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Bomidi et al.

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(54) **CUTTING ELEMENT ASSEMBLIES COMPRISING ROTATABLE CUTTING ELEMENTS**

(71) Applicant: **Baker Hughes, a GE company, LLC**, Houston, TX (US)

(72) Inventors: **John Abhishek Raj Bomidi**, Spring, TX (US); **Alexander Rodney Boehm**, Wheat Ridge, CO (US); **Kegan L. Lovelace**, Houston, TX (US); **William A. Moss, Jr.**, Conroe, TX (US); **Jon David Schroder**, The Woodlands, TX (US)

(73) Assignee: **Baker Hughes, a GE company, LLC**, Houston, TX (US)

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USPC 175/374
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,553,615	A	11/1985	Grainger	
4,751,972	A	6/1988	Jones et al.	
7,604,073	B2	10/2009	Cooley et al.	
7,703,559	B2	4/2010	Shen et al.	
7,762,359	B1 *	7/2010	Miess	E21B 10/633 175/354
7,845,436	B2	12/2010	Cooley et al.	
7,987,931	B2	8/2011	Cooley et al.	
8,061,452	B2	11/2011	Cooley et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

CN	104781496	A	7/2015
CN	104995369	A	10/2015

(Continued)

OTHER PUBLICATIONS

International Written Opinion for International Application No. PCT/US2018/043417 dated Oct. 31, 2018, 7 pages.

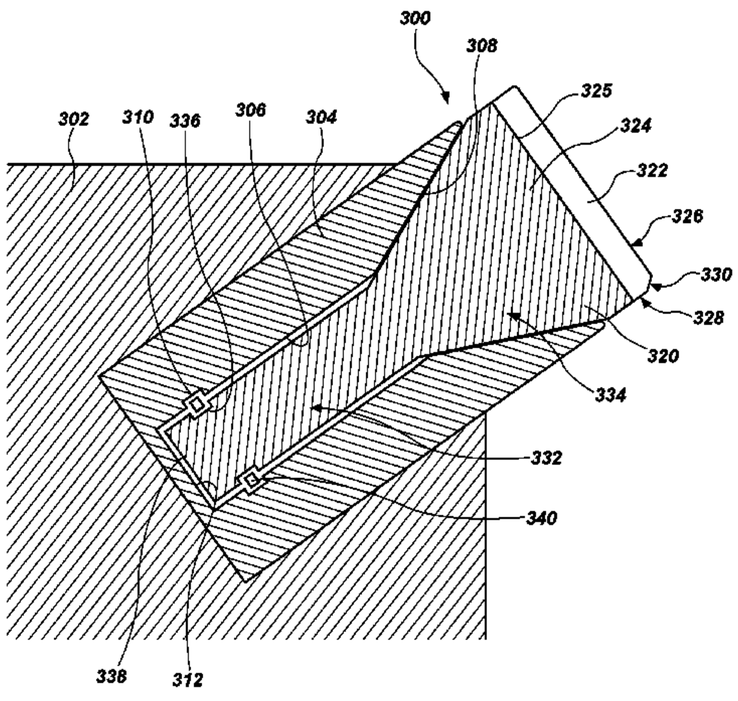
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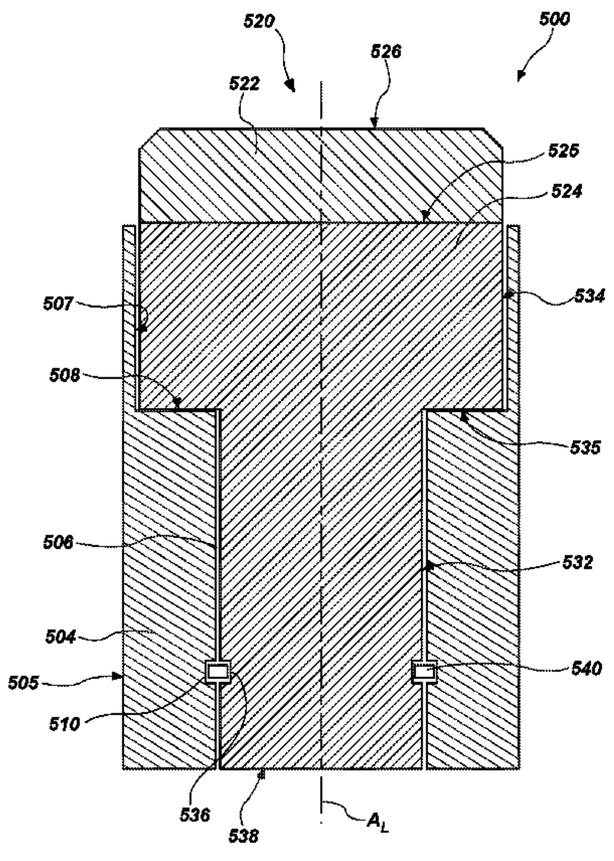
Primary Examiner — Taras P Bemko
(74) *Attorney, Agent, or Firm* — TraskBritt

(57) **ABSTRACT**

A cutting element assembly includes a sleeve, a rotatable cutting element disposed within the sleeve, and a retention element. The sleeve and rotatable cutting element each have frustoconical surfaces. In some embodiments, a rotatable cutting element defines a first generally cylindrical surface, a second generally cylindrical surface, and an axial bearing surface opposite the end cutting surface and intersecting each of the first generally cylindrical surface and the second generally cylindrical surface. A bearing element may be disposed between an upper surface of a sleeve and a bearing surface of the rotatable cutting element. Earth-boring tools having rotating cutting elements are also disclosed.

11 Claims, 6 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

8,079,431	B1	12/2011	Cooley et al.
8,091,655	B2	1/2012	Shen et al.
8,210,285	B2	7/2012	Cooley et al.
8,413,746	B2	4/2013	Shen et al.
8,561,728	B2	10/2013	Cooley et al.
8,800,691	B2	8/2014	Shen et al.
8,881,849	B2	11/2014	Shen et al.
8,931,582	B2	1/2015	Cooley et al.
8,950,516	B2	2/2015	Newman
8,973,684	B1	3/2015	Cooley et al.
8,991,523	B2	3/2015	Shen et al.
9,016,409	B2	4/2015	Zhang et al.
9,033,070	B2	5/2015	Shen et al.
9,187,962	B2	11/2015	Burhan et al.
9,279,294	B1	3/2016	Cooley et al.
9,291,000	B2	3/2016	Zhang et al.
9,322,219	B2	4/2016	Burhan et al.
9,328,564	B2	5/2016	Zhang et al.
9,382,762	B2	7/2016	Cooley et al.
9,388,639	B2	7/2016	Patel et al.
9,464,486	B2	10/2016	Zhang et al.
9,920,579	B2	3/2018	Newman
2008/0251293	A1	10/2008	Mumma et al.
2009/0205870	A1	8/2009	Smith
2009/0321146	A1	12/2009	Dick et al.
2012/0132471	A1*	5/2012	Zhang E21B 10/573 175/338
2014/0054094	A1	2/2014	Burhan et al.
2014/0131118	A1	5/2014	Chen et al.
2014/0326515	A1	11/2014	Shi et al.
2014/0326516	A1	11/2014	Haugvaldstad et al.
2014/0360789	A1	12/2014	Siracki et al.
2014/0360792	A1	12/2014	Azar et al.
2015/0047910	A1	2/2015	Chen et al.
2015/0330153	A1	11/2015	Miller et al.
2016/0290056	A1	10/2016	Propes et al.
2017/0191317	A1*	7/2017	Burhan E21B 10/50

FOREIGN PATENT DOCUMENTS

GB	2512978	A	10/2014
WO	2016/081807	A1	5/2016

OTHER PUBLICATIONS

International Search Report for International Application No. PCT/US2018/043417 dated Oct. 31, 2018, 3 pages.

* cited by examiner

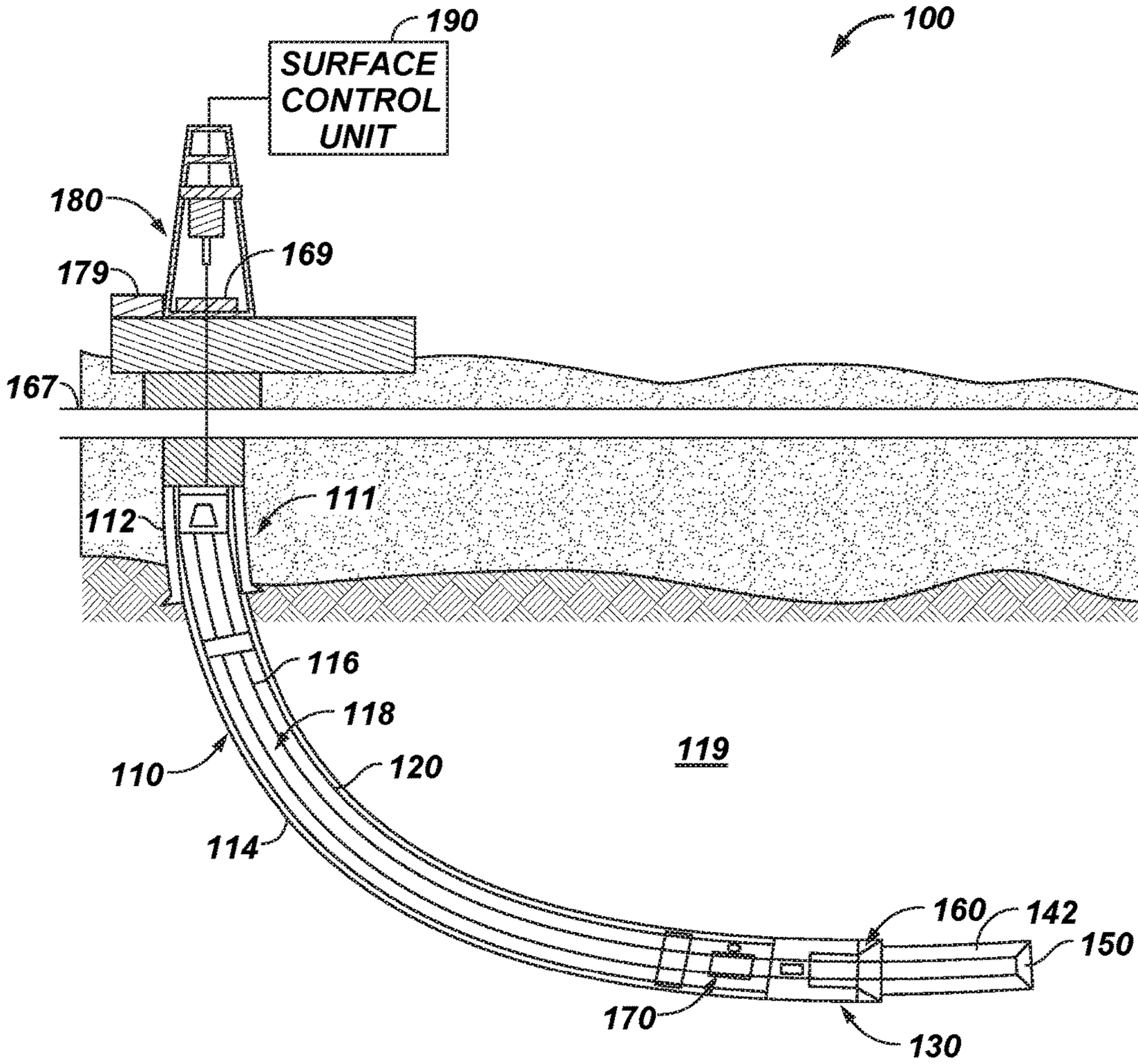

190
SURFACE CONTROL UNIT
100
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FIG. 1

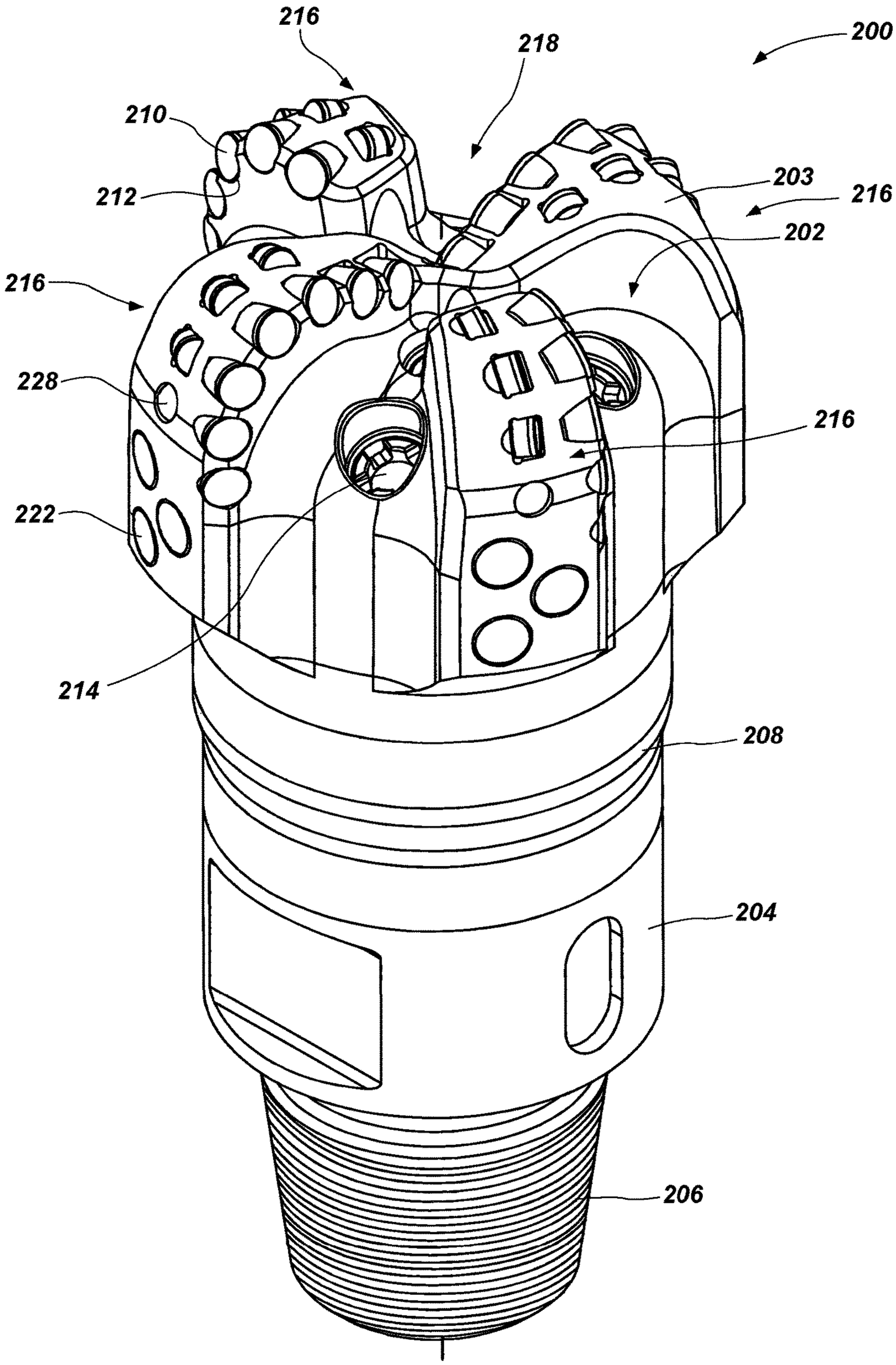


FIG. 2

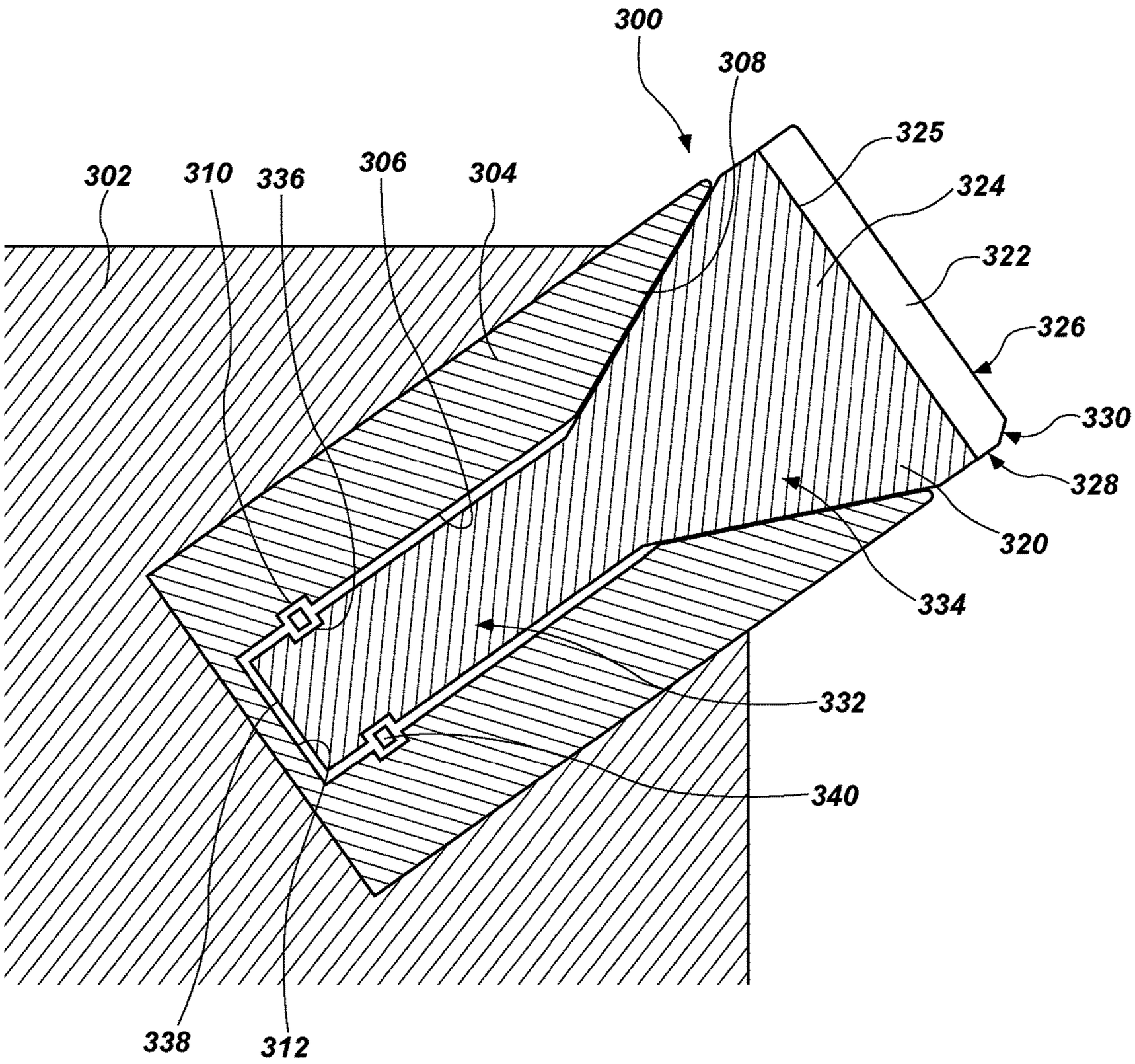

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FIG. 3

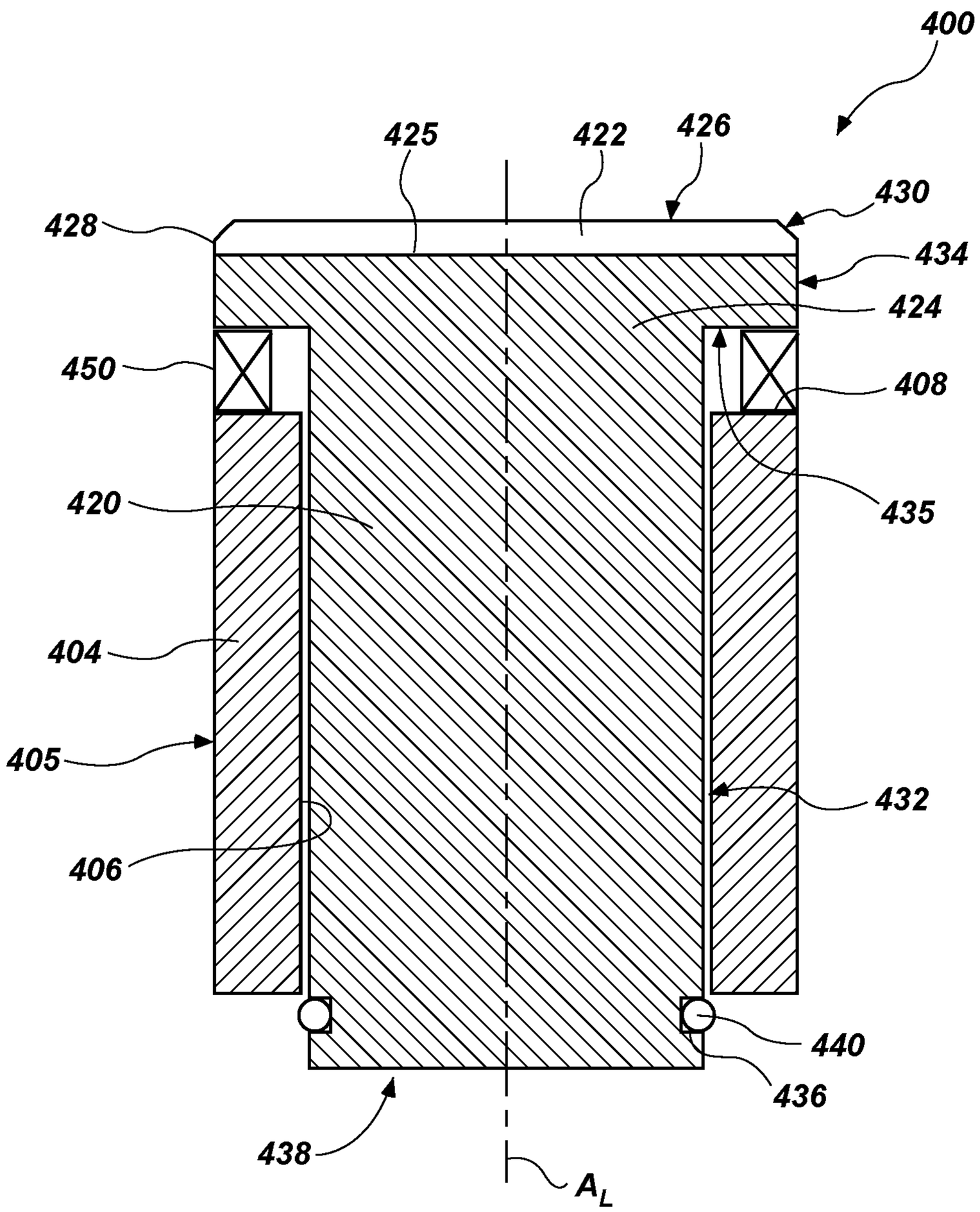

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FIG. 4

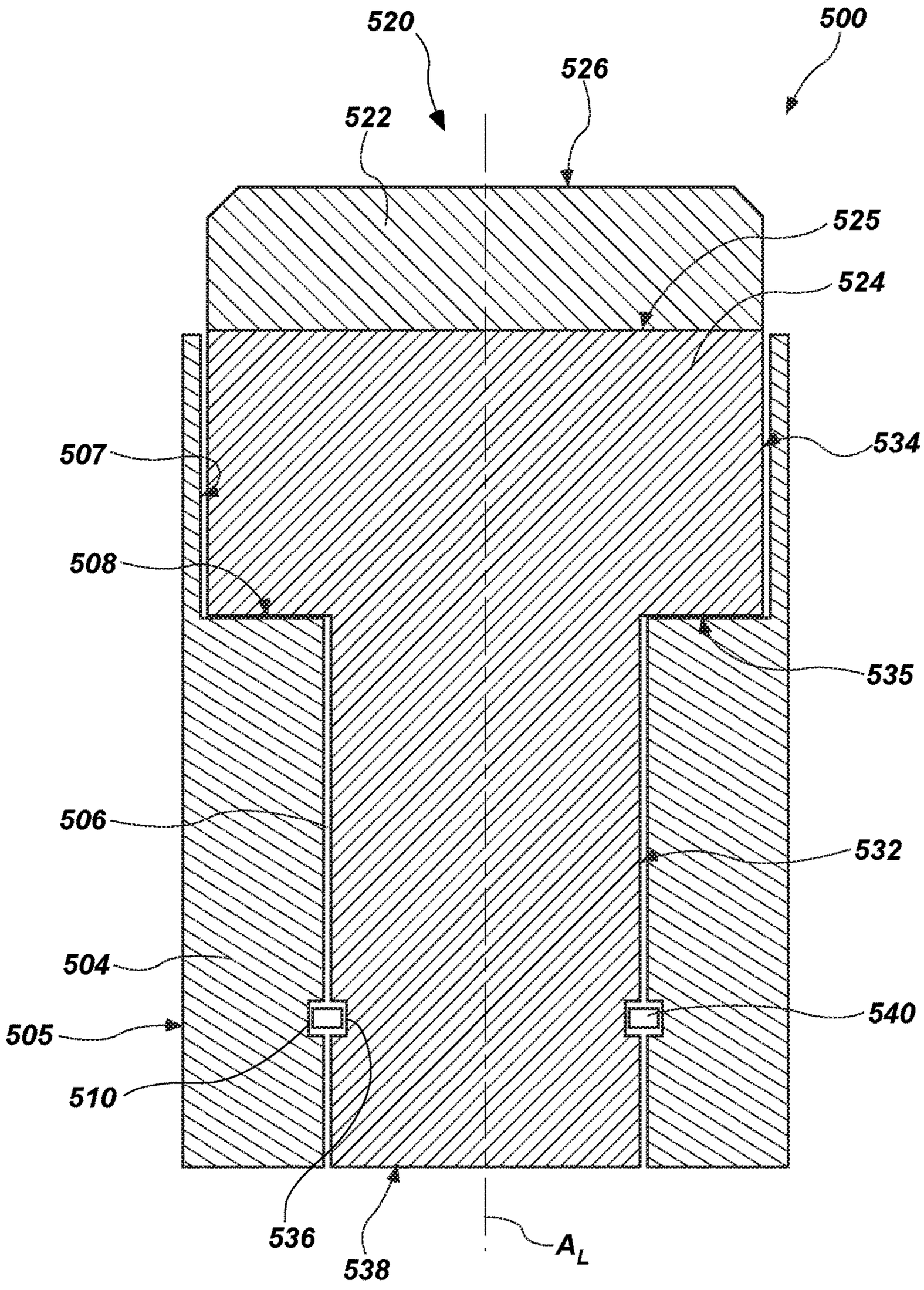

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FIG. 5

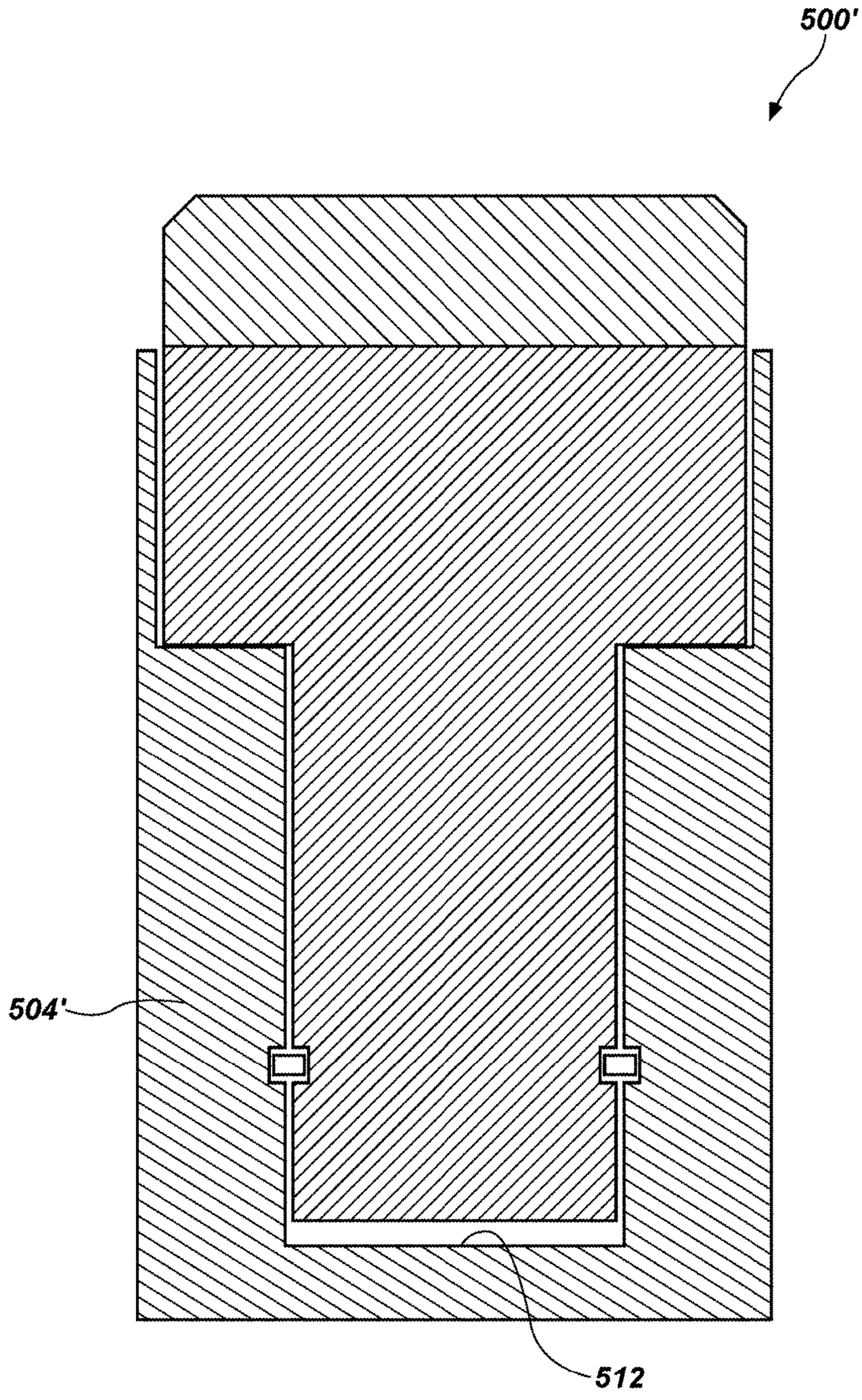


FIG. 6

CUTTING ELEMENT ASSEMBLIES COMPRISING ROTATABLE CUTTING ELEMENTS

FIELD

Embodiments of the present disclosure relate generally to rotatable cutting elements and earth-boring tools having such cutting elements.

BACKGROUND

Wellbores are formed in subterranean formations for various purposes including, for example, extraction of oil and gas from the subterranean formation and extraction of geothermal heat from the subterranean formation. Wellbores may be formed in a subterranean formation using a drill bit, such as an earth-boring rotary drill bit. Different types of earth-boring rotary drill bits are known in the art, including fixed-cutter bits (which are often referred to in the art as "drag" bits), rolling-cutter bits (which are often referred to in the art as "rock" bits), diamond-impregnated bits, and hybrid bits (which may include, for example, both fixed cutters and rolling cutters). The drill bit is rotated and advanced into the subterranean formation. As the drill bit rotates, the cutters or abrasive structures thereof cut, crush, shear, and/or abrade away the formation material to form the wellbore. A diameter of the wellbore drilled by the drill bit may be defined by the cutting structures disposed at the largest outer diameter of the drill bit.

The drill bit is coupled, either directly or indirectly, to an end of what is referred to in the art as a "drill string," which comprises a series of elongated tubular segments connected end-to-end that extends into the wellbore from the surface of earth above the subterranean formations being drilled. Various tools and components, including the drill bit, may be coupled together at the distal end of the drill string at the bottom of the wellbore being drilled. This assembly of tools and components is referred to in the art as a "bottom hole assembly" (BHA).

The drill bit may be rotated within the wellbore by rotating the drill string from the surface of the formation, or the drill bit may be rotated by coupling the drill bit to a downhole motor, which is also coupled to the drill string and disposed proximate the bottom of the wellbore. The downhole motor may include, for example, a hydraulic Moineau-type motor having a shaft, to which the drill bit is mounted, that may be caused to rotate by pumping fluid (e.g., drilling mud or fluid) from the surface of the formation down through the center of the drill string, through the hydraulic motor, out from nozzles in the drill bit, and back up to the surface of the formation through the annular space between the outer surface of the drill string and the exposed surface of the formation within the wellbore. The downhole motor may be operated with or without drill string rotation.

A drill string may include a number of components in addition to a downhole motor and drill bit including, without limitation, drill pipe, drill collars, stabilizers, measuring while drilling (MWD) equipment, logging while drilling (LWD) equipment, downhole communication modules, and other components.

In addition to drill strings, other tool strings may be disposed in an existing well bore for, among other operations, completing, testing, stimulating, producing, and remediating hydrocarbon-bearing formations.

Cutting elements used in earth boring tools often include polycrystalline diamond compact (often referred to as "PDC") cutting elements, which are cutting elements that include so-called "tables" of a polycrystalline diamond material mounted to supporting substrates and presenting a cutting face for engaging a subterranean formation. Polycrystalline diamond (often referred to as "PCD") material is material that includes inter-bonded grains or crystals of diamond material. In other words, PCD material includes direct, intergranular bonds between the grains or crystals of diamond material.

Cutting elements are typically mounted on the body of a drill bit by brazing. The drill bit body is formed with recesses therein, commonly termed "pockets," for receiving a substantial portion of each cutting element in a manner which presents the PCD layer at an appropriate back rake and side rake angle, facing in the direction of intended bit rotation, for cutting in accordance with the drill bit design. In such cases, a brazing compound is applied between the surface of the substrate of the cutting element and the surface of the recess on the bit body in which the cutting element is received. The cutting elements are installed in their respective recesses in the bit body, and heat is applied to each cutting element via a torch to raise the temperature to a point high enough to braze the cutting elements to the bit body in a fixed position but not so high as to damage the PCD layer.

Unfortunately, securing a PDC cutting element to a drill bit restricts the useful life of such cutting element, because the cutting edge of the diamond table and the substrate wear down, creating a so-called "wear flat" and necessitating increased weight-on-bit to maintain a given rate of penetration of the drill bit into the formation due to the increased surface area presented. In addition, unless the cutting element is heated to remove it from the bit and then rebrazed with an unworn portion of the cutting edge presented for engaging a formation, more than half of the cutting element is never used.

Rotatable cutting elements mounted for rotation about a longitudinal axis of the cutting element can wear more evenly than fixed cutting elements, and exhibit a significantly longer useful life without removal from the drill bit. That is, as a cutting element rotates in a bit body, different parts of the cutting edges or surfaces may be exposed at different times, such that more of the cutting element is used. Thus, rotatable cutting elements may have a longer life than fixed cutting elements.

BRIEF SUMMARY

A cutting element assembly includes a sleeve, a rotatable cutting element disposed within the sleeve, and a retention element. The sleeve defines a first internal groove and a first frustoconical surface longitudinally spaced from the first internal groove. The rotatable cutting element includes a polycrystalline hard material and a supporting substrate. The polycrystalline hard material has an end cutting surface. The rotatable cutting element defines a second groove in a surface of the supporting substrate and a second frustoconical surface longitudinally spaced from the second internal groove. The retention element is disposed partially within the first groove and partially within the second groove.

In some embodiments, a cutting element assembly includes a sleeve defining a cylindrical cavity therein and a rotatable cutting element disposed at least partially within the cavity of the sleeve. The sleeve defines a generally planar end surface. The rotatable cutting element includes a polycrystalline hard material bonded to a substrate. The polycrystalline hard material has an end cutting surface generally

parallel to the end surface of the sleeve. The substrate defines a bearing surface and a cylindrical portion extending into the cylindrical cavity of the sleeve. The bearing surface is opposite the end cutting surface. A bearing element is disposed between the upper surface of the sleeve and the bearing surface of the rotatable cutting element.

In certain embodiments, a cutting element assembly includes a sleeve and a rotatable cutting element. The sleeve defines a first interior cylindrical surface, a second interior cylindrical surface, and a generally planar axial bearing surface between the first interior cylindrical surface and the second interior cylindrical surface. The first interior cylindrical surface, the axial bearing surface, and the second interior cylindrical surface together at least partially define a cavity in the sleeve. The rotatable cutting element is disposed at least partially within the cavity. The rotatable cutting element includes a polycrystalline hard material mounted to a substrate and having an end cutting surface generally parallel to the axial bearing surface of the sleeve. The substrate defines a first generally cylindrical surface, a second generally cylindrical surface, and an axial bearing surface opposite the end cutting surface and extending between the first generally cylindrical surface and the second generally cylindrical surface. The substrate is substantially disposed within an interior of each of the first interior cylindrical surface and the second interior cylindrical surface, and the axial bearing surface of the rotatable cutting element is in contact with the axial bearing surface of the sleeve.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified schematic diagram of an example of a drilling system using cutting element assemblies disclosed herein.

FIG. **2** is a simplified perspective view of a fixed-blade earth-boring rotary drill bit that may be used in conjunction with the drilling system of FIG. **1**.

FIG. **3** is a simplified cross section showing a cutting element assembly mounted in a blade of an earth-boring tool, such as the rotary drill bit of FIG. **2**.

FIGS. **4-6** are simplified cross sections showing additional cutting element assemblies.

DETAILED DESCRIPTION

The illustrations presented herein are not actual views of any particular cutting assembly, tool, or drill string, but are merely idealized representations employed to describe example embodiments of the present disclosure. The following description provides specific details of embodiments of the present disclosure in order to provide a thorough description thereof. However, a person of ordinary skill in the art will understand that the embodiments of the disclosure may be practiced without employing many such specific details. Indeed, the embodiments of the disclosure may be practiced in conjunction with conventional techniques employed in the industry. In addition, the description provided below does not include all elements to form a complete structure or assembly. Only those process acts and structures necessary to understand the embodiments of the disclosure are described in detail below. Additional conventional acts and structures may be used. Also note, any drawings accompanying the application are for illustrative purposes only, and are thus not drawn to scale. Additionally, elements common between figures may have corresponding numerical designations.

As used herein, the terms "comprising," "including," "containing," "characterized by," and grammatical equivalents thereof are inclusive or open-ended terms that do not exclude additional, unrecited elements or method steps, but also include the more restrictive terms "consisting of" and "consisting essentially of" and grammatical equivalents thereof.

As used herein, the term "may" with respect to a material, structure, feature, or method act indicates that such is contemplated for use in implementation of an embodiment of the disclosure, and such term is used in preference to the more restrictive term "is" so as to avoid any implication that other compatible materials, structures, features and methods usable in combination therewith should or must be excluded.

As used herein, the term "configured" refers to a size, shape, material composition, and arrangement of one or more of at least one structure and at least one apparatus facilitating operation of one or more of the structure and the apparatus in a predetermined way.

As used herein, the singular forms following "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

As used herein, spatially relative terms, such as "beneath," "below," "lower," "bottom," "above," "upper," "top," "front," "rear," "left," "right," and the like, may be used for ease of description to describe one element's or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Unless otherwise specified, the spatially relative terms are intended to encompass different orientations of the materials in addition to the orientation depicted in the figures.

As used herein, the term "substantially" in reference to a given parameter, property, or condition means and includes to a degree that one of ordinary skill in the art would understand that the given parameter, property, or condition is met with a degree of variance, such as within acceptable manufacturing tolerances. By way of example, depending on the particular parameter, property, or condition that is substantially met, the parameter, property, or condition may be at least 90.0% met, at least 95.0% met, at least 99.0% met, or even at least 99.9% met.

As used herein, the term "about" used in reference to a given parameter is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the given parameter).

As used herein, the term "hard material" means and includes any material having a Knoop hardness value of about 1,000 Kg_f/mm^2 (9,807 MPa) or more. Hard materials include, for example, diamond, cubic boron nitride, boron carbide, tungsten carbide, etc.

As used herein, the term "intergranular bond" means and includes any direct atomic bond (e.g., covalent, metallic, etc.) between atoms in adjacent grains of material.

As used herein, the term "polycrystalline hard material" means and includes any material comprising a plurality of grains or crystals of the material that are bonded directly together by intergranular bonds. The crystal structures of the individual grains of polycrystalline hard material may be randomly oriented in space within the polycrystalline hard material.

As used herein, the term "earth-boring tool" means and includes any type of bit or tool used for drilling during the formation or enlargement of a wellbore and includes, for example, rotary drill bits, percussion bits, core bits, eccentric

bits, bi-center bits, reamers, mills, drag bits, roller-cone bits, hybrid bits, and other drilling bits and tools known in the art.

FIG. **1** is a schematic diagram of an example of a drilling system **100** using cutting element assemblies disclosed herein. FIG. **1** shows a wellbore **110** that includes an upper section **111** with a casing **112** installed therein and a lower section **114** that is being drilled with a drill string **118**. The drill string **118** includes a tubular member **116** that carries a drilling assembly **130** at its bottom end. The tubular member **116** may be coiled tubing or may be formed by joining drill pipe sections. A drill bit **150** (also referred to as the "pilot bit") is attached to the bottom end of the drilling assembly **130** for drilling a first, smaller diameter borehole **142** in the formation **119**. A reamer bit **160** may be placed above or uphole of the drill bit **150** in the drill string **118** to enlarge the borehole **142** to a second, larger diameter borehole **120**. The terms wellbore and borehole are used herein as synonyms.

The drill string **118** extends to a rig **180** at the surface **167**. The rig **180** shown is a land rig for ease of explanation. The apparatus and methods disclosed herein equally apply when an offshore rig is used for drilling underwater. A rotary table **169** or a top drive may rotate the drill string **118** and the drilling assembly **130**, and thus the pilot bit **150** and reamer bit **160**, to respectively drill boreholes **142** and **120**. The rig **180** also includes conventional devices, such as mechanisms to add additional sections to the tubular member **116** as the wellbore **110** is drilled. A surface control unit **190**, which may be a computer-based unit, is placed at the surface **167** for receiving and processing downhole data transmitted by the drilling assembly **130** and for controlling the operations of the various devices and sensors **170** in the drilling assembly **130**. A drilling fluid from a source **179** thereof is pumped under pressure through the tubular member **116** that discharges at the bottom of the pilot bit **150** and returns to the surface via the annular space (also referred to as the "annulus") between the drill string **118** and an inside wall of the wellbore **110**.

During operation, when the drill string **118** is rotated, both the pilot bit **150** and the reamer bit **160** rotate. The pilot bit **150** drills the first, smaller diameter borehole **142**, while simultaneously the reamer bit **160** enlarges the borehole **142** to a second, larger diameter borehole **120**. The earth's subsurface may contain rock strata made up of different rock structures that can vary from soft formations to very hard formations, and therefore the pilot bit **150** and/or the reamer bit **160** may be selected based on the formations expected to be encountered in a drilling operation.

FIG. **2** is a perspective view of a fixed-cutter earth-boring rotary drill bit **200** that may be used in conjunction with the drilling system **100** of FIG. **1**. For example, the drill bit **200** may be the pilot bit **150** shown in FIG. **1**. The drill bit **200** includes a bit body **202** that may be secured to a shank **204** having a threaded connection portion **206** (e.g., an American Petroleum Institute (API) threaded connection portion) for attaching the drill bit **200** to a drill string (e.g., drill string **118**, shown in FIG. **1**). In some embodiments, the bit body **202** may be secured to the shank **204** using an extension **208**. In other embodiments, the bit body **202** may be secured directly to the shank **204**.

The bit body **202** may include internal fluid passageways that extend between the face **203** of the bit body **202** and a longitudinal bore, extending through the shank **204**, the extension **208**, and partially through the bit body **202**. Nozzle inserts **214** also may be provided at the face **203** of the bit body **202** within the internal fluid passageways. The bit body **202** may further include a plurality of blades **216** that are separated by junk slots **218**. In some embodiments, the bit body **202** may include gage wear plugs **222** and wear knots **228**. A plurality of cutting element assemblies **210** may be mounted on the face **203** of the bit body **202** in cutting element pockets **212** that are located along each of the blades **216**. The cutting element assemblies **210** may include PDC cutting elements, or may include other cutting elements. For example, some or all of the cutting element assemblies **210** may include rotatable cutters, as described below and shown in FIGS. **3-6**.

FIG. **3** is a simplified cross section showing a cutting element assembly **300** mounted in a blade **302** of an earth-boring tool. The blade **302** may be, for example, one of the blades **216** shown in FIG. **2**. The cutting element assembly **300** may be one of the cutting element assemblies **210** shown in FIG. **2**.

The cutting element assembly **300** may include a sleeve **304** secured to the blade **302**. For example, the sleeve **304** may be brazed or welded within a pocket of the blade **302**. In other embodiments, the sleeve **304** may be integrally formed with the blade **302**, such that there is no physical interface between the sleeve **304** and the blade **302**.

The sleeve **304** may have a generally cylindrical interior surface **306** and a frustoconical interior surface **308**, together defining a cavity in the sleeve **304**. The sleeve **304** may have a groove **310**, which may be, for example, a cylindrical channel sized and configured to receive an O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, or another retaining element. The sleeve **304** may have an interior back surface **312**, as shown on FIG. **3**, such that the cavity formed by the surfaces **306**, **308** is closed at one end by the interior back surface **312**. In other embodiments, the interior back surface **312** may be absent, and the cavity formed by the surfaces **306**, **308** may be bounded by the blade **302**.

A rotatable cutting element **320** may be at least partially within the sleeve **304**. The rotatable cutting element **320** may include a polycrystalline hard material **322** bonded to a substrate **324** at an interface **325**. In other embodiments, the rotatable cutting element **320** may be formed entirely of the polycrystalline hard material **322**, or may have another material in addition to the polycrystalline hard material **322** and the substrate **324**. The polycrystalline hard material **322** may include diamond, cubic boron nitride, or another hard material. The substrate **324** may include, for example, cobalt-cemented tungsten carbide or another carbide material.

The polycrystalline hard material **322** may have an end cutting surface **326**, and may also have other surfaces, such as a side surface **328**, a chamfer **330**, etc., which surfaces may be cutting surfaces intended to contact a subterranean formation. The polycrystalline hard material **322** may be generally cylindrical, and the interface **325** may be generally parallel to the end cutting surface **326**.

The substrate **324** may have a generally cylindrical portion **332** and a frustoconical portion **334**. The generally cylindrical portion **332** may be disposed within the generally cylindrical interior surface **306** of the sleeve **304**, and may have a groove **336** sized and configured to receive an O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, or another retaining element. For example, the groove **336** may have a width approximately equal to a width of the groove **310** in the sleeve **304**. The frustoconical portion **334** of the substrate **324** may have a shape corresponding to the shape of the frustoconical interior surface **308** of the sleeve **304**, such that when the rotatable cutting element **320** rotates within the sleeve **304**,

the frustoconical portion **334** of the substrate **324** is in sliding contact with the frustoconical interior surface **308** of the sleeve **304**. The substrate **324** may have a back surface **338** perpendicular to an axis of rotation of the generally cylindrical portion **332** of the substrate **324**. In some embodiments, the back surface **338** may be substantially parallel to the end cutting surface **326** of the polycrystalline hard material **322** and/or to the interface **325** between the polycrystalline hard material **322** and the substrate **324**.

The back surface **338** of the substrate **324** and the interior back surface **312** of the sleeve **304** may together partially define a void between the substrate **324** and the sleeve **304**. This void may prevent compressive longitudinal loads (or longitudinal components of loads) on the rotatable cutting element **320** from being transferred to the sleeve **304** through the interior back surface **312** (e.g., because there may not be contact between the interior back surface **312** of the sleeve **304** and the back surface **338** of the substrate **324**). Instead, compressive longitudinal loads may be transferred substantially (e.g., entirely or almost entirely) via a bearing interface at which the frustoconical portion **334** of the substrate **324** contacts the frustoconical interior surface **308** of the sleeve **304**.

The cutting element assembly **300** may also include a retention element **340** within the grooves **310**, **336** to hold the rotatable cutting element **320** in the sleeve **304**. The retention element **340** may be, for example, an O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, a Belleville spring, or another retaining element. The retention element **340** may include a resilient material, and may be configured to spring into place, such that the rotatable cutting element **320** can be inserted into the sleeve **304** without deforming either the sleeve **304** or the rotatable cutting element **320**. For example, if the retention element **340** is an O-ring, the rotatable cutting element **320** may be inserted into the sleeve **304** by compressing the O-ring in the groove **336**. Once the rotatable cutting element **320** slides into position (e.g., a position in which the frustoconical portion **334** of the substrate **324** contacts the frustoconical interior surface **308** of the sleeve **304**), the groove **336** in the substrate **324** may align with the groove **310** of the sleeve **304**. At that point, the O-ring may decompress, such that the rotatable cutting element **320** cannot be removed from the sleeve **304** without compressing the O-ring again. Thus, the O-ring may provide sufficient force to retain the rotatable cutting element **320** within the sleeve **304** under normal operating conditions, but the rotatable cutting element **320** may still be removed from the sleeve **304** if necessary for repair.

FIG. **4** is a simplified cross section showing a cutting element assembly **400**. The cutting element assembly **400** may be one of the cutting element assemblies **210** shown in FIG. **2**.

The cutting element assembly **400** may include a generally cylindrical sleeve **404**, which may be secured to a blade **216** (FIG. **2**). For example, an exterior surface **405** of the sleeve **404** may be brazed or welded within a pocket of the blade **216**. In other embodiments, the sleeve **404** may be integrally formed with the blade **216**, such that there is no physical interface between the sleeve **404** and the blade **216**. The sleeve **404** may have a generally cylindrical interior surface **406** defining a cavity in the sleeve **404**. The sleeve **404** may also have a generally planar upper surface **408**.

A rotatable cutting element **420** may be at least partially within the sleeve **404**. The rotatable cutting element **420** may include a polycrystalline hard material **422** bonded to a substrate **424** at an interface **425**. In other embodiments, the rotatable cutting element **420** may be formed entirely of the polycrystalline hard material **422**, or may have another material in addition to the polycrystalline hard material **422** and the substrate **424**. The polycrystalline hard material **422** may include diamond, cubic boron nitride, or another hard material. The substrate **424** may include, for example, cobalt-cemented tungsten carbide or another carbide material.

The polycrystalline hard material **422** may have an end cutting surface **426**, and may also have other surfaces, such as a side surface **428**, a chamfer **430**, etc., which surfaces may be cutting surfaces intended to contact a subterranean formation. The polycrystalline hard material **422** may be generally cylindrical, and the interface **425** may be generally parallel to the end cutting surface **426**.

The substrate **424** may be generally cylindrical, with a first generally cylindrical surface **432** and a second generally cylindrical surface **434**. A generally planar bearing surface **435** may intersect each of the first generally cylindrical surface **432** and a second generally cylindrical surface **434**. The first generally cylindrical surface **432** may have a smaller diameter than the second generally cylindrical surface **434**, and the surfaces **432**, **434** may share a common axis of rotation, which may coincide with a longitudinal axis A_L of the rotatable cutting element **420**. Thus, the bearing surface **435** may be annular. In some embodiments, the bearing surface **435** may have approximately the same dimensions as the upper surface **408** of the sleeve **404**. The bearing surface **435** may be generally parallel to the end cutting surface **426**.

The rotatable cutting element **420**, and particularly the substrate **424**, may have a groove **436** sized and configured to receive O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, or another retaining element. For example, the groove **436** may be configured such that when the rotatable cutting element **420** rotates within the sleeve **404**, the first generally cylindrical surface **432** of the substrate **424** is in sliding contact with the generally cylindrical interior surface **406** of the sleeve **404**. The substrate **424** may have a back surface **438** perpendicular to the longitudinal axis A_L of rotatable cutting element **420**. In some embodiments, the back surface **438** of the rotatable cutting element **420** may be substantially parallel to the end cutting surface **426** of the polycrystalline hard material **422**, the interface **425** between the polycrystalline hard material **422** and the substrate **424**, the upper surface **408** of the sleeve **404**, and/or the bearing surface **435** of the rotatable cutting element **420**.

A bearing element **450** may be disposed between the upper surface **408** of the sleeve **404** and the bearing surface **435** of the rotatable cutting element **420**. The bearing element **450** may be any material capable of sustaining a compressive load applied to the rotatable cutting element **420**. Compressive longitudinal loads may be transferred from the rotatable cutting element **420** to the sleeve **404** substantially (e.g., entirely or almost entirely) via the bearing element **450**. The bearing element **450** may be a metal, an alloy, a ceramic, a hard material, a hard material coating on the surface of sleeve **404**, etc. In some embodiments, the bearing element **450** may include a material having a composition similar or identical to the substrate **424** and/or the sleeve **404**. In other embodiments, the bearing element **450** may include a material having a composition different from the substrate **424** and/or the sleeve **404**. The bearing element **450** may have one or more polished surfaces to limit sliding friction and enable the rotatable cutting element **420** to freely rotate. In certain embodiments, the bearing element

450 may include a lubricant, a coating, or another feature to reduce friction. For example, the bearing element **450** may include a diamond-like coating. Diamond-like coatings are described in, for example, U.S. Patent Application Publication 2009/0321146, "Earth Boring Bit with DLC Coated Bearing and Seal," published Dec. 31, 2009, the entire disclosure of which is hereby incorporated herein by reference.

The cutting element assembly **400** may also include a retention element **440** within the groove **336** to hold the rotatable cutting element **420** in the sleeve **404**. The retention element **440** may be, for example, an O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, a Belleville spring, or another retaining element. The retention element **440** may include a resilient material, and may be configured to spring into place, such that the rotatable cutting element **420** can be inserted into the sleeve **404** without deforming either the sleeve **404** or the rotatable cutting element **420**. For example, if the retention element **440** is an O-ring, the rotatable cutting element **420** may be inserted into the sleeve **404** by compressing the O-ring in the groove **436**. Once the rotatable cutting element **420** slides into position (e.g., a position in which the bearing element **450** contacts the upper surface **408** of the sleeve **404** and the bearing surface **435** of the rotatable cutting element **420**), the O-ring may decompress, such that the rotatable cutting element **420** cannot be removed from the sleeve **404** without compressing the O-ring again. Thus, the O-ring may provide sufficient force to retain the rotatable cutting element **420** within the sleeve **404** under normal operating conditions, but the rotatable cutting element **420** may still be removed from the sleeve **404** if necessary for repair.

FIG. **5** is a simplified cross section showing a cutting element assembly **500**. The cutting element assembly **500** may be one of the cutting element assemblies **210** shown in FIG. **2**.

The cutting element assembly **500** may include a sleeve **504**, which may be secured to a blade **216** (FIG. **2**). For example, an exterior surface **505** of the sleeve **504** may be brazed or welded within a pocket of the blade **216**. In other embodiments, the sleeve **504** may be integrally formed with the blade **216**, such that there is no physical interface between the sleeve **504** and the blade **216**. The sleeve **504** may have a first generally cylindrical interior surface **506**, a second generally cylindrical interior surface **507**, and a generally planar axial bearing surface **508**, which may together at least partially define a cavity in the sleeve **504**. The cavity may extend through the sleeve, as shown in FIG. **5**. In some embodiments, and in a cutting element assembly **500'** as shown in FIG. **6**, a sleeve **504'** may define an interior back surface **512** that also partially defines a cavity in the sleeve **504'**.

A rotatable cutting element **520** may be at least partially within the sleeve **504**. The rotatable cutting element **520** may include a polycrystalline hard material **522** bonded to a substrate **524** at an interface **525**, which may be configured similar to the polycrystalline hard material **422** and substrate **424** shown in FIG. **4** and described above.

The substrate **524** may be generally cylindrical, with a first generally cylindrical surface **532** and a second generally cylindrical surface **534**. A generally planar bearing surface **535** may intersect each of the first generally cylindrical surface **532** and a second generally cylindrical surface **534**. The first generally cylindrical surface **532** may have a smaller diameter than the second generally cylindrical surface **534**, and the surfaces **532**, **534** may share a common axis of rotation, which may coincide with a longitudinal axis A_L of the rotatable cutting element **520**. Thus, the bearing surface **535** may be annular. In some embodiments, the bearing surface **535** may have approximately the same dimensions as the bearing surface **508** of the sleeve **504**. The bearing surface **535** may be generally parallel to an end cutting surface **526** of the rotatable cutting element **520**. In some embodiments, a bearing element, such as the bearing element **450** shown in FIG. **4**, may be between the bearing surfaces **508**, **535**.

The rotatable cutting element **520** may have a back surface **538** perpendicular to the longitudinal axis A_L of the rotatable cutting element **520**. In some embodiments, the back surface **538** of the rotatable cutting element **520** may be substantially parallel to the end cutting surface **526** of the rotatable cutting element **520**, the bearing surface **508** of the sleeve **504**, and/or the bearing surface **535** of the rotatable cutting element **520**.

Portions of the rotatable cutting element **520** may be disposed within the interior of each of the first generally cylindrical interior surface **506** and the second generally cylindrical interior surface **507** of the sleeve **504**. That is, when the rotatable cutting element **520** rotates within the sleeve **504**, the first generally cylindrical surface **532** of the rotatable cutting element **520** may be in sliding contact with the interior surface **506** of the sleeve **504**. In addition, the second generally cylindrical surface **534** of the rotatable cutting element **520** may be in sliding contact with the interior surface **507**.

The back surface **538** of the rotatable cutting element **520** and blade **216** (FIG. **2**) or the interior back surface **512** of the sleeve **504'** (FIG. **6**) may together partially define a void adjacent the rotatable cutting element **520**. This void may prevent compressive longitudinal loads on the rotatable cutting element **520** from being transferred to the sleeve **504**, **504'** through the back surface **538**. Instead, compressive longitudinal loads may be transferred substantially (e.g., entirely or almost entirely) via an axial bearing interface at which the bearing surface **535** of the rotatable cutting element **520** contacts the bearing surface **508** of the sleeve **504**. In embodiments in which a bearing element is between the bearing surfaces **508**, **535**, compressive loads may be transferred via the bearing element.

The rotatable cutting element **520** may have a groove **536** sized and configured to receive a retention element **540**, which may be configured similar to the groove **336**, shown in FIG. **3**, or the groove **436**, shown in FIG. **4**. For example, and as shown in FIG. **5**, the sleeve **504** may define a groove **510** therein, and when the rotatable cutting element **520** is disposed within the sleeve **504**, the groove **536** in the rotatable cutting element **520** may align with the groove **510** of the sleeve **504**.

Rotatable cutting elements assemblies as disclosed herein may have certain advantages over conventional rotatable cutting elements and over conventional fixed cutting elements. For example, sleeves may be installed into a bit body (e.g., by brazing) before the rotatable cutting elements are installed into the sleeves. Thus, the rotatable cutting elements, and particularly the PDC tables, need not be exposed to the high temperatures typical of brazing. Thus, installing rotatable cutting elements into sleeves already secured to a bit body may avoid thermal damage caused by brazing. Furthermore, rotatable cutting elements as disclosed herein may be removed easily and replaced, such as when the cutting elements are worn or damaged. Separation of rotatable cutting element from a sleeve secured by retention elements may be trivial in comparison to removal of cutting elements or sleeves brazed into a bit body. For example,

rotatable cutting elements may be removed by applying tension (i.e., a pulling force) to the cutting elements. Similarly, insertion of a new cutting element may be effected rapidly and without reheating of the drill bit. Thus, drill bits may be more quickly repaired than drill bits having conventional cutting elements.

Additional nonlimiting example embodiments of the disclosure are described below.

Embodiment 1

A cutting element assembly comprising a sleeve, a rotatable cutting element disposed within the sleeve, and a retention element. The sleeve defines a first internal groove and a first frustoconical surface longitudinally spaced from the first internal groove. The rotatable cutting element comprises a polycrystalline hard material and a supporting substrate. The polycrystalline hard material has an end cutting surface. The rotatable cutting element defines a second groove in a surface of the supporting substrate and a second frustoconical surface longitudinally spaced from the second internal groove. The retention element is disposed partially within the first groove and partially within the second groove.

Embodiment 2

The cutting element assembly of Embodiment 1, wherein the rotatable cutting element defines an interior back surface parallel to the end cutting surface, and wherein the sleeve and the rotatable cutting element define a void adjacent the interior back surface.

Embodiment 3

The cutting element assembly of Embodiment 1 or Embodiment 2, wherein the sleeve further defines an interior cylindrical surface, wherein the substrate of the rotatable cutting element comprises a cylindrical portion, and wherein the cylindrical portion of the substrate is disposed within the interior cylindrical surface of the sleeve.

Embodiment 4

The cutting element assembly of any of Embodiments 1 through 3, wherein the first frustoconical surface is in rotational sliding contact with the second frustoconical surface.

Embodiment 5

The cutting element assembly of any of Embodiments 1 through 4, wherein the retention element comprises an elastomeric material.

Embodiment 6

The cutting element assembly of any of Embodiments 1 through 5, wherein the retention element comprises a metal.

Embodiment 7

The cutting element assembly of any of Embodiments 1 through 6, wherein the retention element comprises at least one selected from the group consisting of an O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, and a Belleville spring.

Embodiment 8

The cutting element assembly of any of Embodiments 1 through 7, wherein the substrate defines the second groove and the second frustoconical surface.

Embodiment 9

A cutting element assembly comprising a sleeve defining a cylindrical cavity therein and a rotatable cutting element disposed at least partially within the cavity of the sleeve. The sleeve defines a generally planar end surface. The rotatable cutting element comprises a polycrystalline hard material bonded to a substrate. The polycrystalline hard material has an end cutting surface generally parallel to the end surface of the sleeve. The substrate defines a bearing surface and a cylindrical portion extending into the cylindrical cavity of the sleeve. The bearing surface is opposite the end cutting surface. A bearing element is between the end surface of the sleeve and the bearing surface of the rotatable cutting element.

Embodiment 10

The cutting element assembly of Embodiment 9, wherein the substrate further defines a groove in the cylindrical portion, and further comprising a retention element disposed partially within the groove and extending radially beyond an inner surface of the cylindrical cavity.

Embodiment 11

The cutting element assembly of Embodiment 10, wherein the retention element comprises at least one selected from the group consisting of an O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, and a Belleville spring.

Embodiment 12

The cutting element assembly of Embodiment 10 or Embodiment 11, wherein the retention element comprises at least one material selected from the group consisting of elastomeric materials, metals, and alloys.

Embodiment 13

The cutting element assembly of any of Embodiments 9 through 12, wherein when a compressive longitudinal load is applied to the end cutting surface of the polycrystalline hard material of the rotatable cutting element, the compressive longitudinal load is transferred to the sleeve substantially via the bearing element.

Embodiment 14

A cutting element assembly comprising a sleeve and a rotatable cutting element. The sleeve defines a first interior cylindrical surface, a second interior cylindrical surface, and a generally planar axial bearing surface between the first interior cylindrical surface and the second interior cylindrical surface. The first interior cylindrical surface, the axial bearing surface, and the second interior cylindrical surface together at least partially define a cavity in the sleeve. The

rotatable cutting element is disposed at least partially within the cavity. The rotatable cutting element comprises a polycrystalline hard material mounted to a substrate and having an end cutting surface generally parallel to the axial bearing surface of the sleeve. The substrate defines a first generally cylindrical surface, a second generally cylindrical surface, and an axial bearing surface opposite the end cutting surface and extending between the first generally cylindrical surface and the second generally cylindrical surface. The substrate is substantially disposed within an interior of each of the first interior cylindrical surface and the second interior cylindrical surface, and the axial bearing surface of the rotatable cutting element is in contact with the axial bearing surface of the sleeve.

Embodiment 15

The cutting element assembly of Embodiment 14, wherein the substrate further defines a groove, and further comprising a retention element disposed at least partially within the groove and extending radially outward therefrom.

Embodiment 16

The cutting element assembly of Embodiment 15, wherein the retention element comprises at least one selected from the group consisting of an O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, and a Belleville spring.

Embodiment 17

The cutting element assembly of Embodiment 15 or Embodiment 16, wherein the retention element comprises at least one material selected from the group consisting of elastomeric materials, metals, and alloys.

Embodiment 18

The cutting element assembly of any of Embodiments 15 through 17, wherein the sleeve defines another groove, and wherein the retention element is partially disposed within the another groove.

Embodiment 19

The cutting element assembly of any of Embodiments 14 through 18, wherein when a compressive longitudinal load is applied to the end cutting surface of the polycrystalline hard material of the rotatable cutting element, the compressive longitudinal load is transferred to the sleeve substantially via the axial bearing interface.

Embodiment 20

The cutting element assembly of any of Embodiments 14 through 19, wherein the cavity extends through the sleeve.

Embodiment 21

The cutting element assembly of any of Embodiments 14 through 20, wherein the sleeve defines a back surface of the cavity.

Embodiment 22

The cutting element assembly of any of Embodiments 1 through 21, wherein the sleeve comprises a carbide.

Embodiment 23

The cutting element assembly of any of Embodiments 1 through 22, wherein the sleeve defines a cylindrical exterior surface.

Embodiment 24

An earth-boring tool comprising a bit body and the cutting assembly of any of Embodiments 1 through 23. The sleeve of the cutting element assembly is secured to the bit body.

Embodiment 25

The earth-boring tool of Embodiment 24, wherein the sleeve is brazed into a pocket defined by the bit body.

While the present invention has been described herein with respect to certain illustrated embodiments, those of ordinary skill in the art will recognize and appreciate that it is not so limited. Rather, many additions, deletions, and modifications to the illustrated embodiments may be made without departing from the scope of the invention as claimed, including legal equivalents thereof. In addition, features from one embodiment may be combined with features of another embodiment while still being encompassed within the scope of the invention as contemplated by the inventors. Further, embodiments of the disclosure have utility with different and various tool types and configurations.

What is claimed is:

1. A cutting element assembly, comprising:

a sleeve defining a first internal groove and a first frustoconical surface longitudinally spaced from the first internal groove;

a rotatable cutting element disposed within the sleeve, the rotatable cutting element comprising a polycrystalline hard material and a supporting substrate, wherein the polycrystalline hard material has an end cutting surface, wherein the rotatable cutting element defines a second internal groove in a surface of the supporting substrate and a second frustoconical surface longitudinally spaced from the second internal groove;

wherein the first frustoconical surface and the second frustoconical surface are in direct sliding contact such that compressive loads are transferred substantially via a bearing interface at which the first frustoconical surface contacts the second frustoconical surface;

wherein the rotatable cutting element also defines an interior planar back surface parallel to the end cutting surface, and wherein a generally planar end surface of the sleeve and the interior planar back surface parallel to the end cutting surface define a void adjacent the interior planar back surface; and

a retention element disposed partially within the first internal groove and partially within the second groove such that the retention element provides sufficient force to retain the rotatable cutting element within the sleeve under normal operating conditions.

2. The cutting element assembly of claim **1**, wherein the sleeve further defines an interior cylindrical surface, wherein the supporting substrate of the rotatable cutting element comprises a cylindrical portion, and wherein the cylindrical

portion of the supporting substrate is disposed within the interior cylindrical surface of the sleeve.

3. The cutting element assembly of claim **1**, wherein the retention element comprises an elastomeric material.

4. The cutting element assembly of claim **1**, wherein the retention element comprises a metal.

5. The cutting element assembly of claim **1**, wherein the retention element comprises at least one selected from the group consisting of an O-ring, a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, and a Belleville spring.

6. The cutting element assembly of claim **1**, wherein the supporting substrate defines the second groove and the second frustoconical surface.

7. A cutting element assembly, comprising:

a sleeve defining a first interior cylindrical surface, a second interior cylindrical surface, and a generally planar axial bearing surface between the first interior cylindrical surface and the second interior cylindrical surface, wherein the first interior cylindrical surface, the generally planar axial bearing surface, and the second interior cylindrical surface together at least partially define a cavity in the sleeve;

a rotatable cutting element disposed at least partially within the cavity, the rotatable cutting element comprising a polycrystalline hard material having an end cutting surface generally parallel to the axial bearing surface of the sleeve and mounted to a substrate, wherein the rotatable cutting element also defines an interior back surface parallel to the end cutting surface, and wherein a generally planar end surface of the sleeve and the interior back surface parallel to the end cutting surface define a void adjacent the interior back surface;

the substrate defining a first generally cylindrical surface, a second generally cylindrical surface, and an axial bearing surface opposite the end cutting surface and extending between the first generally cylindrical surface and the second generally cylindrical surface;

wherein the substrate is substantially disposed within and is in sliding contact with both an interior of each of the first interior cylindrical surface and the second interior cylindrical surface with the axial bearing surface of the rotatable cutting element in sliding contact with the axial bearing surface of the sleeve.

8. The cutting element assembly of claim **7**, wherein the substrate further defines a groove, and further comprising a retention element disposed at least partially within the groove and extending radially outward therefrom.

9. The cutting element assembly of claim **8**, wherein the retention element comprises at least one selected from the group consisting of a split ring, a beveled retaining ring, a bowed retaining ring, a spiral retaining ring, and a Belleville spring.

10. The cutting element assembly of claim **9**, wherein the sleeve defines another groove, and wherein the retention element is partially disposed within the another groove.

11. The cutting element assembly of claim **7**, wherein when a compressive longitudinal load is applied to the end cutting surface of the polycrystalline hard material of the rotatable cutting element, the compressive longitudinal load is transferred to the sleeve substantially via the axial bearing surface.

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