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(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, F-75007 Paris (FR).

(71) **Applicant** (*for GB, JP, NL only*): **SCHLUMBERGER HOLDINGS LIMITED**; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Islands, British, 1110 (VG).

(71) Applicant (for all designated States except AE, AO, BH, CA, CN, FR, GB, GH, IN, JP, LY, MA, MZ, NA, NG, NL, PH, SD, SY, US, VN): **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, KM, LY, MA, ML, MR, MZ, NA, NE, NG, PH, SD, SN, SY, TD, TG, VN only): **PRAD RESEARCH AND DEVELOPMENT LIMITED**; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Island, British, 1110 (VG).

(71) **Applicant (for US only): SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).

(72) Inventors: DELGADO, Miguel Marcel Jose; 131a Reedley Road, Grove View, Flat 3 Bristol BS9 1BG (GB).

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(54) Title: ACTIVELY CONTROLLED ROTARY STEERABLE DRILLING SYSTEM (RSS)

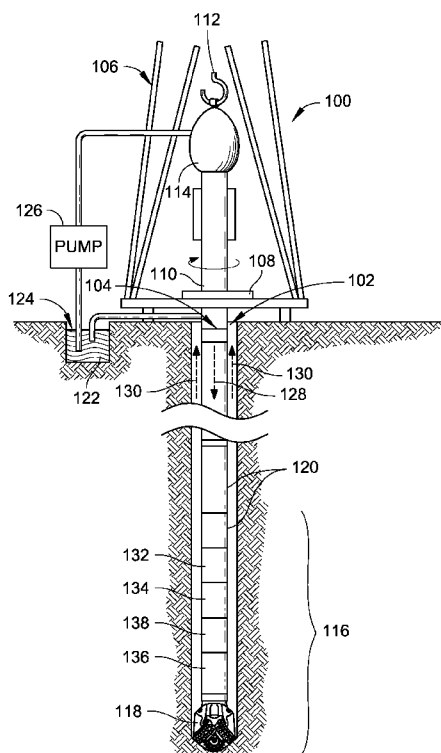


FIG. 1

(57) Abstract: Aspects of the disclosure can relate to a system that includes an input shaft to be driven at a nominal uncontrolled rotational speed, and an output shaft coupled with the input shaft to drive a rotary mechanism. The prime mover can be a mud turbine or a motor, and the input shaft can be driven by, for example, drilling fluid. The system also includes a drive mechanism mechanically coupling the input shaft to the output shaft to drive the rotary mechanism at a controlled rotational speed. The system further includes a secondary input mechanically coupled with the drive mechanism, where the secondary input is driven as a control input to drive the rotary mechanism at the controlled rotational speed. The drive mechanism can be a continuously variable transmission and/or a constant speed drive, and the secondary input can be a servo motor.



BAYLISS, Martin Thomas; Flat 14, Alpine Court, Stratford Road, Stroud Gloucestershire GL5 4AJ (GB).

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(74) **Agents:** SULLIVAN, Chadwick A. et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).

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ACTIVELY CONTROLLED ROTARY STEERABLE DRILLING SYSTEM (RSS)

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to United States Non Provisional Patent Application Serial No. 14/337,073, which was filed on July 21, 2014, and is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Oil wells are created by drilling a hole into the earth using a drilling rig that rotates a drill string (e.g., drill pipe) having a drill bit attached thereto. The drill bit, aided by the weight of pipes (e.g., drill collars) cuts into rock within the earth. Drilling fluid (e.g., mud) is pumped into the drill pipe and exits at the drill bit. The drilling fluid may be used to cool the bit, lift rock cuttings to the surface, at least partially prevent destabilization of the rock in the wellbore, and/or at least partially overcome the pressure of fluids inside the rock so that the fluids do not enter the wellbore. Rotary steerable systems (RSS) can be used for directional drilling. These systems employ down hole equipment that responds to commands (e.g., from surface equipment) and steers into a desired direction. For example, pistons may be used to generate force against a borehole wall or to cause angular displacement of one steerable system component with respect to another to cause a drill bit to move in the desired direction of deviation.

SUMMARY

[0003] Aspects of the disclosure can relate to a down hole drill assembly that includes an input shaft coupled with a prime mover to be driven at a nominal uncontrolled rotational speed, and an output shaft coupled with the input shaft to drive a rotary mechanism. The input shaft can be driven by drilling fluid or another fluid. The down hole drill assembly also includes a drive mechanism mechanically coupling the input shaft to the output shaft to drive the rotary mechanism at a controlled rotational speed. The down hole drill assembly further includes a secondary input mechanically coupled with the drive mechanism, where the secondary input is driven as a control input to drive the rotary mechanism at the controlled rotational speed.

[0004] Other aspects of the disclosure can relate to a method that includes driving an input shaft coupled with a prime mover at a nominal uncontrolled rotational speed. The method also includes driving a rotary mechanism with an output shaft coupled with the input shaft. The method further includes mechanically coupling the input shaft to the output shaft with a drive mechanism to drive the rotary mechanism at a controlled rotational speed, and mechanically coupling a secondary input with the drive mechanism. The method also includes driving the secondary input as a control input to drive the rotary mechanism at the controlled rotational speed.

[0005] Also, aspects of the disclosure can relate to a system that includes an input shaft to be driven at a nominal uncontrolled rotational speed by fluid flow, and an output shaft coupled with the input shaft to drive a rotary mechanism. The system also includes a drive mechanism mechanically coupling the input shaft to the output shaft to drive the rotary mechanism at a controlled rotational speed. The system further includes a secondary input mechanically coupled with the drive mechanism, where the secondary input is driven as a control input to drive the rotary mechanism at the controlled rotational speed.

[0006] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

FIGURES

[0007] Embodiments of an actively controlled rotary steerable drilling system are described with reference to the following figures. The same numbers are used throughout the figures to reference like features and components.

[0008] FIG. 1 illustrates an example system in which embodiments of an actively controlled rotary steerable drilling system can be implemented;

[0009] FIG. 2 illustrates various components of an example device that can implement embodiments of an actively controlled rotary steerable drilling system;

[0010] FIG. 3 illustrates various components of an example device that can implement embodiments of an actively controlled rotary steerable drilling system;

[0011] FIG. 4 illustrates various components of an example device that can implement embodiments of an actively controlled rotary steerable drilling system;

[0012] FIG. 5 illustrates various components of an example device that can implement embodiments of an actively controlled rotary steerable drilling system;

[0013] FIG. 6 illustrates various components of an example device that can implement embodiments of an actively controlled rotary steerable drilling system;

[0014] FIG. 7 illustrates various components of an example device that can implement embodiments of an actively controlled rotary steerable drilling system;

[0015] FIG. 8 illustrates various components of an example device that can implement embodiments of an actively controlled rotary steerable drilling system; and

[0016] FIG. 9 illustrates example method(s) for actively controlling a rotary steerable drilling system in accordance with one or more embodiments.

DETAILED DESCRIPTION

[0017] FIG. 1 depicts a wellsite system 100 in accordance with one or more embodiments of the present disclosure. The wellsite can be onshore or offshore. A borehole 102 is formed in subsurface formations by directional drilling. A drill string 104 extends from a drill rig 106 and is suspended within the borehole 102. In some embodiments, the wellsite system 100 implements directional drilling using a rotary steerable system (RSS). For instance, the drill string 104 is rotated from the surface, and down hole devices move the end of the drill string 104 in a desired direction. The drill rig 106 includes a platform and derrick assembly positioned over the borehole 102. In some embodiments, the drill rig 106 includes a rotary table 108, kelly 110, hook 112, rotary swivel 114, and so forth. For example, the drill string 104 is rotated by the rotary table 108, which engages the kelly 110 at the upper end of the drill string 104. The drill string 104 is suspended from the hook 112 using the rotary swivel 114, which permits rotation of the drill string 104 relative to the hook 112. However, this configuration is

provided by way of example and is not meant to limit the present disclosure. For instance, in other embodiments a top drive system is used.

[0018] A bottom hole assembly (BHA) 116 is suspended at the end of the drill string 104. The bottom hole assembly 116 includes a drill bit 118 at its lower end. In embodiments of the disclosure, the drill string 104 includes a number of drill pipes 120 that extend the bottom hole assembly 116 and the drill bit 118 into subterranean formations. Drilling fluid (e.g., mud) 122 is stored in a tank and/or a pit 124 formed at the wellsite. The drilling fluid can be water-based, oil-based, and so on. A pump 126 displaces the drilling fluid 122 to an interior passage of the drill string 104 via, for example, a port in the rotary swivel 114, causing the drilling fluid 122 to flow downwardly through the drill string 104 as indicated by directional arrow 128. The drilling fluid 122 exits the drill string 104 via ports (e.g., courses, nozzles) in the drill bit 118, and then circulates upwardly through the annulus region between the outside of the drill string 104 and the wall of the borehole 102, as indicated by directional arrows 130. In this manner, the drilling fluid 122 cools and lubricates the drill bit 118 and carries drill cuttings generated by the drill bit 118 up to the surface (e.g., as the drilling fluid 122 is returned to the pit 124 for recirculation).

[0019] In some embodiments, the bottom hole assembly 116 includes a logging-while-drilling (LWD) module 132, a measuring-while-drilling (MWD) module 134, a rotary steerable drilling system 136, a motor, and so forth (e.g., in addition to the drill bit 118). The logging-while-drilling module 132 can be housed in a drill collar and can contain one or a number of logging tools. It should also be noted that more than one LWD module and/or MWD module can be employed (e.g. as represented by another logging-while-drilling module 138). In embodiments of the disclosure, the logging-while drilling modules 132 and/or 138 include capabilities for measuring, processing, and storing information, as well as for communicating with surface equipment, and so forth.

[0020] The measuring-while-drilling module 134 can also be housed in a drill collar, and can contain one or more devices for measuring characteristics of the drill string 104 and drill bit 118. The measuring-while-drilling module 134 can also include components for

generating electrical power for the down hole equipment. This can include a mud turbine generator (also referred to as a “mud motor”) powered by the flow of the drilling fluid 122. However, this configuration is provided by way of example and is not meant to limit the present disclosure. In other embodiments, other power and/or battery systems can be employed. The measuring-while-drilling module 134 can include one or more of the following measuring devices: a weight-on-bit measuring device, a torque measuring device, a vibration measuring device, a shock measuring device, a stick slip measuring device, a direction measuring device, an inclination measuring device, and so on.

[0021] In embodiments of the disclosure, the wellsite system 100 is used with controlled steering or directional drilling. For example, the rotary steerable drilling system 136 is used for directional drilling. As used herein, the term “directional drilling” describes intentional deviation of the wellbore from the path it would naturally take. Thus, directional drilling refers to steering the drill string 104 so that it travels in a desired direction. In some embodiments, directional drilling is used for offshore drilling (e.g., where multiple wells are drilled from a single platform). In other embodiments, directional drilling enables horizontal drilling through a reservoir, which enables a longer length of the wellbore to traverse the reservoir, increasing the production rate from the well. Further, directional drilling may be used in vertical drilling operations. For example, the drill bit 118 may veer off of a planned drilling trajectory because of the unpredictable nature of the formations being penetrated or the varying forces that the drill bit 118 experiences. When such deviation occurs, the wellsite system 100 may be used to guide the drill bit 118 back on course.

[0022] FIGS. 2 through 8 depict drill assemblies 200 that can be used with, for example, a wellsite system (e.g., the wellsite system 100 described with reference to FIG. 1). For instance, the drill assembly 200 can comprise a bottom hole assembly suspended at the end of a drill string (e.g., in the manner of the bottom hole assembly 116 suspended from the drill string 104 depicted in FIG. 1). In some embodiments, a drill assembly 200 is implemented using a drill bit. However, this configuration is provided by way of example and is not meant to limit the present disclosure. In other embodiments, different

working implement configurations are used. Further, use of drill assemblies 200 in accordance with the present disclosure is not limited to wellsite systems described herein. Drill assemblies 200 can be used in other various cutting and/or crushing applications, including earth boring applications employing rock scraping, crushing, cutting, and so forth.

[0023] The drill assembly 200 includes a body 202 for receiving a flow of drilling fluid. The body 202 comprises one or more crushing and/or cutting implements, such as conical cutters and/or bit cones having spiked teeth (e.g., in the manner of a roller-cone bit). In this configuration, as the drill string is rotated, the bit cones roll along the bottom of the borehole in a circular motion. As they roll, new teeth come in contact with the bottom of the borehole, crushing the rock immediately below and around the bit tooth. As the cone continues to roll, the tooth then lifts off the bottom of the hole and a high-velocity drilling fluid jet strikes the crushed rock chips to remove them from the bottom of the borehole and up the annulus. As this occurs, another tooth makes contact with the bottom of the borehole and creates new rock chips. In this manner, the process of chipping the rock and removing the small rock chips with the fluid jets is continuous. The teeth intermesh on the cones, which helps clean the cones and enables larger teeth to be used. A drill assembly 200 comprising a conical cutter can be implemented as a steel milled-tooth bit, a carbide insert bit, and so forth. However, roller-cone bits are provided by way of example and are not meant to limit the present disclosure. In other embodiments, a drill assembly 200 is configured differently. For example, the body 202 of the bit comprises one or more polycrystalline diamond compact (PDC) cutters that shear rock with a continuous scraping motion.

[0024] In embodiments of the disclosure, the body 202 of the drill assembly 200 can define one or more nozzles that allow the drilling fluid to exit the body 202 (e.g., proximate to the crushing and/or cutting implements). The nozzles allow drilling fluid pumped through, for example, a drill string to exit the body 202. For example, as discussed with reference to FIG. 1, drilling fluid 122 is furnished to an interior passage of drill string 104 by pump 126 and flows downwardly through drill string 104 to drill bit

118 of bottom hole assembly 116, which can be implemented using a drill assembly 200. Drilling fluid 122 then exits drill string 104 via nozzles in drill bit 118, and circulates upwardly through the annulus region between the outside of drill string 104 and the wall of borehole 102. In this manner, rock cuttings can be lifted to the surface, destabilization of the rock in the wellbore can be at least partially prevented, the pressure of fluids inside the rock can be at least partially overcome so that the fluids do not enter the wellbore, and so forth.

[0025] The body 202 houses components for actuating a rotary mechanism included with the down hole equipment (e.g., a rotary valve used for directionally controlling a biasing unit of the rotary steerable drilling system 136, another mechanism involved in the directional control of a bias unit, and so forth). For example, the body 202 houses a primary input mechanism, such as a mud turbine 204 powered by the flow of the drilling fluid 122, a motor 205 (e.g., an alternating current (AC) induction motor), or another prime mover. The primary input mechanism comprises an input shaft 206, which can be driven by a fluid flow, such as the flow of the drilling fluid 122. In other embodiments, the input shaft 206 can be driven by the motor 205, or by another prime mover. The drill assembly 200 also includes an output shaft 208 coupled with the input shaft 206 to drive a rotary mechanism (e.g., a rotary valve of RSS equipment).

[0026] Further, the drill assembly 200 includes a drive mechanism 212 mechanically coupling the input shaft 206 to the output shaft 208. In embodiments of the disclosure, the drill assembly 200 is configured so that the drive mechanism 212 is operable to drive the rotary mechanism using a variable transmission ratio such that the input shaft 206 can run independently or at least substantially independently at one or more nominal angular speeds selected for the hydraulic mud motor/turbine or prime mover, while the output shaft 208 can run at a controlled angular speed such that it can maintain a constant geostationary angular position relative to a geostationary coordinate system, even with external disturbances, such as varying collar speed, mud weight, mud flow and so forth.

[0027] For rotary steerable drilling system equipment, the actuation of a biasing mechanism can be driven by a rotary valve, which remains fixed with respect to a geostationary coordinate system. This can be accomplished using a high speed, high torque servo mechanism. With a drilling system that implements a rotating sleeve tool, the torque used to rotate the valve can be furnished directly from an impeller, such as the impeller of a mud turbine rotary mechanism. Depending upon the flow of drilling fluid and the direction the drilling equipment is aimed, systems called “torquers” can be used to break the rotation of a control unit. However, this technique may generate heat due to high induction current in the torquers (referred to as “magnetic friction”). With a drilling system that does not implement rotating sleeve tools, the energy used to actuate the rotary valve can be supplied by a turbine power rotary mechanism, which can convert hydraulic power from the flow of drilling fluid into electricity, which is supplied to a servo motor. However, the energy needed to actuate the valve can be in the range of hundreds of Watts, and this configuration can occupy a large volume of space within the drilling equipment (e.g., using a power rotary mechanism, power converter electronics, a high power control system, and a control valve actuator).

[0028] In some embodiments, the nominal torque output of the primary input mechanism is supplied to a drive mechanism 212 that comprises a continuously variable transmission (CVT) 210, a constant speed drive (CSD) 211, a combination of a continuously variable transmission 210 and a constant speed drive 211, and so forth. The drive mechanism 212 mechanically couples the input shaft 206 to the output shaft 208 and operates to drive the rotary valve. In this manner, the input shaft 206 of the primary input mechanism is not directly actuating the rotary valve. Instead, the mechanical drive mechanism 212 modifies the rotation speed of the rotary valve using a secondary input 214 (e.g., an electric motor, a hydraulic motor, and so on). The secondary input 214 is mechanically coupled with the drive mechanism 212 and can be driven at a controlled (e.g., variable) input speed. This technique provides control actuation input for modifying the angular velocity of the rotary valve (e.g., according to a control system and/or position feedback loops). In this manner, the rotary steerable system can drill in a desired direction, even in suboptimal conditions for the primary input mechanism.

[0029] As described herein, the amount of electrical power used to drive an RSS biasing mechanism can be reduced (e.g., with respect to a drilling system where the torque used to rotate the valve is furnished directly from an impeller, or a drilling system where the energy used to actuate the rotary valve is supplied by a turbine power rotary mechanism). Further, the electrical power supply requirements and/or the control electronics can be simpler. In this manner, the drill assembly 200 can provide increased power efficiency and/or reduced heat dissipation (e.g., using the operating principles described herein based upon energy conversion from speed to torque and/or from torque to speed). Further, in a nominal condition for the primary input mechanism, a simplified control method may be used (e.g., without driving, where the valve rotates at or near the angular velocity used to aim the RSS in the desired direction).

[0030] The primary input mechanism (e.g., the motor 205, the mud turbine 204, or another prime mover), does not necessarily provide control to the rotary valve. Instead, direct servo control can be applied by actuation of the continuously variable transmission 210 and/or the constant speed drive 211. In this manner, the primary input mechanism can use a simplified control architecture such as open loop control to operate the output shaft 208 at a controlled speed. For example, the continuously variable transmission ratio can be actuated without direct feedback measurement (e.g., using indirect measurement of the speed of the output shaft 208). In some embodiments, the continuously variable transmission ratio can be actuated with a stepper motor or scalar AC induction motor control. In this manner, the output shaft 208 can be maintained at a controlled geostationary position, while the input shaft 206 can rotate at an uncontrolled nominal speed, which can be subject to external disturbances and/or not under direct control. In some embodiments, an actuator for the continuously variable transmission 210 and/or the constant speed drive 211 can provide direct feedback controlled actuation for geopositioning of the rotary valve.

[0031] With reference to FIG. 4, the output rotation of the continuously variable transmission 210 can be determined by the input rotation and the CVT ratio, where the

ratio can be driven by the position of the secondary input 214. In a low power configuration, the bias unit can use the mud turbine 204 as the prime mover, without using additional power generation other than what is used to drive the continuously variable transmission 210 and/or power associated sensors, signal conditioning, supervisory electronics, and so on. In some embodiments, electric power can be generated via an alternator actuated using the mud turbine 204. In this configuration, control system electronics can vary the driving input position depending on turbine rotation (e.g., based upon mud flow), housing and/or collar rotation, aimed valve position, and so on. When mud flow is substantially constant in a given drilling condition, the system can be less complex to drive (e.g., as compared to a drilling system where the torque used to rotate the valve is furnished directly from an impeller, or a drilling system where the energy used to actuate the rotary valve is supplied by a turbine power rotary mechanism). In some embodiments, a servo driving the position can have a limited angular rotation and can use relatively less actuation power (e.g., using a digital servo, an analog servo, a stepper motor, and so forth).

[0032] Referring now to FIG. 5, in some embodiments the primary input mechanism can be implemented using the motor 205, which can comprise, but is not necessarily limited to, an open loop motor (e.g., an AC induction motor, a stepper motor, a hydraulic motor, and so forth). As described previously, the torque and rotation for the motor 205 can be substantially constant under similar torque load, making the system simple to drive. As described herein, the rotation and torque for the motor 205 can be substantially constant at various mud flow rates (e.g., when sufficient energy enters the system). Further, in some embodiments, an alternative power source may be used to drive the secondary input 214 (e.g., a mud flow alternator, a battery, an energy harvesting device, and so on). In embodiments of the disclosure, the continuously variable transmission 210 can be implemented using, for example, a variable pulley system, toroidal and/or roller friction, and so forth. In some embodiments a hydrostatic configuration can be employed, e.g., with a continuously variable transmission 210 that employs a variable swash plate hydraulic motor and/or a hydraulic pump.

[0033] With reference to FIG. 6, the output rotation of the constant speed drive 211 can be determined based upon the rotation of two inputs and possibly a fixed CSD ratio. In this manner, the output angular velocity and torque can be a function of the two inputs. For example, one of the inputs can be the mud turbine 204 and the secondary input 214 can be a motor 216 (e.g., a servo motor), where the angular velocity of the motor 216 is controlled relative to a desired valve position (e.g., using an electronic controller 218). The controller 218 can implement control logic, and can receive and process signals from sensors configured to determine (e.g., sense, measure) one or more operating characteristics (e.g., angular velocity) of the mud turbine 204, the motor 216, the rotary valve, and so on. The CSD ratio for the mud turbine 204 can be selected so that the rotary valve can remain substantially fixed at nominal drilling fluid flow (e.g., with respect to the housing and/or collar coordinate system). In this manner, the motor 216 can supply a complementing rotation velocity and torque to drive the rotary valve in the aimed position. In some embodiments, power for actuating the motor 216 is supplied via an alternator set in motion directly through the input of the mud turbine 204.

[0034] Referring now to FIG. 7, the primary input mechanism can be implemented using a motor 205, which can comprise, but is not necessarily limited to, an open loop motor (e.g., an AC induction motor, a stepper motor, a hydraulic motor, and so forth). In this implementation, the secondary input 214 can be a motor 216 (e.g., a servo motor), where the angular velocity of the motor 216 is controlled relative to a desired valve position (e.g., using an electronic controller 218). The controller 218 can implement control logic, and can receive and process signals from sensors configured to determine (e.g., sense, measure) one or more operating characteristics (e.g., angular velocity) of the motor 205, the motor 216, the rotary valve, and so on. The basic rotation of the motor 205 can be adjusted (e.g., statically and/or with a slow dynamic) to a desired rotation regardless of drilling fluid flow, which can reduce the power requirement from the driving mover.

[0035] With reference to FIG. 8, the mud turbine 204 can be used with a continuously variable transmission 210 and a constant speed drive 211. The constant speed drive 211 can be implemented using a full freedom epicycloids gear train (e.g., where the solar, the

planet carrier, and the annulus are each free to rotate), and where two of these components are the inputs (e.g., the primary input mechanism and the secondary input 214), and the third component is the output (e.g., the rotary valve). For example, the secondary input 214 can be configured as, for instance, a driving motor, such as a motor 216 (e.g., a servo motor). In embodiments of the disclosure, the gear ratios between the epicycloids gear train components are calculated using epicycloids equations.

[0036] A system implementing a drill assembly 200, including some or all of its components, can operate under computer control. For example, a processor can be included with or in a system to control the components and functions of systems described herein using software, firmware, hardware (e.g., fixed logic circuitry), manual processing, or a combination thereof. The terms “controller,” “functionality,” “service,” and “logic” as used herein generally represent software, firmware, hardware, or a combination of software, firmware, or hardware in conjunction with controlling the systems. In the case of a software implementation, the module, functionality, or logic represents program code that performs specified tasks when executed on a processor (e.g., central processing unit (CPU) or CPUs). The program code can be stored in one or more computer-readable memory devices (e.g., internal memory and/or one or more tangible media), and so on. The structures, functions, approaches, and techniques described herein can be implemented on a variety of commercial computing platforms having a variety of processors.

[0037] The drill assembly 200 can be coupled with a controller (e.g., controller 218) for controlling the output of the drive mechanism 212. The controller can include a processor, a memory, and a communications interface. The processor provides processing functionality for the controller and can include any number of processors, micro-controllers, or other processing systems, and resident or external memory for storing data and other information accessed or generated by the controller. The processor can execute one or more software programs that implement techniques described herein. The processor is not limited by the materials from which it is formed or the processing

mechanisms employed therein and, as such, can be implemented via semiconductor(s) and/or transistors (e.g., using electronic integrated circuit (IC) components), and so forth.

[0038] The memory is an example of tangible, computer-readable storage medium that provides storage functionality to store various data associated with operation of the controller, such as software programs and/or code segments, or other data to instruct the processor, and possibly other components of the controller, to perform the functionality described herein. Thus, the memory can store data, such as a program of instructions for operating the system (including its components), and so forth. It should be noted that while a single memory is described, a wide variety of types and combinations of memory (e.g., tangible, non-transitory memory) can be employed. The memory can be integral with the processor, can comprise stand-alone memory, or can be a combination of both. The memory can include, but is not necessarily limited to: removable and non-removable memory components, such as random-access memory (RAM), read-only memory (ROM), flash memory (e.g., a secure digital (SD) memory card, a mini-SD memory card, and/or a micro-SD memory card), magnetic memory, optical memory, universal serial bus (USB) memory devices, hard disk memory, external memory, and so forth.

[0039] The communications interface is operatively configured to communicate with components of the system. For example, the communications interface can be configured to transmit data for storage in the system, retrieve data from storage in the system, and so forth. The communications interface is also communicatively coupled with the processor to facilitate data transfer between components of the system and the processor (e.g., for communicating inputs to the processor received from a device communicatively coupled with the controller). It should be noted that while the communications interface is described as a component of a controller, one or more components of the communications interface can be implemented as external components communicatively coupled to the system via a wired and/or wireless connection. The system can also comprise and/or connect to one or more input/output (I/O) devices (e.g., via the communications interface), including, but not necessarily limited to: a display, a mouse, a touchpad, a keyboard, and so on.

[0040] The communications interface and/or the processor can be configured to communicate with a variety of different networks, including, but not necessarily limited to: a wide-area cellular telephone network, such as a 3G cellular network, a 4G cellular network, or a global system for mobile communications (GSM) network; a wireless computer communications network, such as a WiFi network (e.g., a wireless local area network (WLAN) operated using IEEE 802.11 network standards); an internet; the Internet; a wide area network (WAN); a local area network (LAN); a personal area network (PAN) (e.g., a wireless personal area network (WPAN) operated using IEEE 802.15 network standards); a public telephone network; an extranet; an intranet; and so on. However, this list is provided by way of example and is not meant to limit the present disclosure. Further, the communications interface can be configured to communicate with a single network or multiple networks across different access points.

[0041] Referring now to FIG. 9, a procedure 900 is described in an example embodiment in which a rotary steerable drilling system is actively controlled. At block 910, an input shaft, such as the input shaft 206, coupled with a prime mover, such as the mud turbine 204 or the motor 205, is driven at a nominal uncontrolled rotational speed, such as by a flow of the drilling fluid 122 and/or another fluid. At block 920, a rotary mechanism, such as a rotary valve of the rotary steerable drilling system 136, is driven with an output shaft, such as the output shaft 208, coupled with the input shaft. At block 930, the input shaft is mechanically coupled to the output shaft with a drive mechanism, such as the drive mechanism 212, to drive the rotary mechanism at a controlled rotational speed. At block 940, a secondary input, such as the secondary input 214, is mechanically coupled with the drive mechanism. At block 950, the secondary input is driven as a control input to drive the rotary mechanism at the controlled rotational speed.

[0042] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from an actively controlled rotary steerable drilling system. Features shown in individual embodiments referred to above

may be used together in combinations other than those which have been shown and described specifically. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words ‘means for’ together with an associated function.

What is claimed is:

1. A down hole drill assembly comprising:
an input shaft coupled with a prime mover to be driven at a nominal uncontrolled rotational speed;
an output shaft coupled with the input shaft to drive a rotary mechanism;
a drive mechanism mechanically coupling the input shaft to the output shaft to drive the rotary mechanism at a controlled rotational speed; and
a secondary input mechanically coupled with the drive mechanism, the secondary input to be driven as a control input to drive the rotary mechanism at the controlled rotational speed.
2. The down hole drill assembly as recited in claim 1, wherein the prime mover comprises at least one of a mud turbine or a motor.
3. The down hole drill assembly as recited in claim 1, wherein the rotary mechanism comprises a rotary valve of a rotary steerable drilling system.
4. The down hole drill assembly as recited in claim 1, wherein the drive mechanism comprises at least one of a continuously variable transmission or a constant speed drive.
5. The down hole drill assembly as recited in claim 1, wherein the drive mechanism comprises a continuously variable transmission and a constant speed drive.
6. The down hole drill assembly as recited in claim 1, wherein the secondary input comprises a servo motor.

7. A method comprising:
driving an input shaft coupled with a prime mover at a nominal uncontrolled rotational speed;
driving a rotary mechanism with an output shaft coupled with the input shaft;
mechanically coupling the input shaft to the output shaft with a drive mechanism to drive the rotary mechanism at a controlled rotational speed;
mechanically coupling a secondary input with the drive mechanism; and
driving the secondary input as a control input to drive the rotary mechanism at the controlled rotational speed.

8. The method as recited in claim 7, wherein the prime mover comprises at least one of a mud turbine or a motor.

9. The method as recited in claim 7, wherein the rotary mechanism comprises a rotary valve of a rotary steerable drilling system.

10. The method as recited in claim 7, wherein the drive mechanism comprises at least one of a continuously variable transmission or a constant speed drive.

11. The method as recited in claim 7, wherein the drive mechanism comprises a continuously variable transmission and a constant speed drive.

12. The method as recited in claim 7, wherein the secondary input comprises a servo motor.

13. A system comprising:
an input shaft to be driven at a nominal uncontrolled rotational speed by fluid flow;
an output shaft coupled with the input shaft to drive a rotary mechanism;
a drive mechanism mechanically coupling the input shaft to the output shaft to drive the rotary mechanism at a controlled rotational speed; and
a secondary input mechanically coupled with the drive mechanism, the secondary input to be driven as a control input to drive the rotary mechanism at the controlled rotational speed.
14. The system as recited in claim 13, wherein the fluid flow comprises drilling fluid flow.
15. The system as recited in claim 13, wherein the input shaft is coupled with a prime mover.
16. The system as recited in claim 15, wherein the prime mover comprises a mud turbine.
17. The system as recited in claim 13, wherein the rotary mechanism comprises a rotary valve of a rotary steerable drilling system.
18. The system as recited in claim 13, wherein the drive mechanism comprises at least one of a continuously variable transmission or a constant speed drive.
19. The system as recited in claim 13, wherein the drive mechanism comprises a continuously variable transmission and a constant speed drive.
20. The system as recited in claim 13, wherein the secondary input comprises a servo motor.

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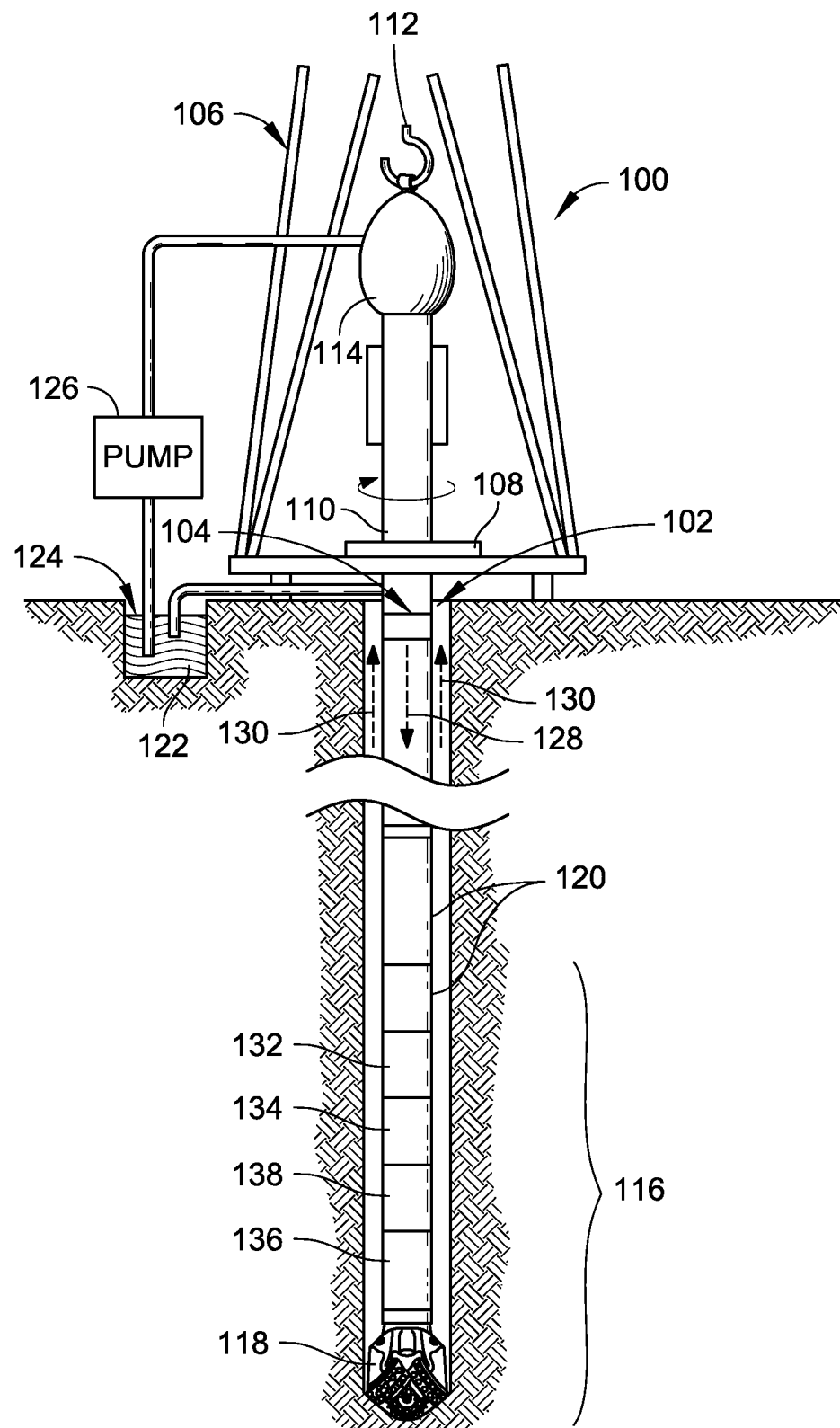


FIG. 1

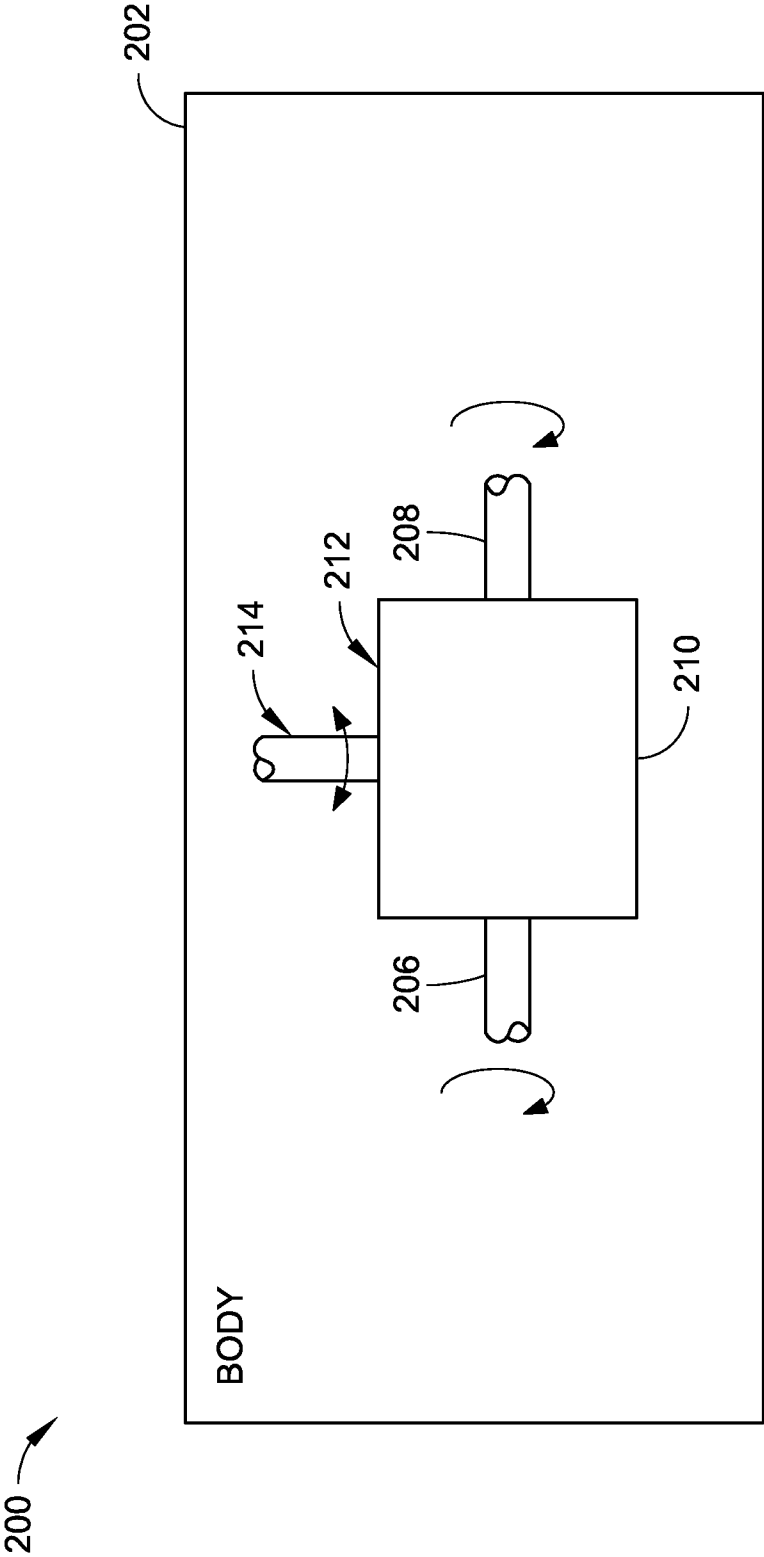


FIG. 2

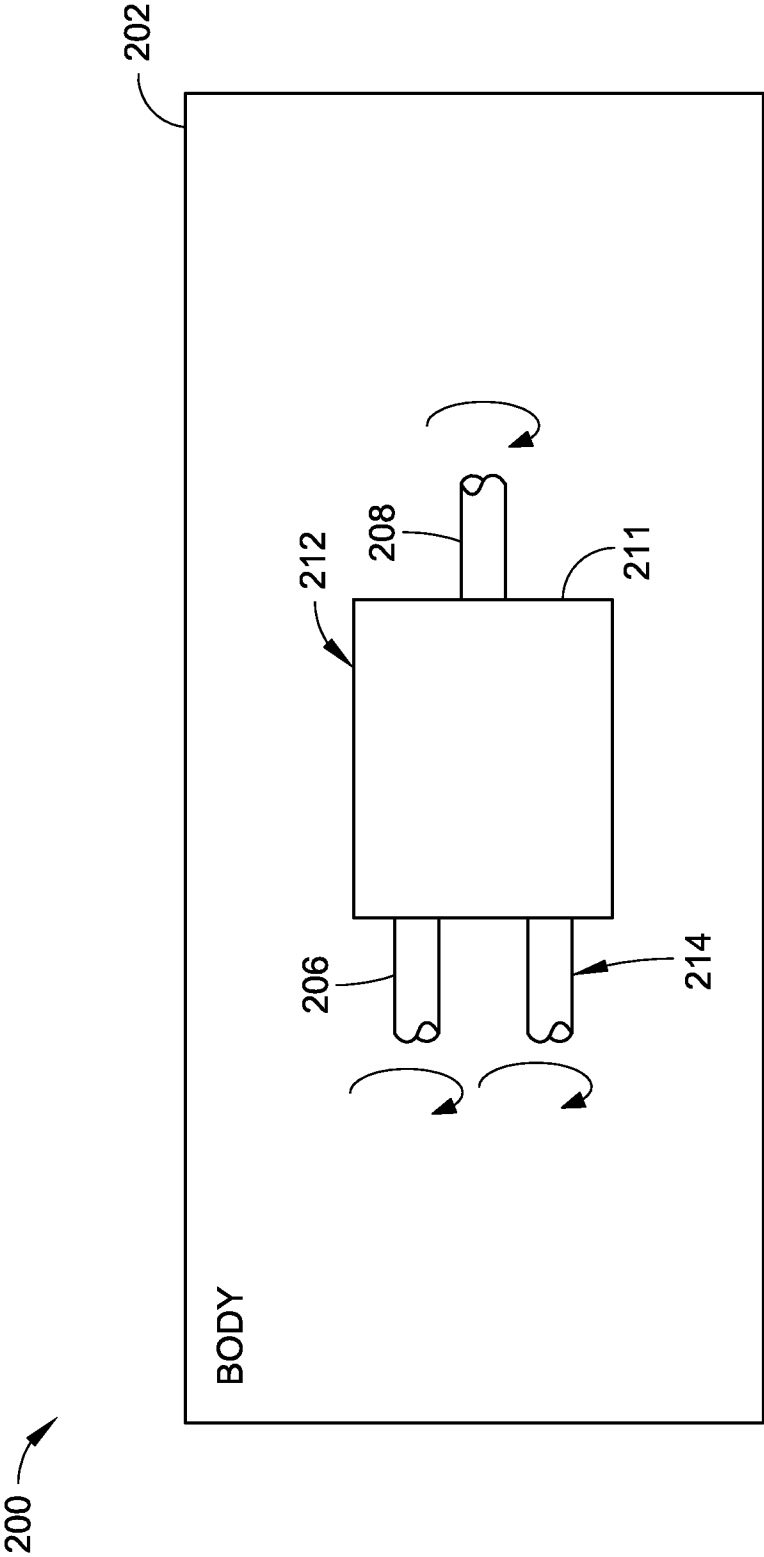


FIG. 3

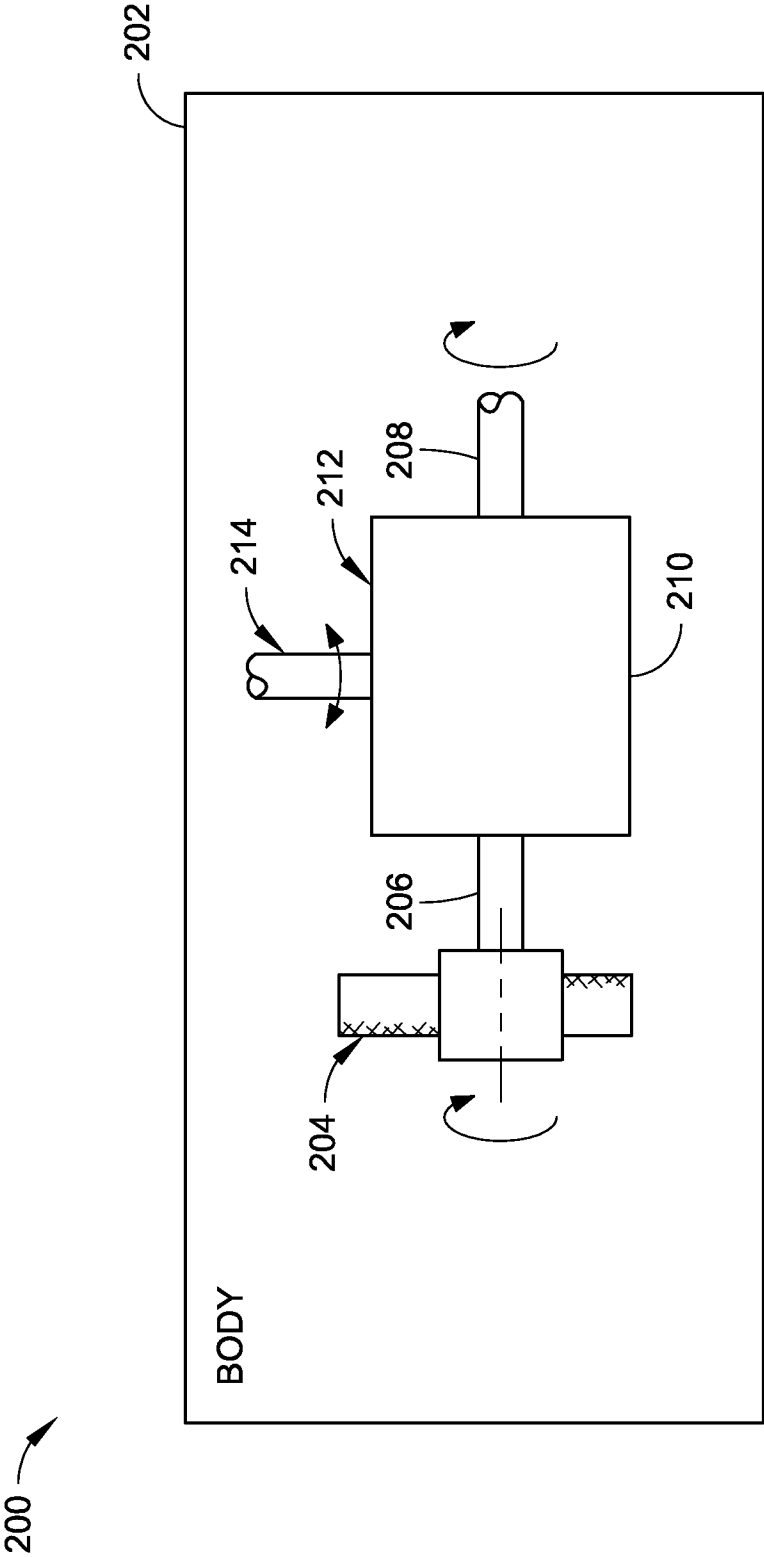


FIG. 4

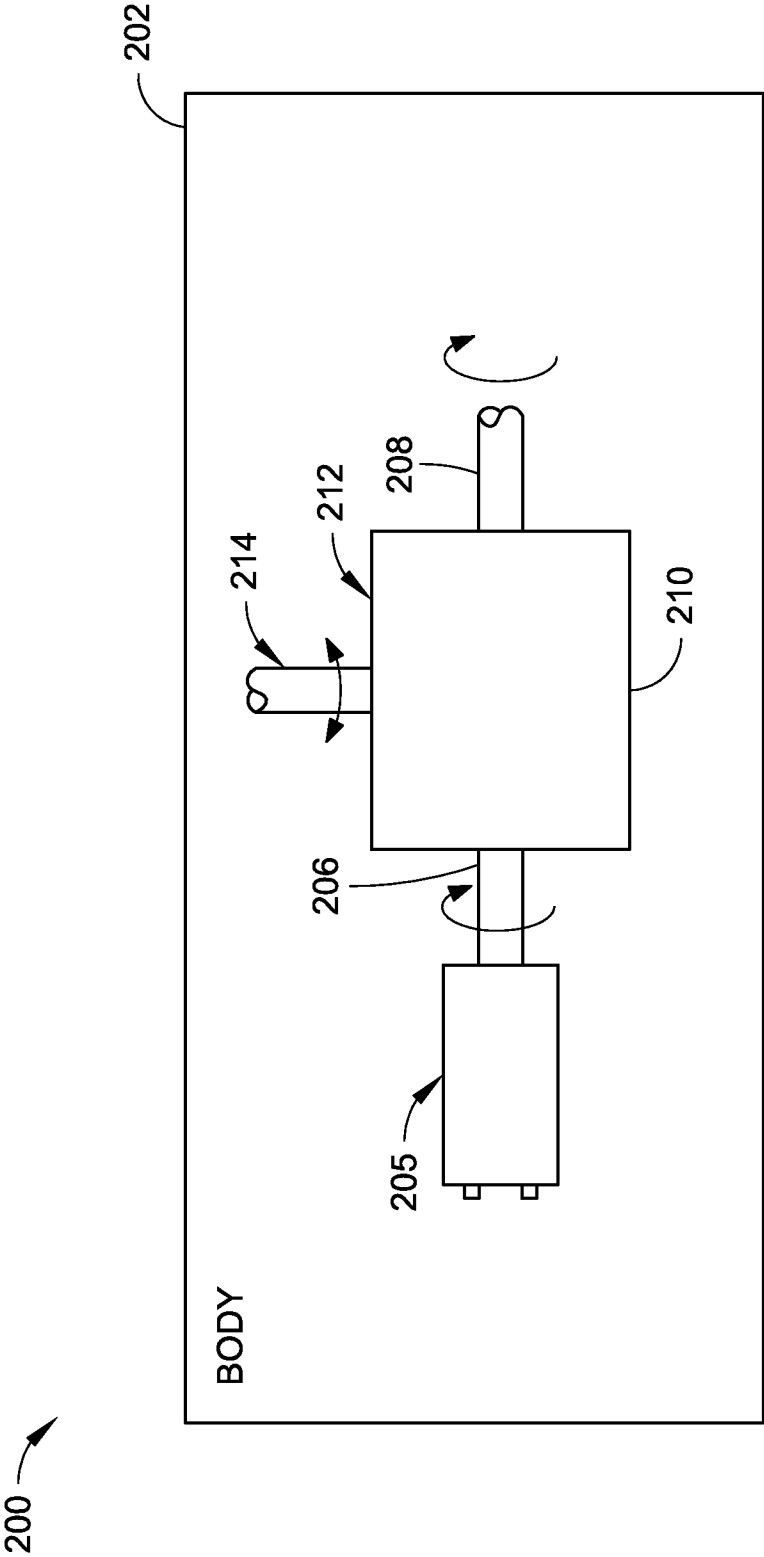


FIG. 5

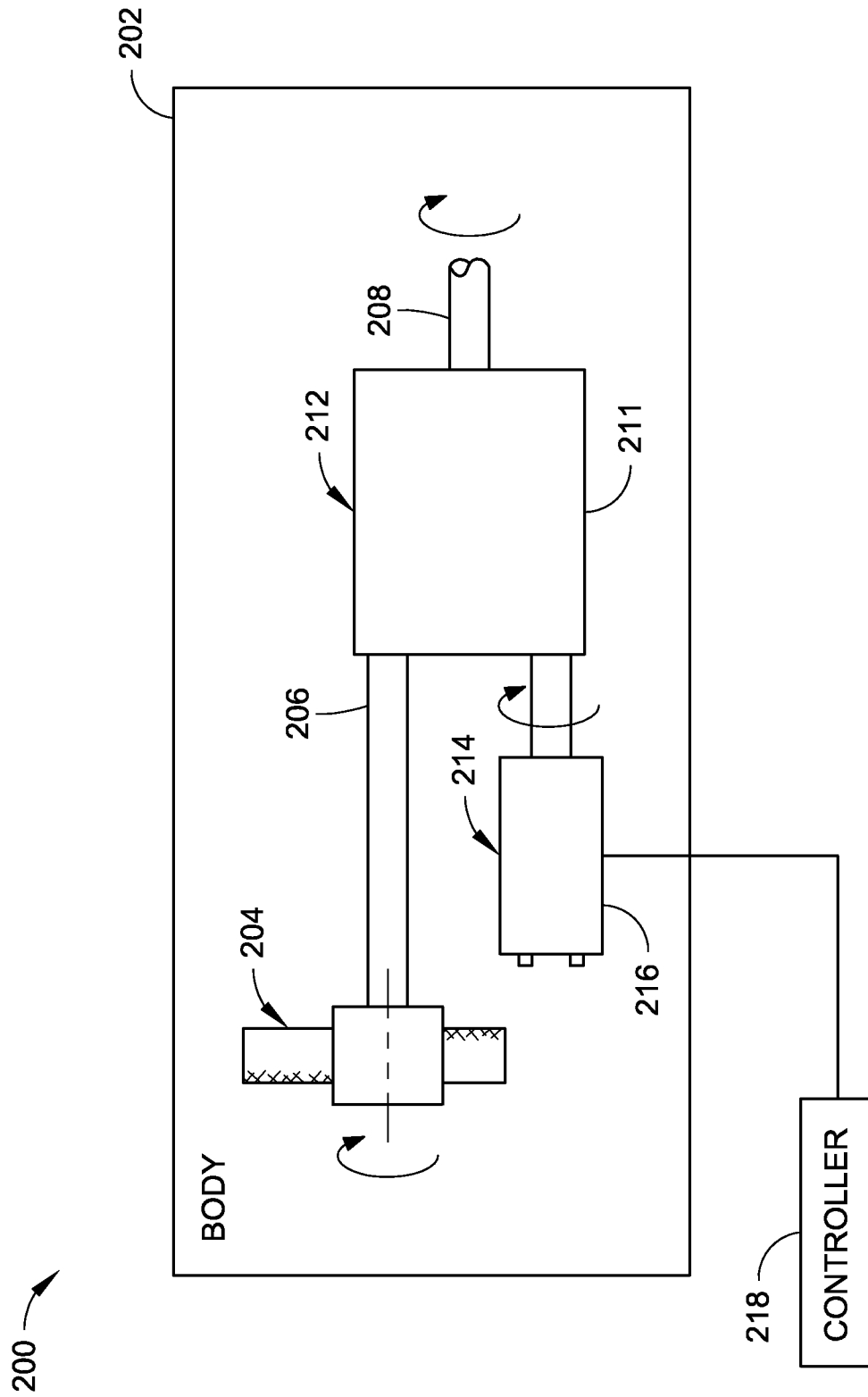


FIG. 6

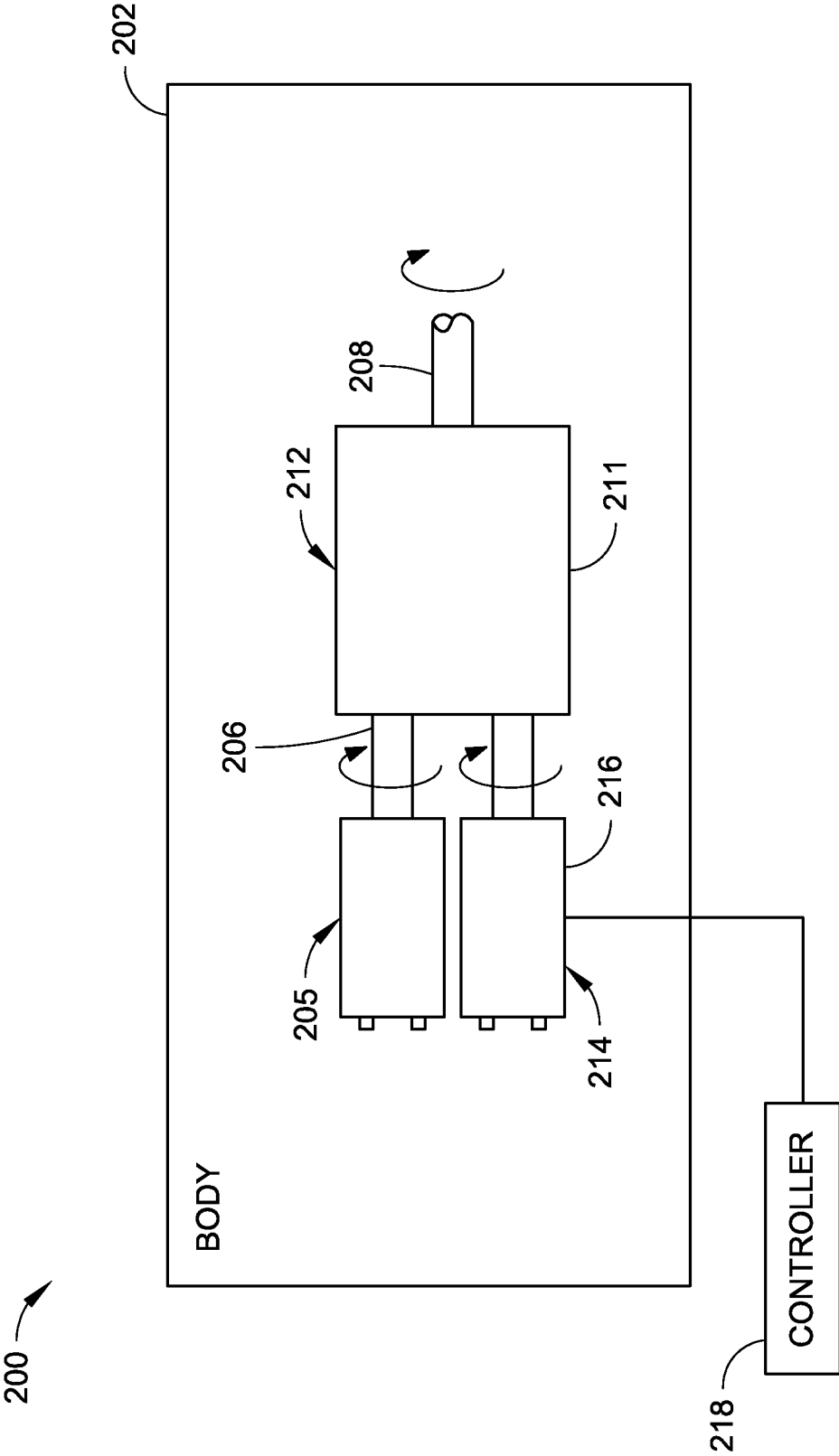


FIG. 7

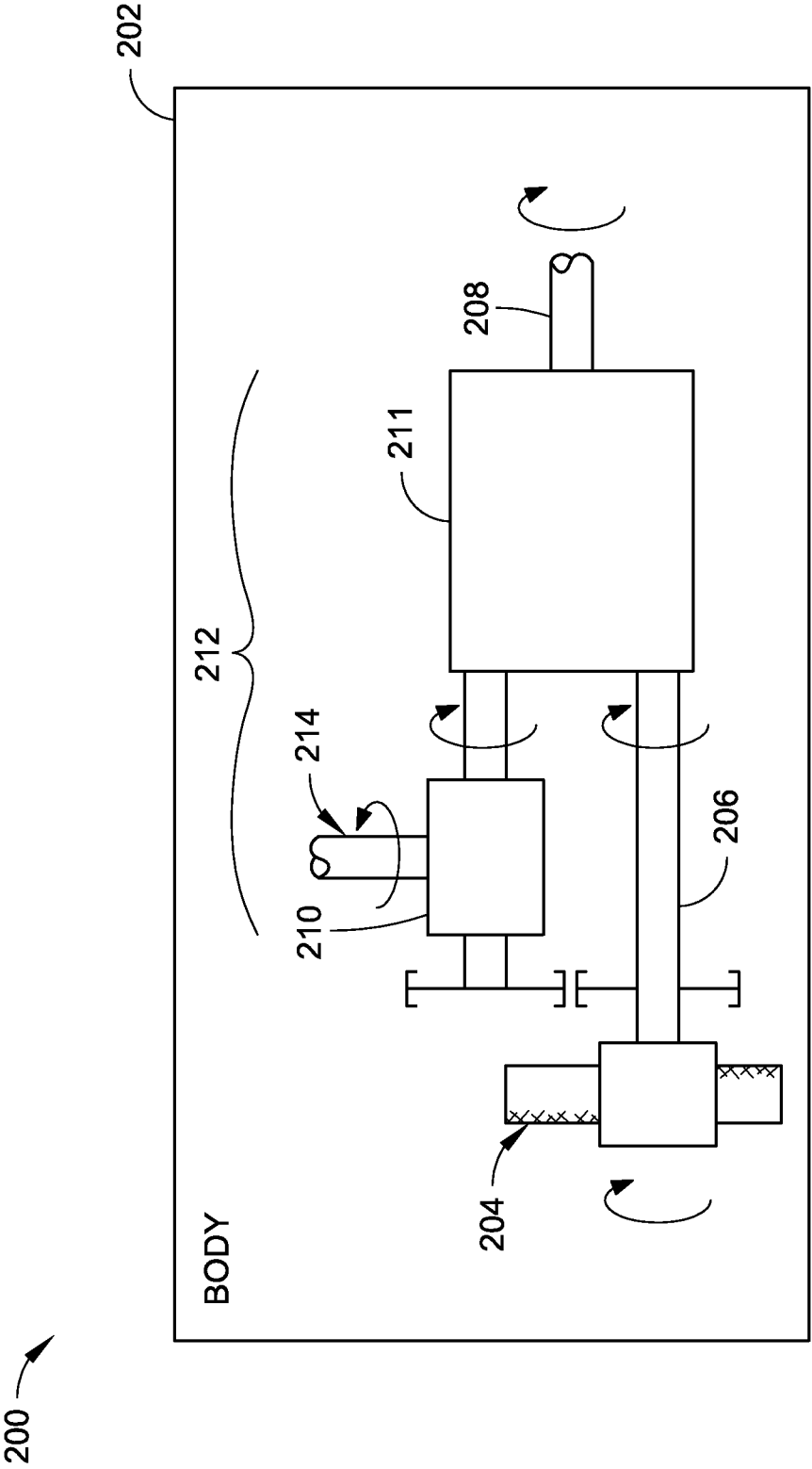
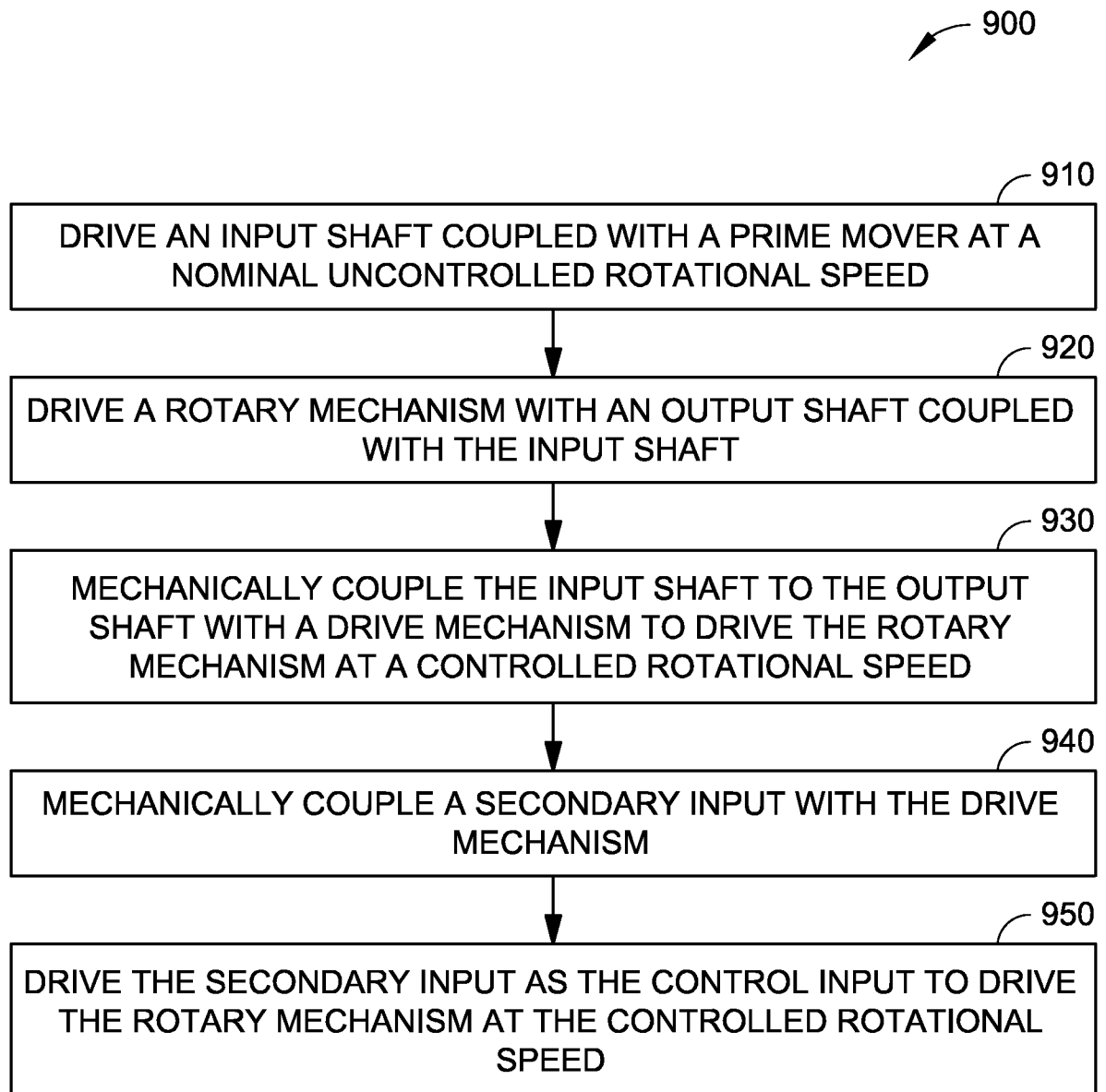


FIG. 8

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**FIG. 9**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/041053**A. CLASSIFICATION OF SUBJECT MATTER****E21B 7/06(2006.01)i, E21B 7/08(2006.01)i, E21B 17/00(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 7/06; E21B 4/00; F16H 3/72; F16H 37/06; F16H 47/04; E21B 7/08; E21B 7/04; E21B 17/00

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: input shaft, output shaft, prime mover, rotary mechanism, drive mechanism, second input, and servo motor**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4254669 A (SCHULZ, HORST) 10 March 1981 See abstract, column 3, line 3 - column 4, line 14, and figure 2.	1-20
Y	US 5820505 A (PARKER, DOUGLAS F.) 13 October 1998 See abstract, column 1, line 38 - column 2, line 17, and figure 1.	1-20
Y	US 2012-0160563 A1 (CLARK et al.) 28 June 2012 See abstract, paragraphs [0051]-[0054], and figure 2.	3, 9, 17
A	US 2004-0058769 A1 (LARKIN, ROBERT P.) 25 March 2004 See abstract, paragraphs [0031]-[0038], and figure 1A.	1-20
A	US 2012-0145458 A1 (DOWNTON, GEOFF) 14 June 2012 See abstract, paragraphs [0016]-[0021], and figure 1.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

24 September 2015 (24.09.2015)

Date of mailing of the international search report

24 September 2015 (24.09.2015)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 35208,
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/US2015/041053

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