



- (51) International Patent Classification:
E21B 17/02 (2006.01) *E21B 47/01* (2012.01)
- (21) International Application Number:
PCT/US2014/018816
- (22) International Filing Date:
27 February 2014 (27.02.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
13/850,236 25 March 2013 (25.03.2013) US
- (71) Applicant (for CA only): **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G-0P6 (CA).
- (71) Applicant (for FR only): **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, 75007 Paris (FR).
- (71) Applicant (for GB, JP, NL only): **SCHLUMBERGER HOLDINGS LIMITED** [GB/GB]; P.O. Box 71, Craigmuir Chambers, Road Town, 1110 Tortola, Virgin Islands, British Virgin Islands (GB).
- (71) Applicant (for all designated States except CA, FR, GB, JP, NL, US): **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).
- (71) Applicant (for AE, AO, BF, BH, BJ, CF, CG, CI, CM, CN, GA, GH, GN, GQ, GW, IN, LY, MA, ML, MR, MZ, NA, NE, NG, PH, SD, SN, SY, TD, TG, VN only): **PRAD RESEARCH AND DEVELOPMENT LIMITED** [GB/GB]; P.O. Box 71, Craigmuir Chambers, Road Town, 1110 Tortola, Virgin Islands, British Virgin Islands (GB).
- (71) Applicant (for US only): **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, TX 77478 (US).
- (72) Inventors: **NIINA, Nobuyoshi**; 14 Coburn Gardens, Cheltenham, Gloucestershire, GL51 0GE (GB). **POLYNTSEV, Oleg**; 76 Kempton Grove, Cheltenham, Gloucestershire, GL51 0JU (GB). **MENGER, Christian**; Hugostrasse 7, 49509 Recke (DE). **DOWNTON, Geoffrey C.**; 2 Ricardo Road, Minchinhampton, Stroud, GL6 9BY (GB).
- (74) Agents: **SULLIVAN, Chadwick A.** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, TX 77042 (US).

[Continued on next page]

(54) Title: MONITORING SYSTEM FOR DRILLING INSTRUMENTS

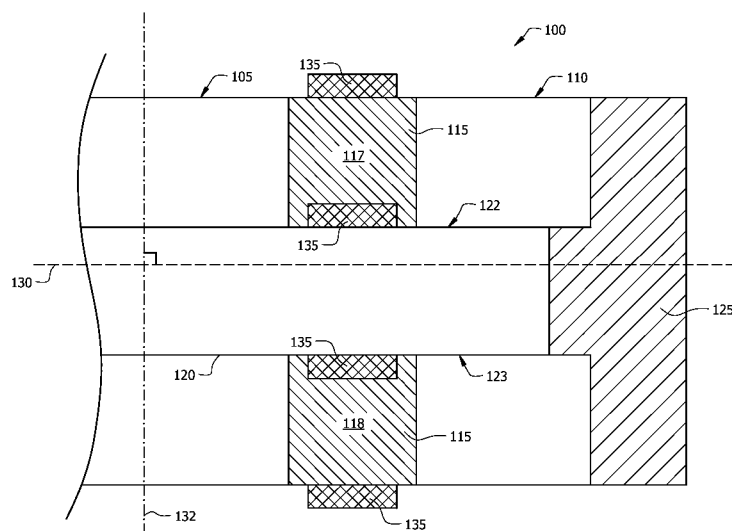


FIG. 1

(57) Abstract: Drilling instruments may include a flexible portion, such as a flexible conduit and/or a universal joint. Sensors may be utilized to detect the position of various portions of the drilling instrument, such as the flexible conduit, the universal joint, and/or a drill bit assembly.



(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

Monitoring System for Drilling Instruments

Background

[0001] In some drilling applications, drilling may be implemented in a variety of directions. For example, directional drilling and/or horizontal drilling may be implemented in various formations, such as oil and gas formations, shale formations, coal bed formations, and/or tar sand formations. As another example, lateral holes or drainage holes may be drilled to increase communication of a formation with a main borehole drilled in a formation for production of various compounds.

Summary

[0002] In various implementations, a drilling instrument may include a flexible conduit, a universal joint, and/or sensor(s). The flexible conduit may be disposed at least partially in the universal joint. The sensor(s) may detect position information about the flexible conduit. A drilling instrument may be monitored. A signal may be detected from sensor(s) disposed on a flexible conduit and position information of the flexible conduit may be determined based at least partially on the detected signal. The performance of a drilling instrument may be tested. A first control signal(s) for a drill bit assembly of a drilling instrument may be transmitted and a signal from sensor(s) may be detected. The control signal may be associated with a first position of the drill bit assembly. The position information of the drill bit may be determined at least partially based on the detected signal, and the determined position information of the drill bit assembly may be compared to the first position of the drill bit assembly.

Brief Description of the Drawings

[0003] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements, and:

[0004] Figure 1 illustrates a cross-sectional view of an implementation of a portion of an example drilling instrument.

[0005] Figure 2 illustrates a cross-sectional view of an implementation of a portion of an example drilling instrument.

[0006] Figure 3 illustrates a cross-sectional view of an implementation of an example sensor arrangement.

[0007] Figure 4 illustrates an implementation of an example sensor arrangement.

[0008] Figure 5 illustrates an implementation of deflection in an example flexible conduit.

[0009] Figure 6 illustrates an implementation of deflection in an example flexible conduit.

[0010] Figure 7 illustrates an implementation of an example process for monitoring a drilling instrument.

[0011] Figure 8 illustrates an implementation of an example processes for testing and/or monitoring a drilling instrument.

Detailed Description

[0012] The following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

[0013] In some implementations, monitoring systems for drilling instruments or tools may be utilized when drilling into formations in the earth. For example, formations may include petroleum and/or gas reserves that may be produced by drilling using drilling instrument(s) into the formation. The drilling may be multidirectional and thus, a drill instrument capable of drilling in various directions may be utilized. The drilling instrument may include a universal joint, a flexible portion, sensors, and/or a drill bit assembly. For example, a drilling instrument may include a flexible portion, such as a flexible conduit, that has the ability to bend in the direction of the drill bit assembly. A universal joint and/or the flexible conduit may bend in the direction of drilling and/or may transmit rotational power (e.g., via the transmission of drilling

mud) to the drill bit to form the main borehole, lateral boreholes, drain holes, etc. The direction of drilling by the drill bit assembly may be based at least partially on the movement and/or position of the universal joint and/or the flexible conduit.

[0014] As loads due to drilling operations and/or the formation are transmitted to the flexible conduit, universal joint, and/or bottom hole assembly, the orientation of the flexible conduit, universal joint, and/or bottom hole assembly (e.g., drill bit) may be distorted and/or altered from the expected orientation based on control signals to the drilling instrument. For example, the axial load path may pass through the universal joint (e.g., the flexible conduit may not be utilized to transmit torsional energy). In some implementations, the flexible conduit may transmit the torsional energy and/or axial loads across the drilling instrument. The universal joint and the flexible conduit may transmit the torsional energy and/or axial loads across the drilling instrument, in some implementations. By measuring the distortions and/or altered orientations (e.g., from reference orientations and/or from expected orientations), a more accurate orientation of the flexible conduit, universal joint, and/or bottom hole assembly may be determined. The determined orientation may be utilized in monitoring components of the drilling instrument, feedback loops, and/or in any other appropriate manner.

[0015] Figure 1 illustrates a cross-sectional view of an implementation of a portion 100 of an example drilling instrument. Figure 2 illustrates a cross-sectional view of an implementation of a portion 200 of an example drilling instrument. The drilling instrument may include other components not illustrated in Figures 1 and 2.

[0016] As illustrated in Figures 1 and 2, the drilling instrument may include a first part 105 coupled to a second part 110. To allow multidirectional drilling (e.g., vertical, horizontal, and/or slant drilling), the second part 110 may move with respect to the first part 105.

[0017] A universal joint 115 may be disposed between the first part 105 and the second part 110. The universal joint 115 may allow movement (e.g., bending, torsion about an axis, deflecting and/or axial compression or tension) of the second part 110 with respect to the first part 105. The universal joint 115 may have one degree of freedom (e.g., a hinge), two degrees of freedom (e.g., a Hooke's joint), and/or three degrees of freedom (e.g., a spherical ball joint). For example, a universal joint 115 may bend in an x and/or y direction and/or the universal joint may include a spherical joint that may move in an x, y, and/or z direction. The movement of the

universal joint 115 may be measured radially about an axis and/or with respect to two or more axes (e.g., x, y coordinates).

[0018] A flexible conduit 120 (e.g., a flexible tube) may be positioned at least partially in the universal joint 115. For example, the flexible conduit 120 may pass through the universal joint 115 and couple with a drill bit assembly 125.

[0019] In some implementations, one or more electrical wires may be disposed in or on the flexible conduit 120, and the one or more wires may pass from one end to the opposing end of the flexible conduit 120 to enable the passage of power and communication between systems disposed on either side of, or even attached to the flex tube.

[0020] The flexible conduit 120 may include at least a portion that is flexible. The flexible portion of the flexible conduit 120 may be elastically deformable and/or bendable. In some implementations, one or more of the materials that form the flexible conduit 120 may be selected for properties of the materials. For example, at least a portion of the flexible conduit 120 may include materials that are conductive or nonconductive. At least a portion of the flexible conduit 120 may include materials that are magnetic, nonmagnetic, and/or locally magnetized, in some implementations. At least a portion of the flexible conduit 120 may include embedded magnets. In some implementations, the flexible conduit 120 and/or portions thereof may include materials that are opaque or transparent (e.g., to light, magnetic field and/or electrical fields). For example, the flexible conduit 120 and/or portions thereof may include materials with properties to facilitate visualization of sensors external to the conduit, imaging and/or sensing the fluid flowing within the flexible conduit 120 and/or sensors. In some implementations, the flexible conduit 120 may include markings inside the flexible conduit to facilitate measuring the deflection of the flexible conduit.

[0021] The flexible conduit 120 may have one, two, and/or three degrees of freedom. For example, the flexible conduit 120 may bend in an x and/or y direction (e.g., along an x-axis (not shown) and y-axis 132) and/or the flexible conduit 120 may deflect in an x, y, and/or z direction (e.g., along an x-axis (not shown), y-axis 132, and z-axis 130, where the x-axis is perpendicular to the y-axis and the z-axis and/or torsionally about the z-axis). The movement of the flexible conduit 120 may be measured radially about an axis and/or with respect to two or more axes. For example, torsion of the flexible conduit 120 about the z-axis 130 may occur. The flexible conduit 120 may bend about the x-axis and/or y-axis.

[0022] In some implementations, the movement of the flexible conduit 120 may be restricted. For example, at least a portion of a first surface 122 of the flexible conduit 120 may be coupled to at least a portion of a first part 117 of the universal joint 115 and/or at least a portion of a second surface 123 of the flexible conduit 120 may be coupled to at least a portion of a second part 118 of the universal joint 115. The movement of the flexible conduit 120 may be restricted by this coupling arrangement, such that the flexible conduit 120 may be restricted from rotating by the universal joint 115 and/or allowed to bend in two directions (e.g., with respect to the first axis 130, the second axis 132 perpendicular to the first axis, and a third axis (not shown) perpendicular to the first axis and the second axis).

[0023] In some implementations, the movement of the flexible conduit 120 relative to the universal joint 115 may be based at least partially on the type of coupling between the flexible conduit 120 and the universal joint 115. For example, the flexible conduit 120 may conform to the lateral bending of the universal joint 115. The flexible conduit 120 may be independently driven to rotate about the z-axis 130, for example, if the bit is driven with a motor (e.g., the motor is using the joint to transmit torque). In some implementations, the flexible conduit 120 or portions thereof may be free to rotate about the z-axis 130 (e.g., due to the insertion of a rotary bearing that allows one end of the flexible conduit 120 to rotate independently from the other end). For example, the flexible conduit 120 may be able to rotate about the z-axis 130 without restriction when a universal joint, such as a 3D ball joint, is utilized and either end of the flexible conduit 120 may be attached to the adjacent collar.

[0024] In some implementations, drilling mud may be channeled through the center of the flexible conduit and/or around the outside of the flexible conduit . For example, the flexible conduit may transport drilling fluid across the joint such that a pre-determined pressure is maintained. Thus, a seal for the universal joint, which may be structurally complex and/or the load/torsion transmitting member, against high pressures may not be utilized when the drilling fluid is channeled through the flexible conduit.

[0025] In some implementations, drilling fluid may be transmitted across the universal joint external to the flexible conduit 120. The universal joint may be sealed to inhibit damage and/or wear from the high pressure drilling fluid. The fluid in the flexible conduit may be maintained separately from the drilling fluid external to the flexible conduit. For example, in a reverse

circulating systems, where flow returns to the surface via the flexible conduit, drilling fluid may be transmitted across the universal joint external to the flexible conduit.

[0026] In some implementations, the sensors or portions thereof (e.g., the wires) may be protected (e.g., disposed in a protective housing) from the drilling mud. The direction of the drilling may be based at least partially on the movement of the universal joint 115.

[0027] The drill bit assembly 125 may be coupled to the second part 110 of the drilling instrument and/or the flexible conduit 120. The drill bit assembly 125 may include a drill bit used in the cutting of the formation. In some implementations, as control of the position of the drill bit is increased, the cutting tolerance may be improved. The drill bit assembly 125 may also include other components, such as a bit shaft; a collar; and/or receiving members to couple with the flexible conduit 120, the second part 110 of the drilling instrument, and/or other components of the drilling instrument.

[0028] The drill bit assembly 125 may include a rigid portion. In some implementations, the drill bit assembly 125 may be more rigid (e.g., less flexible) than the flexible conduit 120. Thus, knowledge of position information (e.g., relative and/or absolute, with respect to one or more axes) of the flexible conduit 120 may allow the position information of the drill bit assembly 125 to be determined.

[0029] The drilling instrument may include one or more sensors 135 to monitor various components and/or properties of the drilling instrument. As illustrated in Figures 1 and 2, the sensors 135 may be coupled (e.g., directly and/or indirectly) to the flexible conduit 120 and/or the universal joint 115. The sensor(s) 135 may be disposed inside and/or outside the flexible conduit, in some implementations. The sensor(s) may be within the flexible conduit (e.g., at least partially integrated and/or embedded into the flexible conduit). In some implementations, the sensors 135 may be communicably coupled to the flexible conduit 120 and/or the universal joint 115 such that properties of the flexible conduit 120 and/or the universal joint 115 may be monitored.

[0030] The sensors 135 may include any appropriate sensing element, such as strain gauges and/or displacement sensors. In some implementations, sensors 135 may include optical fibers. Sensors 135 may include eddy current displacement sensors, capacitive displacement sensors, magnetic proximity sensors (e.g., Hall Effect sensors/ magnetometers) , linear variable differential transformer sensors (LVDT sensors), differential variable reluctance transformer

sensors (DVRT sensors), and/or non-contact DVRT sensors, optical and ultrasonic ranging sensors. The sensors 135 may detect temperature, pressure, position, linear and or angular deflection, compression, extension, axial loads, torque, and/or any other appropriate property of the drilling instrument and/or portions thereof.

[0031] The sensors 135 may measure changes in the shape of a component (e.g., an optical fiber may be utilized to measure changes in the shape of the flexible conduit 120). In some implementations, sensors that include eddy current displacement sensors may measure distances, displacements, and/or positions of electrically conductive components and/or portions thereof. The eddy current displacement sensors may be communicably coupled to various components of the drilling instrument and/or may allow measurement without direct coupling to a component. The eddy current displacement sensors may inhibit wear on components of the drilling instrument due to the sensor, during measurement. Capacitive displacement sensors may allow measurements in high linearity and/or wide ranges (e.g., from a few centimeters to a few nanometers).

[0032] The measurements by sensors 135 may be relative, differential and/or absolute measurements, in some implementations. For example, the deflection of the flexible conduit 120 may be measured with respect to the first part 105 or a portion thereof, such as with respect to a collar 108 of the drilling instrument, as illustrated in Figure 2.

[0033] Sensors 135 may measure one or more properties of a component of the drilling instrument with which it is communicably coupled (e.g., a displacement sensor may not make direct contact with a flexible conduit but may allow measurement of deflection of and/or strain on a flexible conduit). In some implementations, sensors 135 may measure more than one property, and an arrangement of sensors and/or selection of types of sensors may measure a first property while inhibiting measurement of a second property and/or interference with the measurement of the first property due to the second property. For example, a flexible conduit 120 may expand due to temperature and/or forces on the drilling instrument. The measurement of the expansion due to temperature may be inhibited while the measurement of the expansion due to forces on the drilling instrument may be allowed. In some implementations, measurement of properties from pressure effects due to operation downhole may be inhibited.

[0034] The sensors 135 of the drilling instrument may be selected based on the property that is to be measured. The sensors 135 of the drilling instrument may be selected based upon

downhole conditions and/or the ability of a sensor to resist damage due to exposure to downhole conditions. For example, sensors, such as eddy current sensors, may resist damage from oil, dirt, dust, moisture, interference fields, and/or other downhole conditions.

[0035] The sensors 135 may transmit a signal that may be used, at least in part, to determine position information (e.g., relative to a predetermined position and/or an absolute position) of at least a portion of the drilling instrument. For example, sensors may be coupled (e.g., communicably, directly and/or indirectly) to a flexible conduit 120 to measure a property of the flexible conduit 120. The sensors 135 may directly measure deflection and/or the sensors 135 may measure a property through which deflection may be determined. The sensors 135 may transmit the signal from a measurement and the signal may be used to determine position information of the flexible conduit 120.

[0036] Position information may include a relative and/or an absolute position of a component. The position information may include deflection, degree of bending, degree of torsion about an axis, degree of axial compression and tension, and/or other information related to the position of a component. For example, the position information may include a deviation in position of a flexible conduit 120 from a predetermined position of the flexible conduit 120 (e.g., a reference position, an expected position associated with a control signal, and/or a previous position) and/or with respect to a component of the drilling instrument.

[0037] During operation, the position of the drill bit assembly 125 may fluctuate since the flexible conduit 120 bends and/or moves torsionally during use due to the flexible properties of the flexible conduit 120. The position information of the flexible conduit 120 may be measured and at least partially utilized to determine a position of the drill bit assembly 125 and/or portions thereof. The direction of drilling may be determined based at least partially on a position of the drill bit assembly 125.

[0038] For example, utilizing measurements of the sensor(s) on the flexible conduit and/or the universal joint, the pointing angle of the universal joint may be determined. The position (e.g., direction) of the drill bit may be determined from the determined pointing angle of the universal joint. In some implementations, the sensor(s) on the flexible conduit and/or the universal joint may be utilized to determine the loads and torsions being experienced by the universal joint and/or the flexible conduit. The measurements from the sensor(s) on the flexible conduit and/or the universal joint may be utilized to determine the extent of any angular rotation

across the joint (e.g. in a 3D ball joint). The measurements from the sensor(s) on the flexible conduit and/or universal joint may be utilized to determine differential pressure across the flexible conduit, temperature of the joint (e.g., for wear assessments), measurement of accumulated fatigue damage of the flexing members etc.

[0039] In some implementations, a rotation of a collar (e.g., collar 108 in Figure 2) above a flexible conduit 120 and/or universal joint 115 may be determined. The rotation of the collar may be utilized with the determined position information of the flexible conduit 120, universal joint 115, and/or drill bit assembly 125 to obtain real time (e.g., during use) drill bit pointing direction. The drill bit pointing direction may be utilized to improve control and/or steering (e.g., when compared to a drilling instrument in which position information may not be determined such that the drill bit pointing direction is assumed).

[0040] In some implementations, the measurements from sensors 135 may be utilized to determine the condition of a component of the drilling instrument. For example, wear on a component and/or catastrophic mechanical failure may be inhibited by determining a condition of a component. In some implementations, the range of motion of a component in good condition may be restricted to a predetermined range, and detecting motion of the component outside of that range may identify wear on the component. Thus, the component may be replaced and/or fixed, for example, prior to excessive wear on the component and/or prior to catastrophic mechanical failure of the drilling instrument.

[0041] In some implementations, the measurements from the sensors 135 may be utilized to determine the behavior and/or properties of components in the bottom hole assembly. For example, one or more sensors may be disposed anywhere along the bottom hole assembly, such as between connections, for example. Information about the behavior of the bottom hole assembly may be determined based at least partially on measurements from such sensors disposed along the bottom hole assembly and/or the sensors disposed proximate the flexible conduit. In some implementations, the measurements from the sensors proximate one or more components of the bottom hole assembly and/or the flexible conduit may be utilized to determine performance issues, such as whether sticking in the bottom hole assembly is located near the drill bit or near another component of the bottom hole assembly.

[0042] In some implementations, the rotating position proximate the drill bit may be determined based at least partially on the information from one or more additional sensors. For

example, the additional sensors may include a multi-axis accelerometer and/or a magnetometer. The rotating position of the bottom hole assembly may be determined at least partially based on information from the additional sensors and drill bit pointing information may be determined at least partially from the sensors 135 proximate the flexible conduit 120. The bottom hole assembly rotating position and the drill bit pointing direction may be utilized in a variety of operations of the drilling instrument. For example, how the tool face is maintained and/or how resultant forces are applied may be determined. A resultant force may include information about the distribution angle and absolute force amount in the desired direction. During slip-stick scenarios, there may be a lag due to fast angular rotation and/or deceleration and a control system attempting to react to quickly changing conditions may not be able to reduce the slip-stick scenario, in some implementations. In some implementations, the control system may utilize the information from the additional sensors and the sensors 135 near the flexible conduit 120 to apply a resultant force over a time period. The absolute force in the desired direction may be reduced by the control system to result in less dog leg severity. Thus, in some implementations, slip-stick may be reduced since the control system may be able to change over time rather than too quickly.

[0043] As illustrated in Figures 1 and 2, sensors 135 may be disposed proximate and/or coupled to the universal joint 115. The sensors 135 may generate signals related to the position of the universal joint 115 and/or the flexible conduit 120. The position information about the universal joint 115 may provide a degree of bending and/or torsion of the universal joint 115 and/or information about the condition of the universal joint. For example, excessive bending and/or torsional movement (e.g., bending greater than a predetermined range) may be associated with excessive wear on the universal joint 115. In some implementations, sensors 135 on the universal joint 115 may detect a seal breach causing oil to leak and drilling fluid to seep in. For example, a sensor may short circuit if drilling fluid contacts the sensor. The short circuit may generate a signal that indicates the damage and thus the condition of a component (e.g., the portion proximate a leak). By monitoring the condition of the universal joint, the universal joint may be repaired and/or replaced prior to mechanical failure during use, for example.

[0044] In some implementations, a drilling instrument with sensors 135 communicably coupled to a flexible conduit 120 and/or a universal joint 115 may be simple and/or easy to maintain. Incorporating the sensors 135 in, on, and/or proximate the universal joint 115 and/or

flexible conduit 120 may facilitate maintenance on components of the drilling instrument, cause less wear on parts, and/or simplify assembly of the drilling instrument. Wires coupling sensors 135 on the flexible conduit 120 may be coupled to the flexible conduit 120 and thus provide easy access to the wires, avoiding the need to pass wires through the universal joint 115.

[0045] In some implementations, the wires coupling sensors 135 on the flexible conduit 120 may pass through the universal joint 115. Slip rings and/or inductive couplers may be utilized, in some implementations, to bypass the joints.

[0046] In some implementations, sensor position in the drilling instrument may be determined based on properties of the drilling instrument, such as deflection properties of components (e.g., flexible conduit and/or universal joint) of the drilling instrument. For example, a sensor position may be based on deflection properties of the flexible conduit. A flexible conduit may have restricted movement (e.g., due to coupling with the universal joint). The sensors may be positioned proximate a portion and/or a surface of the flexible conduit that is more prone to movement than another position. Sensor positions in the drilling instrument may be determined based at least partially using finite element analysis. For example, finite element analysis may determine that a first portion on a flexible conduit may be less sensitive to deflection (e.g., bending and/or torsion) than a second portion, and thus a sensor may be communicably coupled to (e.g., capable of measuring) the second portion to detect deflection (e.g., bending and/or torsion) of the flexible conduit.

[0047] In some implementations, a position of the flexible conduit may be determined based on properties of the drilling instrument, such as strains in the structures that couple the flexible conduit and the collar. For example, by measuring the strain in the structures that lock and/or otherwise couple the flexible conduit and the collar (e.g., above and/or below the joint) a deflection (e.g., bending and/or torsion) of the flexible conduit may be determined (e.g., since the flexible conduit may act similar to a cantilevered beam imposing moments and loads on its retention means).

[0048] Figure 3 illustrates an implementation of an example arrangement 300 of sensors. The sensors may include sensing elements, such as sets of strain gauges 305, 310, 315, 320, 325, 330, 335, 340 coupled to a flexible conduit 345. The strain gauges 305, 310, 315, 320, 325, 330, 335, 340 may be used to measure the extent of strain on the flexible conduit 345. The positional information may be determined from the signals transmitted by the sensing elements 305, 310,

315, 320, 325, 330, 335, 340. For example, the magnitude and/or the direction of deflection (e.g., bending and/or torsion) of the flexible conduit 345 may be measured using the sensors.

[0049] As illustrated, the sets of sensing elements (e.g., two sensing elements are shown per set, such as set 305, 315) are disposed at approximately 90 degrees apart from each other circumferentially. In some implementations, the sensors and/or sets of sensing elements may be disposed between approximately 60 degrees and approximately 120 degrees apart from each other circumferentially. Positioning the sets of sensing elements (e.g., set 305, 315) at approximately 90 degrees apart from another set of sensing elements (e.g., 340, 330 and/or 335, 325) may allow measurement of bending strains in two perpendicular planes. Although positioning the sets of sensing elements at 90 degrees apart is described, the sets of sensing elements may be disposed about a component at various angles and positional information may be determined based on the signals from the sensing elements and/or the angles at which the sensing elements are disposed.

[0050] As illustrated, strain gauges 305, 315 are disposed about the flexible conduit 345 at approximately 180 degrees apart circumferentially from strain gauges 310, 320. The positioning of the strain gauges may allow identification of nonpositional influences, such as thermal stresses, compression loads, and/or tension loads, on the signal from the strain gauges. Identification and/or reduction of the influence of nonpositional influences may allow positional information to be more accurately determined using the signal(s) from the strain gauges. Pressure differentials (e.g., from operation downhole) may be identified in the signal due to the arrangement of the strain gauges and so positional information may be more accurately determined.

[0051] In some implementations, the strain gauges may be coupled in a Wheatstone bridge arrangement, as illustrated in the implementation of an example sensor arrangement 400 in Figure 4. The strain gauges 305, 310, 315, 320 of a sensor arrangement 400 may be coupled in a Wheatstone bridge arrangement. The sensor arrangement 400 may reduce the effect of nonpositional influences on the signal from the sensor. For example, the arrangement stays balanced (e.g., the effect of nonpositional influences is inhibited) with thermal stresses, pressure stresses, compression loads, and/or tension loads. Wheatstone bridge imbalances and/or imbalances in the arrangement may result in a voltage reading, ϵ_0 , that indicates bending strain. For example,

$$\epsilon_o = K_s \times \epsilon_o \times E$$

where **Ks** is the gauge factor, **εo** is the bending strain, and **E** is the applied bridge voltage. Utilizing an arrangement, such as sensor arrangement 400, may allow a determination of positional information within plus or minus ten degrees, in some implementations.

[0052] Figure 5 illustrates an implementation of an example arrangement 500 of sensors. The movement (e.g., deflection, bending and/or torsion) of the flexible conduit 120 from a first position 505 to a second position 510 may be monitored by sensors 515, 520. The sensors 515, 520 may be displacement sensors. The displacement sensors 515, 520 may measure radial deflection of the flexible conduit 120. For example, the displacement sensors 515, 520 may measure the torsion of the flexible conduit 120 about a first axis, which is normal to the second axis 530 and the third axis 535. The displacement sensors 515, 520 may measure the bending of the flexible conduit 120 in a direction along the second axis 530 and/or the third axes 535. The sensors 515, 520 may generate a signal related to the movement. The deflection 525 of the flexible conduit 120 in a plane (e.g., the plane of the second axis 530 and the third axis 535) may be determined from the generated signal. The determined deflection 525 may then be utilized to determine the position of the drill bit assembly 125. The movement may be in relation to another position, such as in relation to a predetermined reference position, an initial determined position, and/or one or more components of the drilling instrument (e.g., a collar, a plane perpendicular to at least a portion of drilling string, to the wellbore, and/or a first portion of the drilling instrument).

[0053] Figure 6 illustrates an implementation of an example movement of a portion 600 of the drilling instrument. At least a portion of the flexible conduit 120 may move during use from a first position 605 to a second position 610 and the deflection 615 may be determined. The movement may be due to movement of the universal joint 115 and/or stress on the flexible conduit 120 (e.g., from downhole operation and/or from movement of the drill bit assembly 125). As illustrated in Figure 6 and Figure 5, in some implementations, the flexible conduit 120 may be capable of deflection in three directions along a first axis 620, a second axis 530, and a third axis 535. The sensors may be disposed to be capable of measuring the deflection in these three directions along axes 620, 530, 535. The sensors may be capable of measuring the torsion of the

flexible conduit 120 about axes 620, 530, and/or 535 and/or the bending and/or torsion of the flexible conduit along the axes 620, 530, and/or 535.

[0054] In some implementations, deflections during use may be based on control signals received by the drilling instrument to guide the drill bit assembly 125 to a predetermined position. The deflections may be due to other operational properties during use. For example, during use, the formation and/or drilling in the formation may act upon the drill bit assembly 125, universal joint 115, and/or flexible conduit 120 to deflect various components. As another example, the condition of components of the drilling instrument may allow deflections during use outside a predetermined range, which may indicate a condition, such as component wear.

[0055] Figure 7 illustrates an implementation of an example process 700 for monitoring a drilling instrument. Signal(s) may be detected from sensor(s) (operation 705). For example, sensors may measure positional information and generate a signal related to positional information and/or health/condition of a component of the drilling instrument. The sensing elements of the sensor may detect a change (e.g., due to position and/or strain on the component) and generate a signal based on the change. The sensors may be coupled (e.g., communicably, directly, indirectly) to the flexible conduit and/or universal joint.

[0056] Position information for one or more components of the drilling instrument may be determined at least partially based on the detected signal(s) (operation 710). For example, signals from sensors coupled to the flexible conduit may be utilized to determine position information (e.g., deflection) of the flexible conduit. Signals from sensors coupled to the universal joint may be utilized to determine position information of the universal joint. In some implementations, the signals from sensors coupled to the flexible conduit and/or the universal joint may be utilized to determine position information of the drill bit assembly. Knowledge of the drill bit assembly may improve control of the drilling direction during use.

[0057] A determination may be made regarding whether the determined position information is within a predetermined range (operation 715). For example, a predetermined range of movement may be allowed during use and determinations may be made regarding whether the movement is outside the predetermined range of allowed movement. As another example, to account for fluctuations in sensor readings and/or inconsequential movements, a predetermined range of movement tolerance may be allowed. A determination may be made whether the

flexible conduit, for example, is deflecting based on a comparison of the determined position information to the predetermined range of movement tolerance.

[0058] Property information may be determined based at least partially on the determined position information (operation 720). A property, such a health/condition of a component, may be determined based on the position information. For example, when drilling mud in the drilling instrument contacts a sensor, which is ordinarily isolated from the drilling mud, the sensor may short-circuit. The signal from the sensor may thus indicate the oil leakage/ drilling mud ingress and the health/condition of the drilling instrument. As another example, as a component, such as the flexible conduit, wears, the flexible conduit may allow a greater elastic deformation than when the flexible conduit was initially put in use. The sensors may detect the position of the flexible conduit, and thus the increase in movement of the flexible conduit, and thereby the health/condition of the flexible conduit may be determined. Monitoring a health/condition of various components of the drilling instrument may allow early detection of problems and thus, inhibit mechanical failure during use. For example, components may be repaired and/or replaced based on the determined health/condition of the component.

[0059] A control signal may be determined based at least partially on the determined position information (operation 725). In some implementations, sensors may be coupled to the flexible conduit. The sensors may indicate position information for the flexible conduit and the position of the drill bit assembly may be determined based on the flexible conduit position. The control signal may be determined based on the determined position of the drill bit assembly. For example, the determined control signal may move the drill bit assembly (e.g., the determined control signal may be different from a previous control signal). As another example, the determined control signal may maintain the drill bit assembly position (e.g., the determined control signal may be the same or substantially similar to a previous control signal).

[0060] Process 700 may be implemented by various systems, such as systems 100, 200, 300, 400, 500, and/or 600. In addition, various operations may be added, deleted, or modified. For example, property information may not be determined. As another example, a deflection may be determined based on the signal(s). For example, a first position of a component may be determined from a first signal from a sensor and/or predetermined. A second position of a component may be determined based on a second signal. The deflection may be determined based on the difference between the first position and the second position. In some

implementations, the determined control signal may be generated to reconcile differences between an expected position (e.g., based on a position associated with a previous control signal) of a drill bit assembly and the determined position of the drill bit assembly.

[0061] Figure 8 illustrates an implementation of example processes 800 for testing and/or monitoring a drilling instrument. A request for testing of a drilling instrument may be received (operation 805). The testing may be downhole and/or prior to positioning the drill bit assembly downhole. Testing may be performed to calibrate control signals to account for deviations between expected drill bit assembly positions (e.g., based on position associated with a first control signal) and a determined drill bit position (e.g., based on position determined in response to receiving the first control signal). By calibrating the control signals, the drill bit assembly drilling direction and/or position may be more accurately controlled and/or control of a cutting of a formation may be increased (e.g., when compared to not calibrating the control signals). Testing the drilling instrument while downhole may allow deviations from expected positions due to downhole influences to be identified and control signals may be altered based on the deviations.

[0062] First control signal(s) associated with a first position may be transmitted (operation 810). The control signal may include a speed, a direction and/or a position at which component(s) of the drilling instrument should operate. For example, a first control signal may be transmitted to a drilling instrument and various components of the drilling instrument may operate based on the control signal. For example, the universal joint and/or the flexible conduit may change and/or maintain a position. The flexible conduit may transmit rotational power to the drill bit assembly. The first position may be associated with the first control signal based on previous testing of the drilling instrument, factory presets, and/or expected position (e.g., based on models, calculations, and/or observations), for example.

[0063] Signal(s) may be detected from sensor(s) coupled to at least a portion of the drilling instrument (operation 815). For example, strain gauge sensing elements may be coupled to the flexible conduit in a Wheatstone bridge arrangement and detect deviations in position of the flexible conduit. As another example, a displacement sensor communicably coupled to the flexible conduit may detect deviations in position along three axes. Sensors may be coupled to the universal joint. Sensors may be inhibited from directly measuring the drill bit assembly due

to properties of the drill bit assembly during use (e.g., drilling mud interference and/or interference from cuttings).

[0064] Position information may be determined at least partially based on the detected signal(s) (operation 820). For example, a position of a flexible conduit and/or drill bit assembly may be determined based at least partially on signals from sensors coupled to the flexible conduit. The positional information may be deflections from a predetermined reference point, in some implementations. The positional information may be in relation to a portion of the drilling instrument or a plane through the drilling instrument.

[0065] The determined position information may be compared to the first position associated with the control signal (operation 825). For example, the determined position information may be compared to the first position and the deviation from the expected position (e.g., the first position) may be determined. The deviations from the expected position may indicate a health/condition of a component (e.g., wear on a component may cause greater flexibility of a component). The deviations from the first position may be based on formation properties (e.g., greater resistance than expected) and/or downhole conditions (e.g., pressure and/or temperature). The deviations from the expected position (e.g., first position) may allow the control signal to be altered to account for the deviations. For example, in some implementations, drilling instruments deviate from expected behavior during use downhole. Downhole operations may include unknowns, such as various resistance zones. Since the actual position of the drill bit assembly cannot be visually determined by users when in use downhole, determining the position of the drill bit assembly (e.g., through the sensors on the flexible conduit) may identify deviations in expected position. Once the deviations are identified, control signals may be altered to account for the deviations in operations downhole and greater control (e.g., when compared with systems that do not compensate for deviations and/or when compared with systems that assume a direction of a drill bit) of the cutting of a formation and/or greater cutting tolerances may be achieved, in some implementations.

[0066] In some implementations, the drilling instrument may be monitored (operation 830). For example, the components of the drilling instrument such as the flexible conduit, universal joint, and/or drill bit assembly may be monitored continuously and/or periodically.

[0067] During monitoring, the signal(s) from sensors may be detected (operation 815) and position information may be determined at least partially based on the detected signal(s)

(operation 820). A comparison between the determined position information and an expected position (e.g., the first position, position(s) and/or average position associated with previous control signal(s), or other predetermined reference position) may be made. In some implementations, the monitoring may allow the control signals to be altered in real time (e.g., during use downhole) to alter control signals to ensure a particular position during operations.

[0068] Process 800 may be implemented by various systems, such as systems 100, 200, 300, 400, 500, and/or 600. In addition, various operations may be added, deleted, or modified. In some implementations, various operations of processes 700 and 800 may be combined and/or modified. For example, the request for testing may not be received. In some implementations, the drilling instrument and/or properties (e.g., positional information and/or property information) thereof may not be monitored. A health/condition of component(s) and/or property information may be determined based on the signals from the sensors.

[0069] In some implementations, the positional information may be utilized to increase a cutting tolerance. For example, cutting tolerance and thus the ability to make sharper cuts may be increased if deflection of the flexible conduit and/or drill bit assembly may be maintained within a predetermined range. The positional information may be utilized to generate subsequent control signals to maintain the deflection of the flexible conduit within the predetermined range. For example, the positional information of the flexible conduit and/or drill bit assembly may be determined based at least partially on signals from sensors coupled to the flexible conduit. The positional information may be compared to the predetermined range. If the positional information is outside the predetermined range, then a control signal may be altered such that deflection may be maintained within the predetermined range.

[0070] In some implementations, various systems and/or processes may allow visualization of the behavior of the drill bit and/or drill bit assembly in-situ. For example, a drilling instrument may include a sensor with two sets of Wheatstone bridge strain gauge sensing elements coupled to a surface of the flexible tube. The sensor may generate a signal that allows a determination of the pointing direction (e.g., position relative to a collar above the flexible conduit) of the drill bit and/or the amount of pointing displacement with respect to a tool face. An absolute deflection (e.g., bending and/or torsion about an axis) and/or amount of pointing may be determined at least partially based on signals from the sensor, calibrations (e.g., calibrations based on testing of the drilling instrument and/or comparisons of the control signals,

associated positions, and/or determined position information), temperature (e.g., measured by a sensor coupled to the drilling instrument), and/or tool face information (e.g., properties of the tool face such as position and/or property information). In some implementations, sticking and/or slipping of the drill bit may be identified and the bending direction and effective pointing measurement may be adjusted based on the sticking and/or slipping when determining an absolute bending and/or amount of pointing of the drill bit.

[0071] In some implementations, determined position information and/or property information may be averaged and/or presented to a user (e.g., through a computer interface).

[0072] In some implementations, since the performance of the drilling instrument downhole may differ from the expected performance, determining the position information while downhole may enhance performance of the drilling instrument downhole. Determining property and/or position information in real time (e.g., concurrent with operation of the drilling instrument) may facilitate steering adjustments and/or rate of penetration controls. For example, the control signals may be automatically adjusted based at least partially on determined position information and/or property information. The automatic adjustment may increase cutting tolerance and/or allow sharper cutting (e.g., when compared with drilling instruments in which control signals are not adjusted based on determined information from sensors.)

[0073] In some implementations, compression and/or torque may be measured for the drilling instrument or portions thereof. Since the flexible conduit may be disengaged from the compression and torque applied to the universal joint, a sensor (e.g., strain gauge) may be coupled to a surface of the universal joint. The sensor may measure compression and/or torque on the universal joint. The compression and/or torque on the universal joint may be related to the compression and/or torque on the drill bit and/or drill bit assembly. Thus, compression and/or torque on the drill bit and/or drill bit assembly (e.g., weight on bit and/or torque on bit information) may be determined at least partially based on the signals from the sensor on the universal joint.

[0074] Property information such as compression and torque on the drill bit assembly and/or universal joint based on the measurements by the sensor on the universal joint may provide real-time and/or in-situ performance information. Performance information may indicate a quality and/or health/condition of a universal joint and/or bearings. For example, the universal joint may experience noise, such as knocking. Detection of the knocking, using the sensor on the universal

joint, may facilitate identification of premechanical failure events and/or inhibit catastrophic failures during use through the identification. In some implementations, a determination may be made whether performance information deviates from expected values (e.g., based on modeling, simulation, and/or previous values) and/or predetermined values. The deviations in positional and/or property information from expected values and/or predetermined values may indicate a health/condition of the universal joint and/or formation properties. The control signals may be automatically adjusted based on deviations from expected values and/or predetermined values to obtain a drill bit position.

[0075] In some implementations, deflection and/or displacement of the universal joint may be restricted. For example, strike ring(s) may restrict maximum displacement. An angle sensor coupled (e.g., communicably, indirectly, and/or directly) to the universal joint may generate a signal and position information of the universal joint may be determined based on the signal. The absolute pointing displacement of the drill bit assembly may be determined based on the position information of the universal joint and the specified restricted displacement. In some implementations, the health/condition of the drilling instrument may be determined based on the determined position information. For example, wear on the strike ring may increase the displacement range of the universal joint. The wear may be identified when a displacement greater than the predetermined maximum displacement is detected. In some implementations, a loosening of the universal joint (e.g., from bending the bit box at the surface of the formation) may be identified when a displacement greater than a predetermined maximum displacement is detected by sensors coupled to the universal joint. Identifying decreasing health/condition of the universal joint (e.g., wear causing deflections greater than a maximum deflection) may allow repair and/or replacement of the universal joint prior to catastrophic mechanical failure during use and/or inhibit mechanical failure during use.

[0076] In some implementations, sensors may be coupled to various portions of a bottom hole assembly (e.g., drill bit, drill collars, drill stabilizers, downhole motors, and/or rotary steerable system). For example, the flex or drill collar may facilitate bending of the bottom hole assembly. The sensor may detect and/or monitor position information and/or properties of the bottom hole assembly so that a health/condition of the bottom hole assembly may be determined. The determined position information may facilitate achieving a dogleg. For example, the determined position information may provide greater control of steering systems through real-

time position information. In addition, sensors coupled to the bottom hole assembly may allow determination of mechanical load and force information, which may allow determination of the health/condition of various components (e.g., fatigue of flex collars and/or American Petroleum Institute or “API” connections). Identification of the health/condition of various components of the bottom hole assembly may allow preventative maintenance (e.g., repair and/or replacement of components in declining health/condition) and/or inhibit catastrophic mechanical failure during use.

[0077] In some implementations, sensors, such as strain gauges, may be disposed about a circumference of a flexible conduit in an arrangement to inhibit sensitivity to deflection (e.g., bending and/or torsion about an axis). The sensors may detect inflation and/or deflation of the flexible conduit due to differential pressure between the internal pressure of the flexible conduit and the annular pressure exerting an external pressure on the flexible conduit. The signals from these sensors may allow determination of properties such as downhole properties (e.g., bit plugging, bit nozzle washout, excessive pad pressure, and/or insufficient pad pressure).

[0078] In some implementations, a sensor arrangement may be selected that allows measurements of differential pressures on the flexible conduit without inhibiting the measurement of effects due to temperature and/or pressures (e.g., weight on bit, compression, and/or mono-axial stress). For example, if a flexible conduit is pre-stretched prior to positioning the flexible conduit downhole, weight on bit may release an amount of the pre-stretching. A weight on bit and/or an indication of weight on bit may be determined based on the stretching of the flexible conduit (e.g., as measured by the sensor arrangement).

[0079] In some implementations, shallow hole testing may be performed. For example, sleeve motion may be visually checked during shallow hole testing. However, visual testing may be restricted (e.g., blocked, impaired, or otherwise difficult to visually ascertain) when attempting to evaluate full displacement (e.g., in environments where steam is generated and/or at night). Sensors coupled to the sleeve and/or universal joint, for example, may measure displacement and allow testing to be performed when visual testing is restricted. Testing may include strike ring placement (e.g., maximum displacements may be measured by sensors and compared to predetermined maximum displacements and/or expected displacements). Strike ring placement may be difficult to visually inspect (e.g., when strike rings are close in size such

as 0.6, 0.8 and 1 degree strike rings) and sensor measurements may facilitate testing to ensure selection of the appropriate strike ring and/or placement of the strike ring.

[0080] In some implementations, similar testing to the shallow hole testing may be performed downhole. For example, since visual testing may be difficult downhole, sensors may allow measurements for testing downhole. For example, displacement of a steering sleeve may be tested (e.g., a sensor coupled to the steering sleeve may be utilized to measure the displacement of the steering sleeve and the measured displacement may be compared to predetermined ranges for displacements and/or expected displacements in response to control signals). In some implementations, when the drilling instrument is off bottom, the universal joint may be easily moved and testing of displacement ranges for various components of the drilling instrument may be performed (e.g., displacement may be measured, compared to predetermined ranges and/or expect ranges, and/or a performance of the component may be determined based on the comparison).

[0081] In some implementations, the sensors may measure temperatures. For example, a sensor may be positioned proximate the universal joint such that the temperature change of the joint may be determined. A health (e.g., failure and/or degradation) of the universal joint may be determined based on the temperature changes, such as relatively large temperature increases. Determinations of a health of the universal joint may allow preventative action and/or maintenance (e.g., repair and/or replacement) of the universal joint.

[0082] In some implementations, sensors coupled to the universal joint may determine a property of the universal joint. For example, mud invasion into the universal joint may be determined by short circuit(s) in the sensors. Mud invasion may damage and cause various components in the drilling instrument to fail. The short circuit will generate signals that indicate the abnormality. The early detection of mud in the universal joint, using the sensors, may reduce damage to components of the drilling instrument.

[0083] In some implementations, information from the sensors (e.g., position information and/or properties) may be used in a closed loop feedback to provide control of the direction in which a directional drilling instrument propagates the hole (e.g., wellbore). The loop may be closed downhole and/or include the surface of the formation.

[0084] In some implementations, position information may be graphically visualized. The signals may be transmitted via conventional mud pulse telemetry, wired drill pipes, and/or

electromagnetic (EPulse) transmission. The signals may be utilized to generate a graphical user interface that presents the information to a user. The position information may be presented using auditory signals, in some implementations. For example, a wired drill pipe may carry signals from sensors to the surface of the formation and auditory signals may be presented to users based on the signals.

[0085] In some implementations, various sensors may be utilized to determine properties of the formation. For example, the sensor may be utilized to determine the forces on the drill bit (e.g., based at least partially on positional information and/or property information determined based at least in part on signals from sensors on the flexible conduit and/or universal joint). The determined forces may be utilized to determine properties of the formation, such as the type of rock and/or other properties. For example, a type of rock may be identified based at least in part on the resistance to cutting by, and thus creating forces acting on, the drill bit. The properties of the formation may be utilized in determining bit destruction characterizations and/or in commercially available simulation programs related to drilling in formations.

[0086] In some implementations, the sensors may be utilized in association with stuck bits. For example, when the bottom hole assembly gets stuck downhole, it may be difficult to determine which component is the cause. The sensors may be utilized to identify if the drill bit is stuck based at least partially on determined position information, determined property information, and/or the health of the drill bit. If a stuck drill bit is identified, a control signal (e.g., a control signal to apply more torque may be transmitted) may be transmitted based on the identification and/or the drill bit sticking may be reduced.

[0087] In some implementations, although several universal joints have been described, other types of universal joints may be utilized as appropriate. For example, the universal joint surrounding the flexible conduit may be a larger flexible conduit (e.g., a flexible collar). Thus, rather than instrument the flexible collar, the bending of an instrumented flexible conduit may be utilized (e.g., in conjunction with or in place of) in the various described systems and processes. The sensors of the flexible conduit may measure the deflection of the collar. The sensor(s) of the flexible conduit may include its own sensors, power supply, and/or communication devices. For example, extension rods that pass through the flexible collar may be utilized to place the communication sonde (e.g., Shorthop) closer to the PowerDrive.

[0088] In various implementations, a drilling instrument may include a flexible conduit, a universal joint, and/or sensor(s). The flexible conduit may be disposed at least partially in the universal joint. The sensor(s) may detect position information about the flexible conduit.

[0089] Implementations may include one or more of the following features. Sensor(s) may be coupled to the flexible conduit. The position information may include a measurement of the deviation in the position of a flexible conduit from a predetermined position of the flexible conduit. The position information may include a deflection of the flexible conduit. The drilling instrument may include a drill bit assembly and the flexible conduit may be coupled to at least a portion of the drill bit assembly. Sensor(s) may detect temperature, pressure, deflection, position, compression, extension, and/or torque. The position of a sensor may be based at least partially on deflection properties of the flexible conduit. A sensor may include sensing element(s), such as strain gauge(s) and/or displacement sensor(s). A sensor may include two or more sensing elements, such as a first sensing element set and a second sensing element set. The first sensing element set and the second sensing element set may be radially disposed about the flexible conduit. The first sensing element set may be disposed approximately 60 degrees to approximately 120 degrees from the second sensing element set. Sensor(s) may be coupled to the universal joint. At least one of the sensors may detect positional information about the universal joint.

[0090] In various implementations, a drilling instrument may be monitored. A signal may be detected from sensor(s). The sensor(s) may be disposed on a flexible conduit, and the flexible conduit may be disposed at least partially in a universal joint of the drilling instrument. Position information of the flexible conduit may be determined based at least partially on the detected signal.

[0091] Implementations may include one or more of the following features. A control signal for the drilling instrument may be determined at least partially based on the determined position information. A determination may be made whether the determined position information is within a predetermined range. A control signal may be determined based at least partially on whether the detected signal is within the predetermined range. Property information may be determined based at least partially on the determined positional information. The property information may include temperature, pressure exerted on the universal joint, compressive force exerted on the universal joint, and/or health information about the drilling instrument.

[0092] In various implementations, the performance of a drilling instrument may be tested. First control signal(s) for a drill bit assembly of a drilling instrument may be transmitted. The control signal may be associated with a first position of the drill bit assembly. A signal from sensor(s) may be detected. The sensor(s) may be disposed on a flexible conduit of the drilling instrument. The flexible conduit may be coupled to the drill bit assembly. The position information of the drill bit may be determined at least partially based on the detected signal. The determined position information of the drill bit assembly may be compared to the first position of the drill bit assembly.

[0093] Implementations may include one or more of the following features. Second control signal(s) may be transmitted at least partially based on the comparison of the determined position information of the drill bit assembly to the first position of the drill bit assembly. The second control signal(s) may be substantially similar to the first control signal(s) and/or substantially different from the first control signal(s). Position information of a universal joint may be determined at least partially based on signals transmitted from additional sensor(s) coupled to the universal joint. The flexible conduit may be disposed at least partially in the universal joint of a drilling instrument. The drilling instrument may be monitored based at least partially on the comparison of the determined position information of the drill bit assembly to the first position of the drill bit assembly.

[0094] Although strain gauges and/or displacement sensors have been described as sensing elements in sensor(s), any appropriate sensing elements and/or combinations thereof may be utilized in various implementations. Although sensors have been described as including sensing element(s), the sensors may include sets of sensing elements. A set of sensing elements may include one or more sensing elements.

[0095] In various implementations, coupling has been described. Coupling may include direct and/or indirect coupling. For example, coupling may include gluing, bonding, affixing, and/or otherwise adhering. Coupling may include disposing at least a portion of an object in a receiving member of another object. For example, a portion of the drill bit assembly may include a receiving member for the flexible conduit. The flexible conduit and the drill bit assembly may be coupled through the receiving member. Communicably coupling may include coupling such that a first object is in communication with another object, for example. A sensor

that is communicably coupled to a flexible conduit may or may not be directly coupled to the flexible conduit and may measure the flexible conduit deflection and/or other properties.

[0096] Although users have been described as a human, a user may be a person, a group of people, a person or persons interacting with one or more computers, and/or a computer system. Various implementations of the systems and techniques described here can be realized in digital electronic circuitry, integrated circuitry, specially designed ASICs (application specific integrated circuits), computer hardware, firmware, software, and/or combinations thereof. These various implementations can include implementation in one or more computer programs that are executable and/or interpretable on a programmable system including at least one programmable processor, which may be special or general purpose, coupled to receive data and instructions from, and to transmit data and instructions to, a storage system, at least one input device, and at least one output device.

[0097] These computer programs (also known as programs, software, software applications or code) include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the term "machine-readable medium" refers to any computer program product, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The term "machine-readable signal" refers to any signal used to provide machine instructions and/or data to a programmable processor.

[0098] To provide for interaction with a user, the systems and techniques described here can be implemented on a computer (e.g., laptop, tablet, smartphone) that may include a display device (e.g., a LCD (liquid crystal display) monitor) for displaying information to the user, a keyboard, and/or a pointing device (e.g., a mouse) by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user by an output device can be any form of sensory feedback (e.g., visual feedback, auditory feedback, or tactile feedback); and input from the user can be received in any form, including acoustic, speech, or tactile input (e.g., touch screens).

[0099] It is to be understood the implementations are not limited to particular systems or processes described which may, of course, vary. It is also to be understood that the terminology

used herein is for the purpose of describing particular implementations only, and is not intended to be limiting. As used in this specification, the singular forms “a”, “an” and “the” include plural referents unless the content clearly indicates otherwise. Thus, for example, reference to “a sensing element” includes a combination of two or more sensing elements and reference to “a sensor” includes different types and/or combinations of sensors.

[00100] The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

[00101] Although the preceding description has been described herein with reference to particular means, materials and embodiments, it is not intended to be limited to the particulars disclosed herein; rather, it extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims

WHAT IS CLAIMED IS:

1. A drilling instrument comprising:
a universal joint;
a flexible conduit disposed at least partially in the universal joint; and
one or more sensors to detect position information of the flexible conduit.
2. The drilling instrument of claim 1 wherein one or more of the sensors is coupled to the flexible conduit.
3. The drilling instrument of claim 1 wherein the position information comprises at least one of a measure of a deviation in position of the flexible conduit from a predetermined position of the flexible conduit or a deflection of the flexible conduit.
4. The drilling instrument of claim 1 further comprising a drill bit assembly, wherein the flexible conduit is coupled to at least a portion of the drill bit assembly.
5. The drilling instrument of claim 1 wherein at least one of the sensors measures at least one of temperature, pressure, deflection, position, compression, extension, or torque.
6. The drilling instrument of claim 1 wherein a position of at least one of the sensors is based at least partially on deflection properties of the flexible conduit.
7. The drilling instrument of claim 1 wherein at least one of the sensors comprises at least one sensing element, and wherein at least one of the sensing elements comprises at least one of a strain gauge or a displacement sensor.
8. The drilling instrument of claim 1 wherein at least one of the sensors comprises a first sensing element set and a second sensing element set radially disposed about the flexible conduit, and wherein the first sensing element set is disposed approximately 60 degrees to approximately 120 degrees apart circumferentially from the second sensing element set.
9. The drilling instrument of claim 1 wherein at least one of the sensors is coupled to the universal joint.
10. The drilling instrument of claim 1 wherein at least one of the sensors detects positional information of the universal joint.
11. A method of monitoring a drilling instrument comprising:

detecting a signal from one or more sensors, wherein at least one of the sensors is disposed on a flexible conduit positioned at least partially in a universal joint of a drilling instrument; and

determining position information of the flexible conduit based at least partially on the detected signal.

12. The method of claim 11 further comprising determining a control signal for the drilling instrument based at least partially on the determined position information.

13. The method of claim 12 further comprising determining whether the determined position information is within a predetermined range, and wherein the control signal is determined based at least partially on whether the detected signal is within the predetermined range.

14. The method of claim 11 further comprising determining property information based at least partially on the determined positional information.

15. The method of claim 14 wherein the property information includes at least one of temperature, pressure exerted on the universal joint, compressive force exerted on the universal joint, or condition of the drilling instrument.

16. A method for testing the performance of a drilling instrument comprising:
transmitting at least one first control signal for a drill bit assembly of the drilling instrument, wherein the at least one first control signal is associated with a first position of the drill bit assembly;

detecting a signal from one or more sensors, wherein at least one of the sensors is disposed on a flexible conduit coupled to the drill bit assembly;

determining position information of the drill bit assembly based at least partially on the detected signal; and

comparing the determined position information of the drill bit assembly to the first position of the drill bit assembly.

17. The method of claim 16 further comprising transmitting at least one second control signal based at least partially on comparing the determined position information of the drill bit assembly to the first position of the drill bit assembly.

18. The method of claim 17 wherein at least one of the second control signals is either substantially similar to at least one of the first control signals or substantially different from at least one of the first control signals.

19. The method of claim 16 further comprising determining position information of a universal joint of the drilling instrument at least partially based on signals transmitted from one or more additional sensors, wherein the one or more additional sensors are coupled to the universal joint, and wherein the flexible conduit is disposed at least partially in the universal joint.

20. The method of claim 16 further comprising monitoring the drilling instrument based at least partially on comparing the determined position information of the drill bit assembly to the first position of the drill bit assembly.

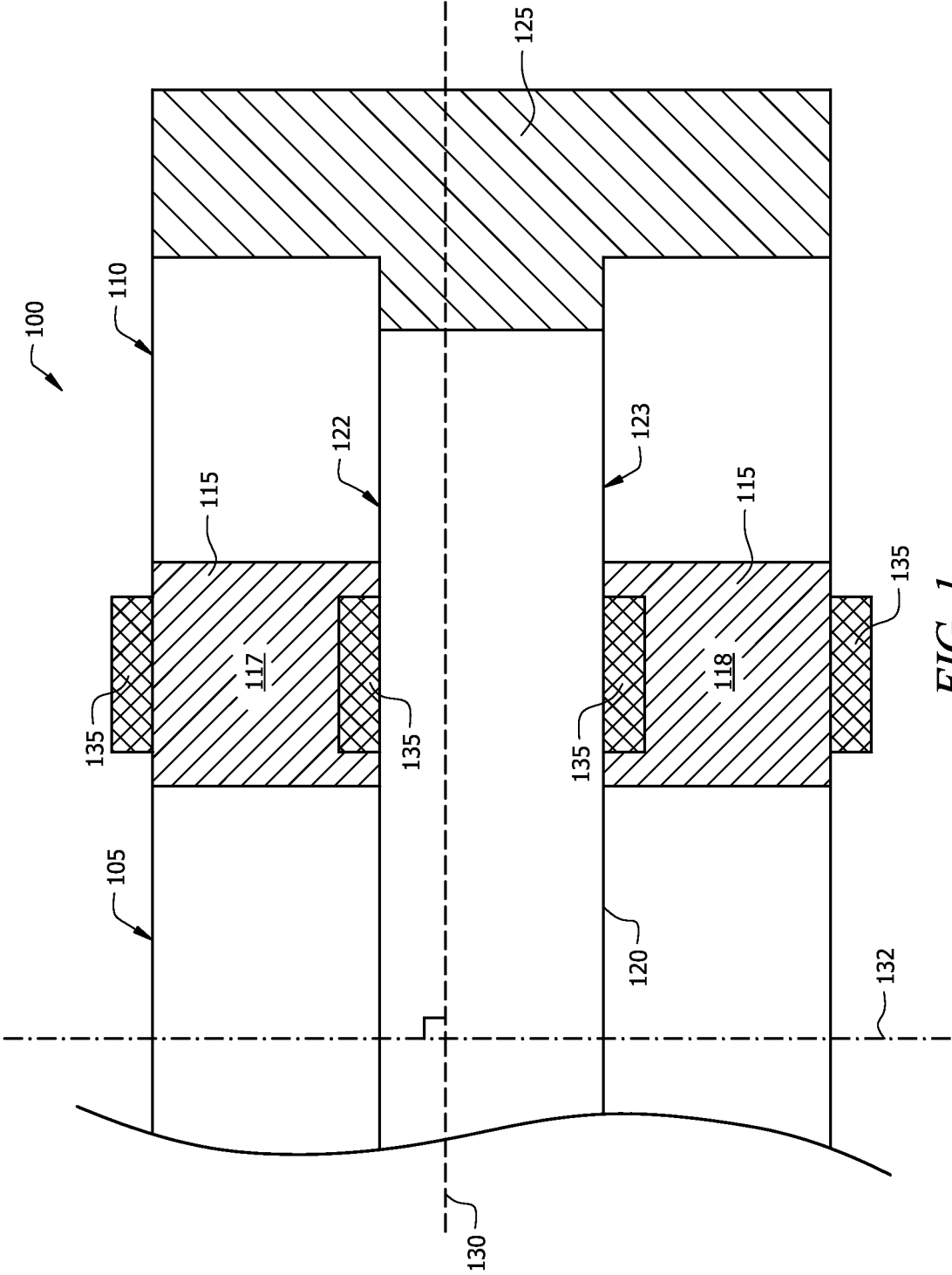


FIG. 1

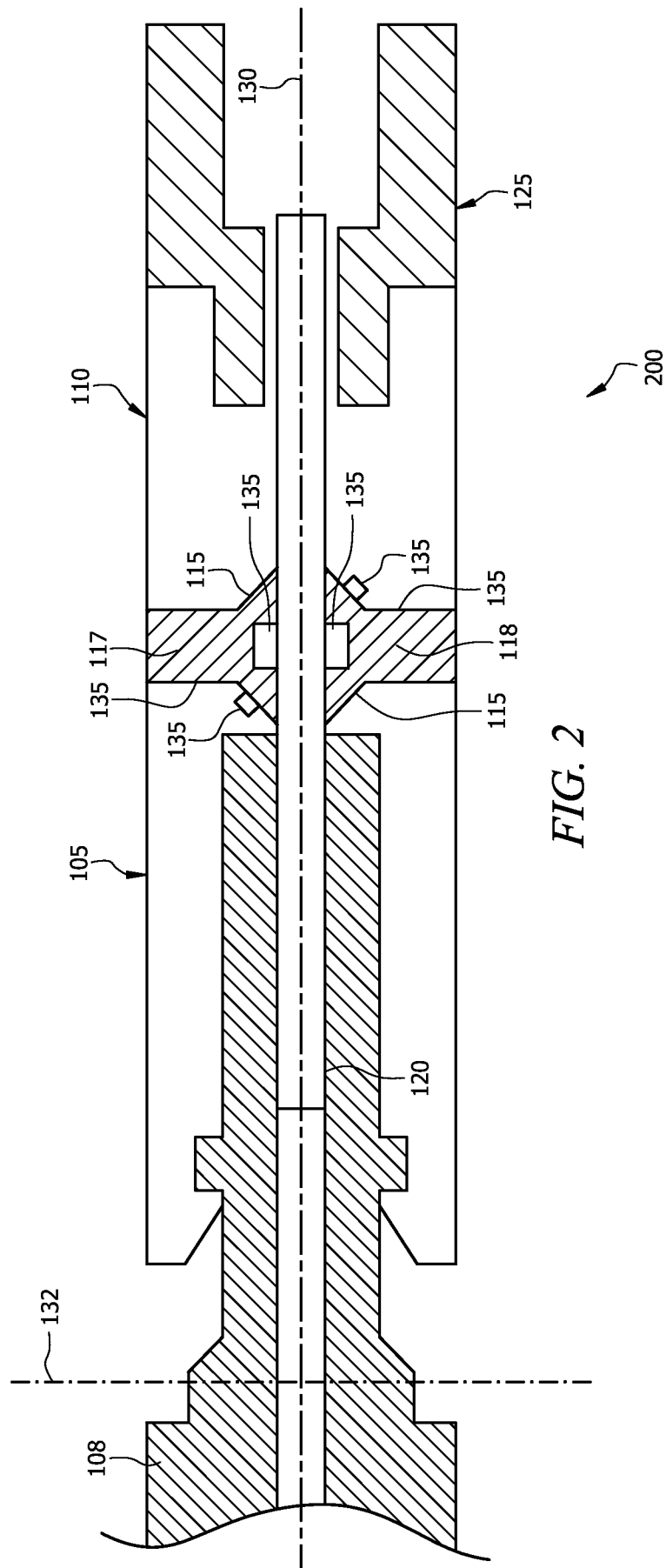


FIG. 2

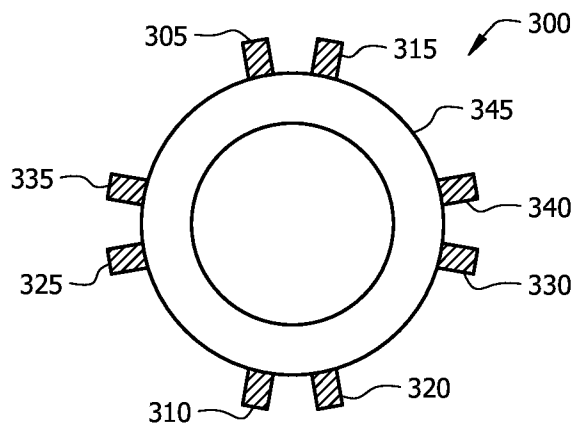


FIG. 3

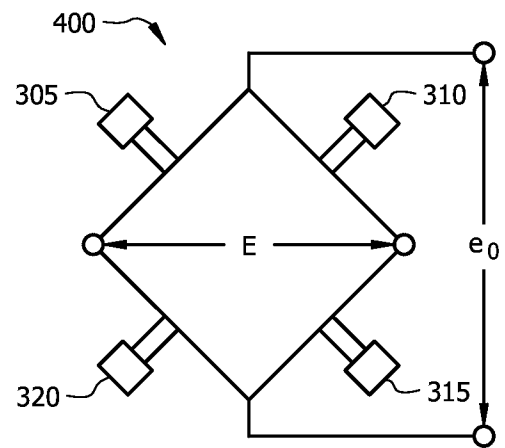


FIG. 4

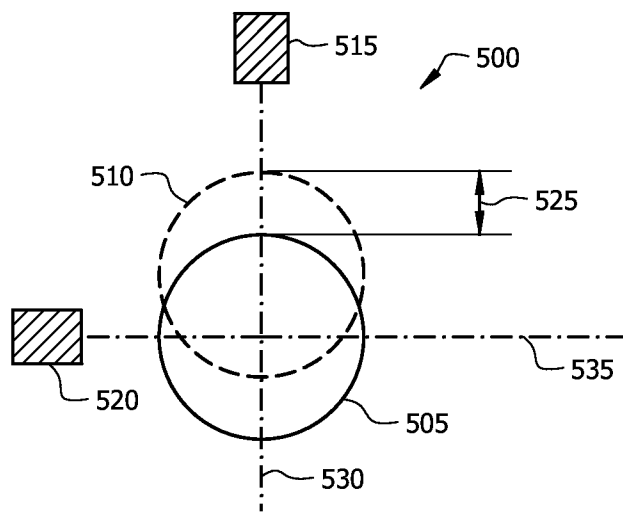


FIG. 5

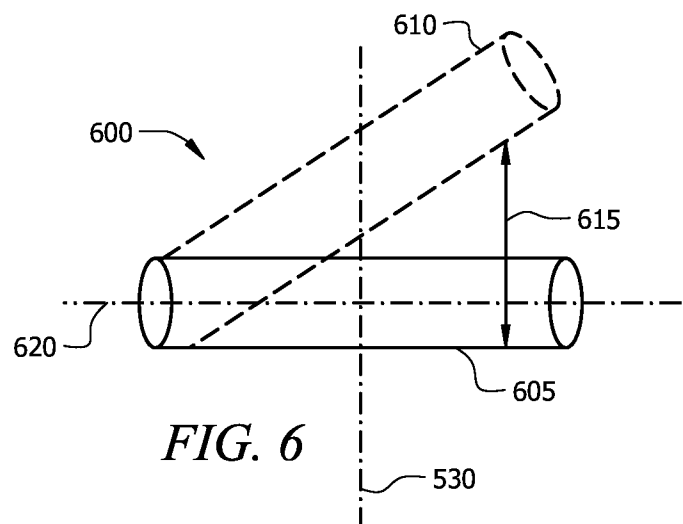


FIG. 6

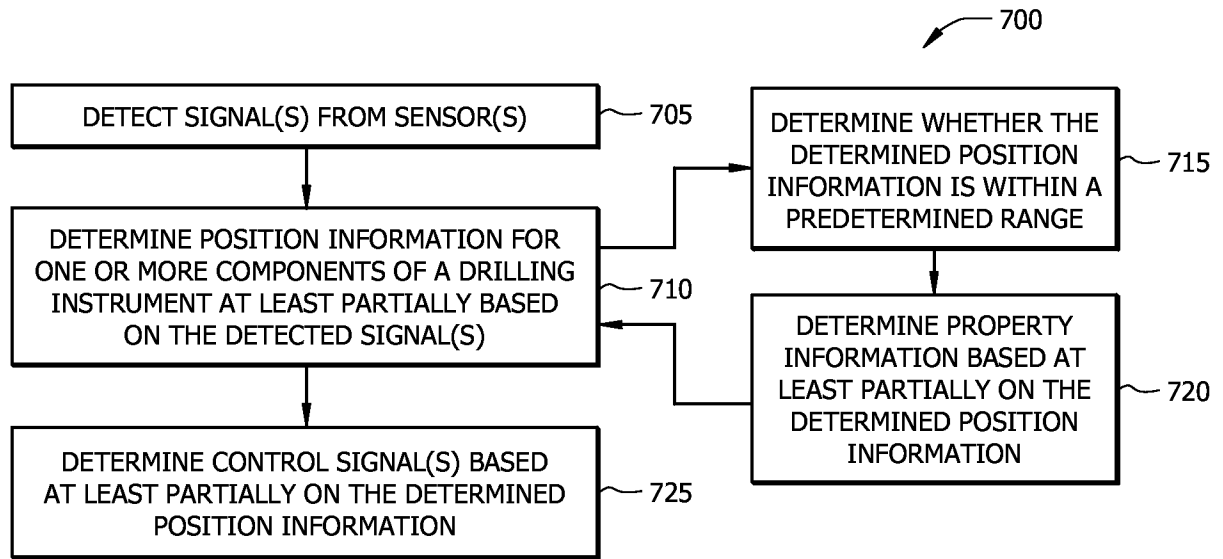


FIG. 7

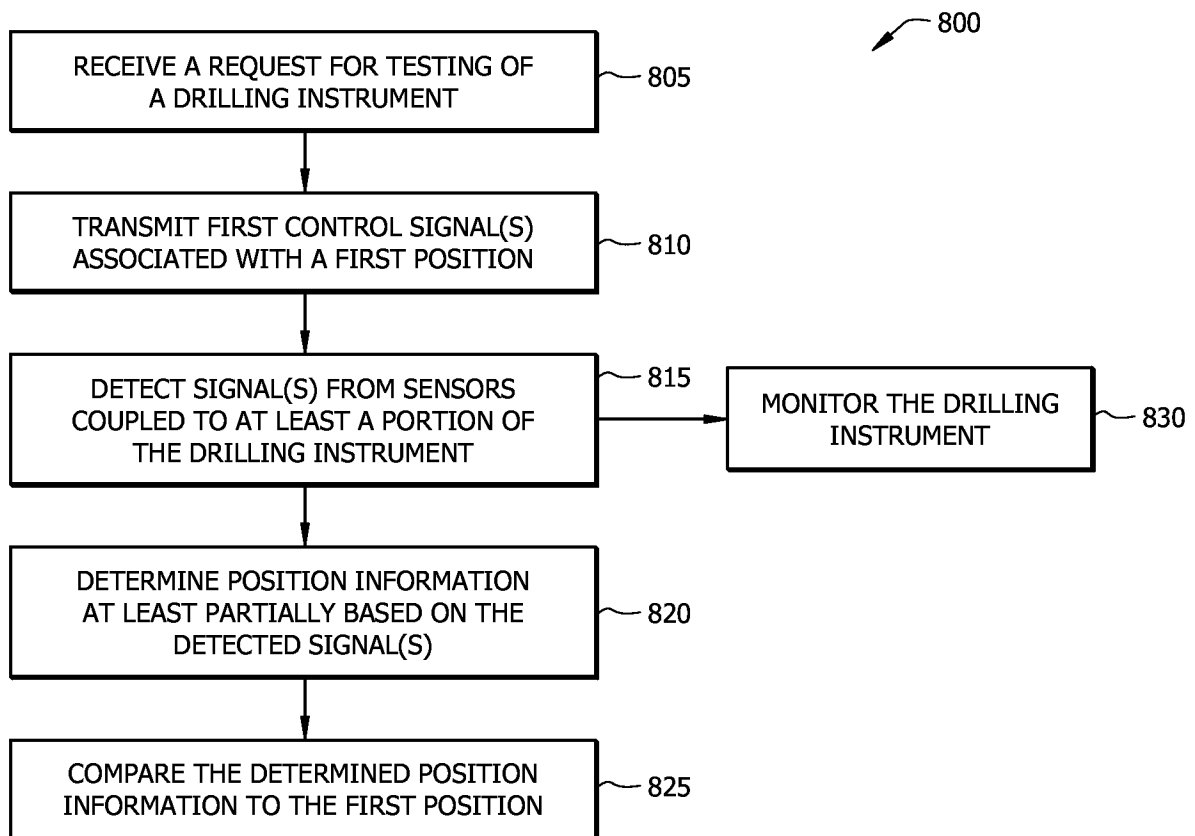


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/018816**A. CLASSIFICATION OF SUBJECT MATTER****E21B 17/02(2006.01)i, E21B 47/01(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 17/02; E21B 47/024; E21B 44/00; B23P 11/00; E21B 7/08; E21B 7/06; E21B 7/04; E21B 4/18; E21B 47/01

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: universal joint, sensor, deviation, deflection, drill bit, strain, compare, and determine

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0308858 A1 (MENGGER et al.) 22 December 2011 See abstract, paragraphs [0010],[0016],[0018]-[0019], and figure 1.	1-2,4-6,8-12,14-15
Y		7
A		3,13,16-20
Y	US 7870912 B2 (DOLGIN et al.) 18 January 2011 See abstract, column 17, lines 49-57, and figure 15.	7
A	WO 97-15749 A2 (BAKER HUGHES INCORPORATED) 01 May 1997 See abstract and claims 13-21.	1-20
A	US 2011-0042144 A1 (DOWNTON, GEOFFREY C.) 24 February 2011 See abstract, paragraphs [0015],[0022], and figure 2.	1-20
A	US 2008-0149394 A1 (DOWNTON, GEOFF) 26 June 2008 See abstract, paragraphs [0021]-[0023], and figure 1.	1-20

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 July 2014 (15.07.2014)

Date of mailing of the international search report

17 July 2014 (17.07.2014)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

LEE, Jong Kyung

Telephone No. +82-42-481-3360



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/018816

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011-0308858 A1	22/12/2011	CA 2801852 A1 CN 103299021 A GB 201222132 D0 GB 2495235 A NO 20121505 A WO 2012-014068 A2 WO 2012-014068 A3	02/02/2012 11/09/2013 23/01/2013 03/04/2013 13/12/2012 02/02/2012 07/03/2013
US 7870912 B2	18/01/2011	CA 2591691 A1 EP 1831502 A2 EP 1831502 A4 JP 2008-525762 A JP 2012-83360 A JP 5362994 B2 US 2006-0157278 A1 US 2010-0038068 A1 US 7584808 B2 WO 2006-065923 A2 WO 2006-065923 A3	22/06/2006 12/09/2007 07/07/2010 17/07/2008 26/04/2012 11/12/2013 20/07/2006 18/02/2010 08/09/2009 22/06/2006 09/04/2009
WO 97-15749 A2	01/05/1997	AU 1999-48695 A1 CA 2235134 A1 CA 2235134 C CA 2269498 C CA 2336655 A1 CA 2336655 C DE 69636054 D1 EP 0857249 A2 EP 0857249 A2 EP 0857249 B1 GB 2354325 A NO 320888 B1 NO 981802 A NO 981802 D0 US 2003-0014190 A1 US 5842149 A US 6021377 A US 6023443 A US 6084826 A US 6088294 A US 6206108 B1 US 6233524 B1 US 6427124 B1 US 6581010 B2 US 6614360 B1 WO 00-03269 A1 WO 96-21871 A1 WO 97-15749 A3 WO 98-17894 A2	01/02/2000 01/05/1997 09/01/2007 11/01/2005 20/01/2000 25/01/2005 24/05/2006 09/06/1999 12/08/1998 19/04/2006 21/03/2001 06/02/2006 22/06/1998 22/04/1998 16/01/2003 24/11/1998 01/02/2000 08/02/2000 04/07/2000 11/07/2000 27/03/2001 15/05/2001 30/07/2002 17/06/2003 02/09/2003 20/01/2000 18/07/1996 24/07/1997 30/04/1998

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/018816

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011-0042144 A1	24/02/2011	CA 2710222 A1	09/07/2009
		CN 101946057 A	12/01/2011
		EP 2238310 A2	13/10/2010
		EP 2238310 B1	16/05/2012
		GB 0724900 D0	30/01/2008
		JP 2011-524477 A	01/09/2011
		JP 5364104 B2	11/12/2013
		RU 2010130479 A	27/01/2012
		RU 2452839 C2	10/06/2012
		US 8517121 B2	27/08/2013
		WO 2009-085753 A2	09/07/2009
		WO 2009-085753 A3	17/09/2009
US 2008-0149394 A1	26/06/2008	CA 2614466 A1	21/06/2008
		CA 2614466 C	02/04/2013
		GB 0625385 D0	31/01/2007
		GB 2445019 A	25/06/2008
		GB 2445019 B	15/06/2011
		NO 20076541 A	23/06/2008
		US 8302705 B2	06/11/2012