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(54) Title: ROLLING CUTTER ASSEMBLIES AND COMPONENTS INCORPORATED THEREIN

(57) Abstract: A cutting element assembly for a drill bit includes a housing, an inner rotatable cutting element, and a pre-load assembly. The inner rotatable cutting element has a cutting end and a portion that is retained in the housing. A base of the cutting end and an end of the housing act as radial bearing surfaces. The pre-load assembly is between the radial bearing surfaces.

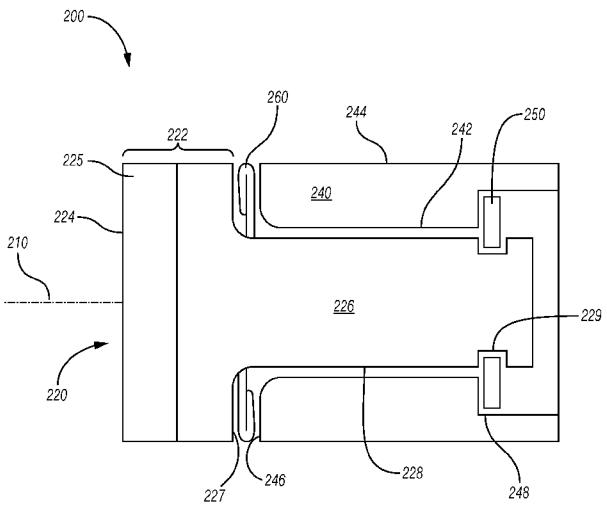


FIG. 2

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ROLLING CUTTER ASSEMBLIES AND COMPONENTS INCORPORATED THEREIN

CROSS REFERENCE TO RELATED APPLICATION

[0001] This Application claims the benefit of and priority to U.S. Provisional Application 62/082,744 filed on November 21, 2014, the entirety of which is incorporated herein by reference.

BACKGROUND

[0002] Drill bits used to drill wellbores through earth formations generally are made within one of two broad categories of bit structures. Depending on the application/formation to be drilled, the appropriate type of drill bit may be selected based on the cutting action type for the bit and its appropriateness for use in the particular formation. Some drill bits are known as "roller cone" bits, which include a bit body having one or more roller cones rotatably mounted to the bit body. The bit body may be formed from steel or another high strength material. The roller cones may also be formed from steel or other high strength material and include a plurality of cutting elements disposed at selected positions about the cones. The cutting elements may be formed from the same base material as is the cone. These bits may be referred to as "milled tooth" bits. Other roller cone bits include "insert" cutting elements that are press (interference) fit into holes formed and/or machined into the roller cones. The inserts may be formed from, for example, tungsten carbide, natural or synthetic diamond, boron nitride, or any one or combination of hard or superhard materials.

[0003] Some other drill bits may be referred to as "fixed cutter" or "drag" bits. Drag bits, include bits that have cutting elements attached to the bit body, which may be a steel bit body or a matrix bit body formed from a matrix material such as tungsten carbide surrounded by a binder material. Drag bits having abrasive material, such as diamond, impregnated into the surface of the material which forms the bit body are commonly referred to as "impreg" bits. Drag bits having cutting elements made of an ultra hard cutting surface layer or "table" (such as made of polycrystalline diamond

material or polycrystalline boron nitride material) deposited onto or otherwise bonded to a substrate are known in the art as polycrystalline diamond compact ("PDC") bits.

[0004] PDC bits drill soft formations easily, but they are frequently used to drill moderately hard or abrasive formations. They cut rock formations with a shearing action using small cutters that do not penetrate deeply into the formation. Because the penetration depth is shallow, high rates of penetration are achieved through relatively high bit rotational velocities.

[0005] PDC cutters have been used in industrial applications including rock drilling and metal machining for many years. In PDC bits, PDC cutters are received within cutter pockets, which are formed within blades extending from a bit body, and may be bonded to the blades by brazing to the inner surfaces of the cutter pockets. The PDC cutters are positioned along the leading edges of the bit body blades so that as the bit body is rotated, the PDC cutters engage and drill the earth formation. In use, high forces may be exerted on the PDC cutters, particularly in the forward-to-rear direction. Additionally, the bit and the PDC cutters may be subjected to substantial abrasive forces. In some instances, impact, vibration, and/or erosive forces have caused drill bit failure due to loss of one or more cutters, or due to breakage of the blades.

[0006] In a typical PDC cutter, a compact of polycrystalline diamond ("PCD") (or other superhard material, such as polycrystalline cubic boron nitride) is bonded to a substrate material, which may be a sintered metal-carbide to form a cutting structure. PCD comprises a polycrystalline mass of diamond grains or crystals that are bonded together to form an integral, tough, high-strength mass or lattice. The resulting PCD structure produces enhanced properties of wear resistance and hardness, making PCD materials extremely useful in aggressive wear and cutting applications where high levels of wear resistance and hardness are desired.

[0007] An example of a PDC bit having a plurality of cutters with ultra hard working surfaces is shown in FIG. 1. The drill bit 100 includes a bit body 110 having a threaded pin end 111 and a cutter end 115. The cutter end 115 includes a plurality of ribs or blades 120 arranged about the rotational axis 11 of the drill bit and extending radially outward from the bit body 110. Cutting elements, or cutters, 150 are

embedded in the blades 120 at predetermined angular orientations and radial locations relative to a working surface and with a desired back rake angle against a formation to be drilled.

[0008] A plurality of orifices 116 is positioned on the bit body 110 in the areas between the blades 120, which may be referred to as "gaps" or "fluid courses." The orifices 116 are commonly adapted to accept nozzles. The orifices 116 allow drilling fluid to be discharged through the bit in selected directions and at selected rates of flow between the cutting blades 120 for lubricating and cooling the drill bit 100, the blades 120 and the cutters 150. The drilling fluid also cleans and removes the cuttings as the drill bit 100 rotates and penetrates the geological formation. The fluid courses are positioned to provide additional flow channels for drilling fluid and to provide a passage for formation cuttings to travel past the drill bit 10 toward the surface of a wellbore.

[0009] A factor in determining the longevity of PDC cutters is the exposure of the cutter to heat. The thermal operating range of conventional PDC cutters is about 700-750 °C or less. Exposure to excessive heat (e.g., as a result of friction between the cutting element and the formation) can cause thermal damage to the diamond table and eventually result in the formation of cracks (due to differences in thermal expansion coefficients) which can lead to spalling of the polycrystalline diamond layer, delamination between the polycrystalline diamond and substrate, and/or conversion of the diamond into graphite causing rapid abrasive wear.

[0010] Deterioration of polycrystalline diamond may be due to the large difference in the coefficient of thermal expansion of the binder material, cobalt, as compared to diamond. Upon heating of polycrystalline diamond, the cobalt and the diamond lattice will expand at different rates, which may cause cracks to form in the diamond lattice structure and result in deterioration of the polycrystalline diamond. Damage may also be due to graphite formation at diamond-diamond necks leading to loss of microstructural integrity and strength loss, at extremely high temperatures.

[0011] In conventional drag bits, PDC cutters are fixed onto the surface of the bit such that a common cutting surface contacts the formation during drilling. Over time and/or when drilling certain hard but not necessarily highly abrasive rock formations,

the edge of the working surface on a cutting element that constantly contacts the formation begins to wear down, forming a local wear flat, or an area worn disproportionately to the remainder of the cutting element. Local wear flats may result in longer drilling times due to a reduced ability of the drill bit to effectively penetrate the work material and a loss of rate of penetration caused by dulling of the edge of the cutting element. That is, the worn PDC cutter acts as a friction bearing surface that generates heat, which accelerates the wear of the PDC cutter and slows the penetration rate of the drill. Such flat surfaces effectively stop or reduce the rate of formation cutting because conventional PDC cutters are not able to adequately engage and efficiently remove the formation material from the area of contact. Additionally, the cutters may be under constant thermal and mechanical load. As a result, heat builds up along the cutting surface, and results in cutting element fracture. When a cutting element breaks, the drilling operation may sustain a loss of rate of penetration, and additional damage to other cutting elements, should the broken cutting element contact a second cutting element.

SUMMARY

[0012] 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.

[0013] In one aspect, embodiments disclosed herein relate to a cutting element assembly for a drill bit that includes a housing, an inner rotatable cutting element having a cutting end and a portion that is retained in the housing. A base of the cutting end and an end of the housing may include radial bearing surfaces, and a pre-load assembly may be between the radial bearing surfaces.

[0014] In another aspect, embodiments disclosed herein relate to a cutting element assembly for a drill bit that includes a housing, an inner rotatable cutting element having a cutting end and a portion that is retained in the housing. A base of the cutting end and an end of the housing may define radial bearing surfaces, and a pre-load assembly may be between the radial bearing surfaces and along an axial length of the body.

[0015] In yet another aspect, embodiments disclosed herein relate to a cutting tool that includes a tool body having a cutting element support structure and a rotatable cutting element retained within the cutting element support structure. The inner rotatable cutting element may include a cutting end, a base of the cutting end and the cutting element support structure having radial bearing surfaces therebetween, and a pre-load assembly may be between the radial bearing surfaces.

[0016] Other aspects and advantages of the claimed subject matter will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0017] FIG. 1 is a perspective of a conventional PDC drill bit.

[0018] FIG. 2 shows a cross-sectional view of a cutting element assembly according to embodiments of the present disclosure.

[0019] FIG. 3 shows a cross-sectional view of a cutting element assembly according to embodiments of the present disclosure.

[0020] FIG. 4 shows a PDC bit having a plurality of rolling cutters and fixed cutters including one or more cutting element assemblies according to embodiments of the present disclosure.

[0021] FIG. 5 shows a profile of a bit including one or more cutting element assemblies according to embodiments of the present disclosure.

[0022] FIG. 6 shows a downhole cutting tool including one or more cutting element assemblies of the present disclosure.

DETAILED DESCRIPTION

[0023] In one aspect, embodiments disclosed herein relate to drill bits or other cutting tools having rotating cutting element assemblies disposed thereon and components incorporated within the assembly. Specifically, embodiments disclosed herein relate to the incorporation of a component within the assembly to reduce the amount of contact between the rotating component and the outer sleeve or other support structure

in which it is retained. Such rotating cutting elements may be used as the sole cutting structure on a bit or cutting tool or may be used with conventional cutting structures such as fixed cutters such as those brazed into cutter pockets on blades.

[0024] Referring now to FIG. 2, a cross-sectional view of a cutting element assembly according to embodiments of the present disclosure is shown. The cutting element assembly 200 has a housing 240 and an inner rotatable cutting element 220 assembled together. The inner cutting element 220 has a cutter axis 210 extending there through, a body 226 operable to rotate about the cutter axis, a side surface 228, and a cutting face 224. The inner cutting element 220 may have at least two different diameters, wherein the diameter of the cutting end 222 is larger than the diameter at a portion of the body 226. In such embodiments, the cutting end 222 may include an ultrahard material, such as a diamond table 225, and a portion of the body 226 material, such as a carbide material, however, the present disclosure is not so limited and may include inner rotatable cutting elements formed of a single material or more than two materials. The body 226 of the inner cutting element 220 is at least partially disposed within the housing 240, and the cutting end 222 is outside the housing 240. The housing 240 has an inner surface 242 and an outer surface 244 and may be made of any material, including titanium, carbide, stainless steel, high carbon steel, alloys of these listed materials, or any other material suitable for use in drilling operations. As shown, the portion of the body 226 that is disposed within the housing 240 has a diameter that is substantially equal to the inner diameter of the housing 240 (measured between the inner surface 242 of the housing 240) with tolerance to allow for rotation of the inner cutting element, and the cutting end 222 of the inner cutting element 220 has a diameter that is substantially equal to the outer diameter of the housing 240 (measured between the outer surface 244 of the housing 240) but other diameters may be used without departing from the scope of the present disclosure.

[0025] Between inner cutting element 220 and housing 240 are a retention mechanism 250 (for retaining inner cutting element within housing 240) and a pre-load assembly 260. The pre-load assembly 260 may include a load dampening component employing mechanical, magnetic, or engineered materials to reduce the displacement of the inner cutting element 220 within the housing 240 due to loading (especially high frequency) during operation. Further, the contact between the body

226 and housing 240 interface may be reduced when the pre-load assembly 260 is between the radial bearing surfaces. Furthermore, the retention mechanism 250 may be pre-loaded when the pre-load assembly 260 is between the radial bearing surfaces, creating another contact point for load distribution during operation. As a result, the life of the cutting element assembly 200 may be increased, e.g., significantly increased.

[0026] In one embodiment, a Belleville spring may be used as the pre-load assembly 260. Although a Belleville spring is used as the pre-load assembly 260 in the illustrated embodiment, any other mechanical, magnetic, or engineered materials may be used as the pre-load assembly 260 without departing from the scope and spirit of the present disclosure. For example, in some embodiments, one or more of a wave spring, spacer, washer, or combinations thereof may be used as the pre-load assembly 260. The pre-load assembly 260 may be formed from a metallic material, other metal alloy, or other suitable material, for example, a plastic or elastomeric material. In some embodiments, the pre-load assembly 260 may include a protective finish, for example, plating, oxide, chromate, or anodizing coating. In other embodiments, the pre-load assembly 260 may include an impregnated material, such as graphite or PTFE.

[0027] As mentioned above, the pre-load assembly 260 may be located between the radial bearing surfaces of the inner cutting element 220 and the housing 240. The radial bearing surface of the inner cutting element 220 may be one of the transition surfaces between the cutting end 222 and the body 226 (having different diameters). For example, as shown in FIG. 2, the cutting end base 227 may form the transition from the larger diameter of the cutting end 222 to the smaller diameter of the body 226 of the inner cutting element 220, where the cutting end base 227 acts as a radial bearing surface. As previously discussed, the inner surface 242 of the housing may substantially correspond with an inner cutting element 220, specifically the side surface 228 of the body 226. The end 246 of the housing 240 nearest the cutting end 222 substantially corresponds with the transition of the body 226 and acts as another radial bearing surface. In addition to radial bearing surfaces, various geometries such as a gradual slope or a curved surface may form the transition between the larger

diameter of the cutting end 222 and the smaller diameter of the body 226 disposed within the housing 240.

[0028] According to some embodiments, the compression and recoil of the inner cutting element 220 within the housing 240 may be adjusted by varying the spring rate of the pre-load assembly 260, for example, by varying the material and/or geometry of the pre-load assembly 260. By adjusting the compression and recoil of the inner cutting element 220, the displacement of the inner cutting element 220 within the housing 240 and the load distribution on the cutting face 224 of the inner cutting element 220 may be defined for different applications, for example, when drilling different formations. In some embodiments, pre-loading the cutting element assembly 200 may reduce or eliminate the need for shimming or spacing as it relates to tolerance variance by reducing or eliminating any slack or play of the inner cutting element 220 within the housing 240. The cutting element assembly 200 may be pre-loaded such that the pre-load assembly 260 may have a lower limit of any of at least 0%, 20%, 40%, 60%, or 80% of maximum cutting force of inner cutting element 220 (e.g., the maximum cutting force the cutting element would experience from interactions with the formation during drilling), and an upper limit of any of 20%, 40%, 60%, 80%, or 100% of maximum cutting force of inner cutting element 220, where any lower limit can be used in combination with any upper limit. For example, the cutting element assembly 200 may be pre-loaded so that it has 20-40% or 60-80% of maximum cutting force. In such embodiments, the pre-load assembly 260 may reduce or eliminate rattling between the components of the assembly, compensate for expansion and/or contraction of the assembly materials, and/or absorb intermittent shock loads.

[0029] According to some embodiments, the pre-load assembly 260 may extend along the entire radial bearing surface or extend a distance less than the entire radial bearing surface. In some embodiments, the pre-load assembly 260 may be substantially the same thickness along the radial bearing surface. In other embodiments, the pre-load assembly 160 may have a varying thickness along the radial bearing surface such that a radially outward portion of the pre-load assembly 260 has a greater thickness than a radially inward portion of the pre-load assembly

260. In such embodiments, the pre-load assembly 260 may provide a higher pre-load to the radially outer portions of the cutting face 224 where higher loading may occur.

[0030] As mentioned above, the inner cutting element 220 may be axially retained within the housing 240 using a retention mechanism 250 disposed between the housing 240 and the body 226 of the inner cutting element 220. The retention mechanism 250 is used to axially retain the inner cutting element 220 within the housing 240 and may allow the inner cutting element 220 to rotate as it contacts the formation to be drilled, while at the same time retaining the inner cutting element 220 within the housing 240 and on the cutting tool. According to other embodiments, the retention mechanism 250 may retain the inner cutting element 220 within the housing 240, but limit or prevent rotation of the inner cutting element 220 within the housing 240.

[0031] Referring again to FIG. 2, the retention mechanism 250 is disposed between the housing 240 and the body 226 of the inner cutting element 220. The retention mechanism 250 shown is a retaining ring disposed in a first groove (e.g., a first circumferential groove) 248 in an inner surface of the housing 240 and a second groove (a second circumferential groove) 229 in an outer surface of the body 226. The retaining ring protrudes from the first groove to a diameter greater than an inner diameter of the housing 240 to retain the inner cutting element 220 axially in the housing 240. In one or more embodiments, the retaining ring extends at least around the entire circumference of the body 226 of the inner cutting element 220. The first groove 248 and second groove 229 may have any profile that is able to retain the retaining ring, such as semi-round circle or irregular geometries.

[0032] A retaining ring may be planar or non-planar, or a combination of one or more planar rings may be used with one or more non-planar rings. Further, a retaining ring may have overlapping ends or unattached ends, so that it may be radially compressed or tightened. The non-planar retaining ring may have an undulating shape, which may act as a spring when axial force is applied to the inner cutting element, such as during drilling operations. Further, according to some embodiments of the present disclosure, two or more retaining rings may be attached or stacked together to form a spring, where at least one retaining ring is non-planar and at least one retaining ring is planar. For example, a non-planar retaining ring may be disposed between two planar

retaining rings and welded together at crests formed by the undulating shape of the non-planar retaining ring, a planar retaining ring may be disposed between two non-planar retaining rings, two or more non-planar retaining rings may be attached, or two or more non-planar and two or more planar retaining rings may be attached. Further, in combinations using two or more non-planar retaining rings, the non-planar retaining rings may be attached at unsynchronized undulations to form a spring.

[0033] The retaining mechanism 250 is not limited to a retaining ring and may include any type of mechanism that will axially retain an inner cutting element within a housing. In some embodiments, the retention mechanism 250 may include a pin that protrudes from a hole formed in the housing 240 and extends into a groove formed in the inner cutting element body 226. However, in other embodiments, the retention mechanism 250 may protrude from a hole formed in the body 226 of the inner cutting element 220 and extends into a groove formed in an inner surface 242 of the housing 240. As used herein, a hole may refer to a blind hole (a hole that does not extend completely through the thickness of the material) or a through hole (a hole that extends completely through the thickness of the material). In some embodiments, the retention mechanism 250 may include at least one spring, at least one pin, and/or at least one ball. For example, in some embodiments having a retention mechanism disposed between at least one blind hole and/or groove, the retention mechanism 250 may include a spring, such that the retention mechanism 250 may be compressed when the inner cutting element 220 is being fitted into the housing 240 and may expand into the corresponding blind holes and/or grooves to retain the inner cutting element 220 in a certain axial position within the housing 240. In some embodiments, the retention mechanism 250 may include at least one ball disposed between corresponding grooves formed in an inner surface 242 of the housing 240 and the side surface 228 of the inner cutting element body 226.

[0034] According to embodiments of the present disclosure, the wall thickness of a support structure is measured between an inner surface and an outer surface. Referring again to FIG. 2, the housing 240 has a thickness measured between an inner surface 242 and an outer surface 244. The inner surface 242 of the housing 240 may have a substantially cylindrical shape to correspond with an inner cutting element 220 to be inserted therein; however, is not so limited to a substantially cylindrical shape.

The outer surface 244 of the housing 240 may have at least one non-planar surface and/or at least one planar surface that do not correspond with the inner surface 242, or the body 226 of the inner cutting element 220 may have a non-cylindrical shape (such as a conical shape) with a substantially mating housing, such that the housing 240 thickness varies around the circumference of the housing 240.

[0035] In one or more embodiments, the inner cutting element 220 may have a diamond or other ultrahard material table bonded to a substrate, where the ultrahard material table forms the cutting face of the inner cutting element, and where the substrate forms the body of the inner cutting element. For example, as shown in FIG. 2, the inner cutting element 220 has a cutting face 224 formed by a diamond table 225, which is bonded to a body 226. The diamond table 225 may include polycrystalline diamond and/or thermally stable polycrystalline diamond. In some embodiments, the cutting face 224 of the inner cutting element 220 may be formed of other ultrahard materials, such as cubic boron nitride, or a combination of diamond and at least one of a carbide, nitride, or boride material. For example, the inner cutting element 220 may have a diamond table 225 bonded to a tungsten carbide body.

[0036] Cutting element assemblies of the present disclosure may be attached within cutter pockets formed in cutting tools, such as a drill bit, reamer, or other tool used to cut an earthen formation. For example, a drill bit may have a bit body with a plurality of blades extending radially therefrom. At least one cutting element assembly according to embodiments of the present disclosure may be disposed in a cutter pocket formed on the plurality of blades. The at least one cutting element assembly may include a housing and an inner cutting element having a cutting end and a portion that is retained in the housing, where the inner cutting element has a cutter axis, a body operable to rotate about the cutter axis, and a cutting face disposed on an upper surface of the body. The base of the cutting end and an end of the housing may act as radial bearing surfaces where a pre-load assembly is between the radial bearing surfaces. The housing may be brazed or attached by other methods known in the art to a cutter pocket formed on one of the plurality of blades. Further, the housing may be replaced, for example, if a component in the cutting element assembly has failed and needs replacement.

[0037] FIG. 3 illustrates a cross-sectional view of a cutting element assembly according to embodiments of the present disclosure. In this embodiment, the cutting element assembly 300 may include a pre-load assembly 360 located between the radial bearing surfaces and along an axial length of the body 326 (side surface 328). The pre-load assembly 360 may extend at least onto the side surface 328 and at most a distance equal to where the second groove 329 begins in the body 326. The pre-load assembly 360 between the radial bearing surfaces and along an axial length of the body 326 may be integral. The pre-load assembly 360 may include a load dampening component employing mechanical, magnetic, or engineered materials to reduce the displacement of the inner cutting element 320 within the housing 340 due to loading (especially high frequency) during operation. Further, the contact between the body 326 and housing 340 interface is even less when a pre-load assembly 360 is between the radial bearing surfaces and along an axial length of the body 326, as compared to embodiments that solely have contact at the radial bearing surface. Furthermore, the retention mechanism 350 may be pre-loaded when a pre-load assembly 360 is between the radial bearing surfaces, creating another contact point for load distribution during operation. As a result, the life of the cutting element assembly 300 may be increased, e.g., significantly increased.

[0038] In this embodiment, a flanged bushing is used as the pre-load assembly 360. Although a flanged bushing is used as the pre-load assembly 360, any other mechanical, magnetic, or engineered materials may be used as the pre-load assembly 360 without departing from the scope and spirit of the present disclosure. The pre-load assembly 360 may be formed from a metallic material, other metal alloy, or other suitable material, for example, a plastic or elastomeric material. In some embodiments, the pre-load assembly 360 may include a protective finish, for example, plating, oxide, chromate, or anodizing coating. In other embodiments, the pre-load assembly 360 may include an impregnated material, such as graphite or polytetrafluoroethylene (PTFE). Further, it is also within the scope of the present disclosure that the component interfacing between the inner cutting element 320 and the housing 340 (or other support structure) does not provide a pre-load but may simply serve as a sacrificial material to reduce the contact area between the inner cutting element and the housing and/or reduce the friction therebetween. In such embodiments, the pre-load assembly 360 may be formed from a softer material, for

example, brass, elastomeric materials, or other suitable materials having friction-reducing properties.

[0039] According to some embodiments, the pre-loading of the inner cutting element 320 within the housing 340 and the contact area between the inner cutting element 320 and the housing 340 may be adjusted by varying the material and/or geometry of the pre-load assembly 360, for example, the thickness along the radial bearing surface 327, 346 and/or the thickness along the axial length of the body 326. In some embodiments, adjusting the contact area between the inner cutting element 320 and the housing 340 as well as pre-loading the cutting element assembly 300 may reduce or eliminate tolerance variance in both the radial and axial directions. The cutting element assembly 200 may be pre-loaded such that the pre-load assembly 360 may have a lower limit of any of at least 0%, 20%, 40%, 60%, or 80% of maximum cutting force of inner cutting element 320 (e.g., the maximum cutting force the cutting element would experience from interactions with the formation during drilling), and an upper limit of any of 20%, 40%, 60%, 80%, or 100% of maximum cutting force of inner cutting element 320, where any lower limit can be used in combination with any upper limit. For example, the cutting element assembly 300 may be pre-loaded so that it has 20-40% or 60-80% of maximum cutting force.

[0040] According to some embodiments, the pre-load assembly 360 may extend along the entire axial length of the body 326 (up to a first groove 348 (e.g., a first circumferential groove) in an inner surface of the housing 340 and a second groove 329 (e.g., a second circumferential groove) in an outer surface of the body 326) or extend a distance less than the entire axial length of the body 326.

[0041] Cutting elements of the present disclosure may be retained within a sleeve to form a cutting element assembly, or may be retained directly within a cutter pocket formed in a cutting tool. According to some embodiments of the present disclosure having a cutting element retained within a sleeve, the cutting element assembly may include the cutting element partially disposed within the sleeve, where the cutting element is retained within the sleeve or cutter pocket by one or more retention features. According to embodiments of the present disclosure, a downhole cutting tool, such as a drill bit, may include a tool body and at least two cutting element assemblies disposed within cutter pockets formed on the tool body. The cutting

element assemblies may be secured to the cutter pocket, for example, by brazing the sleeve to the cutter pocket, or by other means of attachment. In either embodiment (a cutting element disposed in a housing or directly in a cutting tool), the cutting element may be interfaced with a pre-load assembly or other sacrificial material between it and the housing or tool body.

[0042] One or more embodiments described herein may have an ultrahard material disposed on a substrate. Such ultrahard materials may include a conventional polycrystalline diamond table (a table of interconnected diamond particles having interstitial spaces therebetween in which a metal component (such as a metal catalyst) may reside), a thermally stable diamond layer (*i.e.*, having a thermal stability greater than that of conventional polycrystalline diamond, 750 °C) formed, for example, by substantially removing metal from the interstitial spaces between interconnected diamond particles or from a diamond / silicon carbide composite, or other ultrahard material such as a cubic boron nitride. Further, in some embodiments, the rolling cutter may be formed entirely of ultrahard material(s), but the element may include a plurality of diamond grades used, for example, to form a gradient structure (with a smooth or non-smooth transition between the grades). In a particular embodiment, a first diamond grade having smaller particle sizes and/or a higher diamond density may be used to form the upper portion of the inner rotatable cutting element (that forms the cutting edge when installed on a bit or other tool), while a second diamond grade having larger particle sizes and/or a higher diamond density may be used to form the lower, non-cutting portion of the cutting element. Further, it is also within the scope of the present disclosure that more than two diamond grades may be used.

[0043] As known in the art, thermally stable diamond may be formed in various manners. A typical polycrystalline diamond layer includes individual diamond "crystals" that are interconnected. The individual diamond crystals thus form a lattice structure. A metal catalyst, such as cobalt, may be used to promote recrystallization of the diamond particles and formation of the lattice structure. Thus, cobalt particles are generally found within the interstitial spaces in the diamond lattice structure. Cobalt has a substantially different coefficient of thermal expansion as compared to diamond. Therefore, upon heating of a diamond table, the cobalt and the diamond

lattice will expand at different rates, causing cracks to form in the lattice structure and resulting in deterioration of the diamond table.

[0044] To obviate this problem, strong acids may be used to "leach" the cobalt from a polycrystalline diamond lattice structure (either a thin volume of diamond or the entire diamond table) to at least reduce the damage experienced from heating diamond-cobalt composite at different rates upon heating. Briefly, a strong acid, such as hydrofluoric acid or combinations of several strong acids may be used to treat the diamond table, removing at least a portion of the co-catalyst from the PDC composite. Suitable acids include nitric acid, hydrofluoric acid, hydrochloric acid, sulfuric acid, phosphoric acid, or perchloric acid, or combinations of these acids. In addition, caustics, such as sodium hydroxide and potassium hydroxide, have been used by the carbide industry to digest metallic elements from carbide composites. In addition, other acidic and basic leaching agents may be used as desired. Those having ordinary skill in the art will appreciate that the molarity of the leaching agent may be adjusted depending on the time desired to leach, concerns about hazards, etc.

[0045] By leaching out the cobalt, thermally stable polycrystalline ("TSP") diamond may be formed. In certain embodiments, a select portion of a diamond composite is leached, in order to gain thermal stability without losing impact resistance. As used herein, the term TSP includes both of the above (*i.e.*, partially and completely leached) compounds. Interstitial volumes remaining after leaching may be reduced by either furthering consolidation or by filling the volume with a secondary material.

[0046] In one or more other embodiments, TSP may be formed by forming the diamond layer in a press using a binder other than cobalt, one such as silicon, which has a coefficient of thermal expansion more similar to that of diamond than cobalt has. During the manufacturing process, a large portion, 80 to 100 volume percent, of the silicon reacts with the diamond lattice to form silicon carbide which also has a thermal expansion similar to diamond. Upon heating, any remaining silicon, silicon carbide, and the diamond lattice will expand at more similar rates as compared to rates of expansion for cobalt and diamond, resulting in a more thermally stable layer. PDC cutters having a TSP cutting layer have relatively low wear rates, even as cutter temperatures reach 1200 °C. However, one of ordinary skill in the art would recognize that a thermally stable diamond layer may be formed by other methods

known in the art, including, for example, by altering processing conditions in the formation of the diamond layer.

[0047] The substrate on which the cutting face is optionally disposed may be formed of a variety of hard or ultrahard particles. In one embodiment, the substrate may be formed from a suitable material such as tungsten carbide, tantalum carbide, or titanium carbide. Additionally, various binding metals may be included in the substrate, such as cobalt, nickel, iron, metal alloys, or mixtures thereof. In the substrate, the metal carbide grains are supported within the metallic binder, such as cobalt. Additionally, the substrate may be formed of a sintered tungsten carbide composite structure. It is well known that various metal carbide compositions and binders may be used, in addition to tungsten carbide and cobalt. Thus, references to the use of tungsten carbide and cobalt may be for illustrative purposes, and no limitation on the type substrate or binder used is intended. In other embodiments, the substrate may also be formed from a diamond ultrahard material such as polycrystalline diamond or thermally stable diamond. While the illustrated embodiments show the cutting face and substrate as two distinct pieces, one of skill in the art should appreciate that it is within the scope of the present disclosure the cutting face and substrate are integral, identical compositions. In such embodiments, it may be desirable to have a single diamond composite forming the cutting face and substrate or distinct layers. Specifically, in embodiments where the cutting element is a rotatable cutting element, the entire cutting element may be formed from an ultrahard material, including thermally stable diamond (formed, for example, by removing metal from the interstitial regions or by forming a diamond/silicon carbide composite).

[0048] The retention element may be formed from any suitable material, such as tool steel or other alloy steels, nickel-based alloys, or cobalt-based alloys. One of ordinary skill in the art would also recognize that one or more components may be coated with a hardfacing material or other wear resistant material for increased erosion protection. Such coatings may be applied by various techniques known in the art such as, for example, detonation gun (d-gun) and spray-and-fuse techniques.

[0049] The cutting elements of the present disclosure may be incorporated in various types of cutting tools, including for example, as cutters in fixed cutter bits or hole

enlargement tools such as reamers. Bits having the cutting elements of the present disclosure may include a single rolling cutter with the remaining cutting elements being conventional fixed cutting elements, all cutting elements being rotatable, or any combination therebetween of rolling cutters and conventional (brazed), fixed cutters, as well as mechanically retained fixed cutters (including those of the present disclosure). Further, cutting elements of the present disclosure may be disposed on cutting tool blades (such as drag bit blades or reamer blades) having other wear elements incorporated therein. For example, cutting elements of the present disclosure may be disposed on diamond impregnated blades. Additionally, one of ordinary skill in the art would recognize that there exists no limitation on the sizes of the cutting elements of the present disclosure. For example, in various embodiments, the cutting elements may be formed in sizes including, but not limited to, 9 mm, 11 mm, 13 mm, 16 mm, and 19 mm.

[0050] Further, one of ordinary skill in the art would also appreciate that any of the design modifications as described above, including, for example, side rake, back rake, variations in geometry (e.g., surface geometry), surface alteration/etching, seals, bearings, material compositions, diamond or similar low-friction bearing surfaces, etc., may be included in various combinations not limited to those described above in the cutting elements of the present disclosure. In one embodiment, a cutter may have a side rake ranging from 0 to ± 45 degrees. In another embodiment, a cutter may have a back rake ranging from about 5 to 35 degrees.

[0051] An example of PDC bit having a plurality of rolling cutters and fixed cutters is shown in FIG. 4. The drill bit 400 includes a bit body 410 having a threaded upper pin end 411 and a cutting end 415. The cutting end 415 includes a plurality of ribs or blades 420 arranged about the rotational axis L (also referred to as the longitudinal or central axis) of the drill bit and extending radially outward from the bit body 410. Conventional fixed cutting elements, or cutters, 450 are embedded in the blades 420 at predetermined angular orientations and radial locations relative to a working surface and with a desired back rake angle and side rake angle against a formation to be drilled. In addition to fixed cutters 450, the bit 400 also includes a plurality of rolling cutters 460, retained by retaining elements (not shown), as disclosed herein.

[0052] A plurality of orifices 416 are positioned on the bit body 410 in the areas between the blades 420, which may be referred to as "gaps" or "fluid courses." The orifices 416 are commonly adapted to accept nozzles. The orifices 416 allow drilling fluid to be discharged through the bit in selected directions and at selected rates of flow between the blades 420 for lubricating and cooling the drill bit 400, the blades 420, fixed cutters 450, and rolling cutters 460. The drilling fluid also cleans and removes the cuttings as the drill bit 400 rotates and penetrates the geological formation. The fluid courses are positioned to provide additional flow channels for drilling fluid and to provide a passage for formation cuttings to travel past the drill bit 400 toward the surface of a wellbore (not shown).

[0053] In one or more embodiments, rolling cutters may be disposed in locations of the bit or other tool experiencing the greatest wear, such as the nose or shoulder of the bit. Referring now to FIG. 5, a profile of bit 10 is shown as it would appear with all blades and cutting faces 44 of all cutting elements 40 (including both fixed cutters such as those referenced as 450 in FIG. 4 and rolling cutters such as those referenced as 460 in FIG. 4) rotated into a single rotated profile. In rotated profile view, blade tops of all blades of bit form and define a combined or composite blade profile 39 that extends radially from bit axis 60 to outer radius 23 of bit 10. Thus, as used herein, the phrase "composite blade profile" refers to the profile, extending from the bit axis to the outer radius of the bit, formed by the blade tops of all the blades of a bit rotated into a single rotated profile (i.e., in rotated profile view). In one or more embodiments, the cutters referenced as 460 may be mechanically retained in accordance with the present disclosure, but not able to rotate, for example by using an adhesive (such as an epoxy configured to withstand conventional drilling temperatures) to fix the cutters in place.

[0054] Composite blade profile 39 (most clearly shown in the right half of bit 10 in FIG. 5) may generally be divided into three regions conventionally labeled cone region 24, shoulder region 25, and gage region 26. Cone region 24 is the radially innermost region of bit 10 and composite blade profile 39 extending generally from bit axis 60 to shoulder region 25. As shown in FIG. 5, in most conventional fixed cutter bits, cone region 24 is generally concave. Adjacent cone region 24 is shoulder (or the upturned curve) region 25. In most conventional fixed cutter bits, shoulder

region 25 is generally convex. Moving radially outward, adjacent shoulder region 25 is the gage region 26 which extends parallel to bit axis 60 at the outer radial periphery of composite blade profile 39. Thus, composite blade profile 39 of bit 10 includes one concave region--cone region 24, and one convex region--shoulder region 25.

[0055] The axially lowermost point of convex shoulder region 25 and composite blade profile 39 defines a blade profile nose 27. At blade profile nose 27, the slope of a tangent line 27a to convex shoulder region 25 and composite blade profile 39 is zero. Thus, as used herein, the term "blade profile nose" refers to the point along a convex region of a composite blade profile of a bit in rotated profile view at which the slope of a tangent to the composite blade profile is zero. For most conventional fixed cutter bits (e.g., bit 10), the composite blade profile includes only one convex shoulder region (e.g., convex shoulder region 25), and only one blade profile nose (e.g., nose 27). In one or more embodiments, rolling cutters of the present disclosure may be located in the nose and/or shoulder region of the cutting profile, and fixed cutters may be located in the cone and/or gage of the cutting profile. In other embodiments, the rolling cutters may also be disposed in the cone and/or gage of the cutting profile. For example, referring back to FIG. 4, rolling cutters 460 are located in at least some of the nose and shoulder regions of the blades 420, while fixed cutters 450 are located in the cone and gage regions of the blade 420. It is also within the scope of the present disclosure that the nose and shoulder may also include fixed cutters as either primary or back-up cutting elements.

[0056] As described throughout the present disclosure, the cutting elements may be used on any downhole cutting tool, including, for example, a fixed cutter drill bit or a hole opener. FIG. 6 shows a general configuration of a hole opener 630 that includes one or more cutting elements of the present disclosure. The hole opener 630 includes a tool body 632 and a plurality of blades 638 disposed at selected azimuthal locations about a circumference thereof. The hole opener 630 generally includes connections 634, 636 (*e.g.*, threaded connections) so that the hole opener 630 may be coupled to adjacent drilling tools that comprise, for example, a drill string and/or bottom hole assembly (BHA) (not shown). The tool body 632 generally includes a bore therethrough so that drilling fluid may flow through the hole opener 630 as it is pumped from the surface (*e.g.*, from surface mud pumps (not shown)) to a bottom of

the wellbore (not shown). The tool body 632 may be formed from steel or from other materials known in the art. For example, the tool body 632 may also be formed from a matrix material infiltrated with a binder alloy. The blades 638 shown in FIG. 6 are spiral blades and are generally positioned at substantially equal angular intervals about the perimeter of the tool body. This arrangement is not a limitation on the scope of the disclosure, but rather is used for illustrative purposes. A plurality of cutting elements 640 are on the blades. Those having ordinary skill in the art will recognize that any suitable downhole cutting tool may be used. While FIG. 6 does not detail the location of the rolling cutters, their placement on the tool may be according to any of the variations described above.

[0057] 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 this disclosure. Accordingly, all such modifications are intended to be included within the scope of this disclosure. While the disclosure contains many specifics, these specifics should not be construed as limiting the scope of the disclosure or of any of the appended claims, but merely as providing information pertinent to one or more specific embodiments that may fall within the scope of the disclosure and the appended claims. Any described features from the various embodiments disclosed may be employed in any combination. Equivalent constructions, including functional "means-plus-function" clauses are intended to cover the structures described herein as performing the recited function, including both structural equivalents that operate in the same manner, and equivalent structures that provide the same function. It is the express intention of the applicant not to invoke means-plus-function or other functional claiming for any claim except for those in which the words 'means for' appear together with an associated function.

CLAIMS

What is claimed is:

1. A cutting element assembly for a drill bit, comprising:
   a housing;
   an inner rotatable cutting element having a cutting end and a portion that is retained in the housing;
   a base of the cutting end and an end of the housing comprising radial bearing surfaces; and
   a pre-load assembly between the radial bearing surfaces.

2. The cutting element assembly of claim 1, wherein the pre-load assembly is a Belleville spring.

3. The cutting element assembly of claim 1, further comprising:
   a first groove in an inner surface of the housing;
   a second groove in an outer surface of the body substantially matching the first groove; and
   a retention mechanism disposed within a space defined by the first and second grooves.

4. The cutting element assembly of claim 4, wherein the retention mechanism is a retaining ring.

5. A cutting element assembly for a drill bit, comprising:
   a housing;
   an inner rotatable cutting element having a cutting end and a portion that is retained in the housing;
   a base of the cutting end and an end of the housing comprising radial bearing surfaces; and
   a pre-load assembly between the radial bearing surfaces and along an axial length of the body.

6. The cutting element assembly of claim 5, wherein the pre-load assembly between the radial bearing surfaces and along an axial length of the body is integral.

7. The cutting element assembly of claim 5, wherein the pre-load assembly is a flanged bushing.

8. The cutting element assembly of claim 7, wherein the flanged bushing comprises a thermoplastic polymer.

9. The cutting element assembly of claim 8, wherein the thermoplastic polymer comprises a fluoropolymer or an acetal resin.

10. A cutting tool, comprising:
    a tool body having at least one cutting element support structure;
    at least one rotatable cutting element at least partially retained within the at least one cutting element support structure, the at least one inner rotatable cutting element having a cutting end, a base of the cutting end and the cutting element support structure having radial bearing surfaces therebetween; and
    a pre-load assembly between the radial bearing surfaces.

11. The cutting tool of claim 10, wherein the at least one cutting element support structure comprises a plurality of blades having pockets, at least one pocket receiving and retaining the rotatable cutting element.

12. The cutting tool of claim 10, wherein the tool body comprises a plurality of blades extending therefrom, the plurality of blades having at least one cutter pocket therein, wherein the at least one cutting element support structure is a housing in which the rotatable cutting element is retained, the housing being brazed within the at least one cutter pocket.

13. The cutting tool of claim 10, wherein the pre-load assembly between the radial bearing surfaces further extends along an axial length of the body.

14. The cutting tool of claim 13, wherein the pre-load assembly between the radial bearing surfaces and along an axial length of the body is integral.

15. The cutting tool of claim 13, wherein the pre-load assembly is a flanged bushing.

16. The cutting tool of claim 15, wherein the flanged bushing comprises a thermoplastic polymer.

17. The cutting tool of claim 16, wherein the thermoplastic polymer comprises a fluoropolymer or an acetal resin.

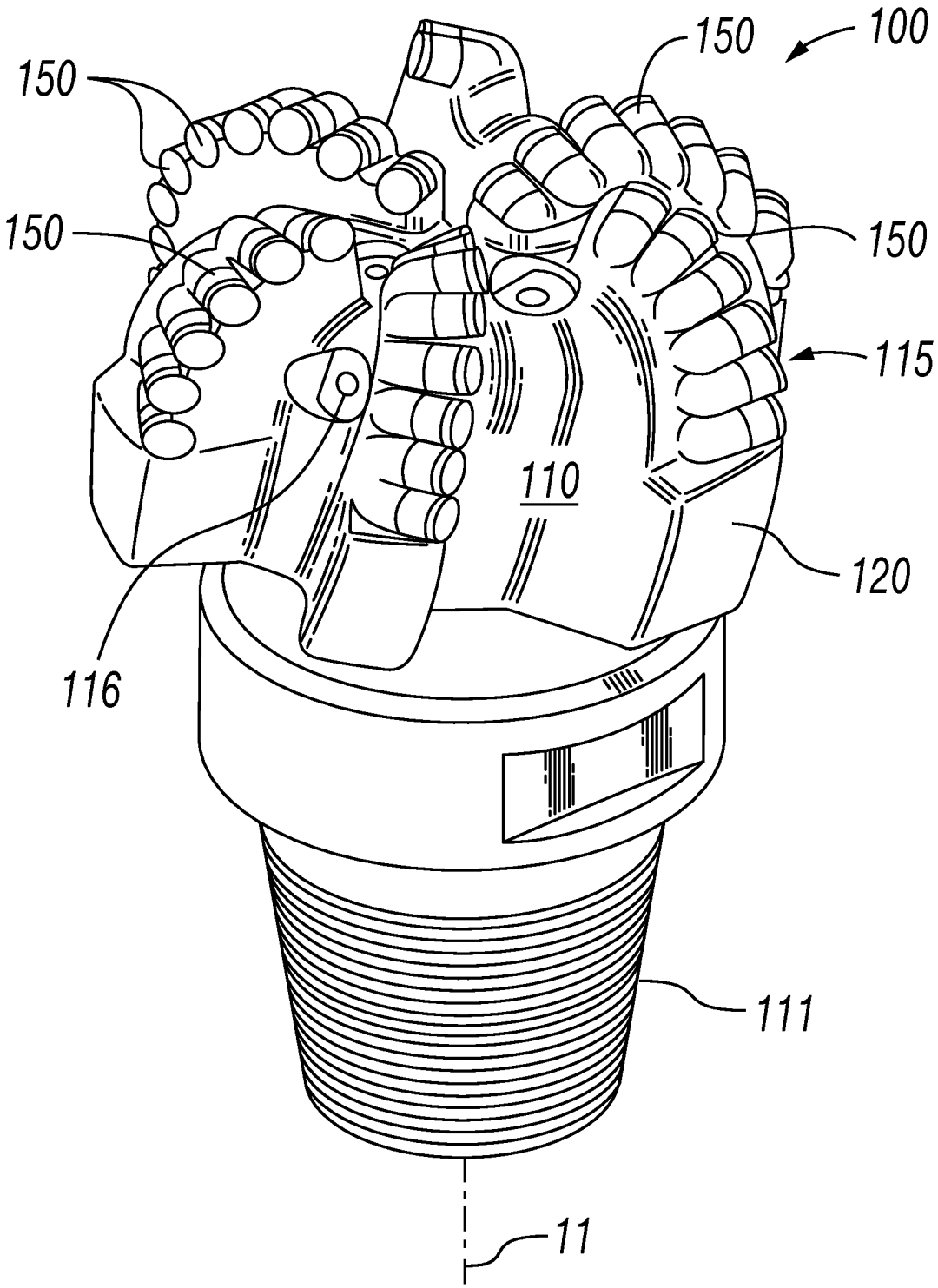


FIG. 1
(Prior Art)

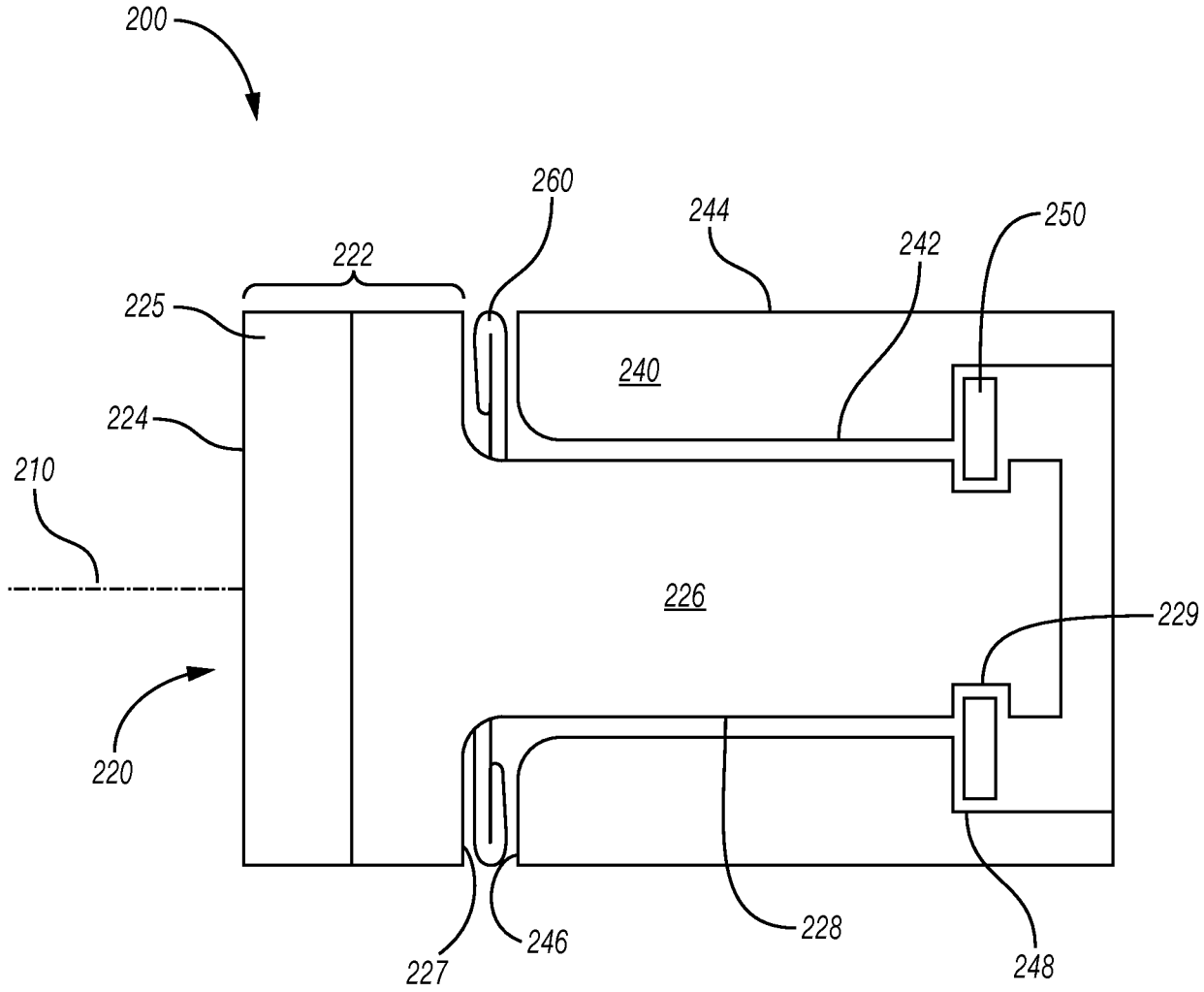

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FIG. 2

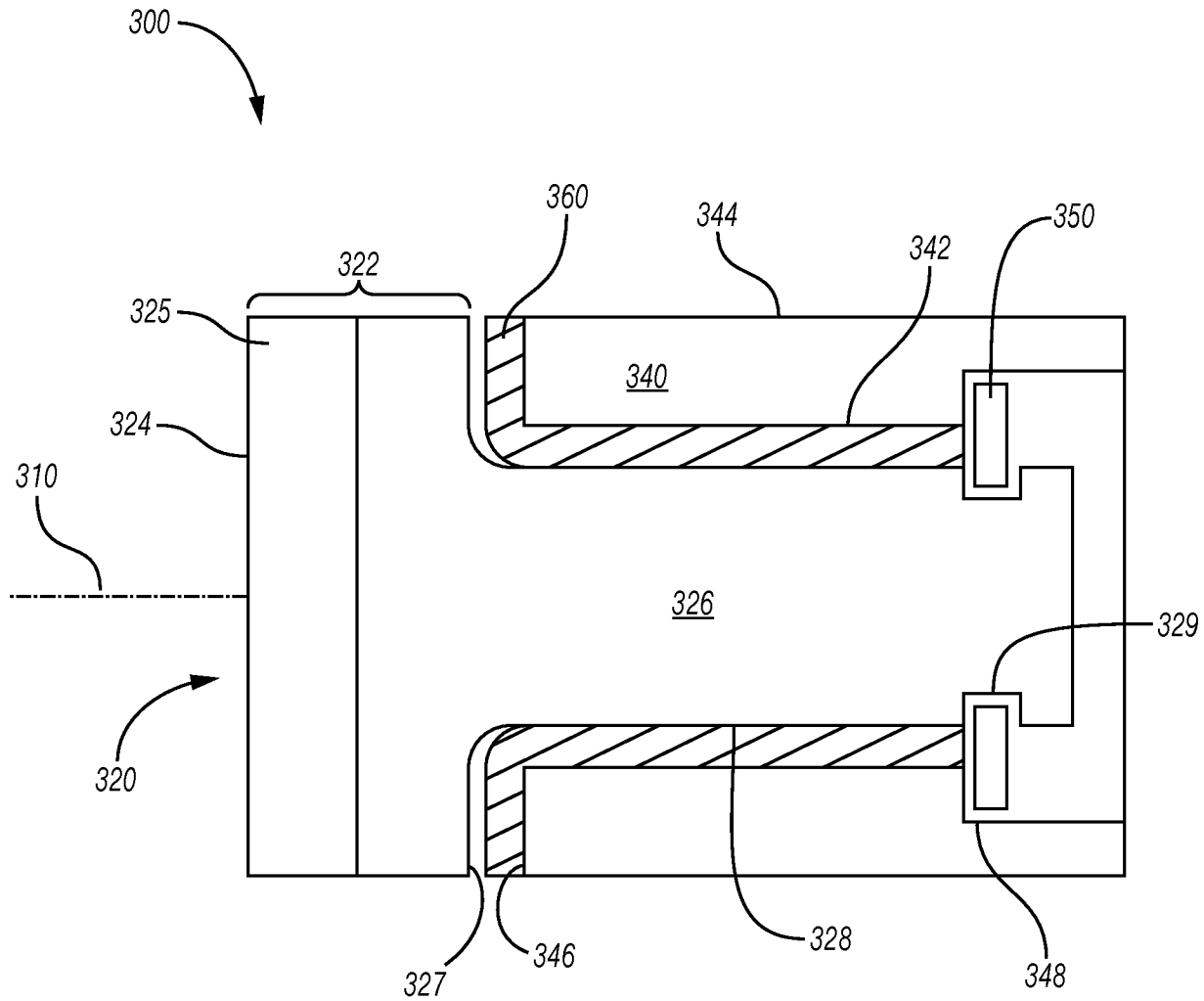

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FIG. 3

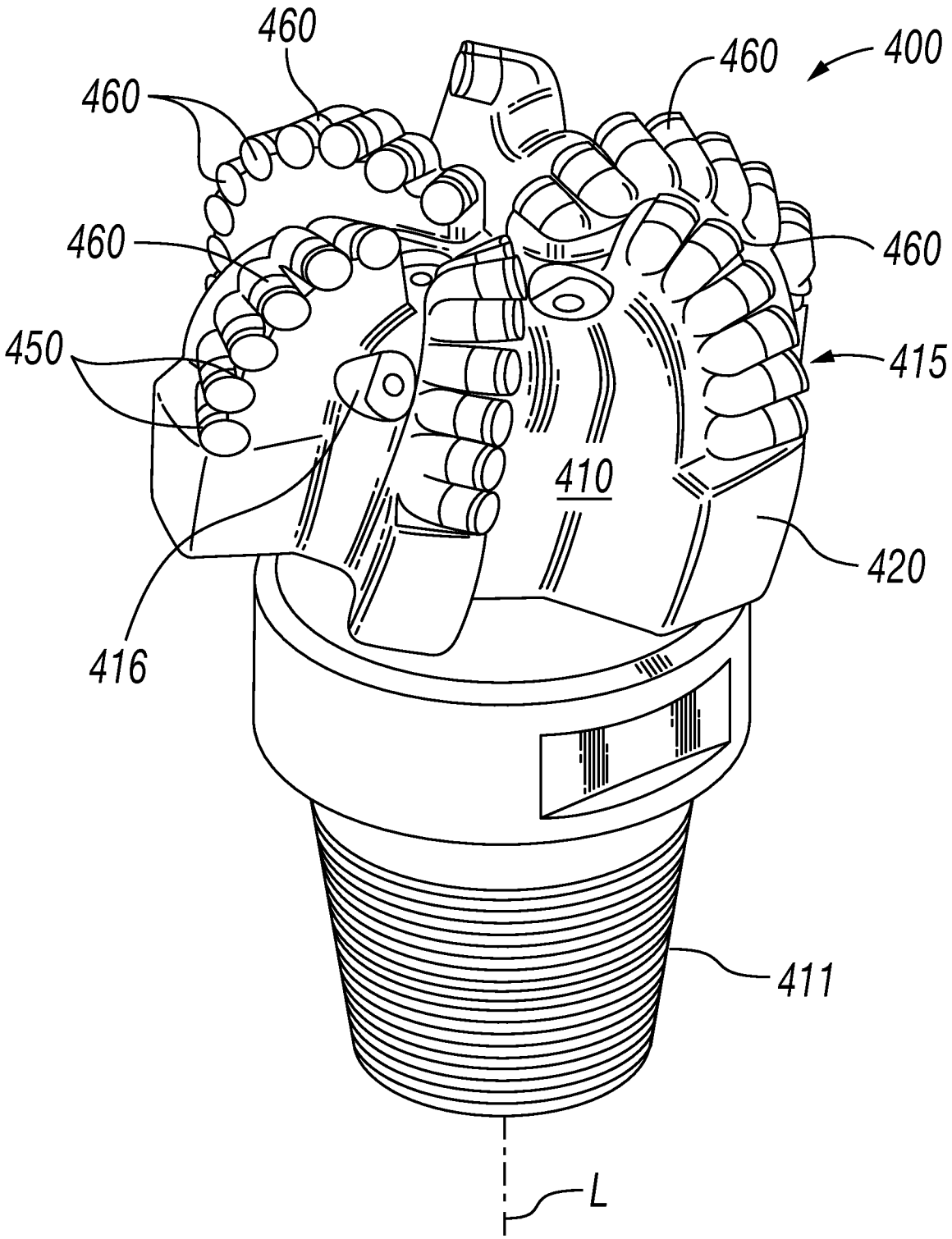


FIG. 4

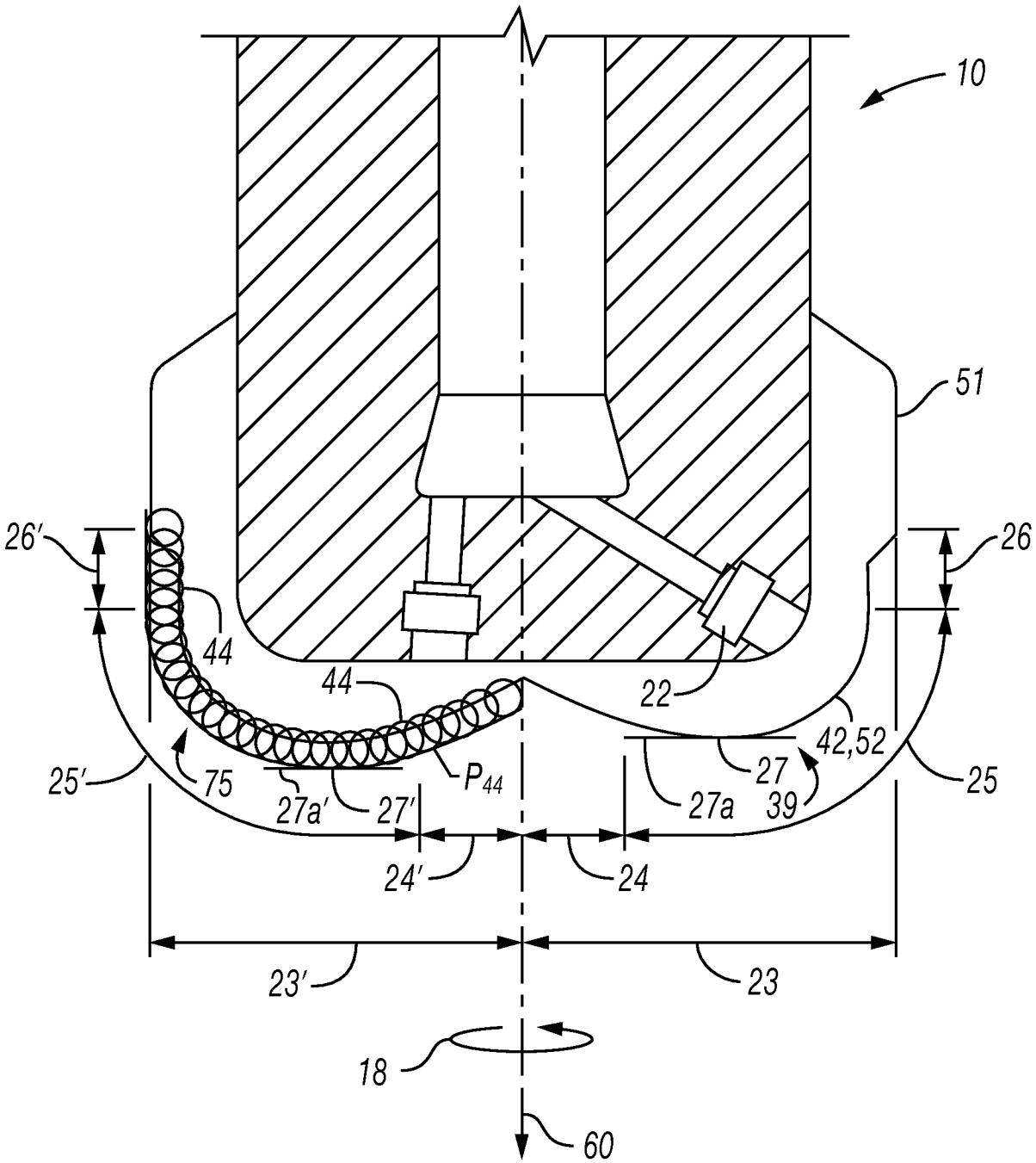

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FIG. 5

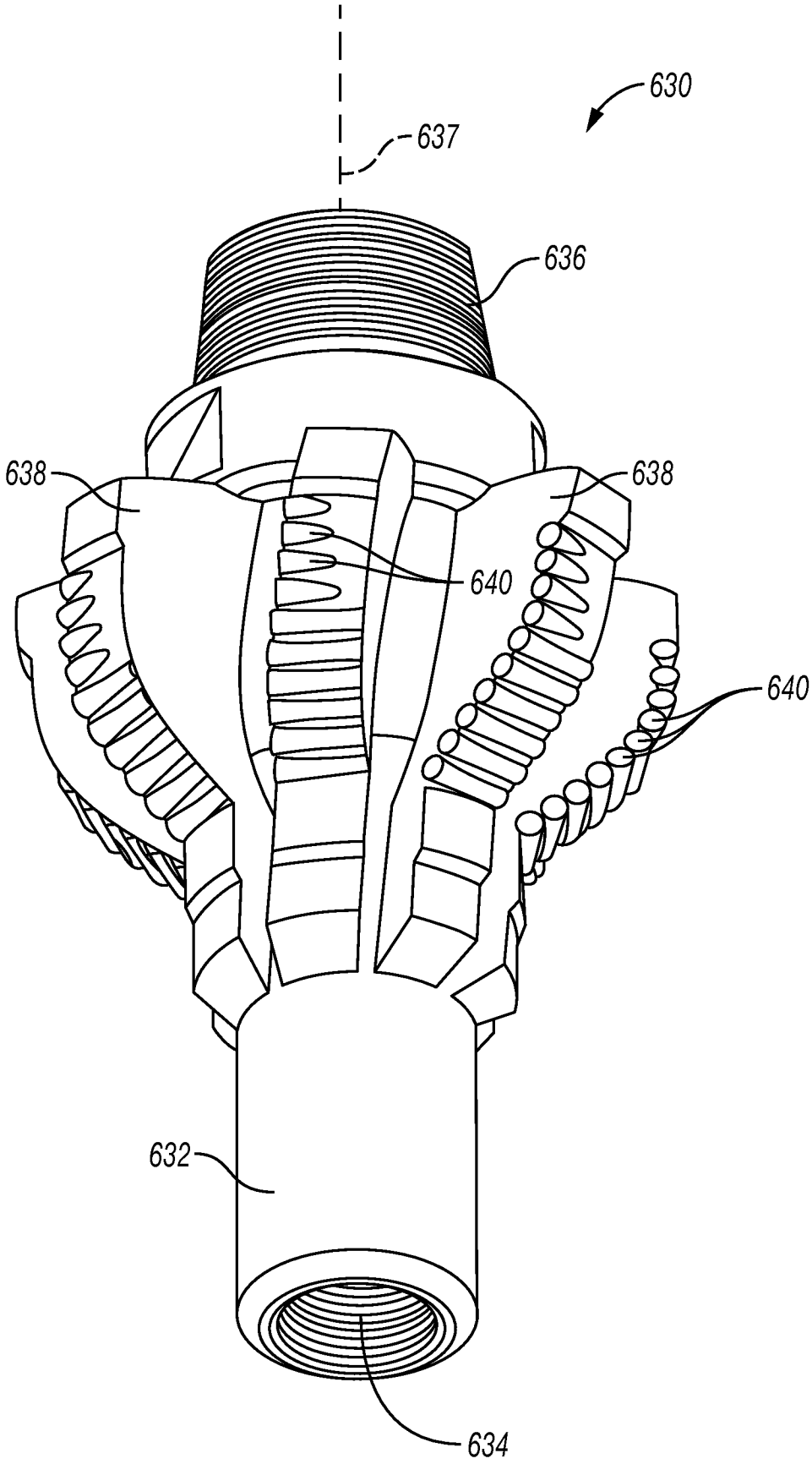


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/061779

A. CLASSIFICATION OF SUBJECT MATTER

E21B 10/42(2006.01)i, E21B 10/43(2006.01)i, E21B 10/62(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; E21B 10/46; E21B 10/43; E21B 10/573; E21B 10/22; E21B 10/62

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:cutting element, drill bit, radial bearing surface, pre-load assembly, inner rotatable cutting element

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7762359 B1 (MIESS, DAVID P.) 27 July 2010 See column 1, line 34 - column 6, line 46; column 12, lines 14-51; and figures 1-2, 4B-4E, 13.	1-17
Y	US 2008-0251293 A1 (MUMMA et al.) 16 October 2008 See paragraphs [0020]-[0028]; and figures 1-5.	1-17
A	US 2013-0105229 A1 (SCHRODER, JON D.) 02 May 2013 See paragraphs [0008]-[0017]; and figures 1-3.	1-17
A	US 2013-0220707 A1 (SMITH INTERNATIONAL, INC.) 29 August 2013 See paragraphs [0052]-[0071]; and figures 1A-1B, 2A-2B, 3A-3B.	1-17
A	WO 2010-014725 A2 (BAKER HUGHES INCORPORATED et al.) 04 February 2010 See page 2, line 30 - page 5, line 14; and figures 1-2.	1-17

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"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
08 March 2016 (08.03.2016)	**08 March 2016 (08.03.2016)**

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Korean Intellectual Property Office
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2015/061779

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		WO 2010-014725 A4	10/06/2010