclosure.

[0011] FIG. 2 depicts an illustrative cutting element, according to one or more embodiments of the present disclosure.

[0012] FIG. 3 depicts another illustrative cutting element, according to one or more embodiments of the present disclosure.

[0013] FIG. 4 depicts another illustrative cutting element, according to one or more embodiments of the present disclosure.

[0014] FIG. 5 depicts another illustrative cutting element, according to one or more embodiments of the present disclosure.

[0015] FIG. 6 depicts another illustrative cutting element, according to one or more embodiments of the present disclosure.

[0016] FIG. 7 schematically depicts an illustrative roller cone having conical cutting elements thereon, according to one or more embodiments of the present disclosure.

[0017] FIG. 8 schematically depicts an illustrative roller cone having a conical and semi-round top cutting elements thereon, according to one or more embodiments of the present disclosure.

[0018] FIG. 9 schematically depicts an illustrative hammer assembly, according to one or more embodiments of the present disclosure.

[0019] FIG. 10 depicts an illustrative drilling assembly, according to one or more embodiments of the present disclosure.

[0020] FIG. 11 depicts an illustrative drilling assembly, according to one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0021] FIG. 1 depicts an illustrative drilling assembly 100 roller cone bit 101, according to one or more embodiments. The roller cone bit 101 may include a bit body 102 made of steel or other high strength material. The bit body 102 may include a coupling (not shown) in some embodiments, to connect a first or “upper” end portion to a drill string (not shown). A second or “lower” end portion of the bit body 102 may include one or more hearings, such as a journal bearing 104, coupled thereto. The journal bearing 104 may be or include a cylindrical hearing that supports a rotating shaft. An angle α may be defined between a rotational axis 106 of the journal bearing 104 and a rotational axis 108 of the roller cone bit 101 and/or the bit body 102. The angle α may range from about 15° to about 80° in some embodiments. For instance, the angle α may range from a low of about 20°, about 30°, or about 40° to a high of about 50°, about 60°, about 70°, or more. For example, the angle α may be between about 20° and about 70° or between about 30° and about 60°.

[0022] In at least some embodiments, one or more roller cones (one is shown as roller cone 110) may be coupled to the journal bearing 104. In at least one embodiment, a single roller cone 110 may be used. The roller cone 110 may be substantially conical or frustoconical in some embodiments, and may be adapted to rotate about the axis 106 of the journal bearing 104. The journal bearing 104 may therefore be used to rotationally couple the roller cone 110 to the bit body 102.

[0023] The roller cone 110 may be retained using one or more bearings (e.g., ball bearings 112) disposed in corresponding grooves, pockets, or the like on an outer surface of the journal bearing 104 and an inner surface of the roller cone 110. The roller cone 110 may be formed from steel or another high strength material. In some embodiments, the outer surface of the roller cone 110 may be at least partially covered with a hardfacing or similar material to reduce abrasive wear of the roller cone 110. In some embodiments, a seal 114 may be disposed between the roller cone 110 and the journal bearing 104 to restrict, if not prevent, fluid or other debris from entering the space between the roller cone 110 and the journal bearing 104. In at least some embodiments, the seal

114 may maintain a lubricant in a desired location (e.g., between the roller cone 110 and the journal bearing 104).

[0024] The roller cone 110 may include or be coupled to a plurality of inserts or cutting elements (collectively cutting elements 116). More particularly, in some embodiments the outer surface of the roller cone 110 may include one or more receiving features (e.g., sockets, pockets, holes, or the like), and the cutting elements 116 may be inserted into the corresponding receiving features. An interference or friction fit may at least partially secure the cutting elements 116 in place. In other embodiments, brazing, welding, adhesives, bearing pockets, or the like may instead be used to couple the cutting elements 116 to the roller cone 110. Combinations of fastening techniques may also be used. In another embodiment, the cutting elements 116 may be coupled to the roller cone 110 by being integrally formed therewith. The bit body 102 and the roller cone 110 may each rotate about different axes, and in some embodiments the motion of the cutting elements 116 during drilling may be roughly defined as falling within a “wall contacting zone” and/or a “bottom contacting zone.” The cutting elements 116 located in the wall contacting zone may at least intermittently contact the outer diameter, gage, or wall of a borehole 118, while the cutting elements 116 in the bottom contacting zone may be in substantially continuous or cyclical contact with the bottom of the borehole 118.

[0025] FIG. 2 depicts an illustrative cutting element 216, according to one or more embodiments. The cutting element 216 may be generally conical or frustoconical in some embodiments. As shown in the illustrative embodiment, a cutting element 216 may include a crest portion 218. In some embodiments, the crest portion 218 may be planar or may be curved. When curved, the radius of curvature may range from about 0.25 mm to about 10 mm in some embodiments. For instance, the radius of curvature may range from a low of about 0.5 mm, about 1 mm, about 1.5 mm, or about 2 mm to a high of about 2.5 mm, about 3 mm, about 4 mm, or more. For example, the radius of curvature of the cutting element 216 may be between about 0.5 mm and about 1.5 mm or between about 1.5 mm and about 3 mm. As used herein, “crest portion” refers to the tip, apex, or other portion of a cutting element that is most distal relative to the outer surface of the cone, and/or the portion of a cutting element that is likely to initially contact the formation during drilling operations.

[0026] In some embodiments, the crest portion may include a variable radius of curvature, a portion of a parabola, a portion of a hyperbola, a portion of a catenary, a parametric spline, or a combination of curved and/or flat features. Further, a cone angle β of the crest portion 218 of the cutting element 216 may be between about 40° and about 160° in some embodiments. For instance, the cone angle β may range from a low of about 50°, about 60°, about 70°, or about 80° to a high of about 90°, about 100°, about 110°, about 120°, or more. For example, the cone angle β may be between about 70° and about 110° or between about 80° and about 100°. In some embodiments, an angle ϕ between a side surface 220 and a longitudinal axis 222 of the cutting element 216 may be between about 20° and about 80°. For instance, the angle ϕ may range from about 35° to about 55° or from about 40° to about 50°. In some embodiments, the angle ϕ may be equal to about half of the cone angle β .

[0027] Further, as shown, the cutting element 216 may include multiple layers or components. For instance, the illustrated embodiment shows an example in which a top layer may be bonded to a bottom layer. In this particular embodi-

ment, the top layer may be an ultrahard material layer **224**, and the bottom layer may include a substrate (e.g., carbide substrate **226**). A height **228** of the ultrahard material layer **224** may be measured as the distance from the crest portion **218** of cutting element **216** to an interface **230** between the ultrahard material layer **224** and the carbide substrate **226**. Such height **228** may range from about 0.25 mm to about 20 mm in some embodiments. For instance, the height **228** may range from a low of about 1 mm, about 2 mm, or about 3 mm to a high of about 5 mm, about 10 mm, about 15 mm, or more. For example, the height **228** may be between about 2 mm and about 12 mm or between about 3 mm and about 7 mm. In some embodiments, a total height **232** of the cutting element **216** may be between about 4 mm and about 50 mm. For instance, the total height **212** may range from a low of about 6 mm, about 8 mm, or about 10 mm to a high of about 15 mm, about 20 mm, about 25 mm, or more.

[0028] Further, as shown in FIG. 2, the interface **230** between the carbide substrate **226** and the ultrahard material layer **224** may be substantially convex. For instance, the interface **230** may include a central portion **234** and a tapered portion **236**. In the illustrated embodiment, the central portion **234** is shown as being substantially flat, while the tapered portion **236** is shown as tapering downward to the outer circumference of the cutting element **216**. In some embodiments, the interface **230** may also include or be defined by one or more additional features (e.g., grooves **238**, ridges, etc.) located on any portion thereof, but illustrated as being formed on the tapered portion **236**. Such grooves **238** or other features may also be present on the interface **230** of the cutting element in other locations, including on the central portion **234** (see FIG. 5).

[0029] The cutting element **216** may be formed in a process similar to that used in forming diamond enhanced cutting elements (e.g., as used in roller cone bits) or may be formed by brazing or otherwise coupling components together. The interface **230** between the ultrahard material layer **224** and the carbide substrate **226** may be planar, curved, or the like. In some embodiments, the interface **230** may be non-planar and/or non-uniform, for example, to aid in reducing incidents of delamination of the ultrahard material layer **224** from the carbide substrate **226** when in operation and/or to improve the strength and impact resistance of the cutting element **216**. Further, the ultrahard material layer **224** may be formed from any polycrystalline or other superabrasive material including, for example, polycrystalline diamond, polycrystalline cubic boron nitride, or thermally stable polycrystalline diamond (formed either by treatment of polycrystalline diamond formed from a metal such as cobalt or polycrystalline diamond formed with a metal having a lower coefficient of thermal expansion than cobalt). A suitable substrate may include a variety of materials, including but not limited to carbide materials (e.g., tungsten carbide, cobalt-cemented tungsten carbide, etc.), metals, or ceramics.

[0030] FIG. 3 depicts another illustrative cutting element **316**, according to one or more embodiments of the present disclosure. The cutting element **316** may include a concave side wall **320**. In some embodiments, the interface **330** between a first or top layer **324** and a second or bottom layer **326** may be substantially smooth and convex (as shown), although the interface **330** may be concave or have other shapes, contours, or combinations thereof in other embodiments.

[0031] FIG. 4 depicts another illustrative cutting element **416**, according to one or more embodiments of the present disclosure. As shown in the illustrated embodiment, the height **428** of a first layer **424** of the cutting element **416** may be greater than the height **228** of the ultrahard material layer **224** in FIG. 2. The height **428** may be between about 4 mm and about 15 mm or between about 5 mm and about 10 mm in some embodiments. In other embodiments, the height **428** may be about the same as or even less than the height **228**, but may be larger as a ratio compared to the total height of the corresponding cutting element.

[0032] FIG. 5 depicts another illustrative cutting element **516**, according to one or more embodiments of the present disclosure. The cutting element **516** may include grooves **538** or other features in the interface **530**. While the grooves **238** in FIG. 2 are shown as convex with respect to the base of the carbide substrate **226** (i.e., opposite the crest portion **234**) of the cutting element **216**, the grooves **538** may be concave with respect to the base of the cutting element **516**.

[0033] FIG. 5 depicts another illustrative cutting element **616**, according to one or more embodiments of the present disclosure. As shown, a cutting element **616** may include a convex side wall **620** in some embodiments. Additional shapes (e.g., shapes of crest portions, side surfaces, interfaces, substrates, etc.) may be used in connection with embodiments of the present disclosure. Certain features of illustrative ultrahard material layers of the present disclosure include those described in U.S. patent application Ser. No. 11/829,577 (U.S. Patent Publication No. 2008/0035380 A1), entitled "Pointed Diamond Working Ends on a Shear Bit", which is incorporated herein by this reference in its entirety.

[0034] FIG. 7 schematically depicts an illustrative roller cone **710** having a plurality of conical cutting elements **716** disposed thereon, according to one or more embodiments of the present disclosure. In operation, the roller cone **710** may operate in a manner similar to that described with respect to the roller cone **110** of FIG. 1. As shown, the cutting elements **716** disposed on or otherwise coupled to the roller cone **710** may have a substantially pointed geometry, including, the geometry of any cutting element described or referenced herein (see, e.g., FIGS. 2-6).

[0035] FIG. 8 depicts another illustrative roller cone **810** having a plurality of conical cutting elements **816** and a plurality of curved or semi-round top ("SRT") cutting elements **817** disposed thereon, according to one or more embodiments of the present disclosure. In accordance with at least some embodiments of the present disclosure, a ratio of the radius of curvature of the crest portion **819** of SRT cutting elements **817** to the diameter (at the base and/or widest point) of the SRT cutting elements **817** may be between about 0.3:1 to about 2:1. For instance, such ratio may range from a low of about 0.3:1, about 0.4:1, or about 0.5:1 to a high of about 0.6:1, about 0.7:1, about 0.8:1, or more. For example, the ratio of the radius of curvature of the crest portion **819** to the diameter of the SRT cutting elements **817** may be between about 0.3:1 and about 0.8:1 or between about 0.4:1 and about 0.7:1. A ratio of the radius of curvature of the crest portion **818** of the conical cutting elements **816** to the diameter of the conical cutting elements **816** may be between about 0.025 and about 1:1 in some embodiments. For instance, such ratio may range from a low of about 0.05:1, about 0.10:1, or about 0.15:1 to a high of about 0.20:1, about 0.25:1, about 0.30:1, or more. For example, the ratio of the radius of curvature of the crest portion **818** to the diameter of the conical cutting elements

ments **816** may be between about 0.05:1 and about 0.30:1 or between about 0.14:1 and about 0.25:1.

[0036] As shown, a crest portion **818** of the conical cutting elements **816** may, in some embodiments, be radially offset from the crest portion **819** of the SRT cutting elements **817** with respect to the outer surface of the roller cone **810**. In other words, a height of the conical cutting elements **816** (as measured from the outer surface of the roller cone **810** to the crest portion **818** of the conical cutting elements) may be greater than a height of the SRT cutting elements **817** (as also measured from the outer surface of the roller cone **810** to the crest portion **819** of the SRT cutting elements **817**) a distance Δ . The distance Δ may be from about 0.05 mm to about 10 mm in some embodiments. For instance, the distance Δ may range from a low of about 0.1 mm, about 0.2 mm, about 0.3 mm, about 0.4 mm, or about 0.5 mm to a high of about 0.75 mm, about 1 mm, about 2 mm, about 4 mm, about 6 mm, or more. For example the distance Δ may be between about 0.1 mm and about 6 mm, between about 0.2 mm and about 2 mm, or between about 0.3 mm and about 1 mm. In some embodiments, the SRT cutting elements **817** may limit the depth of penetration of the conical cutting elements **816** into the subterranean formation.

[0037] Referring again to FIG. 1, the cutting elements **116** on the roller cone **110** may be in one of two zones, namely the bottom contacting zone or the wall contacting zone. In at least one embodiment, at least one of the cutting elements **116** in the bottom contacting zone may be a conical cutting element (e.g., conical cutting element **816** in FIG. 8), and at least one of the cutting elements **116** in the wall contacting zone may be a conical cutting element conical cutting element **816** in FIG. 8). In at least one embodiment, at least one of the cutting elements **116** in the wall or bottom contacting zones may be a semi-round top cutting element (e.g., SRT cutting element **817** in FIG. 8) to limit the depth of penetration of the conical cutting elements.

[0038] In at least one embodiment, a roller cone bit may be used with a percussive action actuated by a drilling fluid. The roller cone bit may have a bearing sized to withstand percussive impact forces and may also provide a rolling/gouging action that helps dislodge a rock chip from a rock face. Providing cutting elements having a substantially pointed geometry on the bit incorporating a roller cone may further aid in the gouging and rock removal.

[0039] A roller cone bit may be coupled to a hammer to create a percussive force on the bit. Further, specific embodiments may be particularly directed to hammers actuated by drilling fluid ("fluid actuated") and/or compressed gas ("gas- or air-actuated").

[0040] FIG. 9 depicts an illustrative hammer assembly **900**, according to one or more embodiments of the present disclosure. As shown, the hammer assembly **900** may include a drill bit (e.g., a roller cone bit **901**). The hammer assembly **900** may also include an outer housing **940** in which a hammer arm **942** may be fully or partially located. The hammer arm **942** may be an axial rod in some embodiments.

[0041] The drill bit **901** may include a bit body **902**, and a shank **944** extending front the bit body **902** and into the outer housing **940**. Specifically, a portion of shank **944** may be slideably retained in the outer housing **940**. As used herein, "slideably retained" refers to allowance of axial movement (sliding) within a threshold amount, but which limits axial movement beyond that threshold. The shank **944** may be slideably retained within the outer housing **940** by a spline

connection **946**, mechanical catches, chucks, in other manners, or using a combination of the foregoing. The spline connection **946** may also allow for torque to be transferred to the drill bit **901** while still allowing for axial movement between the drill bit **901** and the outer housing **940**.

[0042] As illustrated, the drill bit **901** may be hammered downward by contact between an upper impact surface of impact zone **948** on the shank **944** and a corresponding impact surface **950** of the hammer arm **942**. The drill bit **901** may be pulled back upward by contact between a lower impact surface of impact zone **948** on the shank **944** and impact surface **950** of the hammer arm **942**. The axial movement of the hammer arm **942** to make such alternating contact with impact zone **948** of the shank **944** may be achieved by magnetic attraction between magnets **952** coupled to an internal surface of the outer housing **940** and magnets **954** coupled to the hammer arm **942**. Specifically, as the hammer arm **942** and the outer housing **940** rotate relative to one another, magnetic attraction/repulsion between the magnets **952**, **954** may induce shuttling or axial movement between the hammer arm **942** and the outer housing **940**. Further description of such magnetically induced hammering may be found in U.S. Pat. No. 8,561,723, entitled "Magnetic Hammer," which patent is incorporated herein by this reference in its entirety. Further, as illustrated in FIG. 9, the magnets **952**, **954** may be axially offset from one another. However, the present disclosure is not so limited. For example, it is also within the scope of the present disclosure that the magnets **952**, **954** may be radially offset from one another (see FIG. 11). Specifically, as shown in FIG. 11, as the outer housing **1140** and the hammer arm **1142** are rotated relative to one another, magnetic attraction/repulsion between the magnets **1152**, **1154** may induce shuffling or axial movement between the outer housing **1140** and the hammer arm **1142** so that the impact surface **1150** of the hammer arm **1142** contacts the impact zone or surface **1148** of the outer housing **1140**, thereby causing hammering on the bit **1101**. Further discussion of the radial placement of magnets may be found in International Patent Application Publication No. WO2011/136663, entitled "A Vibrational or a Downhole Apparatus with a Magnetically Coupled Drive," which is incorporated herein by this reference in its entirety.

[0043] FIG. 10 depicts an illustrative a drilling assembly **1000**, according to one or more embodiments of the present disclosure. In some embodiments, the drilling assembly **1000** may include a drill bit **1001** at a distal end portion of the assembly **1000** and coupled to a chuck **1056**. The drill bit **1001** may include any of the embodiments or features discussed herein. A hammer **1058** may be located axially above the drill bit **1001**, and the hammer **1058** may contacts the drill bit **1001** at an impact zone **1048**. The hammer **1058** may be actuated by magnet assemblies **1052**, **1054**, similar to the embodiments described with respect to FIGS. 9 and 11. A magnet assembly **1052** may rotate due to the rotation of the drill string (not shown), and a corresponding magnet assembly **1054** may rotate due to the rotation of a motor output shaft **1060** (which may connect to mud motor **1062** in some embodiments). Specifically, as drilling fluid (not shown) is pumped through the mud motor **1062**, the mud motor **1062** may cause the motor output shaft **1060** to rotate, as well as a relative rotation between the magnet assembly **1054** and the magnet assembly **1052**. The relative rotation between the magnet assemblies **1052**, **1054** may cause axial movement therebetween so that the hammer **1058** intermittently contacts the drill bit **1001** with a percussive impact force. Further, as

mentioned above, the mud motor **1062** may be driven by drilling fluid not shown). The drilling fluid at the distal end portion of the mud motor **1062** may flow through a port **1066** into a central passageway **1064** that extends through the motor output shaft **1060**, the hammer **1058**, and potentially through drill bit **1001**. The drilling fluid may then exit the drill bit **1001** into the annulus of the borehole and carry cuttings to the surface.

[0044] The present disclosure is not, however, limited to such magnetic actuation of hammers. Rather, it is also within the scope of the present disclosure that any drilling, fluid or air actuated hammer may also be particularly useful with the bits disclosed herein. Examples of such hammers include, but are not limited to, those described in U.S. Pat. Nos. 5,396,965, 7,240,744, and 7,617,886, as well as in International Patent Application No. WO2011/023829, the disclosures of which are incorporated herein by this reference in their entireties.

[0045] As used herein, the terms “inner” and “outer;” “up” and “down;” “upper” and “lower;” “upward” and “downward;” “above” and “below;” “inward” and “outward;” 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.” Where ranges of values are provided, one skilled in the art will appreciate in view of the disclosure herein that any number within the range may be used as either a lower or upper end of a range claimed herein. Moreover, where sets of numerical values are provided, any number of the set may be used as a lower end of the range and any other number may be used as the upper end of the range.

[0046] 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 the scope of the present disclosure. 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.

What is claimed is:

1. A roller cone drill bit, comprising:

- a bit body;
- a roller cone rotationally coupled to the bit body;
- a first cutting element coupled to the roller cone, a ratio of a radius of curvature of a crest portion of the first cutting element to a diameter of the first cutting element being between about 0.3:1 and about 0.8:1; and
- a second cutting element coupled to the roller cone, a ratio of a radius of curvature of a crest portion of the second cutting element to a diameter of the second cutting element being between about 0.05:1 and about 0.3:1, the

second cutting element having a height between about 0.1 mm and about 6 mm greater than a height of the first cutting element, as measured from an outer surface of the roller cone.

2. The roller cone drill bit of claim 1, the ratio of the radius of curvature of the crest portion of the first cutting element to the diameter of the first cutting element being between about 0.4:1 and about 0.7:1.

3. The roller cone drill bit of claim 1, the first cutting element being a semi-round top cutting element.

4. The roller cone drill bit of claim 1, the ratio of the radius of curvature of the crest portion of the second cutting element to the diameter of the second cutting element being between about 0.14:1 and about 0.25:1.

5. The roller cone drill bit of claim 1, the second cutting element being at least partially conical.

6. The roller cone drill bit of claim 1, the height of the second cutting element being greater than the height of the first cutting element by between about 0.2 mm and about 1 mm.

7. The roller cone drill bit of claim 1, the roller cone being configured to rotate about an axis of a journal bearing coupled to the bit body and the roller cone.

8. The roller cone drill bit of claim 7, the axis through the journal bearing being oriented at an angle between about 20° and about 70° with respect to an axis of the bit body.

9. The roller cone drill bit of claim 1, each of the first and second cutting elements including a diamond layer at least partially disposed on a carbide substrate.

10. The roller cone drill bit of claim 1, the roller cone drill bit having only one roller cone.

11. A hammer assembly, comprising:

- a housing having a bore therein;
- a hammer arm disposed at least partially within the bore;
- a bit body movably coupled to the hammer arm, the bit body being configured to move axially with respect to the hammer arm;
- a journal bearing coupled to an end portion of the bit body;
- a roller cone coupled to the journal bearing;
- a first cutting element coupled to the roller cone, a ratio of a radius of curvature of a crest portion of the first cutting element to a diameter of the first cutting element being between about 0.3:1 and about 0.8:1; and
- a second cutting element coupled to the roller cone, a ratio of a radius of curvature of a crest portion of the second cutting element to a diameter of the second cutting element being between about 0.05:1 and about 0.3:1, the second cutting element having a height between about 0.1 mm and about 6 mm greater than a height of the first cutting element, as measured from an outer surface of the roller cone.

12. The hammer assembly of claim 11, the roller cone being adapted to rotate about an axis of the journal bearing.

13. The hammer assembly of claim 11, further comprising:

- a first magnet coupled to the housing; and
- a second magnet coupled to the hammer arm, the first and second magnets being configured to cause the hammer arm to move with respect to the housing.

14. The hammer assembly of claim 13, the hammer arm being configured to move and thereby cause the bit body and the roller cone to move with respect to the housing.

15. The hammer assembly of claim 11, the ratio of the radius of curvature of the crest portion of the first cutting element to the diameter of the first cutting element being

between about 0.4:1 and about 0.7:1, and the ratio of the radius of curvature of the crest portion of the second cutting element to the diameter of the second cutting element being between about 0.14:1 and about 0.25:1.

16. A method for drilling a borehole, comprising:
 running a hammer assembly into a borehole, the hammer assembly including:
 a housing having a bore therein;
 a hammer arm disposed at least partially within the bore;
 a bit body movably coupled to the hammer arm and configured to move axially with respect to the hammer arm;
 a journal bearing coupled to an end portion of the bit body;
 a roller cone coupled to the journal bearing; and
 first and second cutting elements coupled to the roller cone, a ratio of a radius of curvature of a crest portion of the first cutting element to a diameter of the first cutting element being between about 0.31:1 and about 0.8:1, and a ratio of a radius of curvature of a crest portion of the second cutting element to a diameter of the second cutting element being between about 0.05:1 and about 0.3:1, the second cutting element having a height of between about 0.1 mm and about 6

mm greater than a height of the first cutting element, as measured from an outer surface of the roller cone; and

contacting a subterranean formation with the first and second cutting elements of the hammer assembly to form a borehole.

17. The method of claim **16**, further comprising:
 moving the hammer arm with respect to the housing.

18. The method of claim **17**, wherein moving the hammer arm includes moving the hammer arm in response to interaction between a first magnet coupled to the housing and a second magnet coupled to the hammer arm.

19. The method of claim **17**, further comprising:
 moving the bit body and the roller cone with respect to the hammer arm.

20. The method of claim **16**, wherein the ratio of the radius of curvature of the crest portion of the first cutting element to the diameter of the first cutting element is between about 0.4:1 and about 0.7:1, and wherein the ratio of the radius of curvature of the crest portion of the second cutting element to the diameter of the second cutting element is between about 0.14:1 and about 0.25:1.

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