US 20220136585A1

(19) **United States**

(12) **Patent Application Publication**

Prevost

(10) **Pub. No.: US 2022/0136585 A1**

(43) **Pub. Date: May 5, 2022**

(54) **DRIVELINE WITH DOUBLE CONICAL BEARING JOINTS HAVING POLYCRYSTALLINE DIAMOND POWER TRANSMISSION SURFACES**

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(21) Appl. No.: **17/399,640**

(22) Filed: **Aug. 11, 2021**

Related U.S. Application Data

(63) Continuation-in-part of application No. 17/331,399, filed on May 26, 2021, now Pat. No. 11,274,731, which is a continuation of application No. 16/888,079, filed on May 29, 2020, now Pat. No. 11,054,000.

(60) Provisional application No. 63/064,272, filed on Aug. 11, 2020.

Publication Classification

(51) **Int. Cl.**

F16H 1/20 (2006.01)

F16H 1/16 (2006.01)

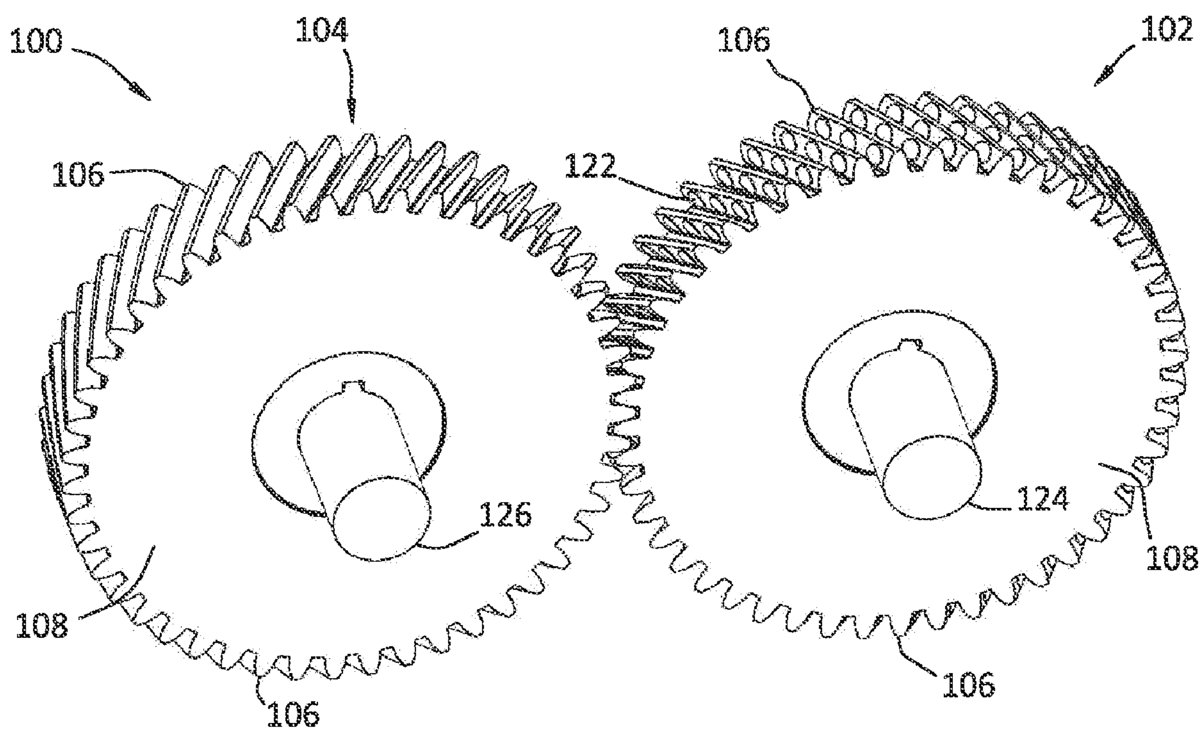
F16D 3/16 (2006.01)

(52) **U.S. Cl.**

CPC ***F16H 1/20*** (2013.01); *F16H 1/14* (2013.01); ***F16D 3/16*** (2013.01); ***F16H 1/16*** (2013.01)

(57) **ABSTRACT**

Drivelines having double conical bearing joints incorporated therein are provided. The double conical bearing joints provide the drivelines with multiple degrees of freedom and allow the driveline to bear load in any direction. The conical bearing joints of the driveline include polycrystalline diamond bearing surfaces.



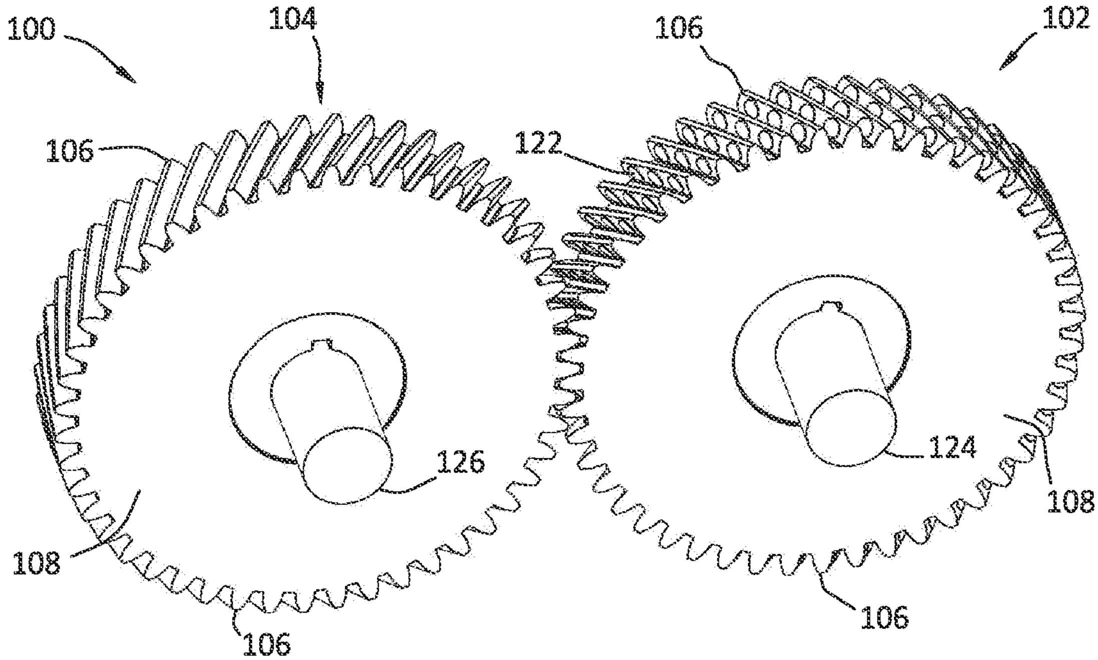

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FIG. 1A

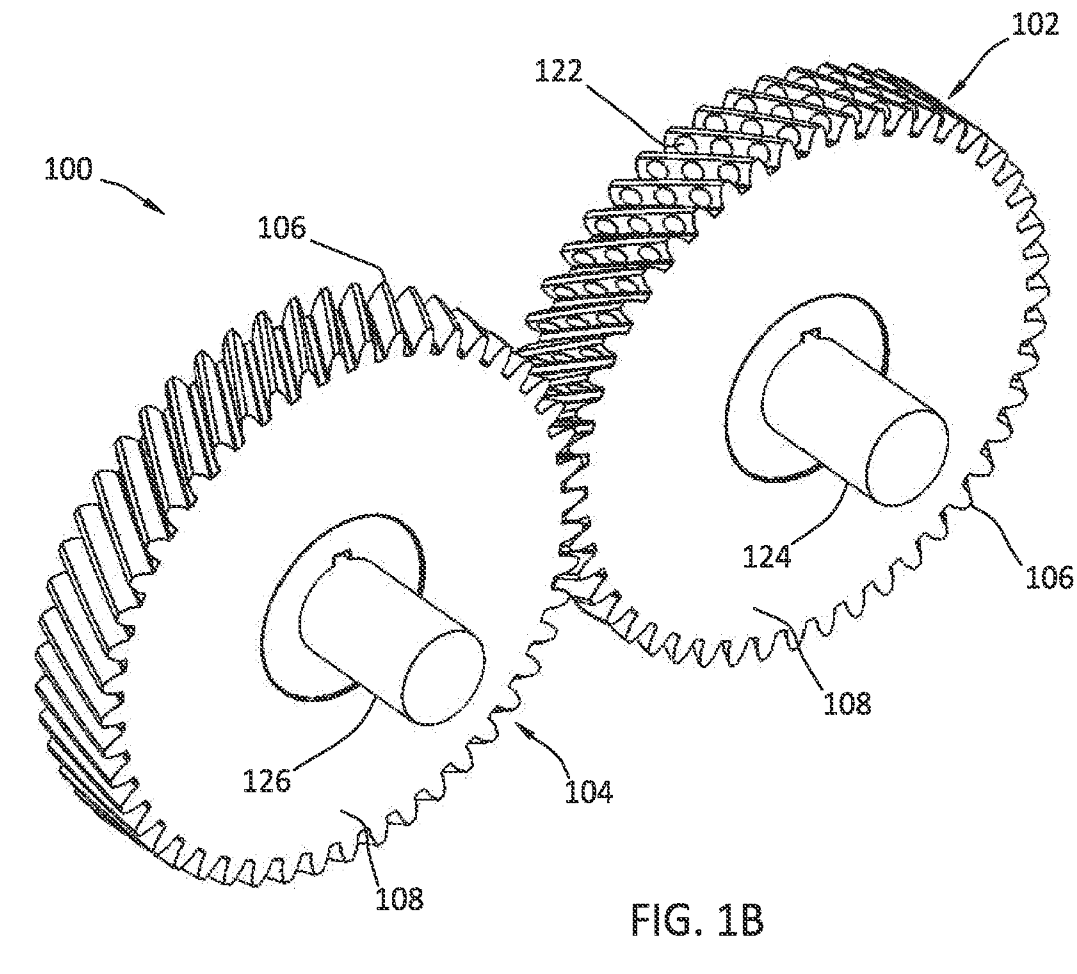
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FIG. 1B

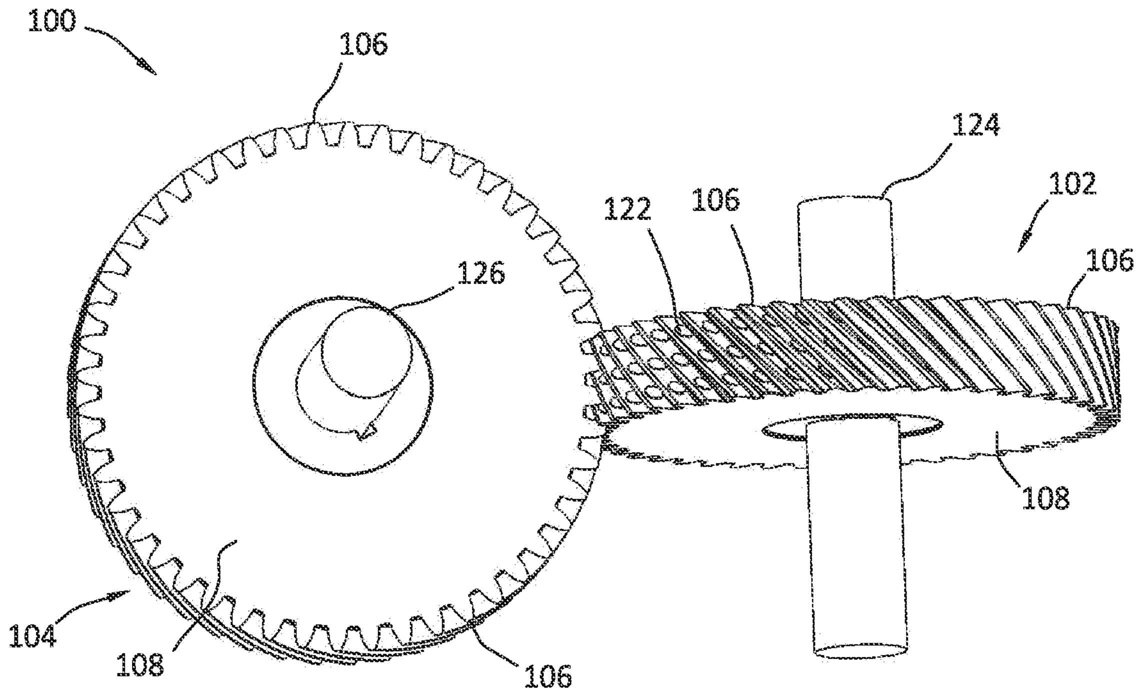
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FIG. 1C

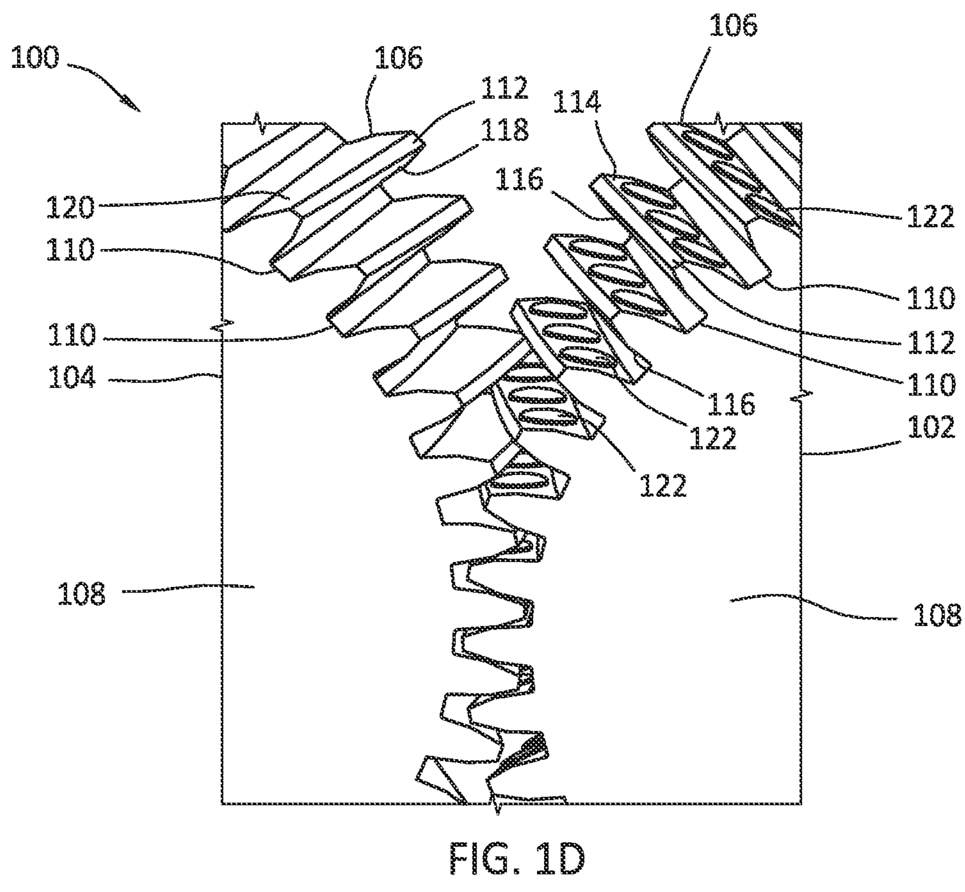
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FIG. 1D

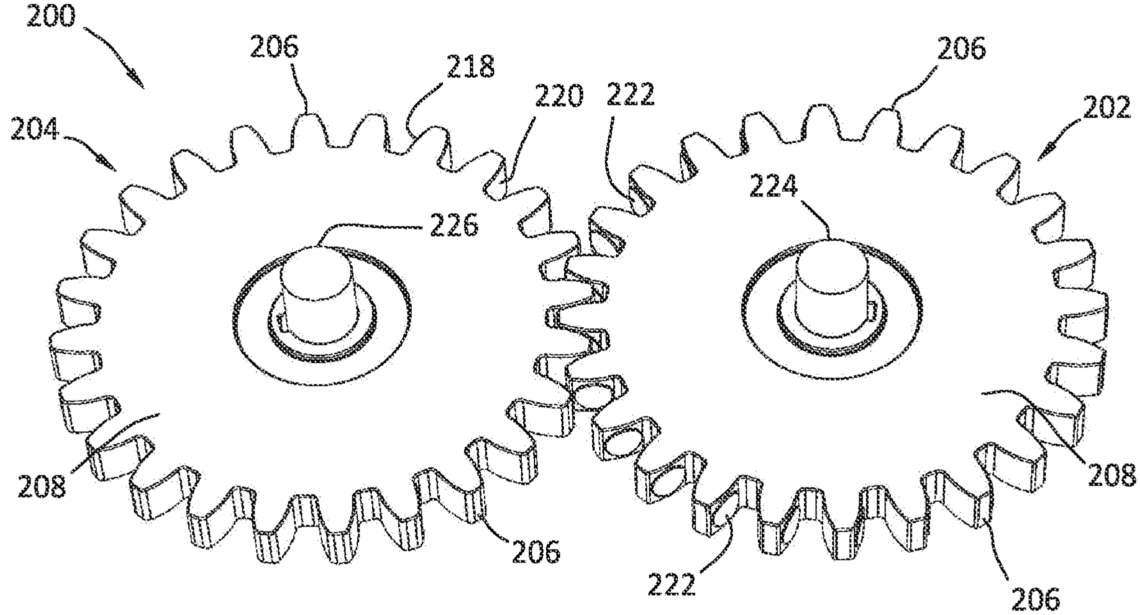
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FIG. 2A

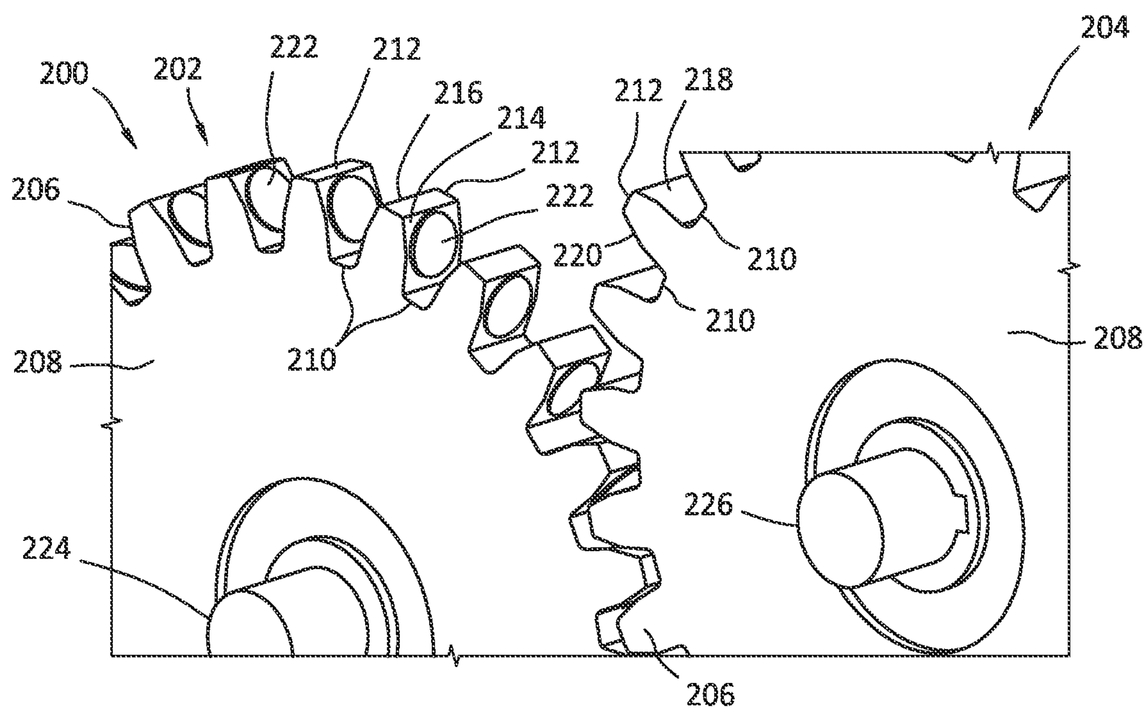
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FIG. 2B

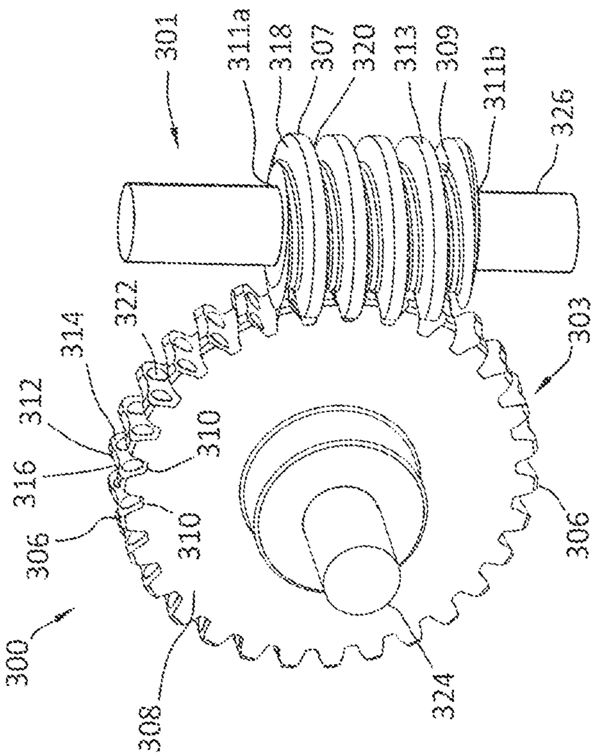

FIG. 3B

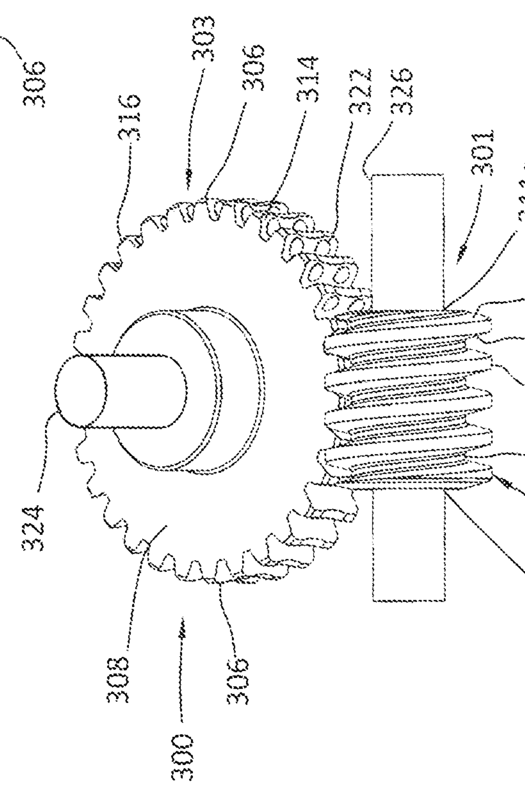

FIG. 3C

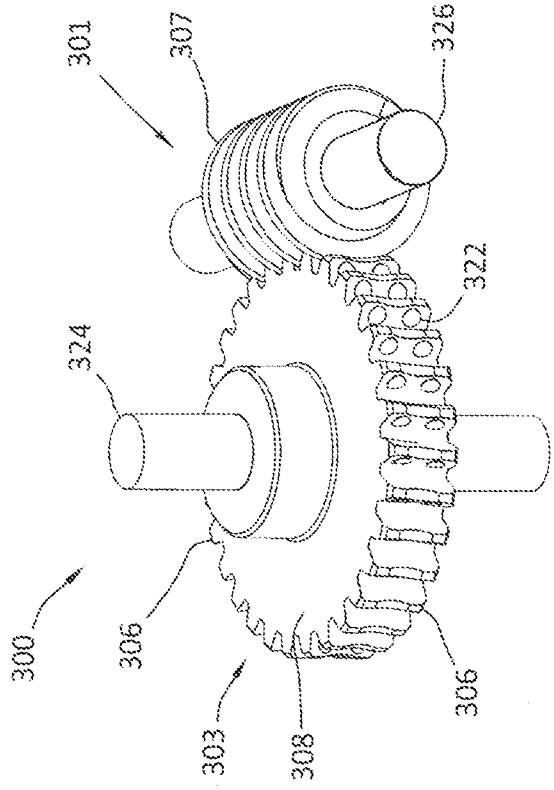

FIG. 3A

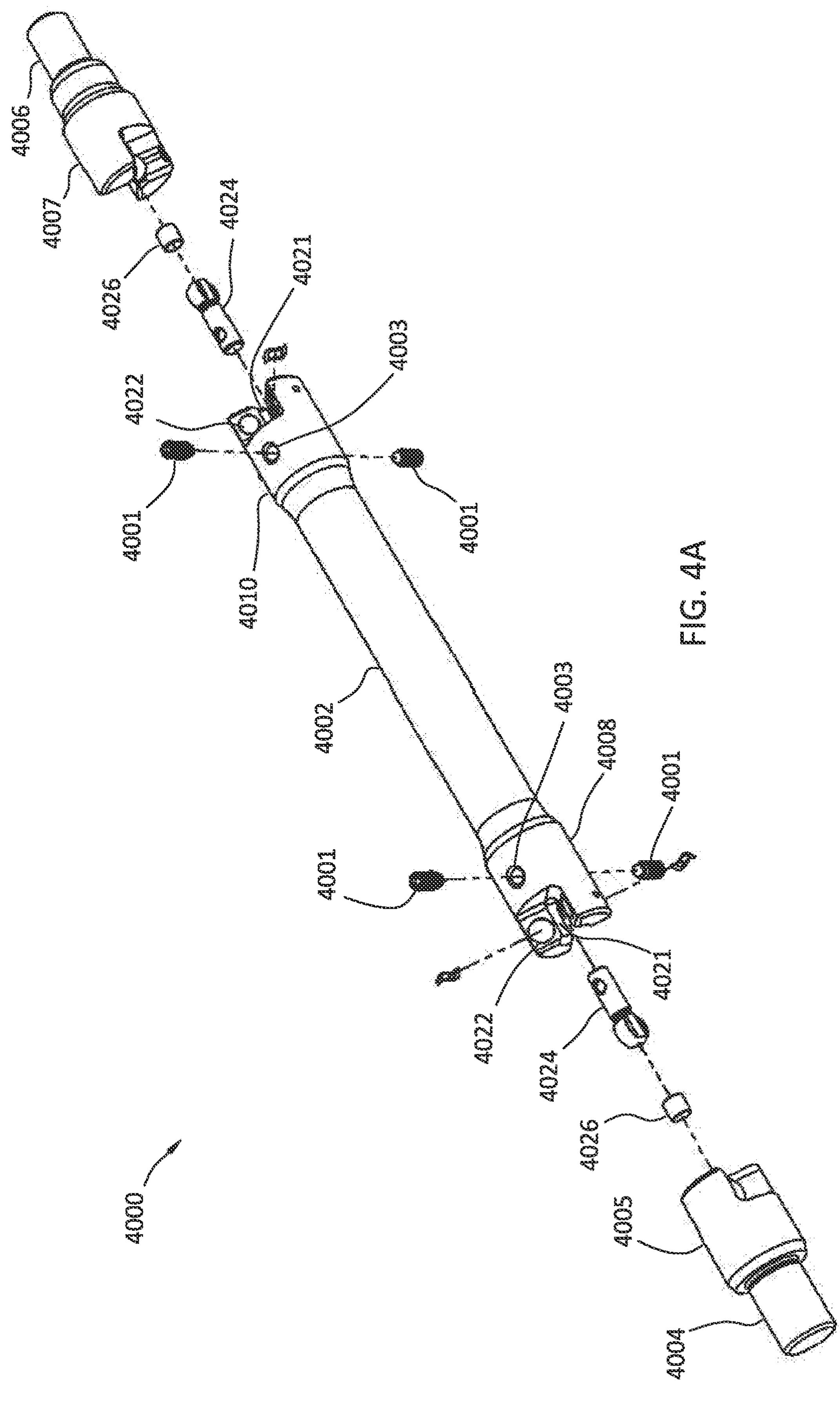
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FIG. 4A

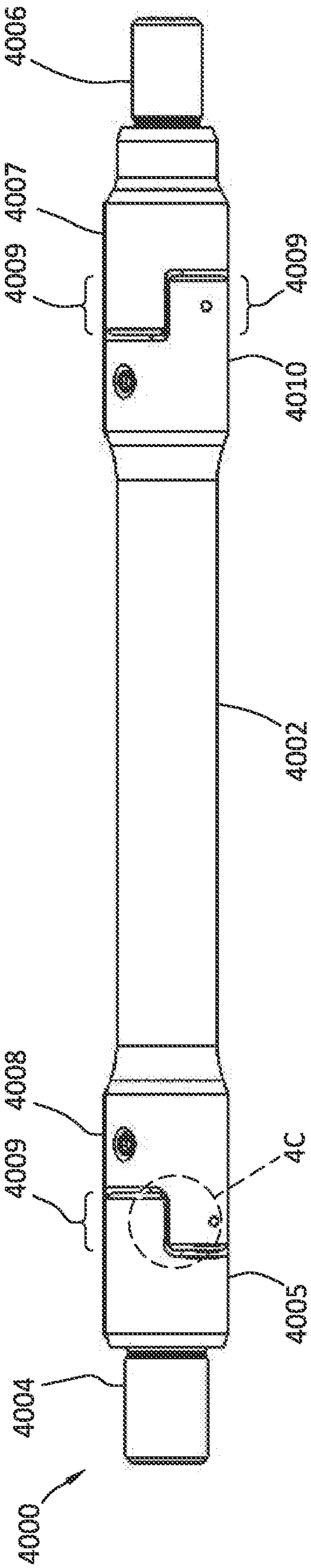
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FIG. 4B

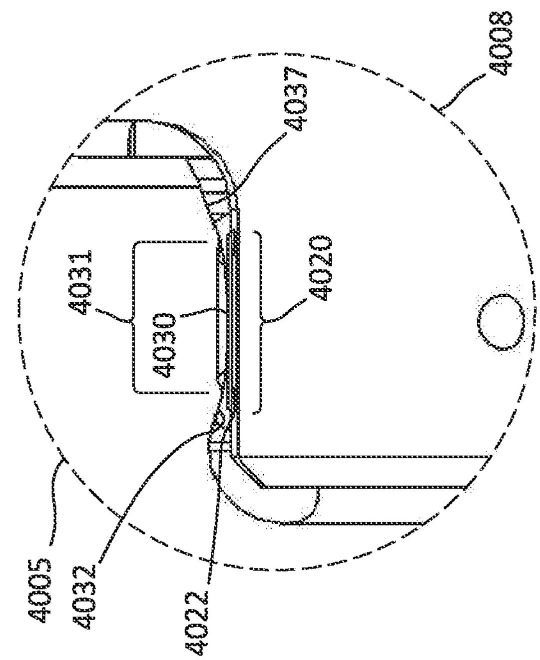
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FIG. 4C

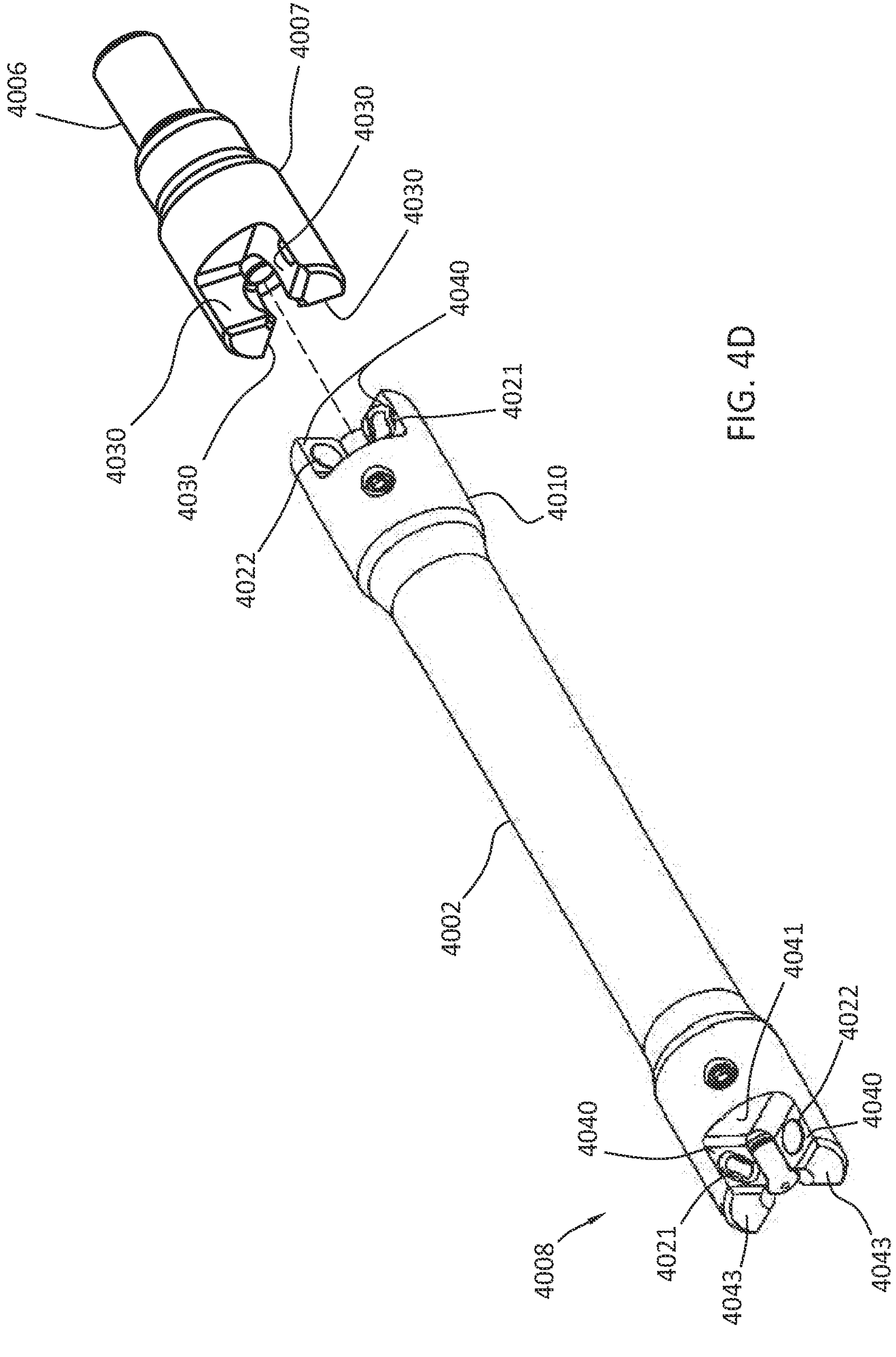
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FIG. 4D

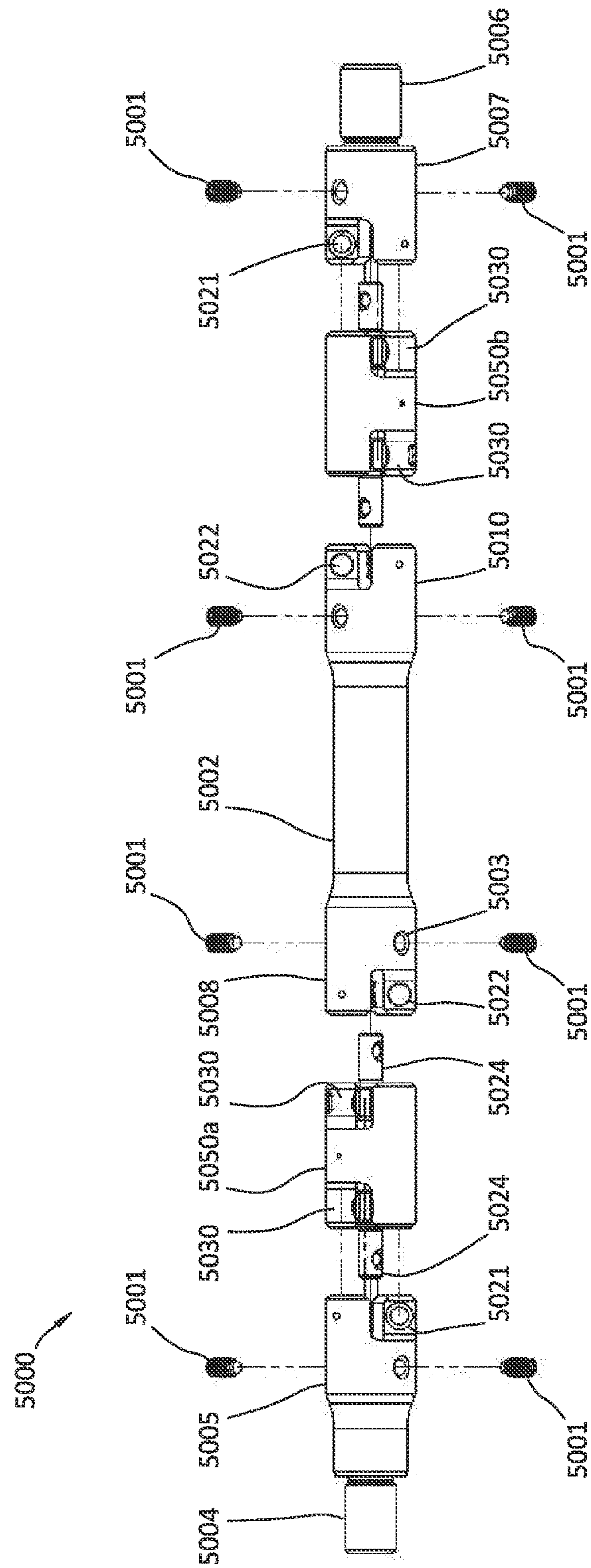
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FIG. 5A

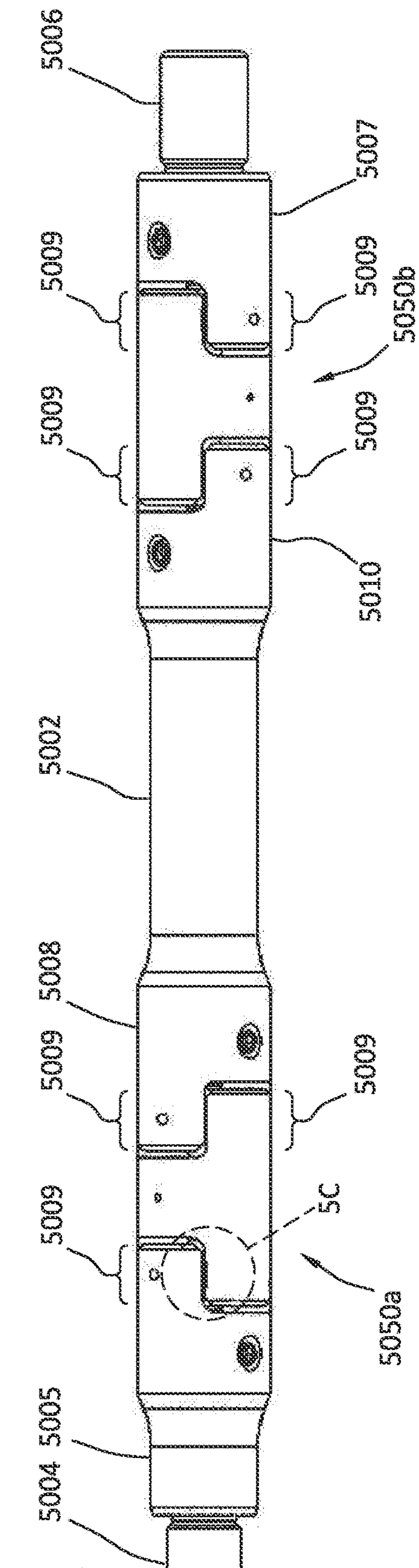
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FIG. 5B

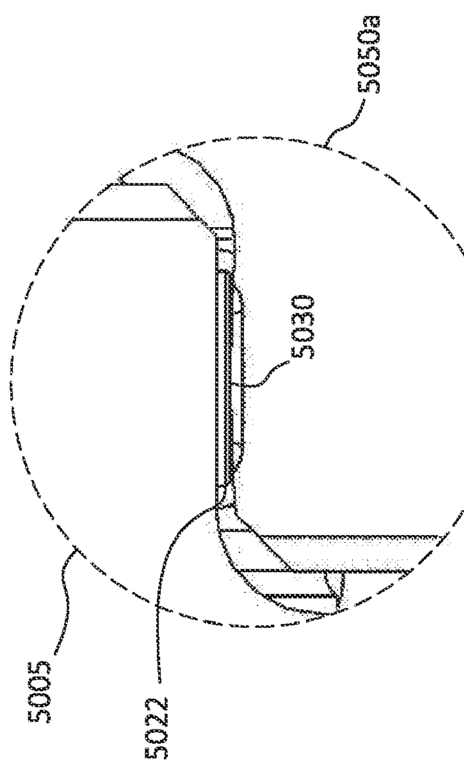
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FIG. 5C

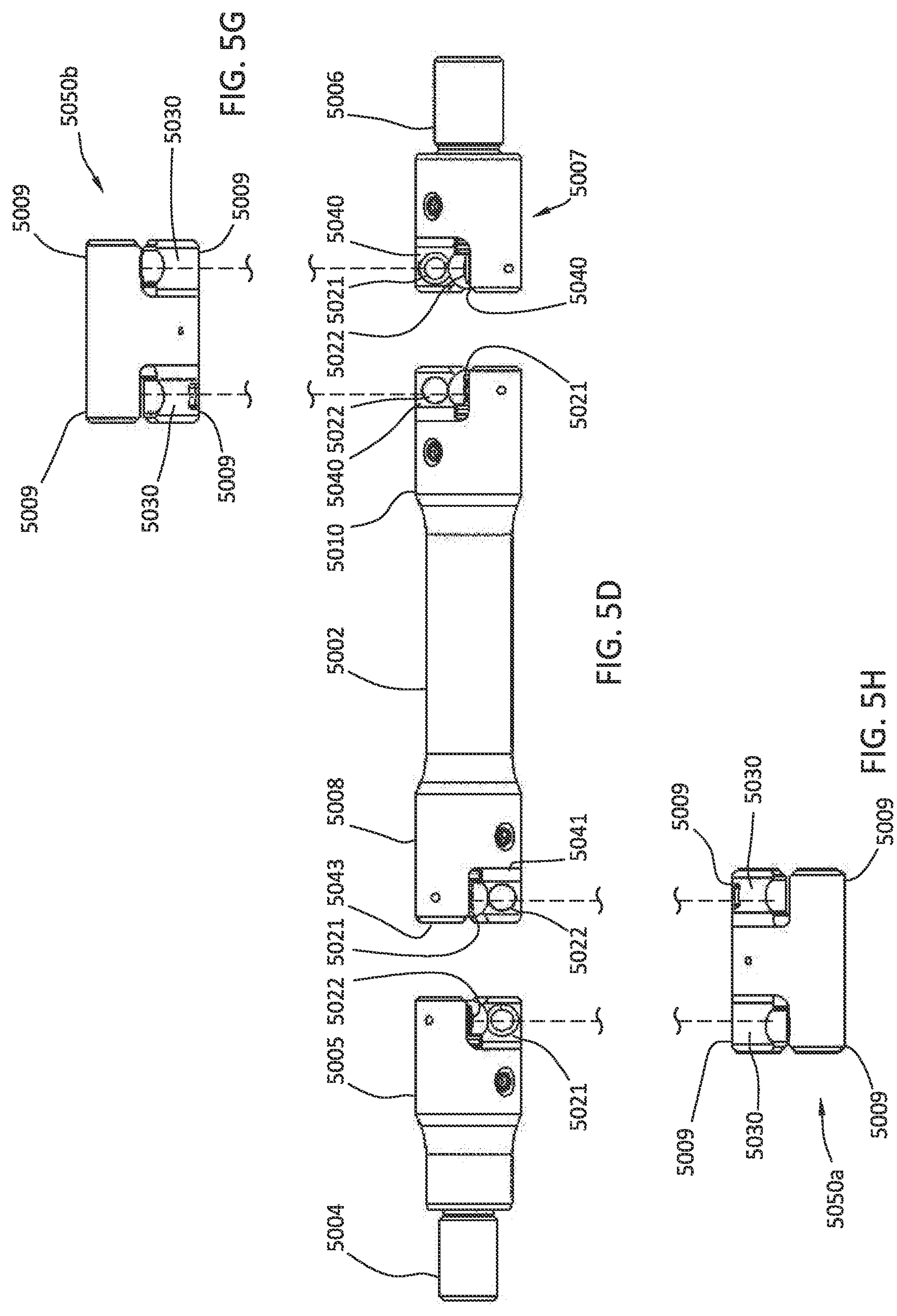

FIG. 5G

FIG. 5D

FIG. 5H

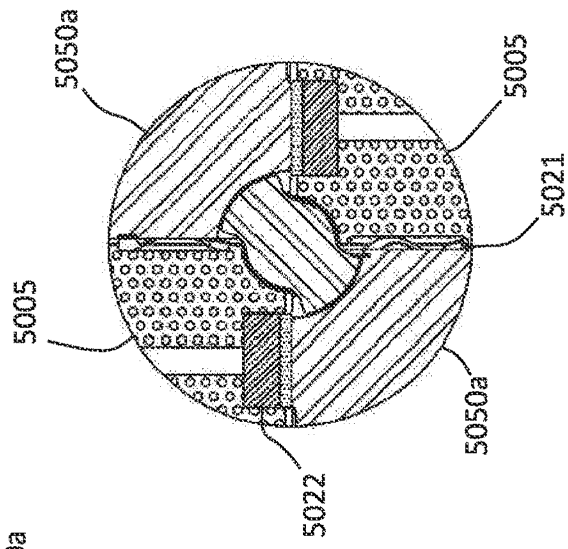

FIG. 5F

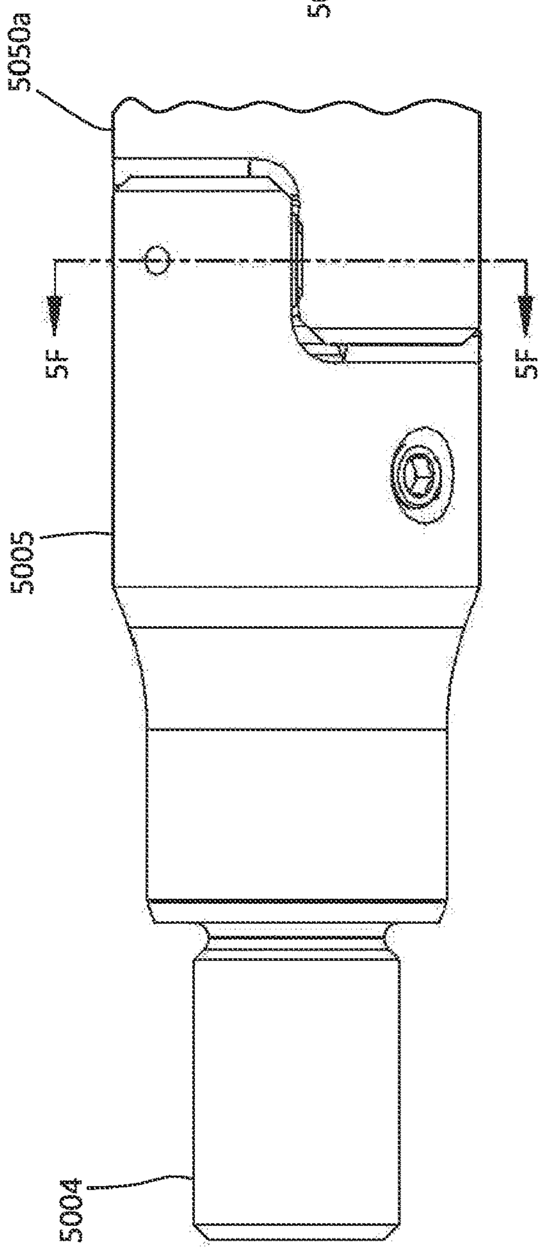

FIG. 5E

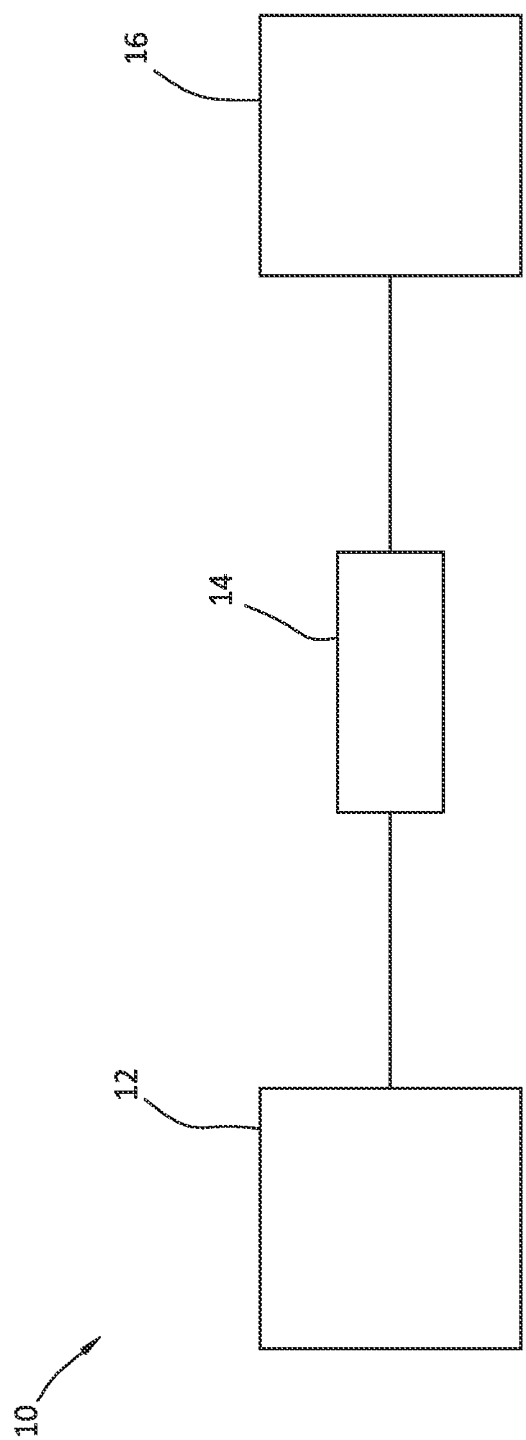

FIG. 6

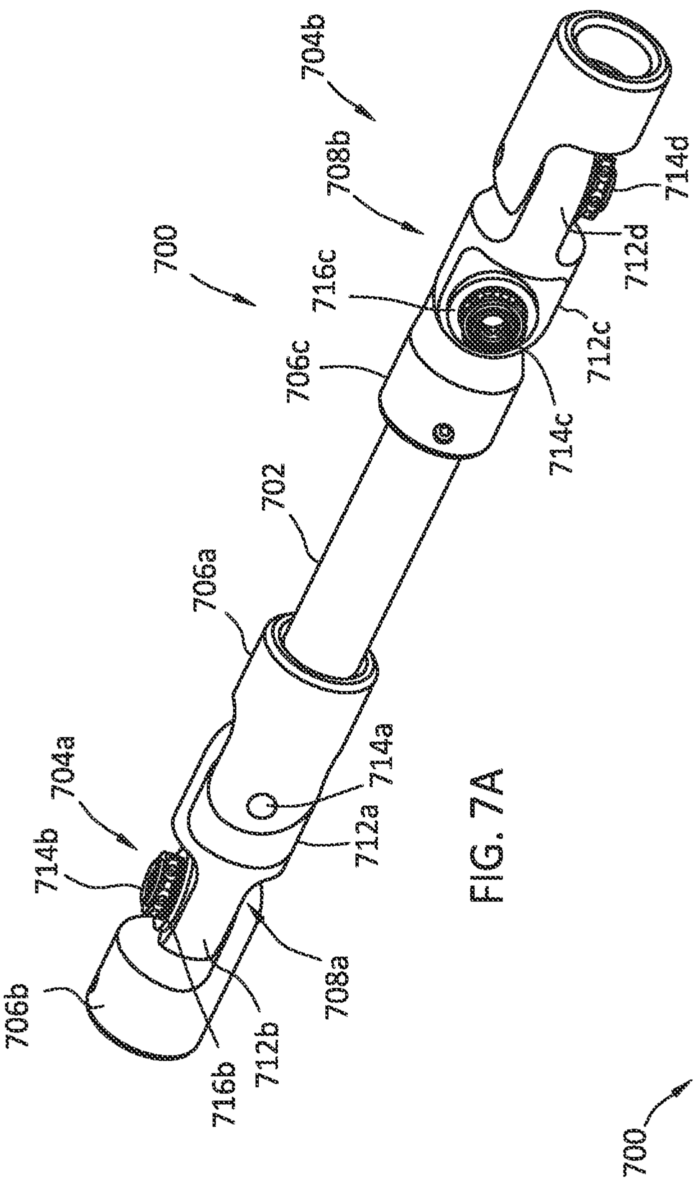
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FIG. 7A

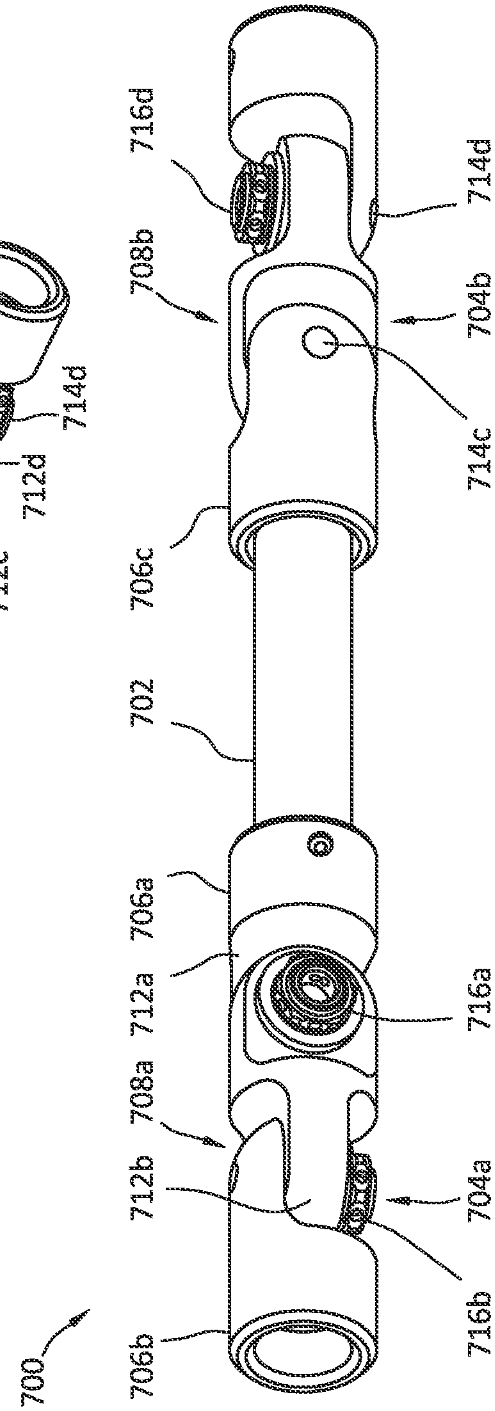
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FIG. 7B

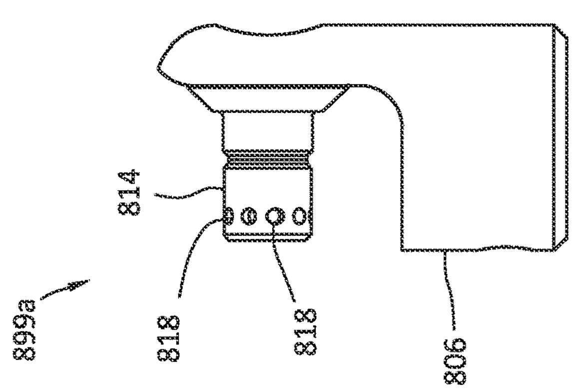

FIG. 8A

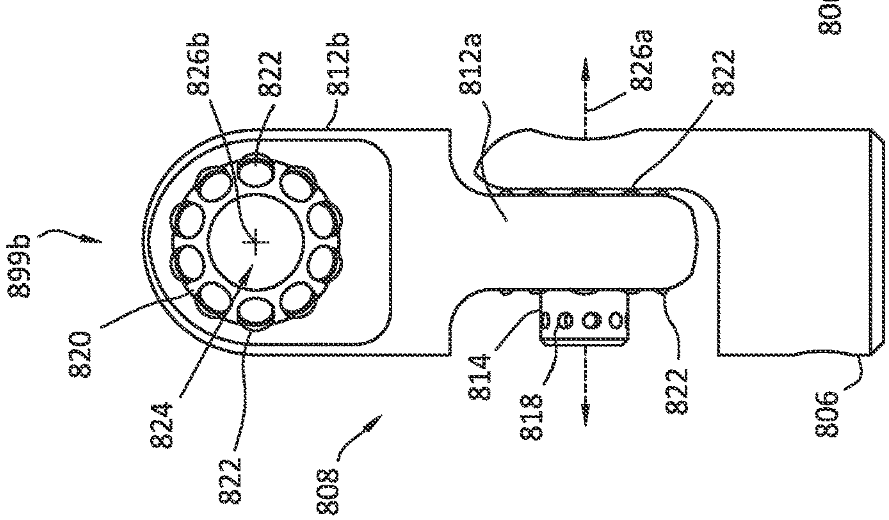

FIG. 8B

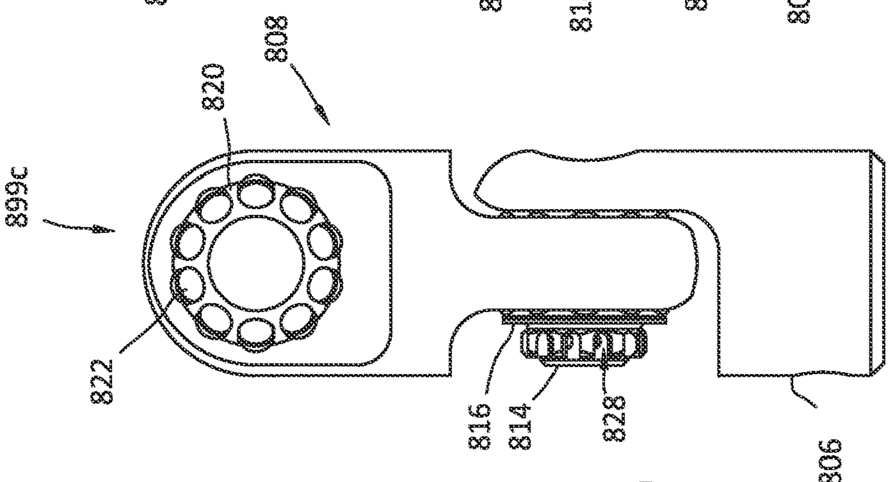

FIG. 8C

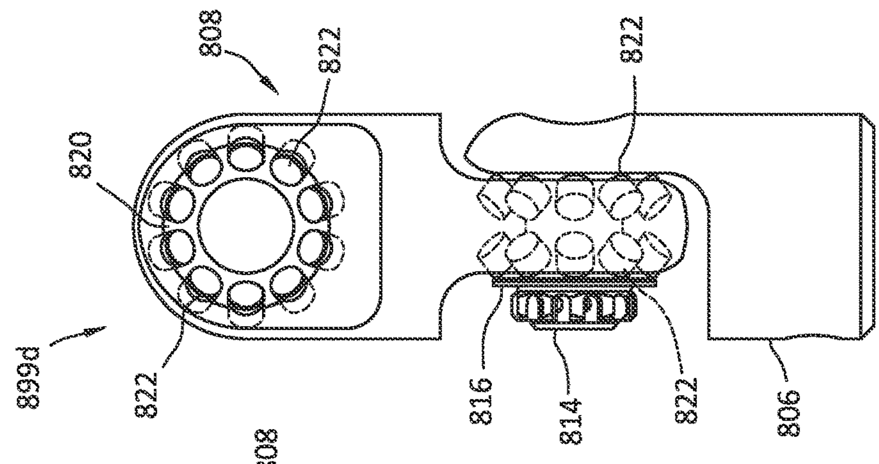

FIG. 8D

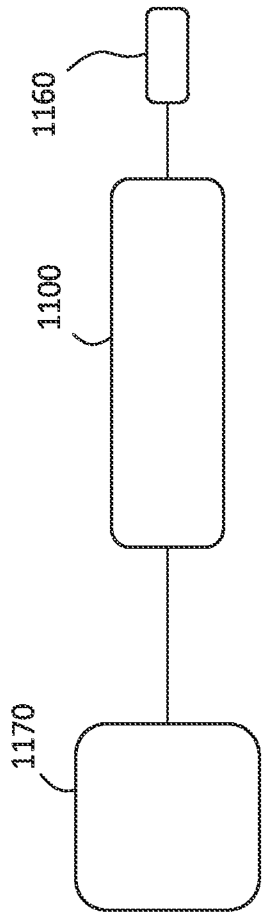
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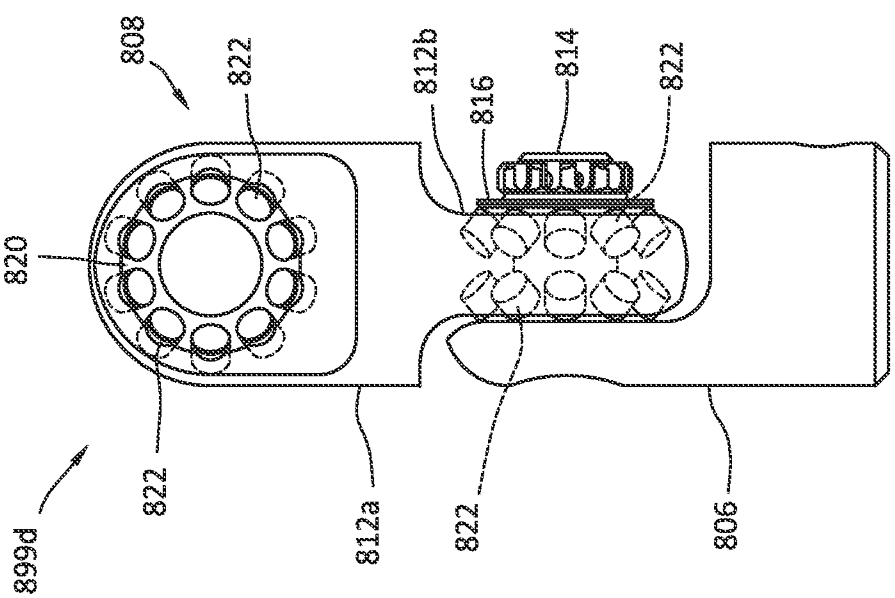
FIG.11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806

FIG.8E

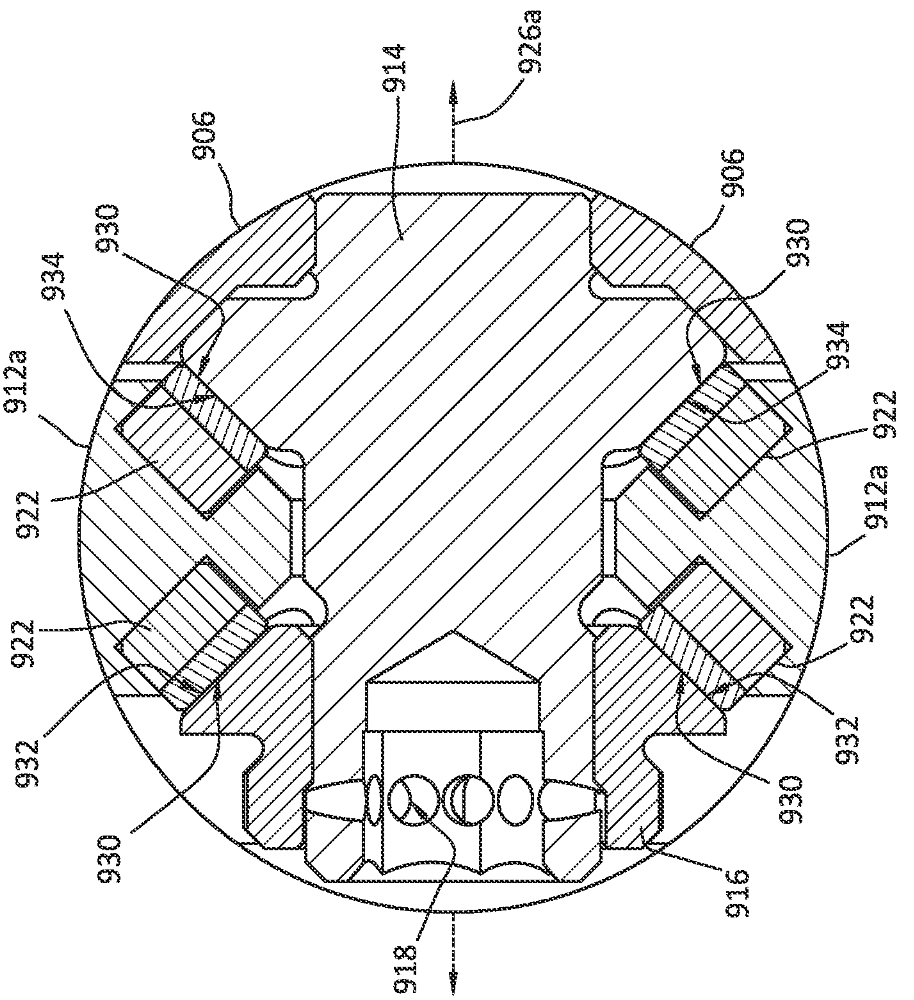

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FIG. 9B

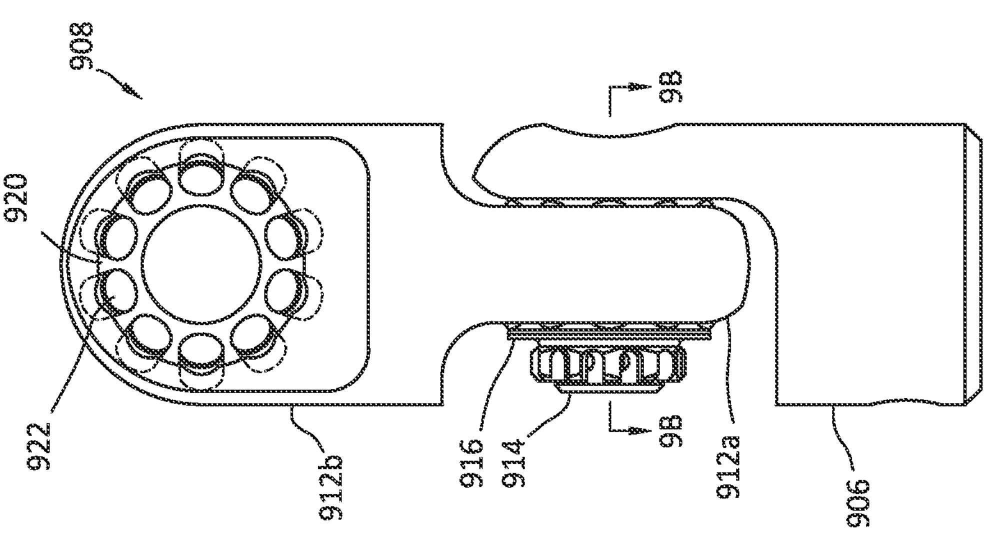

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FIG. 9A

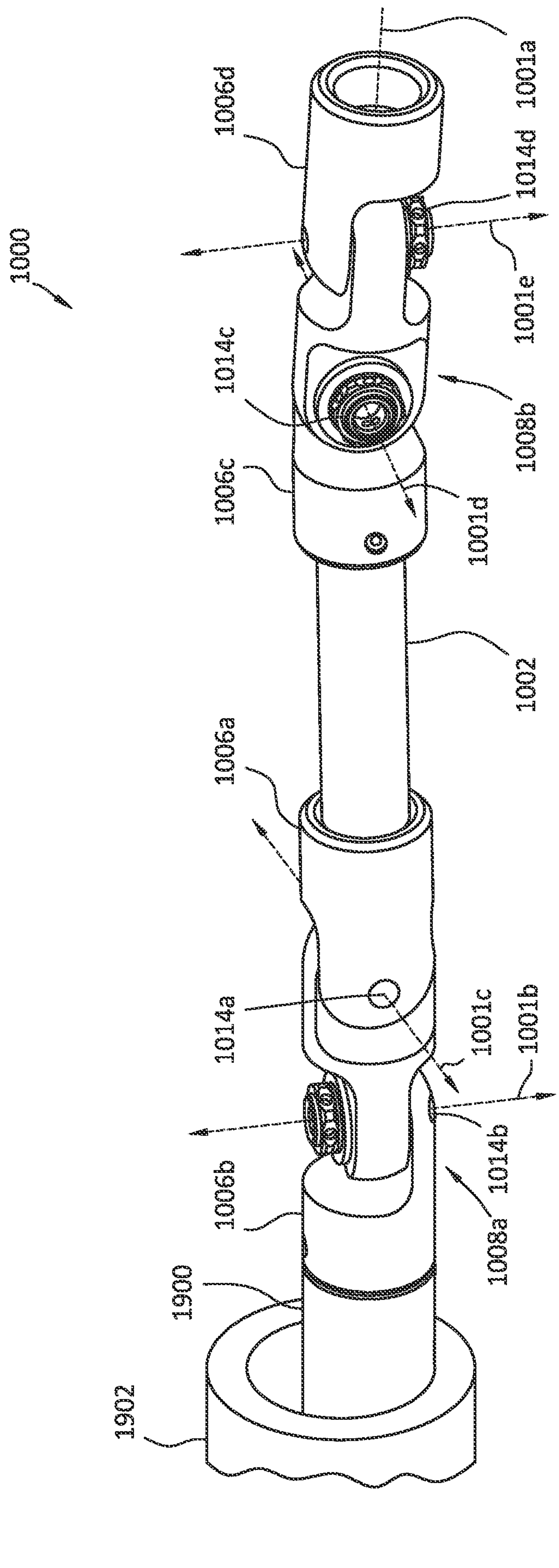
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FIG. 10

DRIVELINE WITH DOUBLE CONICAL BEARING JOINTS HAVING POLYCRYSTALLINE DIAMOND POWER TRANSMISSION SURFACES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Patent Application No. 63/064,272 (pending), filed on Aug. 11, 2020, and entitled "Driveline with Double Conical Bearing Joints having Polycrystalline Diamond Power Transmission Surfaces," the entirety of which is incorporated herein by reference. The present application is also a Continuation-in-Part of U.S. patent application Ser. No. 17/331,399, filed on May 26, 2021, which itself is a Continuation of U.S. Pat. No. 11,054,000, issued on Jul. 6, 2021, the entireties of which are incorporated herein by reference.

FIELD

[0002] The present disclosure relates to polycrystalline diamond for use as a power transmission surface in a driveline; to systems including the same; and to methods of making and using the same.

BACKGROUND

[0003] Mechanical power transmission systems transmit mechanical energy from one component or system to another component or system, such as to perform work. Mechanical power transmission systems can include a first component (e.g., a first gear) coupled with a second component (e.g., a second gear), such that when the first component moves at least some of the mechanical energy of the first component is transferred to the second component, causing the second component to correspondingly move. Often such systems include surfaces that are engaged with one another. For example, during movement of a first gear that is meshed with a second gear, at least a portion of the surfaces of the gear teeth of the first gear come into contact with at least a portion of the surfaces of the gear teeth of the second gear. However, mechanical power transmission systems, such as gears, are subject to failures, including material failures resulting from engagement between surfaces. Some exemplary types of gear failures include bending fatigue, contact fatigue, wear, scuffing, overload, and cracking.

[0004] Some drivelines use gear joint teeth, which do not function well when misalignment is present in the driveline. Also, such drivelines require sealing and lubrication to function properly.

[0005] When polycrystalline diamond (PCD) elements are used in moving parts, such as rotating machinery, typically both the engagement surface and the opposing engagement surface are composed of polycrystalline diamond. This is, at least in part, because thermally stable polycrystalline diamond (TSP), either supported or unsupported by tungsten carbide, and polycrystalline diamond compact (PDC) have been considered as contraindicated for use in the machining of diamond reactive materials. Diamond reactive materials include metals, metal alloys, and composites (e.g., in the form of hardfacings, coatings, or platings) that contain more than trace amounts of diamond catalyst or solvent elements (also referred to as diamond solvent-catalysts or diamond catalyst-solvents) including iron, cobalt, nickel, ruthenium, rhodium, palladium, chromium, manganese, copper, titanium, or tantalum. Further, this prior contraindication of the use of polycrystalline diamond extends to so called "superalloys," including iron-based, cobalt-based and nickel-based superalloys containing more than trace amounts of diamond catalyst or solvent elements. At certain surface speeds in moving parts, load and attendant temperature generated, such as at a cutting tip, often exceeds the graphitization temperature of diamond (i.e., about 700° C.), which can, in the presence of diamond catalyst or solvent elements, lead to rapid wear and failure of components. Without being bound by theory, the specific failure mechanism is believed to result from the chemical interaction of the carbon bearing diamond with the carbon attracting material that is being machined. An exemplary reference concerning the contraindication of polycrystalline diamond for diamond catalyst or solvent containing metal or alloy machining is U.S. Pat. No. 3,745,623. The contraindication of polycrystalline diamond for machining diamond catalyst or diamond solvent containing materials has long caused the avoidance of the use of polycrystalline diamond in all contacting applications with such materials.

BRIEF SUMMARY

[0006] Some embodiments of the present disclosure include a driveline. The driveline includes a drive shaft having a first end and a second end. A first bearing coupler is coupled with the first end of the drive shaft. The first bearing coupler has a bearing surface including a material that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the material. A first double conical joint is coupled with the first bearing coupler. The first double conical joint includes a first conical joint having at least one conical bearing surface with polycrystalline diamond bearing surfaces thereon. A second conical joint is coupled with the first conical joint. The second conical joint includes at least one conical bearing surface having polycrystalline diamond bearing surfaces thereon. The first conical joint is rotatably coupled with the first bearing coupler such that the polycrystalline diamond bearing surfaces of the first conical joint are in sliding contact with the bearing surface of the first bearing coupler.

[0007] Some embodiments of the present disclosure include a method of driving a machine. The method includes providing a driveline. The driveline includes a first double conical joint on a first end thereof and a second double conical joint on a second end thereof. The method includes coupling a first bearing coupler between the first double conical joint and a prime mover such that a bearing surface of the first bearing coupler is in sliding contact with a polycrystalline diamond bearing surface of the first double conical joint. The bearing surface of the first bearing coupler includes a material that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the material. The method includes coupling a second bearing coupler between the second double conical joint and a machine such that a bearing surface of the second bearing coupler is in sliding contact with a polycrystalline diamond bearing surface of the second double conical joint. The bearing surface of the second bearing coupler includes a material that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the material. The method includes driving rotation of the driveline with the prime mover, and driving the machine with the rotating driveline.

[0008] Some embodiments of the present disclosure include a system. The system includes a driveline having a first double conical joint on a first end thereof and a second double conical joint on a second end thereof. The system includes a prime mover, and a first bearing coupler positioned between the first double conical joint and the prime mover. A bearing surface of the first bearing coupler is in sliding contact with a polycrystalline diamond bearing surface of the first double conical joint. The bearing surface of the first bearing coupler includes a material that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the material. The system includes a machine, and a second bearing coupler positioned between the second double conical joint and the machine such that a bearing surface of the second bearing coupler is in sliding contact with a polycrystalline diamond bearing surface of the second double conical joint. The bearing surface of the second bearing coupler includes a material that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the material. The prime mover is configured to drive rotation of the driveline, and the driveline is configured to drive the machine.

[0009] Some embodiments include a driveline with double conical joints. The driveline includes a shaft having a first end and a second end. A bearing coupler is coupled with the shaft at the first end. The bearing coupler has a bearing surface including a material that contains at least 2 wt. % diamond solvent-catalyst based on a total weight of the material. The driveline includes a double conical joint including a first conical joint and a second conical joint. The first and second conical joints each include conical bearing surfaces having polycrystalline diamond bearing surfaces thereon. The first conical joint is rotatably coupled with the bearing coupler such that the polycrystalline diamond bearing surfaces of the first conical joint are in sliding contact with the bearing surface of the bearing coupler.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the features and advantages of the systems, apparatus, and/or methods of the present disclosure may be understood in more detail, a more particular description briefly summarized above may be had by reference to the embodiments thereof which are illustrated in the appended drawings that form a part of this specification. It is to be noted, however, that the drawings illustrate only various exemplary embodiments and are therefore not to be considered limiting of the disclosed concepts as it may include other effective embodiments as well.

[0011] FIG. **1**A depicts meshed, helical gears with one of the helical gears having polycrystalline diamond power transmission surfaces thereon.

[0012] FIG. **1**B depicts another view of the meshed, helical gears of FIG. **1**A.

[0013] FIG. **1**C depicts the meshed, helical gears the same as FIG. **1**A, but coupled at a right angle.

[0014] FIG. **1**D depicts a detail view of meshed, helical gears of FIG. **1**A.

[0015] FIG. **2**A depicts meshed, spur gears with one of the spur gears having polycrystalline diamond power transmission surfaces thereon.

[0016] FIG. **2**B depicts a detail view of the meshed, spur gears of FIG. **2**A.

[0017] FIG. **3**A depicts a worm gear meshed with a worm (also referred to as a worm screw), with the worm gear having polycrystalline diamond power transmission surfaces thereon.

[0018] FIG. **3**B depicts another view of the worm gear meshed with the worm of FIG. **3**A.

[0019] FIG. **3**C depicts another view of the worm gear meshed with the worm of FIG. **3**A.

[0020] FIG. **4**A is an exploded view of a portion of a driveline having an elongated universal joint with polycrystalline diamond power transmission surfaces thereon.

[0021] FIG. **4**B is an assembled view of the portion of the driveline of FIG. **4**A.

[0022] FIG. **4**C is a detail view of a portion of FIG. **4**B.

[0023] FIG. **4**D is a disassembled view of portions of the driveline of FIG. **4**A.

[0024] FIG. **5**A is an exploded view of a portion of a driveline having a double Cardan universal joint with polycrystalline diamond power transmission surfaces thereon.

[0025] FIG. **5**B is an assembled view of the portion of the driveline of FIG. **5**A.

[0026] FIG. **5**C is a detail view of a portion of FIG. **5**B.

[0027] FIG. **5**D is a disassembled view of the driveline of FIG. **5**A.

[0028] FIG. **5**E is a view of the connection between two components of the double Cardan universal joint of FIG. **5**A.

[0029] FIG. **5**F is a cross-sectional view of a FIG. **5**E.

[0030] FIG. **5**G and FIG. **5**H depict disassembled portions of the driveline of FIG. **5**D.

[0031] FIG. **6** is a schematic of a power transmission system driven by a first component and driving a second component.

[0032] FIG. **7**A is a perspective view of a driveline including double conical joints with polycrystalline diamond power transmission surfaces.

[0033] FIG. **7**B depicts a driveline including double conical joints with polycrystalline diamond power transmission surfaces.

[0034] FIGS. **8**A-**8**E depict portions of a driveline, including double conical joints with polycrystalline diamond power transmission surfaces, at various stages of assembly of the driveline.

[0035] FIG. **9**A is a side view of a portion of a driveline including double conical joints with polycrystalline diamond power transmission surfaces.

[0036] FIG. **9**B is a cross sectional view of the driveline of FIG. **9**A, along line **9**B-**9**B.

[0037] FIG. **10** depicts a driveline including double conical joints with polycrystalline diamond power transmission surfaces, with the driveline coupled with a rotor positioned in a stator.

[0038] FIG. **11** is a simplified schematic of a system including the driveline having double conical joints with polycrystalline diamond power transmission surfaces, with the driveline coupled between a prime mover and a machine.

DETAILED DESCRIPTION

[0039] Certain embodiments of the present disclosure include methods and apparatus for providing power transmission systems with polycrystalline diamond power transmission surfaces. The power transmission systems disclosed herein include, but are not limited to, gears and drivelines. The gears disclosed herein include, but are not limited to, helical gears, spur gears, and worm drives. The drivelines disclosed herein include, but are not limited to, mechanical couplings, including flexible mechanical couplings, between moving parts. The drivelines disclosed herein may include shaft couplings. In one exemplary embodiment, the drivelines disclosed herein include universal joints (e.g., single universal joints or single Cardan universal joints or double Cardan universal joints). The power transmission systems disclosed herein may be a component of a larger system, such as a drilling motor or a portion of a drivetrain. The power transmission systems disclosed herein are not limited to the particular applications discussed herein, and may be incorporated into other machinery that includes gears, drivelines, or other power transmission systems that include power transmission surfaces.

[0040] Power transmission surfaces (also referred to as power transfer surfaces) are surfaces of components within a power transmission system that engage surfaces for the transfer of mechanical energy (e.g., via the transfer of torque) between the components. For example, in a power transmission system that includes two gears that are meshed together, the power transmission surfaces include the gear tooth surfaces of the meshed gears that are or come into contact with one another during movement of the gears. Within this disclosure, when referring to engaged power transmission surfaces (e.g., meshed gear teeth), one power transmission surface may be referred to as a "power transmission surface" while the other may be referred to as an "opposing power transmission surface."

[0041] The present disclosure includes engaged power transmission surfaces where one of the power transmission surfaces includes polycrystalline diamond and the other, opposing power transmission surface does not include polycrystalline diamond. As described in more detail below, in some embodiments a first power transmission surface includes polycrystalline diamond, and a second, opposing power transmission surface includes diamond solvent-catalyst. In some embodiments, the opposing power transmission surface is a treated surface in accordance with U.S. Pat. No. 11,035,407. For example, the opposing power transmission surface (also referred to as the opposing engagement surface) may be hardened, such as via cold working and work hardening processes including burnishing and shot peening; and/or heat-treating processes including through hardening, case hardening, and subzero, cryogenic, deep freezing treatments. Also, the opposing power transmission surface may be plated and/or coated, such as via electroplating, electroless plating, including chromium plating, phosphating, vapor deposition, including physical vapor deposition (PVD) and chemical vapor deposition (CVD); or anodizing. Also, the opposing power transmission surface may be cladded, such as via roll bonding, laser cladding, or explosive welding.

[0042] In some embodiments, the power transmission surfaces disclosed herein are a portion of a motor, such as a drilling motor for downhole drilling, including directional drilling, such as a mud motor. The power transmission surfaces disclosed herein may be a surface of a gear (e.g., of a gearbox). While described in reference to downhole drilling applications, the power transmission surfaces disclosed herein may also be used in other applications. In some embodiments, the power transmission surfaces disclosed herein are a portion of a turbine, pump, compressor, mining equipment, construction equipment, combustion engine, windmill, automotive part, aircraft part, marine equipment, transmissions, rail cars, hard drives, centrifuges, medical equipment, robotics, machine tools, amusement rides, amusement devices, brakes, clutches, motors, or other assemblies that include power transmission systems.

DEFINITIONS, EXAMPLES, AND STANDARDS

[0043] Diamond Reactive Materials—As used herein, a "diamond reactive material" is a material that contains more than trace amounts of diamond catalyst or diamond solvent, which are also referred to as "diamond catalyst-solvent," "catalyst-solvent," "diamond solvent-catalyst," or "solvent-catalyst." Some examples of known diamond solvent-catalysts are disclosed in: U.S. Pat. Nos. 6,655,845; 3,745,623; 7,198,043; 8,627,904; 5,385,715; 8,485,284; 6,814,775; 5,271,749; 5,948,541; 4,906,528; 7,737,377; 5,011,515; 3,650,714; 2,947,609; and 8,764,295. As used herein, a diamond reactive material that contains more than "trace amounts" of diamond solvent-catalyst is a material that contains at least 2 percent by weight (wt. %) diamond solvent-catalyst based on a total weight of the material. The diamond reactive materials disclosed herein may contain from 2 to 100 wt. %, or from 5 to 95 wt. %, or from 10 to 90 wt. %, or from 15 to 85 wt. %, or from 20 to 80 wt. %, or from 25 to 75 wt. %, or from 25 to 70 wt. %, or from 30 to 65 wt. %, or from 35 to 60 wt. %, or from 40 to 55 wt. %, or from 45 to 50 wt. % of diamond solvent-catalyst based on a total weight of the diamond reactive material. As would be understood by one skilled in the art, diamond solvent-catalysts are chemical elements, compounds, or materials (e.g., metals) that are capable of reacting with polycrystalline diamond (e.g., catalyzing and/or solubilizing), resulting in the graphitization of the polycrystalline diamond, such as under load and at a temperature at or exceeding the graphitization temperature of diamond (i.e., about 700° C.). Thus, diamond reactive materials include materials that, under load and at a temperature at or exceeding the graphitization temperature of diamond, can lead to wear, sometimes rapid wear, and failure of components formed of or including polycrystalline diamond, such as diamond tipped tools. Diamond reactive materials include, but are not limited to, metals, metal alloys, and composite materials that contain more than trace amounts of diamond solvent-catalysts. The diamond reactive materials may be in the form of hardfacings, coatings, or platings. Some exemplary diamond solvent-catalysts include iron, cobalt, nickel, ruthenium, rhodium, palladium, chromium, manganese, copper, titanium, tantalum, and alloys thereof. Thus, a diamond reactive material may be a material that includes more than trace amounts (i.e., more than 2 wt. %) of iron, cobalt, nickel, ruthenium, rhodium, palladium, chromium, manganese, copper, titanium, tantalum, or alloys thereof. One exemplary diamond reactive material is steel.

[0044] The diamond reactive material may be a superalloy including, but not limited to, an iron-based superalloy, a cobalt-based superalloy, or a nickel-based superalloy.

[0045] In some embodiments, the diamond reactive material is not and/or does not include (i.e., specifically excludes) so called "superhard materials." As would be understood by one skilled in the art, "superhard materials" are a category of materials defined by the hardness of the material, which may be determined in accordance with the Brinell, Rockwell, Knoop and/or Vickers scales. For example, superhard materials include materials with a hardness value exceeding 40 gigapascals (GPa) when measured by the Vickers hardness test. As used herein, "superhard materials" are materials that are at least as hard as tungsten carbide, including tungsten carbide tiles and cemented tungsten carbide, such as is determined in accordance with one of these hardness scales. One skilled in the art would understand that a Brinell scale test may be performed, for example, in accordance with ASTM E10-18; the Vickers hardness test may be performed, for example, in accordance with ASTM E92-17; the Rockwell hardness test may be performed, for example, in accordance with ASTM E18; and the Knoop hardness test may be performed, for example, in accordance with ASTM E384-17. The "superhard materials" disclosed herein include, but are not limited to, tile tungsten carbide, cemented tungsten carbide, infiltrated tungsten carbide matrix, silicon carbide, silicon nitride, cubic boron nitride, and polycrystalline diamond. Thus, in some aspects, the "diamond reactive material" is partially or entirely composed of material(s) (e.g., metal, metal alloy, composite) that is softer (less hard) than superhard materials, such as less hard than tungsten carbide (e.g., tile or cemented), as determined in accordance with one of these hardness tests, such as the Brinell scale.

[0046] Interfacing Polycrystalline Diamond with Diamond Reactive Materials—In some embodiments, the present disclosure provides for interfacing the contact between a first power transmission surface that includes a polycrystalline diamond surface and a second power transmission surface that includes a diamond reactive material surface. For example, the polycrystalline diamond surface may be positioned and arranged on or as the first power transmission surface for sliding and/or rolling contact with the diamond reactive material surface. As used herein, "engagement surface" refers to the surface of a material or component (e.g., polycrystalline diamond or diamond reactive material) that is positioned and arranged within a power transmission system such that, in operation of the power transmission system (e.g., a gearbox), the engagement surface interfaces the contact between two components (e.g., between two gears in a gearbox). In some embodiments, the power transmission surface disclosed herein is in direct contact with an opposing power transmission surface (i.e., boundary lubrication), without a fluid film therebetween. In some embodiments, a fluid film may develop (i.e., hydrodynamic lubrication) between the power transmission surface and the opposing power transmission surface such that the surfaces are not directly in contact with one another, but are engaged through the fluid film. In some aspects, the contact between the power transmission surface and opposing power transmission surface is between (or a mixture of) direct contact and fluid film (i.e., mixed boundary lubrication).

[0047] Lapped or Polished—In certain applications, the polycrystalline diamond, or at least the engagement surface thereof, is lapped or polished, optionally highly lapped or highly polished. Although highly polished polycrystalline diamond is used in at least some applications, the scope of this disclosure is not limited to highly polished polycrystalline diamond and includes polycrystalline diamond that is highly lapped or polished. As used herein, a surface is defined as "highly lapped" if the surface has a surface finish of 20 µin or about 20 µin, such as a surface finish ranging from about 18 to about 22 µin. As used herein, a surface is defined as "polished" if the surface has a surface finish of less than about 10 µin, or of from about 2 to about 10 µin. As used herein, a surface is defined as "highly polished" if the surface has a surface finish of less than about 2 µin, or from about 0.5 µin to less than about 2 µin. In some aspects, the polycrystalline diamond engagement surfaces disclosed herein have a surface finish ranging from 0.5 µin to 40 µin, or from 2 µin to 30 µin, or from 5 µin to 20 pin, or from 8 µin to 15 µin, or less than 20 µin, or less than 10 µin, or less than 2 µin, or any range therebetween. Without being bound by theory, it is believed that polycrystalline diamond that has been polished to a surface finish of 0.5 µin has a coefficient of fiction that is about half of standard lapped polycrystalline diamond with a surface finish of 20-40 µin. U.S. Pat. Nos. 5,447,208 and 5,653,300 to Lund et al. provide disclosure relevant to polishing of polycrystalline diamond. As would be understood by one skilled in the art, surface finish, also referred to as surface texture or surface topography, is a characteristic of a surface as defined by lay, surface roughness, and waviness. Surface finish may be determined in accordance with ASME B46.1-2009. Surface finish may be measured with a profilometer, laser microscope, or with Atomic Force Microscopy, for example. In some embodiments, the opposing engaging surface has a surface finish of from 0.5 to 2,000 µin, or from 1 to 1,900 µin, or from 5 to 1,500 pin, or from 10 to 1,200 µin, or from 50 to 1,000 µin, or from 100 to 800 µin, or from 200 to 600 µin. In some embodiments, the opposing engagement surface has a surface finish that is greater than the engagement surface (i.e., rougher).

Helical Gears

[0048] Some embodiments of the present disclosure include power transmission systems that include meshed gears or cogwheels. In one exemplary embodiment, the meshed gears are helical gears.

[0049] With reference to FIGS. **1A**-**1D**, pairs of meshed helical gears are depicted. Meshed gears **100** may be a portion of a power transmission system. Meshed gears **100** include first gear **102** and second gear **104**, each of which is a helical gear. First gear **102** and second gear **104** are meshed together such that, in operation, mechanical power is transferred from one of first gear **102** and second gear **104** to the other of first gear **102** and second gear **104**. Each of first gear **102** and second gear **104** includes a plurality of teeth **106** protruding from a gear body **108** and extending about the outer circumference thereof. As shown in FIG. **1D**, each gear tooth **106** extends from gear body **108** between two adjacent root surfaces **110**, and includes a gear top land **112**. Each gear tooth **106** of first gear **102** includes a first gear tooth surface **114** extending from one adjacent root surface **110** to the gear top land **112** thereof, and a second gear tooth surface **116** extending from another adjacent root surface **110** to the gear top land **112** thereof. Each gear tooth **106** of second gear **104** includes a first gear tooth surface **118** extending from one adjacent root surface **110** to the gear top land **112** thereof, and a second gear tooth surface **120** extending from another adjacent root surface **110** to the gear top land **112** thereof.

[0050] First gear tooth surface **114** of first gear **102** includes polycrystalline diamond surfaces **122** thereon. While shown as including three discrete polycrystalline diamond surfaces **122** on each first gear tooth surface **114**, the present disclosure is not limited to including this arrangement, and may include more or less than three discrete polycrystalline diamond surfaces. In some embodiments, the entirety of first gear tooth surface **114** is polycrystalline diamond. In other embodiments, less than an entirety of first gear tooth surface **114** is polycrystalline diamond.

[0051] First gear **102** and second gear **104** are meshed such that polycrystalline diamond surfaces **122** of first gear **102** engage with first gear tooth surface **118** of second gear **104**. Second gear tooth surface **118** includes a diamond reactive material. For example, second gear tooth surface **118** may be a steel surface.

[0052] In some embodiments, both of first gear and second gear are or include a diamond reactive material, with the provision that at least one of the first and second gears has polycrystalline diamond elements coupled therewith to provide power transmission surfaces thereon. While polycrystalline diamond surfaces **122** are shown only on one of the gear tooth surfaces of meshed gears **100** (i.e., on first gear tooth surface **114**), the present disclosure is not limited to such an arrangement. For example, in some embodiments, second gear tooth surface **116** of first gear **102** may also include polycrystalline diamond surfaces thereon for engagement with second gear tooth surface **120** of second gear **104** that includes diamond solvent-catalyst. In other embodiments, second gear tooth surface **120** may include polycrystalline diamond surfaces for engagement with second gear tooth surface **116** of first gear **102**. For example, in one embodiment both of surfaces **114** and **116** are or include polycrystalline diamond surfaces, while both of surfaces **118** and **120** are or include diamond solvent-catalyst, such that, regardless of whether the meshed gears **100** rotate clockwise or counterclockwise, the polycrystalline diamond surfaces are engaging with the diamond solvent-catalyst surfaces. In another embodiment, surfaces **114** and **120** are or include polycrystalline diamond surfaces, while surfaces **116** and **118** are or include diamond solvent-catalyst, such that, regardless of whether the meshed gears **100** rotate clockwise or counterclockwise, the polycrystalline diamond surfaces are engaging with the diamond solvent-catalyst surfaces.

[0053] First gear **102** is coupled with gear axle **124**, and second gear **104** is coupled with gear axle **126**. In one exemplary operation, rotation of gear axle **124** causes first gear **102** to rotate, rotation of first gear **102** causes second gear **104** to rotate, and rotation of second gear **104** causes gear axle **126** to rotate. First gear **102** and second gear **104** may be coupled with a first component at a drive end thereof and with a second component at a driven end thereof. Some exemplary components that may be coupled with the first and second gears **102**,**104** at the drive end include, but are not limited to, an electric motor, an internal combustion engine, a gas turbine engine, a wind turbine, a water turbine, a steam turbine, a hydraulic motor, and a drilling motor turbine. The component at the drive end rotates the first gear. For example, the component at the drive end may be coupled with gear axle **124**, and may drive rotation of gear axle **124**, which drives rotation of first gear **102**, which drives rotation of second gear **104**, which drives rotation of gear axle **126**. At the driven end, gear axle **126** may be coupled with a component that is driven by first and second gears **102**,**104**. Some exemplary driven end components include, but are not limited to, a pump, generator, driveline, machine tool spindle or chuck, wench, drill bit, power take off unit, propeller shaft, axle shaft, or other mechanical equipment that performs work. One skilled in the art would understand that numerous and various components may be driven by the gear assemblies disclosed herein.

[0054] During rotation of first gear **102**, gear teeth **106** of first gear **102** engage between gear teeth **106** of second gear **104**, such that first gear teeth surfaces **114** with polycrystalline diamond surfaces **122** engage (e.g., in sliding and/or rolling contact) with first gear teeth surfaces **118** of second gear **104**. As such, during rotation of meshed gears **100**, the polycrystalline diamond surfaces **122** engage, in sliding and/or rolling contact, with the diamond reactive material of first gear teeth surfaces **118**. The power transmissions surfaces disclosed herein are not limited to being in sliding or rolling contact, and may be movingly engaged in other manners where the engagement surface and opposing engagement surface are in contact and apply pressure to one another.

Spur Gears

[0055] In one exemplary embodiment, the power transmission systems disclosed herein include meshed spur gears that include power transmission surfaces. With reference to FIGS. **2**A and **2**B, meshed spur gears **200** include first gear **202** and second gear **204**, each of which is a spur gear. First gear **202** and second gear **204** are meshed together such that, in operation, mechanical power is transferred from one of first gear **202** and second gear **204** to the other of first gear **202** and second gear **204**. Each of first gear **202** and second gear **204** includes a plurality of teeth **206** protruding from a gear body **208**. As shown in FIG. **2**B, each gear tooth **206** extends from gear body **208** between two adjacent root surfaces **210**, and includes a gear top land **212**. Each gear tooth **206** of first gear **202** includes a first gear tooth surface **214** extending from one adjacent root surface **210** to the gear top land **212** thereof, and a second gear tooth surface **216** extending from another adjacent root surface **210** to the gear top land **212** thereof. Each gear tooth **206** of second gear **204** includes a first gear tooth surface **218** extending from one adjacent root surface **210** to the gear top land **212** thereof, and a second gear tooth surface **220** extending from another adjacent root surface **210** to the gear top land **212** thereof.

[0056] First gear tooth surface **214** of first gear **202** includes polycrystalline diamond surfaces **222** thereon. While shown as including one discrete polycrystalline diamond surface **222** on each first gear tooth surface **214**, the present disclosure is not limited to including this arrangement, and may include more than one discrete polycrystalline diamond surfaces. In some embodiments, the entirety of first gear tooth surface **214** is polycrystalline diamond. In other embodiments, less than an entirety of first gear tooth surface **214** is polycrystalline diamond.

[0057] First gear **202** and second gear **204** are meshed such that first gear tooth surface **214** of first gear **202** engages with first gear tooth surface **218** of second gear **204**. Second gear tooth surface **218** includes diamond reactive material.

[0058] While polycrystalline diamond surfaces **222** are shown only on one of the gear tooth surfaces of meshed gears **200** (i.e., on first gear tooth surface **214**), the present disclosure is not limited to such an arrangement. For example, in some embodiments, second gear tooth surface **216** of first gear **202** may also include polycrystalline diamond surfaces thereon for engagement with second gear tooth surface **220** of second gear **204** that includes diamond reactive material. In other embodiments, second gear tooth surface **220** may include polycrystalline diamond surfaces for engagement with second gear tooth surface **216** of first gear **202**. For example, in one embodiment both of surfaces **214** and **216** are or include polycrystalline diamond surfaces, while both of surfaces **218** and **220** are or include diamond solvent-catalyst, such that, regardless of whether the meshed gears **200** rotate clockwise or counterclockwise, the polycrystalline diamond surfaces are engaging with the diamond solvent-catalyst surfaces. In another embodiment, surfaces **214** and **220** are or include polycrystalline diamond surfaces, while surfaces **216** and **218** are or include diamond solvent-catalyst, such that, regardless of whether the meshed gears **200** rotate clockwise or counterclockwise, the polycrystalline diamond surfaces are engaging with the diamond solvent-catalyst surfaces.

[0059] First gear **202** is coupled with gear axle **224**, and second gear **204** is coupled with gear axle **226**. In one exemplary operation, rotation of gear axle **224** causes first gear **202** to rotate, rotation of first gear **202** causes second gear **204** to rotate, and rotation of second gear **204** causes gear axle **226** to rotate. During rotation of first gear **202**, gear teeth **206** of first gear **202** engage between gear teeth **206** of second gear **204**, such that first gear teeth surfaces **214** with polycrystalline diamond surfaces **222** engage (e.g., in sliding and/or rolling contact) with first gear teeth surfaces **218** of second gear **204**. As such, during rotation of meshed gears **200**, the polycrystalline diamond surfaces **222** engage, in sliding and/or rolling contact, with the diamond solvent-catalyst of first gear teeth surfaces **218**.

Worm Drive

[0060] In one exemplary embodiment, the power transmission systems disclosed herein include a worm drive, including a worm meshed with a worm gear, with the worm and worm gear including power transmission surfaces. With reference to FIGS. **3A-3C**, worm drive **300** includes worm **301** and worm gear **303**. Worm gear **303** may be the same or substantially similar to a spur gear. Worm **301** may be similar to a screw. Worm **301** is meshed with worm gear **303** such that, in operation, mechanical power is transferred from one of worm **301** and worm gear **303** to the other of worm **301** and worm gear **303**. Worm **301** includes gear tooth **307** that extends about a full rotation of worm **301**. Geartooth **307** is similar to screw threading, extending helically about axle **326** of worm **301** from position **311***a* to position **311***b*. Gear tooth **307** extends from root surface **309**, and includes gear top land **313**. Gear tooth **307** includes first gear tooth surface **318** and second gear surface **320**. Worm gear **303** includes a plurality of teeth **306** protruding from a gear body **308**. As shown in FIG. **3B**, each gear tooth **306** extends from gear body **308** between two adjacent root surfaces **310**, and includes a gear top land **312**. Each gear tooth **306** of worm gear **303** includes a first gear tooth surface **314** extending from one adjacent root surface **310** to the gear top land **312** thereof, and a second gear tooth surface **316** extending from another adjacent root surface **310** to the gear top land **312** thereof.

[0061] First gear tooth surface **314** of worm gear **303** includes polycrystalline diamond surfaces **322** thereon. While shown as including two discrete polycrystalline diamond surfaces **322** on each first gear tooth surface **314**, the present disclosure is not limited to including this arrangement, and may include more or less than two discrete polycrystalline diamond surfaces. In some embodiments, the entirety of first gear tooth surface **314** is polycrystalline diamond. In other embodiments, less than an entirety of first gear tooth surface **314** is polycrystalline diamond.

[0062] Worm **301** and worm gear **303** are meshed such that first gear tooth surface **314** of worm gear **303** engages with first gear tooth surface **318** of worm **301**. Second gear tooth surface **318** includes diamond reactive material (e.g., steel).

[0063] While polycrystalline diamond surfaces **322** are shown only on one of the gear tooth surfaces of meshed gears **300**, the present disclosure is not limited to such an arrangement. For example, in some embodiments, second gear tooth surface **316** of worm gear **303** may also include polycrystalline diamond surfaces thereon for engagement with second gear tooth surface **320** of worm **301** that includes diamond solvent-catalyst. In other embodiments, second gear tooth surface **320** may include polycrystalline diamond surfaces for engagement with second gear tooth surface **316** of worm wheel **303**. In such embodiments, regardless of whether the worm drive **300** rotates clockwise or counterclockwise, the polycrystalline diamond surfaces are engaging with the diamond reactive material surfaces.

[0064] Worm gear **303** is coupled with gear axle **324**, and worm **301** is coupled with gear axle **326**. In one exemplary operation, rotation of gear axle **326** causes worm **301** to rotate, rotation of worm **301** causes worm gear **303** to rotate, and rotation of worm gear **303** causes gear axle **324** to rotate. During rotation of meshed gears **300**, gear teeth **306** of worm gear **303** engage between surfaces **318** and **320** of gear tooth **307** of worm **301**, such that first gear teeth surfaces **314** with polycrystalline diamond surfaces **322** engage (e.g., in sliding and/or rolling contact) with first gear teeth surface **318** of worm **301**. As such, during rotation of meshed gears **300**, the polycrystalline diamond surfaces **322** engage, in sliding and/or rolling contact, with the diamond solvent-catalyst of first gear teeth surfaces **318**.

[0065] While the gears shown and described in FIGS. **1A-3C** include particular embodiments of helical gears, spur gears, and worm drives, the present disclosure is not limited to these particular embodiments, and the disclosed power transmission surfaces with polycrystalline diamond may be incorporated into other gears. For example, and without limitation, the power transmission surfaces with polycrystalline diamond may be incorporated into spur gears, helical gears, skew gears, double helical gears, bevel gears, spiral bevel gears, hypoid gears, crown gears, worm drives, non-circular gears, rack and pinion gears, epicyclic gears, sun and planet gears, harmonic gears, cage gears, and cycloidal gears. Also, while shown herein as gears having cut teeth, the power transmission surfaces with polycrystalline diamond may be incorporated into cogwheels having inserted teeth. Further, while the gears shown herein are external gears with teeth on the outer surface, the power transmission surfaces with polycrystalline diamond may be incorporated into internal gears with teeth on the inner surface.

Mechanical Couplings

[0066] Some embodiments of the present disclosure include power transmission systems that include mechanical couplings, including flexible mechanical couplings. Some exemplary mechanical couplings include, but are not limited to, jaw couplings, claw couplings, and knuckle joints. In some embodiments, the mechanical couplings disclosed herein include universal joints, which are sometimes referred to as universal couplings, U-joints, Cardan joints, Spicer joints, Hardy Spicer joints, and Hooke's joints. Universal joints are joints used for connecting rigid rods together that have axes that are at least sometimes inclined and/or offset relative to one another. Some exemplary assemblies that include flexible mechanical couplings are constant velocity drivelines, propeller (prop) shafts, universal joint shafts, and double Cardan shafts.

[0067] In some embodiments, the power transmission system disclosed herein includes an elongated universal joint for use in driveline applications, such as for use in drilling motors. With reference to FIGS. **4**A-4D, a portion of an assembly having an elongated universal joint for use in driveline applications is depicted. Assembly **4000** includes shaft **4002**. Shaft **4002** includes a hinge on each end thereof, including hinge **4008** and hinge **4010**. As shown in FIG. **4**B, hinge **4008** may be coupled with hinge **4005**, which is coupled or integral with shaft **4004**. Also, hinge **4010** may be coupled with hinge **4007**, which is coupled or integral with shaft **4006**. Also shown in the exploded view of FIG. **4**A are set screws **4001**, threaded holes **4003**, locking pin **4024**, and cups **4026**. Locking pins **4024** have a ball end for mechanically coupling hinges **4008** and **4010** together and coupling hinges **4005** and **4007** together, and for providing a spherical bearing surface along with locating a pivot point for the hinges to rotate about. When assembled, the locking pins **4024** are turned 90 degrees to mechanically couple the respective hinges together. Set screws **4001** are then tightened to fix the position of the locking pins **4024** to prevent the two mating hinges from separating during operation. Cups **4026** have spherical cups machined therein and function as locaters for pivot points and as spherical bearing surfaces. Hinges **4008** and **4010** couple with hinges **4005** and **4007**, respectively, via meshing the teeth **4009** thereof together. In at least some respects, hinges **4008**, **4010**, **4005**, and **4007** are or are similar to gears, and function the same as or similar to gears in that the "teeth" of hinges mesh together for the transfer mechanical energy therebetween. The coupling of hinges **4008**, **4010**, **4005**, and **4007** is the same as or similar to Hirth couplings or Curvic couplings.

[0068] Shaft **4004** may be coupled with or a portion of, for example, a motor that drives shaft **4004**. When hinge **4005** is coupled with hinge **4008**, rotation of shaft **4004** causes shaft **4002** to rotate. When hinge **4010** is coupled with hinge **4007**, rotation of shaft **4002** causes shaft **4006** to rotate. Shaft **4006** may be coupled with or a portion of a component that is driven by assembly, such as a drill bit.

[0069] Each tooth of hinges **4008** and **4010** has tooth surfaces **4040** extending between root surface **4041** and top landing **4043**. At least one tooth surface **4040** of each of hinges **4008** and **4010** has a polycrystalline diamond **4022** thereon. One of two adjacent teeth **4009** of hinges **4008** and **4010** has a polycrystalline diamond **4022** thereon and the other has a spring **4021** (here shown as a wave spring) thereon, providing compliance to assembly **4000** and reducing impact due to backlash as during transient events, such as at startup or shut-down. While not shown, the opposite side of hinges **4008** and **4010** may have the same arrangement. The tooth surfaces **4030** of hinges **4005** and **4007** include diamond reactive material. For example, in some embodiments, tooth surfaces **4030** of hinges **4005** and **4007** are steel. While springs **4021** are shown, the mechanical couplings disclosed herein are not limited to includes springs.

[0070] As shown in FIG. **4**C, when hinges **4005** and **4008** are engaged, the teeth of hinge **4008** are positioned between adjacent teeth of hinge **4005**, and the teeth of hinge **4005** are positioned between adjacent teeth of hinge **4008**. The polycrystalline diamonds **4022** are engaged with the tooth surfaces **4030**, such that the engagement between the hinges **4005** and **4008** is at least partially interfaced via engagement between the surfaces of the polycrystalline diamonds **4022** tooth surfaces **4030**. The engagement between hinges **4007** and **4010** is the same or substantially similar to that of hinges **4005** and **4008**. In operation, assembly **4000** exploits excess backlash and looseness of fit between the hinges in order to accommodate various ranges of motions. For example, assembly **4000** exploits excess backlash and looseness of fit between the hinges in order to accommodate axial, radial, and/or angular misalignment within assembly **4000**.

[0071] In some embodiments, the polycrystalline diamond surfaces and the diamond reactive material surfaces are arranged within assembly **4000** such that, regardless of the direction of rotation (clockwise or counterclockwise) of the assembly **4000**, polycrystalline diamond surfaces are engaged with diamond reactive material surfaces in the assembly **4000** during rotation. For example, rather than springs **4021** on the surfaces opposite the polycrystalline diamonds **4022**, the springs **4021** of hinges **4008** and **4010** could be replaced with polycrystalline diamonds and all of the tooth surfaces **4030** of hinges **4005** and **4007** could be diamond reactive material surfaces such that, regardless of the direction or rotation of assembly **4000**, polycrystalline diamond surfaces are engaged with diamond reactive material surfaces in the assembly **4000**. Alternatively, rather than springs **4021** on the surfaces opposite the polycrystalline diamonds **4022**, the springs **4021** of hinges **4008** and **4010** could be replaced with diamond reactive material surfaces, the tooth surfaces **4030** of hinges **4005** and **4007** that engage with the diamond reactive material surfaces of hinges **4008** and **4010** could be polycrystalline diamonds, and the tooth surfaces **4030** of hinges **4005** and **4007** that engage with the polycrystalline diamonds **4022** of hinges **4008** and **4010** could be diamond reactive material surfaces such that, regardless of the direction or rotation of assembly **4000**, polycrystalline diamond surfaces are engaging with diamond reactive material surfaces in the assembly **4000**.

[0072] As can be seen in FIG. **4**C, the opposing engagement surface is crowned, with tooth surface **4030** positioned outward relative to curved surfaces **4032** and **4037**. Tooth surface **4030** has a width **4031** that is narrower than a width **4020** of the engagement surface of polycrystalline diamond **4022**. This projection of tooth surface **4030** from tooth **4009** and relative narrowness of tooth surface **4030** relative to polycrystalline diamond **4022** reduces or eliminates the occurrence of edge contact between the polycrystalline diamond **4022** and tooth surface **4030**, such that the polycrystalline diamond **4022** does not gouge the diamond reactive material of tooth surface **4030** during operation thereof.

[0073] In some embodiments, the power transmission system disclosed herein includes a double Cardan universal joint for use in driveline applications, such as for use in drilling motors. Assemblies with double Cardan universal joints include two sets of universal joints. In operation, when the sets of universal joints are aligned, assemblies with double Cardan universal joints can provide constant velocity. With reference to FIGS. **5**A-5F, a portion of an assembly having a double Cardan universal joint for use in driveline applications is depicted. Assembly **5000** is substantially similar to assembly **4000**, with the addition of shaft couplers **5050***a* and **5050***b*. Assembly **5000** includes shaft **5002**. Shaft **5002** includes a hinge on each end thereof, including hinge **5008** and hinge **5010**. Assembly **5000** includes shaft couplers **5050***a* and **5050***b*. Assembly includes hinge **5005** coupled or integral with shaft **5004**, and hinge **5007** coupled or integral with shaft **5006**. Hinge **5008** may be coupled with one end of shaft coupler **5050***a*, and hinge **5005** may be coupled with the opposite end of shaft coupler **5050***a*. Hinge **5010** may be coupled with one end of shaft coupler **5050***b*, and hinge **5007** may be coupled with the opposite end of shaft coupler **5050***b*. Also shown in the exploded view of FIG. **5**A are set screws **5001**, threaded holes **5003**, and locking pins **5024**.

[0074] As shown in FIG. **5**B, each of hinges **5008**, **5010**, **5005**, and **5007**, as well as shaft couplers **5050***a* and **5050***b* include teeth **5009**. Shaft coupler **5050***a* couples with hinges **5008** and **5005** via meshing of the teeth **5009** thereof, and shaft coupler **5050***b* couples with hinges **5010** and **5007** via meshing of the teeth **5009** thereof. In at least some respects, hinges **5008**, **5010**, **5005**, and **5007** and shaft couplers **5050***a* and **5050***b* are or are similar to gears, and function the same as or similar to gears in that the teeth thereof mesh together for the transfer mechanical energy therebetween. The coupling of hinges **5008**, **5010**, **5005**, and **5007** is the same as or similar to Hirth couplings or Curvic couplings.

[0075] Shaft **5004** may be coupled with or a portion of, for example, a motor that drives shaft **5004**. When hinge **5005** is coupled with hinge **5008** via shaft coupler **5050***a*, rotation of shaft **5004** causes shaft coupler **5050***a* to rotate, and rotation of shaft coupler **5050***a* causes shaft **5002** to rotate. When hinge **5010** is coupled with hinge **5007** via shaft coupler **5050***b*, rotation of shaft **5002** causes shaft coupler **5050***b* to rotate, and rotation of shaft coupler **5050***b* causes shaft **5006** to rotate. Shaft **5006** may be coupled with or a portion of a component that is driven by assembly, such as a drill bit.

[0076] With reference to FIGS. **5**D, **5**G, and **5**H, each tooth **5009** of hinges **5005**, **5007**, **5008**, and **5010** has tooth surfaces **5040** extending between a root surface **5041** and top landing **5043**. At least one tooth surface **5040** of each of hinges **5008**, **5010**, **5005**, and **5007** has a polycrystalline diamond **5022** thereon. As shown in FIGS. **5**D, **5**G, and **5**H, each tooth **5009** has a polycrystalline diamond **5022** on one tooth surface **5040** thereof and a spring **5021** on the other tooth surface **5040** thereof. The tooth surfaces **5030** of shaft couplers **5050***a* and **5050***b* include diamond solvent-catalyst. For example, in some embodiments, tooth surfaces **5030** are steel. As such, when assembled, the polycrystalline diamonds **5022** are engaged with the tooth surfaces **5030**, such that the engagement between the hinges **5005**, **5007**, **5008**, and **5010** with shaft couplers **5050***a* and **5050***b* is at least partially interfaced via engagement between the surfaces of the polycrystalline diamonds **5022** tooth surfaces **5030**.

[0077] In some embodiments, the polycrystalline diamond surfaces and the diamond reactive material surface are arranged within assembly **5000** such that, regardless of the direction of rotation (clockwise or counterclockwise) of the assembly **5000**, polycrystalline diamond surfaces are engaged with diamond solvent-catalyst surfaces in the assembly **5000** during rotation. For example, rather than springs **5021** on the surfaces opposite the polycrystalline diamonds **5022**, the springs **5021** of any one or more of hinges **5005**, **5007**, **5008** and **5010** could be replaced with polycrystalline diamonds and all of the tooth surfaces **5030** of couplers **5050***a* and **5050***b* could be diamond reactive material surfaces such that, regardless of the direction or rotation of assembly **5000**, polycrystalline diamond surfaces are engaged with diamond reactive material surfaces in the assembly **5000**. Alternatively, the springs **5021** of any one or more of hinges **5005**, **5007**, **5008** and **5010** could be replaced with diamond reactive material surfaces, one or more of the tooth surfaces **5030** that engage with the diamond reactive material surfaces of hinges **5005**, **5007**, **5008** and **5010** could be polycrystalline diamonds, and the tooth surfaces **5030** that engage with the polycrystalline diamonds **5022** could be diamond reactive material surfaces such that, regardless of the direction or rotation of assembly **5000**, polycrystalline diamond surfaces are engaging with diamond reactive material surfaces in the assembly **5000**.

[0078] FIG. **6** depicts an exemplary system **10**. System **10** includes motor **12**. Motor **12** is coupled with power transmission system **14**. Power transmission system **14** is coupled with component **16**. Power transmission system **14** may be any of the power transmission systems disclosed herein that include polycrystalline diamond power transmission surfaces engaged with diamond reactive material power transmission surfaces. Power transmission system **14** may be or include a set of gears and/or a universal joint. For example, power transmission system **14** may be or include any of the gears shown in FIGS. **1**A-**3**C or any of the universal joints shown in FIGS. **4**A-**5**F. In operation, motor **12** drives power transmission system **14**, such as via rotating a drive shaft coupled with or integral with the power transmission system **14**, and power transmission system **14** drives the component **16**, such as via rotating a shaft coupled with or integral with the component **16**. The component may be any of numerous components, as described elsewhere herein. Some examples of components include, but are not limited to, drill bits and propellers.

Polycrystalline Diamond Bearing Elements

[0079] In some embodiments, the polycrystalline diamond surfaces disclosed herein are surfaces of polycrystalline diamond elements that are coupled with or otherwise incorporated into or with the power transmission system components (e.g., gears or universal joints) disclosed herein. For example, the polycrystalline diamond elements may be coupled with the power transmission surfaces of the power transmission systems. In some embodiments, the polycrystalline diamond elements are positioned to be flush with existing power transmission surfaces. In other embodiments, the polycrystalline diamond elements are positioned to be raised above existing power transmission surfaces. Such polycrystalline diamond elements may be or include thermally stable polycrystalline diamond, either supported or unsupported by tungsten carbide, or polycrystalline diamond compact (PDC). In certain applications, the polycrystalline diamond elements disclosed herein have increased cobalt content transitions layers between the outer polycrystalline diamond surface and a supporting tungsten carbide slug. The polycrystalline diamond elements may be supported by tungsten carbide, or may be unsupported, "standalone" polycrystalline diamond elements that are mounted directly to the power transmission system component. The polycrystalline diamond elements may by non-leached, leached,

leached and backfilled, thermally stable, coated via chemical vapor deposition (CVD), or processed in various ways as known in the art.

[0080] In some embodiments, the engagement surfaces of the polycrystalline diamond elements disclosed herein are planar, convex, or concave. In some embodiments, wherein the engagement surfaces of the polycrystalline diamond elements are concave, the concave engagement surfaces are oriented with the axis of the concavity in line with the circumferential rotation of the respective power transmission system component. In some embodiments, the polycrystalline diamond elements have beveled edges. The polycrystalline diamond elements may have diameters as small as 3 mm (about ⅛") or as large as 75 mm (about 3"), depending on the application. Typically, the polycrystalline diamond elements have diameters between 8 mm (about 5/16") and 25 mm (about 1").

[0081] Although the polycrystalline diamond elements are most commonly available in cylindrical shapes, it is understood that the technology of the application may be practiced with polycrystalline diamond elements that are square, rectangular, oval, any of the shapes described herein with reference to the Figures, or any other appropriate shape known in the art. In some applications, one or more convex, contoured polycrystalline diamond elements are mounted on the power transmission system component (e.g., gear or mechanical coupling) in sliding and/or rolling contact with an opposing surface of another power transmission system component (e.g., another gear or portion of the universal joint).

[0082] The polycrystalline diamond elements may be arranged in any pattern, layout, spacing or staggering within the power transmission system to provide the desired interfacing of contact, without concern for the need for overlapping contact with polycrystalline diamond elements engagement surfaces on the opposing power transmission system component. The polycrystalline diamond elements disclosed herein are, in some embodiments, not shaped to conform to the opposing engagement surface. The polycrystalline diamond elements disclosed herein are, in other embodiments, shaped to conform to the opposing engagement surface.

[0083] One performance criterion is that the polycrystalline diamond element is configured and positioned in such a way as to preclude any edge contact with the opposing engagement surface or component. In some aspects, the polycrystalline diamond elements are subjected to edge radius treatment.

Opposing Engagement Surface

[0084] In some aspects, the opposing engaging surface (e.g., of the opposing gear or portion of the universal joint), that is, the surface that is engaged with the polycrystalline diamond surface, has carbon applied thereto. In some such aspects, the carbon is applied to the opposing bearing surface prior to engagement with the engagement surface. For example, the opposing bearing surface may be saturated with carbon. Without being bound by theory, it is believed that such application of carbon reduces the ability of the diamond solvent-catalyst in the opposing engagement surface to attract carbon through graphitization of the surface of the polycrystalline diamond element. That is, the carbon that is applied to the opposing surface functions as a sacrificial layer of carbon. The opposing surfaces disclosed herein may be surfaces that contain at least 2 wt. % of diamond solvent-catalyst.

[0085] With reference to FIGS. **1**A-**5**F, some exemplary opposing engagement surfaces include first gear tooth surfaces **118**, **218**, and **318**, and tooth surfaces **4030** and **5030**. In some embodiments, the opposing engagement surfaces are or include a metal or metal alloy that contains at least 2 wt. % of a diamond solvent-catalyst based on a total weight of the metal or metal alloy. The diamond solvent-catalyst may be iron, cobalt, nickel, ruthenium, rhodium, palladium, chromium, manganese, copper, titanium, tantalum, or alloys thereof. In some embodiments, the opposing engagement surfaces are or include a metal or metal alloy that contains from 2 to 100 wt. %, or from 5 to 95 wt. %, or from 10 to 90 wt. %, or from 15 to 85 wt. %, or from 20 to 80 wt. %, or from 25 to 75 wt. %, or from 25 to 70 wt. %, or from 30 to 65 wt. %, or from 35 to 60 wt. %, or from 40 to 55 wt. %, or from 45 to 50 wt. % of diamond solvent-catalyst based on a total weight of the metal or metal alloy (e.g., from 2 to 100 wt. %, of iron, cobalt, nickel, ruthenium, rhodium, palladium, chromium, manganese, copper, titanium, tantalum, or alloys thereof).

Driveline with Double Conical Joints

[0086] Certain embodiments of the present disclosure include methods and systems that include use of and/or incorporation of a driveline that includes one or more double conical joints that provide flexibility to the driveline (also referred to herein as a "double conical driveline"). The double conical driveline may be arranged as a flexible mechanical coupling between two moving parts, such as between an electric motor and a positive displacement pump (PDP).

[0087] With reference to FIGS. **7**A and **7**B, double conical driveline **700** is depicted. Double conical driveline **700** includes drive shaft **702**. Drive shaft **702** includes a first oscillatory coupling **704***a* at a first end thereof for coupling with a prime mover (e.g., motor), and a second oscillatory coupling **704***b* at a second end thereof for coupling with a machine (e.g., PDP).

[0088] First oscillatory coupling **704***a* includes bearing coupler **706***a* coupled with shaft **702**. Bearing coupler **706***a* may be pinned to, welded to, or otherwise fixedly attached to shaft **702**. In some embodiments, bearing coupler **706***a* is integral with shaft **702**, such that shaft **702** and bearing coupler **706***a* are a single-piece structure. First oscillatory coupling **704***a* includes double conical joint **708***a*. Double conical joint **708***a* includes first conical joint **712***a* coupled with or integral with second conical joint **712***b*. Each conical joint **712***a* and **712***b* has a conical surface thereon for coupling with and engagement with other parts of double conical driveline **700**. First conical joint **712***a* is coupled with bearing coupler **706***a* via spindle **714***a*. Spindle **714***a* is secured with bearing coupler **706***a* and first conical joint **712***a* via a crown nut **716***a*. Bearing coupler **706***a* and first conical joint **712***a* are each rotatable about spindle **714***a*. First oscillatory coupling **704***a* includes bearing coupler **706***b*. Second conical joint **712***b* is coupled with bearing coupler **706***b* via spindle **714***b*. Bearing coupler **706***b* and second conical joint **712***b* are each rotatable about spindle **714***b*. Spindle **714***b* is secured with bearing coupler **706***b* and second conical joint **712***b* via crown nut **716***b*.

[0089] Second oscillatory coupling **704***b* is identical or substantially identical to first oscillatory coupling **704***a* and includes bearing coupler **706***c* coupled with shaft **702**; double conical joint **708***b* having conical joint **712***c* coupled with or integral with conical joint **712***d*. Conical joint **712***c* is coupled with bearing coupler **706***c* via spindle **714***c*, and conical joint **712***d* is coupled with bearing coupler **706***d* via spindle **714***d*. Spindles **714***c* and **714***d* are secured via crown nuts **716***c* and **716***d*, respectively. Crown nuts **716***a*-**716***d* are each secured via a cotter pin (not shown). The double conical driveline disclosed herein is not limited to the structure shown in FIGS. **7**A and **7**B. For example, the double conical joints may be coupled with the bearing coupler using structures other than a spindle, crown nut, and cotter pin, while still attaining the double conical joint arrangement disclosed herein.

[0090] FIG. **8**A depicts a portion of a double conical driveline, assembly **899***a*, in accordance with embodiments of the present disclosure. Assembly **899***a* includes bearing coupler **806**. Spindle **814** is coupled with or integral with bearing coupler **806**. The position of spindle **814** relative to bearing coupler **806** is fixed, such that spindle **814** does not move relative to bearing coupler **806**. Spindle **814** includes a plurality of holes **818** about and through the outer surface thereof. Holes **818** are arranged and configured to receive cotter pins for securing a crown nut to spindle **814**.

[0091] FIG. **8**B depicts another portion of a double conical driveline, assembly **899***b*. Assembly **899***b* includes the bearing coupler **806** and spindle **814** of FIG. **8**A, but with double conical joint **808** coupled with spindle **814**. Each conical joint **812***a* and **812***b* includes a conical surface **820**, on both sides thereof, surrounding an opening **824**. Each opening **824** defines a conical axis **826***a* (horizontally on the page) and **826***b* (extending out of and going into the page). The conical axes **826***a* and **826***b* of double conical joint **808** are at an angle greater than 0° relative to one another. As shown in FIG. **8**B, the conical axes **826***a* and **826***b* are at an angle of 90°. The conical axes **826***a* and **826***b* are not parallel and do not intersect. In other embodiments, the conical axes do intersect. A plurality of polycrystalline diamond compacts **822** are positioned and coupled on each conical surface **820**. The plurality of polycrystalline diamond compacts **822** are positioned to provide the bearing surface(s) of double conical joint **808**.

[0092] FIG. **8**C depicts another portion of a double conical driveline, assembly **899***c*. Assembly **899***c* includes the bearing coupler **806**, spindle **814**, and double conical joint **808** as shown in FIG. **8**B, but with crown nut **816** coupled therewith. Crown nut **816** includes spaces **828** that are positioned such that at least some of the spaces **828** of crown nut **816** align with at least some of the holes **818** of spindle **814**, allowing for the coupling of a cotter pin therethrough to secure crown nut **816** onto spindle **814**.

[0093] FIG. **8**D depicts another portion of a double conical driveline, assembly **899***d*. Assembly **899***d* includes the bearing coupler **806**, spindle **814**, double conical joint **808**, and crown nut **816** of FIG. **8**C, but with the body of double conical joint **808** at least partially transparent to show the plurality of polycrystalline diamond compacts **822** therein. The surfaces of the polycrystalline diamond compacts **822** are power transmission surfaces of the double conical joint **808**. FIG. **8**E shows the opposite side of assembly **899***d*, as shown in FIG. **8**D, showing that both sides of each conical joint **812***a* and **812***b* include a conical bearing surface **820**.

[0094] With reference to FIGS. **9**A and **9**B, the engagement between the polycrystalline diamond compacts **922** on conical surface **920** and the crown nut **916** and spindle **914** is shown, particularly in the cross-sectional view of FIG. **9**B. Crown nut **916** is coupled with spindle via a pin (not shown) engaged through one of holes **918**. Double conical joint **908** includes conical joints **912***a* and **912***b*. With conical joint **912***a* coupled about spindle **914** and crown nut **916** secured to spindle **914**, diamond bearing surfaces **930** of each polycrystalline diamond compact **922** are engaged with and in sliding contact with an opposing bearing surface. The opposing bearing surfaces include opposing bearing surfaces **932** of crown nut **916** and opposing bearing surfaces **934** of spindle **914**. Each opposing bearing surface **932** and **934** is a metallic surface. Each opposing bearing surface **932** and **934** is a diamond reactive material, such as steel. Bearing coupler **906** moves relative to double conical joint **908** by rotating about conical axis **926***a*. During rotation of bearing coupler **906** about conical axis **926***a*, diamond bearing surfaces **930** are in sliding contact with opposing bearing surfaces **932** and **934**.

[0095] With reference to FIG. **10**, double conical driveline **1000** is coupled with rotor **1900**. More particularly, rotor **1900** is coupled with bearing coupler **1006***b* of double conical driveline **1000**. Rotor **1900** is rotatably engaged within stator **1902**. Rotation of rotor **1900** within stator **1902** imparts rotational force to bearing coupler **1006***b*, which imparts rotational force to double conical joint **1008***a*, which imparts rotational force to bearing coupler **1006***a*, which imparts rotational force to shaft **1002**, which imparts rotational force to bearing coupler **1006***c*, which imparts rotational force to double conical joint **1008***b*, which imparts rotational force to bearing coupler **1006***d*. Bearing coupler **1006***d* may be coupled with a machine or tool, such as a positive displacement pump to drive operation of the pump. Thus, rotation of bearing coupler **1006***d* may drive the machine or tool.

[0096] Double conical driveline **1000** has multiple degrees of freedom of motion in various directions, as provided by double conical joints **1008***a* and **1008***b*. The motions (degrees of freedom) available to double conical driveline **1000** during operation include: (1) rotation of the entire driveline **1000** about axis **1001***a*; (2) rotation of double conical joint **1008***a* about spindle **1014***b* at axis **1001***b*; (3) rotation of double conical joint **1008***a* about spindle **1014***a* at axis **1001***c*; (4) rotation of double conical joint **1008***b* about spindle **1014***c* at axis **1001***d*; and (5) rotation of double conical joint **1008***b* about spindle **1014***d* at axis **1001***e*. Each of these motions (1)-(5) is independent of the others, such that rotation about one of the spindles does not affect the availability of rotation about any of the other of the spindles and does not affect the ability of the entire double conical driveline **1000** to rotate about axis **1001***a*. These multiple degrees of freedom provided by the motions (1)-(5) provide the ability to double conical driveline **1000** to drive machinery under various states of"misalignment" of the double conical driveline **1000**. As used herein a "state of misalignment," in reference to the double conical driveline **1000**, refers to a physical arrangement, positioning, and/or state of the double conical driveline **1000** wherein an imaginary line passing through the center of each portion of the double conical driveline **1000** does not define a straight line. The degrees of freedom of motion that the double conical driveline **1000** has allows the double conical driveline **1000**

to react to various forces imparted onto the double conical driveline **1000** during operation, and allows the double conical driveline **1000** to oscillate during rotation in response to such forces. As the conical bearings bear load in all directions, and as each movable joint of the double conical driveline **1000** is provided by a conical bearing, the double conical driveline **1000** is capable of bearing load in all directions. During operation of the double conical driveline, forces are transmitted from torque in both forward and reverse directions. That is, the double conical driveline **1000** is capable of transmitting torque both when the double conical driveline **1000** is rotating clockwise about axis **1001***a* and when the double conical driveline **1000** is rotating counterclockwise about axis **1001***a*. Because the bearings of the double conical driveline **1000** are double conical bearings, the double conical driveline **1000** can bear axial loads both in tension and in compression.

[0097] In some embodiments, the double conical driveline and the conical bearings thereof are not scaled. In other embodiments, the double conical driveline and the conical bearings thereof are sealed. In some embodiments, the double conical driveline and the conical bearings thereof are not lubricated. In other embodiments, the double conical driveline and the conical bearings thereof are lubricated.

[0098] With reference to FIG. **11**, double conical driveline **1100** is coupled with prime mover **1170** at one end and is coupled with machine or tool **1160** at the other end. Prime mover **1170** may be a motor or engine, such as an eclectic motor or diesel engine. Machine or tool **1160** may be, for example and without limitation, farm equipment, mining equipment, downhole drilling and/or production equipment, assembly line equipment, steel mill equipment, automobile components, or marine (e.g., boat) components. Some exemplary applications of the double conical driveline **1100** disclosed herein are as a driveline between an electric motor and a pump, such as PDP or progressive cavity pump; as a driveshaft of an automobile, such as a heavy duty truck; as a steering column of an automobile; as a driveshaft of a boat propeller; as a driveline coupled with a wind turbine; as a driveline between an electric motor and an air compressor; a driveline for a downhole motor; and as a power take off (PTO) driveline on a tractor, such as to drive ploughing, harvesting, or other farming equipment. The driveline disclosed herein is not limited to these particular applications and may be used in various other applications.

[0099] While double conical driveline disclosed herein is shown as including a plurality of discrete polycrystalline diamond bearing elements in the form of PDCs, the double conical driveline is not limited to this arrangement, and the bearing surfaces of the double conical driveline may include continuous polycrystalline diamond bearing surfaces. Furthermore, while the double conical driveline disclosed herein is shown as having conical bearing surfaces, the drivelines disclosed herein are not limited to this arrangement. For example, the drivelines may include spherical bearing surfaces, a combination of radial and thrust bearing surfaces, or another bearing surface arrangement that is capable of bearing combined axial and radial loads. Also, while the drivelines disclosed herein are shown, in some embodiments, as having double conical joints at each end of the shaft, in other embodiments the driveline has a double conical joint only on one end thereof, such as for driving equipment.

Applications

[0100] In certain embodiments, the power transmission systems disclosed herein are suitable for deployment and use in harsh environments (e.g., downhole). In some such aspects, the power transmission systems are less susceptible to fracture than power transmission systems that include a polycrystalline diamond engagement surface engaged with another polycrystalline diamond engagement surface. In certain aspects, such harsh environment suitable power transmission systems provide enhanced service value in comparison with power transmission systems that include a polycrystalline diamond engagement surface engaged with another polycrystalline diamond engagement surface.

[0101] As would be understood by one skilled in the art, various forms of gear failure can occur including, but not limited to, bending fatigue, contact fatigue, wear, scuffing, overload, and cracking. Without being bound by theory, it is believed that gears incorporating the power transmission surfaces disclosed herein (i.e., a polycrystalline diamond power transmission surface engaged with a diamond reactive material power transmission surface) will exhibit a reduced occurrence of such gear failures. It is further believed that a reduction of universal joint failure will also occur for universal joints that incorporate the power transmission surfaces disclosed herein.

[0102] Although the present embodiments and advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the disclosure. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present disclosure. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

1. The driveline of claim **35**,

wherein the first double conical joint comprises a first conical joint including a conical bearing surface having the polycrystalline diamond element with the polycrystalline diamond bearing surface thereon, and a second conical joint coupled with the first conical joint, the second conical joint including a conical bearing surface having a polycrystalline diamond element with a polycrystalline diamond bearing surface having a surface finish of 20 μin or less;

wherein the first conical joint is rotatably coupled with the first bearing coupler such that the polycrystalline diamond bearing surface of the first conical joint is in sliding contact with the metal bearing surface of the first bearing coupler.

2. The driveline of claim **1**, further comprising:

a second bearing coupler, the second bearing coupler having a metal bearing surface comprising a metal that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the metal;

wherein the second conical joint is rotatably coupled with the second bearing coupler such that the polycrystalline diamond bearing surface of the second conical joint is in sliding contact with the metal bearing surface of the second bearing coupler.

3. The driveline of claim **2**, further comprising:

a third bearing coupler coupled with the second end of the drive shaft, the third bearing coupler having a metal bearing surface, the metal bearing surface comprising a metal that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the metal;

a second double conical joint coupled with the third bearing coupler, the second double conical joint comprising a third conical joint including a conical bearing surface having a polycrystalline diamond element with a polycrystalline diamond bearing surface having a surface finish of 20 μin or less thereon, and a fourth conical joint coupled with the third conical joint, the fourth conical joint including a conical bearing surface having a polycrystalline diamond element with a polycrystalline diamond bearing surface having a surface finish of 20 μin or less thereon;

wherein the third conical joint is rotatably coupled with the second bearing coupler such that the polycrystalline diamond bearing surfaces of the third conical joint is in sliding contact with the metal bearing surface of the second bearing coupler.

4. The driveline of claim **3**, further comprising:

a fourth bearing coupler, the fourth bearing coupler having a metal bearing surface comprising a metal that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the metal;

wherein the fourth conical joint is rotatably coupled with the fourth bearing coupler such that the polycrystalline diamond bearing surface of the fourth conical joint is in sliding contact with the metal bearing surface of the fourth bearing coupler.

5. (canceled)

6. The driveline of claim **2**, wherein the first conical joint is rotatable relative to the first bearing coupler about a first axis, wherein the second conical joint is rotatable relative to the second bearing coupler about a second axis, and wherein the first axis is at an angle of from greater than 0° to 90° relative to the second axis.

7. The driveline of claim **4**, wherein the first conical joint is rotatable relative to the first bearing coupler about a first axis, wherein the second conical joint is rotatable relative to the second bearing coupler about a second axis, and wherein the first axis is at an angle of from greater than 0° to 90° relative to the second axis; and

wherein the third conical joint is rotatable relative to the second bearing coupler about a third axis, wherein the fourth conical joint is rotatable relative to the fourth bearing coupler about a fourth axis, and wherein the third axis is at an angle of from greater than 0° to 90° relative to the fourth axis.

8. (canceled)

9. (canceled)

10. (canceled)

11. (canceled)

12. (canceled)

13. (canceled)

14. The driveline of claim **35**, wherein the diamond solvent-catalyst is selected from the group consisting of: iron, cobalt, nickel, ruthenium, rhodium, palladium, chromium, manganese, copper, titanium, tantalum, and combinations thereof.

15. The driveline of claim **35**, wherein the metal is softer than a superhard material.

16. The driveline of claim **35**, wherein the metal contains at least 55 weight percent of the diamond solvent based on the total weight of the metal.

17. A method of driving a machine, the method comprising:

providing a driveline, the driveline comprising a first double conical joint on a first end thereof and a second double conical joint on a second end thereof, each double conical joint having polycrystalline diamond elements with polycrystalline diamond bearing surfaces, the polycrystalline diamond bearing surfaces having surface finishes of 20 μin or less;

coupling a first bearing coupler between the first double conical joint and a prime mover such that a metal bearing surface of the first bearing coupler is in sliding contact with a polycrystalline diamond bearing surface of the first double conical joint, wherein the metal bearing surface of the first bearing coupler comprises a metal that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the metal;

coupling a second bearing coupler between the second double conical joint and a machine such that a metal bearing surface of the second bearing coupler is in sliding contact with a polycrystalline diamond bearing surface of the second double conical joint, wherein the metal bearing surface of the second bearing coupler comprises a metal that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the metal;

driving rotation of the driveline with the prime mover; and

driving the machine with the rotating driveline.

18. (canceled)

19. The method of claim **17**, wherein, during rotation of the driveline, the first and second conical joints oscillate through rotational positions about axes.

20. (canceled)

21. (canceled)

22. (canceled)

23. (canceled)

24. (canceled)

25. (canceled)

26. (canceled)

27. The method of claim **17**, wherein, during rotation of the driveline, the metal bearing surface of the first bearing coupler slides along the polycrystalline diamond bearing surface of the first double conical joint and the metal bearing surface of the second bearing coupler slides along the polycrystalline diamond bearing surface of the second double conical joint.

28. A system, the system comprising:

a driveline, the driveline comprising a first double conical joint on a first end thereof and a second double conical joint on a second end thereof, wherein the first double conical joints comprises a polycrystalline diamond element having a polycrystalline diamond bearing surface, wherein the second double conical joints comprises a polycrystalline diamond element having a polycrystalline diamond bearing surface, and wherein the polycrystalline diamond bearing surfaces each have a surface finish of 20 μin or less;

a prime mover;

a first bearing coupler positioned between the first double conical joint and the prime mover such that a metal bearing surface of the first bearing coupler is in sliding contact with the polycrystalline diamond bearing surface of the first double conical joint, wherein the metal bearing surface of the first bearing coupler comprises a metal that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the metal;

a machine;

a second bearing coupler positioned between the second double conical joint and the machine such that a metal bearing surface of the second bearing coupler is in sliding contact with the polycrystalline diamond bearing surface of the second double conical joint, wherein the metal bearing surface of the second bearing coupler comprises a metal that contains at least 2 weight percent of diamond solvent-catalyst based on a total weight of the metal;

wherein the prime mover is configured to drive rotation of the driveline, and wherein the driveline is configured to drive the machine.

29. The system of claim **28**, wherein the prime mover is a motor and the machine is a positive displacement pump.

30. The system of claim **29**, wherein the motor comprises a rotor movably positioned within a stator.

31. (canceled)

32. The system of claim **28**, wherein the machine is farm equipment, mining equipment, downhole drilling or production equipment, assembly line equipment, steel mill equipment, an automobile component, or a boat component.

33. The system of claim **28**, wherein the driveline is a driveshaft of an automobile, a steering column of an automobile, a driveshaft of a boat propeller, a driveline coupled with a wind turbine, a driveline coupled with an air compressor, or a power take off driveline on a tractor.

34. (canceled)

35. A driveline with double conical joints, the driveline comprising:

a drive shaft having a first end and a second end;

a first bearing coupler at the first end of the drive shaft, the first bearing coupler having a metal bearing surface, the metal bearing surface including a metal that contains at least 2 wt. % diamond solvent-catalyst based on a total weight of the metal; and

a first double conical joint comprising a polycrystalline diamond element thereon, the polycrystalline diamond element having a polycrystalline diamond bearing surface with a surface finish of 20 μin or less;

wherein the first double conical joint is rotatably coupled with the first bearing coupler such that the polycrystalline diamond bearing surface of the first double conical joint is in sliding contact with the metal bearing surface of the first bearing coupler.

36. The driveline of claim **35**, wherein the first bearing coupler is integral with the drive shaft.

37. The driveline of claim **35**, wherein the first bearing coupler is coupled with the drive shaft.

38. The driveline of claim **35**, wherein the polycrystalline diamond element comprises a polycrystalline diamond compact.

39. A driveline with double conical joints, the driveline comprising:

a drive shaft having a first end and a second end;

a first bearing coupler at the first end of the drive shaft, the first bearing coupler having a metal bearing surface, the metal bearing surface including a metal that contains at least 2 wt. % of iron, cobalt, nickel, ruthenium, rhodium, palladium, chromium, manganese, copper, titanium, tantalum, or combinations thereof based on a total weight of the metal; and

a first double conical joint comprising a polycrystalline diamond element thereon, the polycrystalline diamond element having a polycrystalline diamond bearing surface with a surface finish of 20 μin or less;

wherein the first double conical joint is rotatably coupled with the first bearing coupler such that the polycrystalline diamond bearing surface of the first double conical joint is in sliding contact with the metal bearing surface of the first bearing coupler.

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