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(54) Title: PULSATING JARRING TOOL

(57) Abstract: A rotary device imposes torque in a first direction for a first period of time causing a screw to exert force in a compression direction, causing a spring to compress. The rotary device does not impose torque for a second period of time, causing the spring to decompress at the beginning of the second period of time, causing the screw to move in a decompression direction opposite the compression direction. The rotary device imposes torque in a second direction opposite the first direction for a third period of time causing the screw to exert force in the decompression direction.

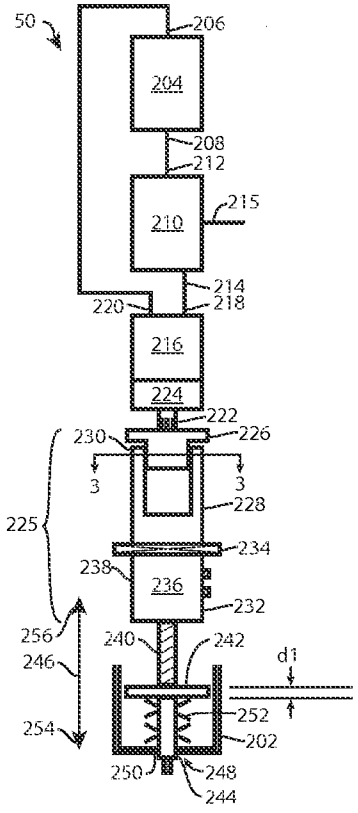


Fig. 2

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Pulsating Jarring Tool

Background

[0001] A jarring tool is typically used to dislodge a well tool that has become stuck in a well bore to allow the well tool to be retrieved to the surface.

Brief Description of the Drawings

[0002] Fig. 1 is a schematic illustration of an offshore oil and gas platform operating a downhole impact generator according to aspects of the present disclosure.

[0003] Figs. 2, 6, and 7 are schematic illustrations of a jarring tool according to aspects of the present disclosure showing operation of the jarring tool.

[0004] Figs. 3-5 are cross sectional views of the jarring tool of Figs. 2, 6, and 7 according to aspects of the present disclosure showing operation of the jarring tool. Fig. 3 is a cross sectional view of the jarring tool illustrated in Fig. 2 along section view lines labeled "3." Figs. 4 and 5 are additional cross sectional views similar to that shown in Fig. 3 but do not necessarily represent the condition of the jarring tool illustrated in Figs. 2, 6, and 7.

[0005] Fig. 8 is two graphs that illustrate a sequence of operations performed by the jarring tool of Figs. 2, 6, and 7.

[0006] Fig. 9 is a flow chart that illustrates operation of the jarring tool of Figs. 2, 6, and 7.

[0007] Fig. 10 is a block diagram showing an environment in which the jarring tool of Figs. 2, 6, and 7 might operate.

Detailed Description

[0008] While this disclosure describes a sea-based production system, it will be understood that the equipment and techniques described herein are applicable in land-based systems, multilateral wells, all types of drilling systems, all types of rigs, measurement while drilling ("MWD")/logging while drilling ("LWD") environments, wired drillpipe environments, coiled tubing (wired and unwired) environments, wireline environments, and similar environments. Referring initially to Fig. 1, in one or more embodiments, a downhole impact generator is being operated from an offshore oil and gas platform that is schematically illustrated and generally designated 10. In one or more embodiments, a semi-

submersible platform 12 is centered over a submerged oil and gas formation 14 located below sea floor 16. In one or more embodiments, a subsea conductor 18 extends from deck 20 of platform 12 to sea floor 16. In one or more embodiments, a wellbore 22 extends from sea floor 16 and traverse formation 14. In one or more embodiments, wellbore 22 includes a casing 24 that is cemented therein by cement 26. In one or more embodiments, casing 24 has perforations 28 in the interval proximate formation 14.

[0009] In one or more embodiments, a tubing string 30 extends from wellhead 32 to formation 14 to provide a conduit for production fluids to travel to the surface. In one or more embodiments, a pair of packers 34, 36 provide a fluid seal between tubing string 30 and casing 24 and direct the flow of production fluids from formation 14 through sand control screen 38. In one or more embodiments, disposed within tubing string 30 is a well tool 40 such as a flow control device, safety device or the like. In one or more embodiments, a downhole impact generator 42 is being run downhole on a conveyance 44, such as a wireline, a slickline, an electric line, a jointed tubing, a coiled tubing or the like. Alternatively, in one or more embodiments, downhole impact generator 42 may be run downhole via an autonomous conveyance such as a downhole robot. In one or more embodiments, downhole impact generator 42 includes a downhole power unit 46, an anchor 48 and a jarring tool 50. In one or more embodiments, jarring tool 50 is operably engageable with well tool 40 in a variety of ways depending upon the action to be performed on well tool 40 such as via a pulling tool, a shifting tool, a blind box or other tool capable of directly or indirectly interacting with well tool 40.

[0010] In one or more embodiments,, downhole impact generator 42 may incorporate a shifting tool such as a Halliburton BO shifting tool designed to actuate well tool 40 from one operational state to another operational state. As those skilled in the art will understand, if well tool 40 becomes stuck in one of its operational states, the force required to shift well tool 40 to another of its operational states may be high and may exceed the force which can be applied thereto by conventional wireline shifting tools. In one or more embodiments, downhole impact generator 42 of the present invention, however, can be used to apply the required jarring force to shift well tool 40 from its stuck operational state to its desired operational state. In one or more embodiments, this is achieved by deploying downhole impact generator 42 to the target location, engaging well tool 40 with jarring tool 50, anchoring downhole impact generator 42 within tubing string 30 with anchor 48, energizing jarring tool 50 with downhole power unit 46 and generating an impact with jarring tool 50 that delivers a jarring force to well tool 40, which operates well

tool 40 from its current operational state to its desired operational state. For example, in one or more embodiments, the jarring force may be used to break shear pins, shift a sliding sleeve or the like.

[0011] Similarly, in one or more embodiments, if downhole impact generator 42 incorporates a blind box or a pulling tool, downhole impact generator 42 is capable of providing sufficient jarring force to dislodge well tool 40 from wellbore 22 even if well tool 40 has become stuck within wellbore 22. Specifically, in one or more embodiments, downhole impact generator 42 can generate the required impact to create the necessary jarring force to dislodge well tools from deep, deviated, inclined or horizontal wellbores which may then be retrieved to the surface if desired. Accordingly, even though Fig. 1 depicts a vertical well, it should be noted by one skilled in the art that the jarring tool 50 described herein is equally well-suited for use in deviated wells, inclined wells or horizontal wells, especially in light of the re-initialization feature described below. As such, the use of directional terms such as above, below, upper, lower, upward, downward and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure. Also, even though Fig. 1 depicts an offshore operation, it should be noted by one skilled in the art that the jarring tool 50 described herein is equally well-suited for use in onshore operations.

[0012] One or more embodiments of the jarring tool 50, illustrated in Fig. 2, include a housing 202. Note that Fig. 2, which is a schematic illustration of the jarring tool 50, only the lower portion of the housing is illustrated. It will be understood that the housing encloses the entire jarring tool 50.

[0013] In one or more embodiments, the jarring tool 50 includes a power source 204, which may be a battery, a downhole generator, a connection to a surface power source, or a similar power source. In one or more embodiments, the power source 204 is a direct current (DC) power source, although with appropriate modifications, an alternating current (AC) power source could be used. In one or more embodiments, the power source 204 includes a first output 206 and a second output 208. The first output 206 may be a positive output and the second output 208 may be a negative output, or vice versa.

[0014] In one or more embodiments, the jarring tool 50 includes a rotary device control logic 210. In one or more embodiments, the rotary device control logic 210 has an input 212 and an output 214. In one or more embodiments, the input 212 of the rotary device control logic 210 is coupled to the second output 208 of the power source 204. In one or more embodiments, the output 214 of the rotary device

control logic 210 is commandable through a command input 215 to provide an electrical output of a first polarity, an electrical output of a second polarity, and no electrical output. The output 214 of the rotary device control logic 210 may also be commandable to vary the amplitude of the signal output on the output 214 of the rotary device control logic 210.

[0015] In one or more embodiments, the jarring tool 50 includes a rotary device 216. While the rotary device 216 is described herein as a DC electric motor, in one or more embodiments other types of rotary devices, such as AC motors and mud-driven motors, can be used as well. In one or more embodiments, the rotary device 216 includes a first electrical input 218 coupled to the rotary device control logic output 214 and a second rotary device input 220 coupled to the first output 206 of the power source 204. In one or more embodiments, the rotary device 216 also includes a rotary device mechanical output 222, which may be a motor shaft, such as that illustrated in Fig. 2. In one or more embodiments, the mechanical output 222 provides torque in a first direction (e.g., clockwise when viewed from above the rotary device 216, where "above" refers to directions on the representation shown in Fig. 2 (i.e., in Fig. 2, the rotary device control logic 210 is above the rotary device 216)) when the first electrical input 218 receives power of the first polarity, provides torque in a second direction (e.g., counterclockwise when viewed from above the rotary device 216) when first electrical input 218 receives power of the second polarity, and provides no torque when the first electrical input 218 receives no power. The absolute value of the magnitude of the torque output by the rotary device may vary depending on the amplitude of the signal on the rotary device control logic output 214. The rotary device may include a gear box 224 to increase the torque provided by the rotary device 216. The gear box 224 may have a gear ratio of approximately (i.e., within 10 percent of) 3000-5000:1 and produce revolutions of the mechanical output 222 of approximately (i.e., within 10 percent of) 2 revolutions per minute and approximately (i.e., within 10 percent of) 3200 inch-pounds of torque.

[0016] In one or more embodiments, the jarring tool 50 includes a transmission device 225 to convert the rotary energy provided by the rotary device 210 to linear energy. In one or more embodiments, the transmission device 225 includes an impact clutch 226 coupled to the rotary device mechanical output 222. In one or more embodiments, the impact clutch 226, illustrated in cross-section in Fig. 3, includes a columnar central shaft 302 aligned with the rotary device mechanical output 222. In one or more embodiments, the impact clutch 226 may be coupled to the rotary device mechanical output 222 by, for example, a set screw, by a pressure fitting on splines cut into a shaft of the rotary drive mechanical output

222, or by similar attachment mechanisms. In one or more embodiments, the columnar central shaft 302 of the impact clutch 226 includes an outer surface 304 and an engagement member 306 integral with the outer surface 304 of the columnar central shaft 302.

[0017] In one or more embodiments, the jarring tool 50 includes a drive shaft 228 (shown in Fig. 2). In one or more embodiments, the drive shaft 228 includes an engagement end 230 concentric with the columnar central shaft 302 of the impact clutch 226, as shown in Fig. 3. In one or more embodiments, the engagement end 230 includes a reaction element 308 engageable with the engagement member 306 of the impact clutch 226. In one or more embodiments, the drive shaft includes a thrust bearing end 232 coupled to, or integral with, the engagement end 230.

[0018] In one or more embodiments, when torque is applied to the impact clutch 226 and opposing torque is applied to the drive shaft 228 by the mechanisms described below, the engagement member 306 of the impact clutch 226 is in contact with the reaction element 308 as shown in Figs. 3, 4, and 5. In Fig. 3, no torque is applied to the impact clutch 226 and, in one or more embodiments, the central shaft 302 may be at any rotational orientation with respect to the engagement end 230 of the drive shaft 228, including the orientation shown. In Fig. 4, the torque indicated by arrow 402 has been applied to the impact clutch 226 and, in one or more embodiments, it is countered by the torque indicated by line 404. In Fig. 5, the torque indicated by the torque indicated by arrow 502 has been applied to the impact clutch 226 and, in one or more embodiments, it is countered by the torque indicated by line 504. In the situations shown in Figs. 4 and 5, in which the engagement member 306 and the reaction element 308 are pressed against each other, in one or more embodiments friction between the engagement member 306 and the reaction element 308 hinders the drive shaft 228 from moving in a longitudinal direction (i.e., in and out of the page on which Figs. 4 and 5 are presented) with respect to the impact clutch 226. In the situation shown in Fig. 3, the engagement member 306 and the reaction element 308 are not engaged and, in one or more embodiments, do not hinder the drive shaft 228 from moving in a longitudinal direction with respect to the impact clutch 226.

[0019] In one or more embodiments, the jarring tool 50 includes a thrust bearing 234 coupled to the housing 202 and slidably coupled to the thrust bearing end 232 of the drive shaft 228. In one or more embodiments, because of the slidable coupling, the drive shaft 228 can move up and down within the thrust bearing 234.

[0020] In one or more embodiments, the thrust bearing end 232 of the drive shaft 228 includes a ball screw 236. In one or more embodiments, the ball screw 236 includes a nut 238 coupled to, or integral with, the thrust bearing end 232 of the drive shaft 228. In one or more embodiments, the ball screw 236 includes a screw 240 engaged with the nut 238. As is conventional with ball screws, rotation of the nut 238 causes linear movement of the screw 240. In one or more embodiments, rotation of the nut 238 in one direction causes the screw 240 to extend away from the drive shaft (i.e., toward the bottom of Figs. 2, 6, and 7) and rotation of the nut 238 in the opposite direction causes the screw 240 to withdraw toward the drive shaft (i.e., toward the top of Figs. 2, 6, and 7).

[0021] In one or more embodiments, the jarring tool 50 includes a compression device 242 coupled to the screw 240 in such a way that a longitudinal movement, indicated by arrowed line 246, of the screw 240 moves the compression device 242 in the same direction.

[0022] In one or more embodiments, the jarring tool 50 includes a power rod 244 coupled to the compression device 242.

[0023] In one or more embodiments, the jarring tool 50 includes a housing exit 248, which is a hole in the housing 202, through which the power rod 244 passes.

[0024] In one or more embodiments, the jarring tool 50 includes a shaft seal 250 between the housing 202 and the power rod 244.

[0025] In one or more embodiments, the jarring tool 50 includes a spring 252 between the compression device 242 and the housing 202. The spring 252 may be a traditional spring. The spring 252 may be a stack of Bellville washers. The spring 252 may be any device that stores energy when it is compressed.

[0026] In one or more embodiments, the output 214 of the rotary device control logic 210 comprises three possible states: no electrical output, an electrical output of the first polarity, and an electrical output of the second polarity. In one or more embodiments, the rotary device 216 and the impact clutch 226 impose no torque on the drive shaft 228 when the output 214 of the rotary device control logic 210 has no electrical output. In this state the rotary device is essentially "off." Note that, while "polarity" indicates a direct current circuit, it will be understood that the circuitry described herein could be modified to operate with alternating current or with a mechanical energy, such as hydraulic energy.

[0027] In one or more embodiments, the rotary device 216 and the impact clutch 226 impose compression torque on the drive shaft 228 in a first direction when the output 214 of the rotary device control logic 210 is the electrical output of the first polarity and the engagement member 306 of the central shaft 302 of the impact clutch 226 engages the reaction element 308 of the engagement end 230 of the drive shaft 228 in the first direction. This is illustrated in Fig. 4, in which the first direction is indicated by arrow 402, and in Fig. 5, where the first direction is indicated by arrow 502. That is, the first direction can be that indicated by arrow 402 or arrow 502 depending on whether ball screw 236 is right-handed, in which case the screw 240 extends from the nut 238 for rotation indicated by arrow 402, or left-handed, in which case the screw 240 extends from the nut 238 for rotation indicated by arrow 502.

[0028] In one or more embodiments, the rotary device 216 and the impact clutch 226 impose decompression torque on the drive shaft 228 in a second direction when the output 214 of the rotary device control logic 210 is the electrical output of the second polarity and the engagement member 306 of the central shaft 302 of the impact clutch 226 engages the reaction element 308 of the engagement end 230 of the drive shaft 228 in the second direction. This is illustrated in Fig. 4, in which the second direction is indicated by arrow 402, and in Fig. 5, where the second direction is indicated by arrow 502. That is, the second direction can be that indicated by arrow 402 or arrow 502 depending on whether ball screw 236 is left-handed, in which case the screw 240 withdraws into the nut 238 for rotation indicated by arrow 402, or right-handed, in which case the screw 240 withdraws into the nut 238 for rotation indicated by arrow 502.

[0029] In one or more embodiments, the compression device 242 and the power rod 244 move in a compression direction, indicated by arrowhead 254 on arrowed line 246, to compress the spring 252 when the drive shaft 228 rotates in the first direction. In one or more embodiments, the compression device 242 and the power rod 244 move in a decompression direction, indicated by arrowhead 256 on arrowed line 246, to decompress the spring 252 when the drive shaft 228 rotates in the second direction.

[0030] In one or more embodiments, the spring 252 imposes a spring torque, indicated by arrow 404 in Fig. 4 for a right-handed ball screw 236 and arrow 504 in Fig. 5 for a left-handed ball screw 236, through the power rod 244, ball screw 236, and drive shaft 228. In one or more embodiments, the spring torque is opposite the compression torque. In one or more embodiments, the spring torque from the spring 252 and compression torque from the rotary device 216 and the impact clutch 226 cause friction between the

engagement member 306 of the impact clutch 226 and the reaction element 308 of the drive shaft 228 that resists the drive shaft 228 moving in the decompression direction 256 with respect to the impact clutch 226.

[0031] In one or more embodiments, setting the state of the rotary device control logic 210 to the "no power" state when the spring 252 is imposing a spring torque on the impact clutch 226 releases the friction between the engagement member 306 of the impact clutch 226 and the reaction element 308 of the drive shaft 228 and allows the power rod 244, compression device 242, ball screw 236, and drive shaft 228 to move in the decompression direction 256.

[0032] One or more embodiments of the operation of the jarring tool 50, illustrated in Figs. 2, 6 and 7, begin with the drive shaft 228 positioned to be relatively snug (i.e., within 10 millimeters) against the impact clutch 226, as shown in Fig. 2. To initiate the jarring action, in one or more embodiments, the rotary device control logic 210 is put into a state in which the rotary device 216 drives the transmission device 225 in the compression direction 254. In this state, in one or more embodiments, the ball screw 236 causes the screw 240 to extend, alternately compressing the spring 252, by an amount d1, and overcoming the friction between the engagement member 306 of the impact clutch 226 and the reaction element 308 of the engagement end 230 of the drive shaft 228. In one or more embodiments, the later action causes the drive shaft 228 to slip in the compression direction 254 with respect to the impact clutch, as can be seen by comparing Figs. 2 and 6. In one or more embodiments, these combined actions cause the power rod 244 to extend from the jarring tool 50 in the compression direction 254, which applies a tensile load on the well tool 40 that is the subject of the jarring exercise. In one or more embodiments, depending on the power available to the rotary device 216, the gear ration of the gear box 224, and other factors, the power rod 244 will advance at approximately (i.e., within 10 percent of) 0.5 inches/minute in an unloaded state and approximately (i.e., within 10 percent of) 0.2 inches/minute in an loaded state and exert approximately (i.e., within 10 percent of) 50,000 pounds of linear force.

[0033] In one or more embodiments, to continue the jarring action, the rotary device control logic 210 is put into a state in which it is applying no torque. In one or more embodiments, this releases the friction between the engagement member 306 of the impact clutch 226 and the reaction element 308 of the engagement end 230 of the drive shaft 228, which allows the spring to decompress and drive the compression device 242, ball screw 236, and drive shaft 228 in the decompression direction 256 by an amount d2, returning the jarring tool 50 to the position shown in Fig. 2 or the position shown in Fig. 7.

In one or more embodiments, this latter action applies an impulse load on the well tool 40 that is the subject of the jarring exercise. In one example, in one or more embodiments, the jarring tool 50 will apply an impulse of approximately (i.e., within 10 percent of) 40,000 pounds of impact force over a period of 3-8 milliseconds. In one or more embodiments, the compression spring rate and mass of the spring 252 can be varied to create higher or lower impact forces. If the spring 252 is a traditional spring (i.e., a coil or helix of wire), the amount of force produced by the spring 252 is related to the spring constant *k* of the spring 252. In one or more embodiments, the spring constant is related to the material used (e.g., spring wire, alloy steel wire, stainless steel wire, etc.), the diameter of the wire, the diameter of the coil or helix, the length of the spring, and the number of coils in the spring, all of which can be varied.

[0034] At this point, in one or more embodiments, it may be necessary to re-initialize the jarring tool 50 to prepare it for another jarring event. In one or more embodiments, to accomplish this the rotary device control logic 210 is put into a state in which in which the rotary device 216 drives the transmission device 225 in the decompression direction 256. In one or more embodiments, in this state, the ball screw 236 causes the screw 240 to withdraw, pulling the impact clutch 226 in the decompression direction 256 until it reaches the starting position shown in Fig. 2. Note that, in one or more embodiments, this re-initialization can be done when the jarring tool 50 is in a vertical orientation, as shown in Fig. 1, or, because the re-initialization does not rely on gravity, it can be done in a non-vertical orientation, which might occur in a deviated well.

[0035] In one or more embodiments, the re-initialization capability of the jarring tool allows it to be used to apply repeated, or "pulsating," jarring events, as shown in Fig. 8. Fig. 8 consists of 2 graphs. The top graph shows the rotary device control logic 210 state versus time. In one or more embodiments, the rotary device control logic 210 can be in one of three states: 1, in which the rotary device 216 is driving the power rod 244 in the compression direction; 0, in which the rotary device 216 is "off"; and -1, in which the rotary device 216 is driving the power rod 244 in the decompression direction. It will be understood that the rotary device control logic 216 can have additional states. For example, the rotary device control logic 216 may have additional states representing different rates of rotation (e.g., full speed, half speed, quarter speed, or a rotational speed defined by a rational number) for the rotary device 216. The bottom graph shows the energy applied by the power rod 244, where the energy has a magnitude and a direction (toward the surface or away from the surface) versus time. The time scale on

the top graph is aligned with the time scale on the bottom graph. The two graphs are intended to be illustrative only and should not be interpreted literally. For example, the bottom graph does not show variations caused by the alternations between compressing the spring 252 and sliding the engagement member 306 of the impact clutch 226 with respect to the reaction element 308 of the engagement end 230 of the drive shaft 228. The amplitudes of the various peaks of the graph may vary either singly or in comparison with each other.

[0036] The upper graph of Fig. 8 shows the rotary device control logic 210 in:

- state 0 for time period (t0,t1),
- state 1 for time period (t1,t2),
- state 0 for time period (t2,t3),
- state -1 for time period (t3,t4),
- state 0 for time period (t4,t5),
- state 1 for time period (t5,t6),
- state 0 for time period (t6,t7),
- state -1 for time period (t7,t8),
- state 0 for time period (t8,t9),
- state 1 for time period (t9,t10), and
- state 0 thereafter.

[0037] The lower graph of Fig. 8 shows the energy applied by the power rod:

- is 0 for time period (t0,t1),
- increases in the away-from-surface direction for time period (t1,t2),

- produces an impulse in the toward-surface direction at time t2,
- is 0 for time period (t3,t4), during which the jarring tool 50 is re-initializing,
- is 0 for time period (t4,t5),
- increases in the away-from-surface direction for time period (t5,t6),
- produces an impulse in the toward-surface direction at time t6,
- is 0 for time period (t7,t8), during which the jarring tool 50 is re-initializing,
- is 0 for time period (t8,t9),
- increases in the away-from-surface direction for time period (t9,t10), and
- produces an impulse in the toward-surface direction at time t6.

[0038] Thus, in this example, the jarring tool 50 applies tensile loads away from the surface during time periods (t1,t2), (t5,t6), and (t9,t10) and impulse loads toward the surface at times t2, t6, and t10.

[0039] In one or more embodiments of operation, as shown in Fig. 9, the jarring tool 50 imposes torque in a first direction (e.g., the compression direction shown in Fig. 8) for a first period of time (e.g., time period (t1, t2), (t5,t6) or (t9,t10) in Fig. 8) (block 902). The amplitude of the torque imposed by the jarring tool 50 during time period (t1,t2) may be different from that imposed during time period (t5,t6), which may be different from the amplitude of the torque imposed during time period (t9,t10). In one or more embodiments, the jarring tool 50 then removes torque for a second period of time (e.g., time period (t2,t3) or (t6,t7) in Fig. 8). In one or more embodiments, the jarring tool then imposes torque in a second direction (e.g., the decompression direction shown in Fig. 8) for a third period of time (e.g., time periods (t3,t4) or (t7,t8)) (block 902).

[0040] In one or more embodiments of an environment, such as that shown in Fig. 10, the jarring tool 50 is controlled by software in the form of a computer program on a non-transitory computer readable media 1005, such as a CD, a DVD, a USB drive, a portable hard drive or other portable memory. In one or more embodiments, a processor 1010, which may be the rotary device control logic 210 or a surface processor (not shown), reads the computer program from the computer readable media 1005 through an

input/output device 1015 and stores it in a memory 1020 where it is prepared for execution through compiling and linking, if necessary, and then executed. In one or more embodiments, the system accepts inputs through an input/output device 1015, such as a keyboard or keypad, mouse, touchpad, touch screen, etc., and provides outputs through an input/output device 1015, such as a monitor or printer. In one or more embodiments, the system stores the results of calculations in memory 1020 or modifies such calculations that already exist in memory 1020.

[0041] In one or more embodiments, the results of calculations that reside in memory 1020 are made available through a network 1025 to a remote real time operating center 1030. In one or more embodiments, the remote real time operating center 1030 makes the results of calculations available through a network 1035 to help in the planning of oil wells 1040 or in the drilling of oil wells 1040.

[0042] The word "coupled" herein means a direct connection or an indirect connection.

[0043] In one or more embodiments, an apparatus includes a rotary device having an output that can have a compression state in which it outputs compression torque, a jarring state in which it does not output torque, and an initializing state in which it outputs decompression torque in the opposite direction of the compression torque. In one or more embodiments, the apparatus further includes a transmission device coupled to the rotary device. In one or more embodiments, the apparatus further includes a screw coupled to the transmission device. In one or more embodiments, the apparatus further includes a spring coupled to the screw, wherein the spring compresses when the screw moves in a compression direction. In one or more embodiments, the transmission device converts compression state torque to linear motion of the screw in the compression direction, prevents the screw from moving in a decompression direction opposite the compression direction when the rotary device is in the compression state, and allows the screw to move in the decompression direction when the rotary device is in the jarring state.

[0044] Implementations of the apparatus may include one or more of the following. The transmission device may convert decompression torque into linear motion of the screw in the decompression direction. The spring may be a Bellville washer. The decompression direction may not be aligned with a direction of gravity. The transmission device may allow the screw to move in the decompression direction when the rotary device is in the jarring state in the absence of gravity. The spring may include a wire coil. A jarring force provided by the apparatus may be adjusted by selecting a spring constant factor selected

from the group consisting of a wire material, the diameter of the wire, the diameter of the coil, the length of the spring, and the number of coils in the spring.

[0045] In one or more embodiments, an apparatus includes a housing. In one or more embodiments, the apparatus further includes a rotary device control logic having an output that is commandable to provide an electrical output of a first polarity, an electrical output of a second polarity, and no electrical output. In one or more embodiments, the apparatus further includes a rotary device. In one or more embodiments, the rotary device includes an electrical input coupled to the rotary device control logic output and a mechanical output that provides torque in a first direction when the electrical input receives power of the first polarity, provides torque in a second direction when electrical input receives power of the second polarity, and provides no torque when the electrical input receives no power. In one or more embodiments, the apparatus further includes a transmission device. In one or more embodiments, the transmission device includes a rotary input coupled to the mechanical output of the rotary device and a screw coupled to the rotary input by friction caused by resistance of the screw to torque provided by the rotary input. In one or more embodiments, the screw moves in a compression direction away from the rotary input in response to rotation of the rotary input in the first direction, and the screw moves in a decompression direction toward the rotary input in response to rotation of the rotary input in the second direction. In one or more embodiments, the apparatus further includes a spring that is compressed when the screw moves in the compression direction. In one or more embodiments, the spring urges the screw in the decompression direction. In one or more embodiments, when the rotary device provides no torque, a previously-compressed spring causes the screw to move in the decompression direction.

[0046] Implementations of the apparatus may include one or more of the following. An amplitude of the electrical output of the rotary device control logic may be commandable. The rotary device may include a direct current motor. The screw may move in the decompression direction toward the rotary input in response to rotation of the rotary input in the second direction in the absence of gravity. The spring may include a wire coil. A jarring force provided by the apparatus may be adjusted by selecting a spring constant factor selected from the group consisting of a wire material, the diameter of the wire, the diameter of the coil, the length of the spring, and the number of coils in the spring.

[0047] In one or more embodiments, an apparatus includes a housing. In one or more embodiments, the apparatus further includes a power source. In one or more embodiments, the power source has a first output and a second output. In one or more embodiments, the apparatus further includes a rotary device

control logic which includes an input coupled to the first output of the power source, and an output. In one or more embodiments, the apparatus further includes a rotary device which includes a first rotary device input coupled to the second output of the power source, a second rotary device input coupled to the output of the rotary device control logic, and a rotary device mechanical output. In one or more embodiments, the apparatus further includes an impact clutch coupled to the rotary device mechanical output. In one or more embodiments, the impact clutch includes a columnar central shaft aligned with the rotary output mechanical output. In one or more embodiments, the columnar central shaft includes an outer surface and an engagement member integral with the outer surface of the columnar central shaft. In one or more embodiments, the apparatus further includes a drive shaft which includes an engagement end concentric with the columnar central shaft of the impact clutch. In one or more embodiments, the engagement end includes a reaction element engageable with the engagement member of the impact clutch. In one or more embodiments, the drive shaft further includes a thrust bearing end coupled to the engagement end. In one or more embodiments, the apparatus further includes a thrust bearing coupled to the housing and slidably coupled to the thrust bearing end of the drive shaft. In one or more embodiments, the apparatus further includes a ball screw which includes a nut coupled to the thrust bearing end of the drive shaft and a screw engaged with the nut. In one or more embodiments, the apparatus further includes a power rod coupled to the screw of the ball screw. The apparatus further includes a compression device coupled to the screw so that a longitudinal movement of the screw moves the compression device. In one or more embodiments, the apparatus further includes a housing exit comprising a hole in the housing through which the power rod passes. In one or more embodiments, the apparatus further includes a shaft seal between the housing and the shaft seal. In one or more embodiments, the apparatus further includes a spring between the anti-rotation device and the housing.

[0048] Implementations of the invention may include one or more of the following. The output of the rotary device control logic may have three possible states: no electrical output, an electrical output of the first polarity, and an electrical output of the second polarity. The rotary device and the impact clutch may impose no torque on the drive shaft when the output of the rotary device control logic has no electrical output. The rotary device and the impact clutch may impose compression torque on the drive shaft in a first direction when the output of the rotary device control logic is the electrical output of the first polarity and the engagement member of the central shaft of the impact clutch engages the reaction element of the engagement end of the drive shaft in the first direction. The rotary device and the impact clutch may impose decompression torque on the drive shaft in a second direction when the output of the

rotary device control logic is the electrical output of the second polarity and the engagement member of the central shaft of the impact clutch engages the reaction element of the engagement end of the drive shaft in the second direction. The compression device and the power rod may move in a compression direction to compress the spring when the drive shaft rotates in the first direction. The compression device and the power rod may move in a decompression direction to decompress the spring when the drive shaft rotates in the second direction. The spring may impose a spring torque through the power rod, ball screw, and drive shaft. The spring torque may be opposite the compression torque. The spring torque from the spring and compression torque from the rotary device and the impact clutch may cause friction between the engagement member of the impact clutch and the reaction element of the drive shaft that resists the drive shaft moving in the decompression direction with respect to the impact clutch. Setting the state of the rotary device control logic to the no power state when the spring is imposing a spring torque on the impact clutch may release the friction between the engagement member of the impact clutch and the reaction element of the drive shaft and allow the power rod, ball screw, and drive shaft to move in the decompression direction. The compression device and the power rod may move in a decompression direction to decompress the spring when the drive shaft rotates in the second direction in the absence of gravity. The spring may include a wire coil. A jarring force provided by the apparatus may be adjusted by selecting a spring constant factor selected from the group consisting of a wire material, the diameter of the wire, the diameter of the coil, the length of the spring, and the number of coils in the spring. The engagement end of the drive shaft may include a hollow columnar shell comprising an inner surface. The reaction element may be integral with the inner surface of the hollow columnar shell.

[0049] In one or more embodiments, a method includes a rotary device imposing torque in a first direction for a first period of time causing a screw to exert force in a compression direction, causing a spring to compress. In one or more embodiments, the method further includes the rotary device not imposing torque for a second period of time, causing the spring to decompress at the beginning of the second period of time, causing the screw to move in a decompression direction opposite the compression direction. In one or more embodiments, the method further includes the rotary device imposing torque in a second direction opposite the first direction for a third period of time causing the screw to exert force in the decompression direction.

[0050] Implementations of the invention may include one or more of the following. The rotary device imposing rotary device imposing torque in the first direction for the first period of time, the rotary device not imposing torque for the second period of time, and the rotary device imposing torque in the second direction opposite the first direction for the third period of time may be repeated. An amplitude of the torque imposed for the first period of time may be different from an amplitude of the torque imposed for the repetition of the first period of time. The rotary device imposing torque in the second direction opposite the first direction for the third period of time may cause the screw to exert force in the decompression direction in the absence of gravity. The spring may include a wire coil. The method may further include adjusting a jarring force provided by the screw by selecting a spring constant factor selected from the group consisting of a wire material, the diameter of the wire, the diameter of the coil, the length of the spring, and the number of coils in the spring. The first period of time, the second period of time, and the third period of time may not all be the same. The force exerted by the screw in the decompression direction may include an impulse of force. The force exerted by the screw in the compression direction may include a tensile force.

[0051] The text above describes one or more specific embodiments of a broader invention. The invention also is carried out in a variety of alternate embodiments and thus is not limited to those described here. The foregoing description of an embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

Claims

What is claimed is:

1. An apparatus comprising:

a rotary device having an output that can have a compression state in which it outputs compression torque, a jarring state in which it does not output torque, and an initializing state in which it outputs decompression torque in the opposite direction of the compression torque;

a transmission device coupled to the rotary device;

a screw coupled to the transmission device,

a spring coupled to the screw, wherein the spring compresses when the screw moves in a compression direction;

wherein the transmission device:

converts compression state torque to linear motion of the screw in the compression direction,

prevents the screw from moving in a decompression direction opposite the compression direction when the rotary device is in the compression state, and

allows the screw to move in the decompression direction when the rotary device is in the jarring state.

2. The apparatus of claim 1 wherein the transmission device further converts decompression torque into linear motion of the screw in the decompression direction.

3. The apparatus of claim 1 wherein the spring is a Bellville washer.

4. The apparatus of claim 1 wherein the decompression direction is not aligned with a direction of gravity.

5. The apparatus of claim 1 wherein the transmission device allows the screw to move in the decompression direction when the rotary device is in the jarring state in the absence of gravity.

6. The apparatus of claim 1 wherein the spring comprises a wire coil and a jarring force provided by the apparatus is adjusted by selecting a spring constant factor selected from the group consisting of a wire

material, the diameter of the wire, the diameter of the coil, the length of the spring, and the number of coils in the spring.

7. An apparatus comprising:

a housing;

a rotary device control logic having an output that is commandable to provide an electrical output of a first polarity, an electrical output of a second polarity, and no electrical output;

a rotary device comprising:

an electrical input coupled to the rotary device control logic output,

a mechanical output that:

provides torque in a first direction when the electrical input receives power of the first polarity,

provides torque in a second direction when electrical input receives power of the second polarity, and

provides no torque when the electrical input receives no power;

a transmission device comprising:

a rotary input coupled to the mechanical output of the rotary device, and

a screw coupled to the rotary input by friction caused by resistance of the screw to torque provided by the rotary input,

wherein the screw moves in a compression direction away from the rotary input in response to rotation of the rotary input in the first direction, and

wherein the screw moves in a decompression direction toward the rotary input in response to rotation of the rotary input in the second direction;

a spring that is compressed when the screw moves in the compression direction, the spring urging the screw in the decompression direction;

wherein, when the rotary device provides no torque, a previously-compressed spring causes the screw to move in the decompression direction.

8. The apparatus of claim 7 wherein an amplitude of the electrical output of the rotary device control logic is commandable.

9. The apparatus of claim 7 wherein the rotary device comprises a direct current motor.

10. The apparatus of claim 7 wherein the screw moves in the decompression direction toward the rotary input in response to rotation of the rotary input in the second direction in the absence of gravity.

11. The apparatus of claim 7 wherein the spring comprises a wire coil and a jarring force provided by the apparatus is adjusted by selecting a spring constant factor selected from the group consisting of a wire material, the diameter of the wire, the diameter of the coil, the length of the spring, and the number of coils in the spring.

12. An apparatus comprising:

a housing;

a power source comprising a first output and a second output;

a rotary device control logic comprising:

an input coupled to the first output of the power source, and

an output;

a rotary device comprising:

a first rotary device input coupled to the second output of the power source,

a second rotary device input coupled to the output of the rotary device control logic, and

a rotary device mechanical output;

an impact clutch coupled to the rotary device mechanical output, the impact clutch comprising:

a columnar central shaft aligned with the rotary output mechanical output, the columnar central shaft comprising an outer surface, and

an engagement member integral with the outer surface of the columnar central shaft;

a drive shaft comprising:

an engagement end concentric with the columnar central shaft of the impact clutch, the engagement end comprising a reaction element engageable with the engagement member of the impact clutch, and

a thrust bearing end coupled to the engagement end;

a thrust bearing coupled to the housing and slidably coupled to the thrust bearing end of the drive shaft;

a ball screw comprising:

a nut coupled to the thrust bearing end of the drive shaft, and

a screw engaged with the nut;

a power rod coupled to the screw of the ball screw;

a compression device coupled to the screw so that a longitudinal movement of the screw moves the compression device;

a housing exit comprising a hole in the housing through which the power rod passes;

a shaft seal between the housing and the shaft seal; and

a spring between the anti-rotation device and the housing.

13. The apparatus of claim 12 wherein:

the output of the rotary device control logic comprises three possible states:

no electrical output,

an electrical output of the first polarity, and

an electrical output of the second polarity;

the rotary device and the impact clutch impose no torque on the drive shaft when the output of the rotary device control logic has no electrical output;

the rotary device and the impact clutch impose compression torque on the drive shaft in a first direction when the output of the rotary device control logic is the electrical output of the first polarity and the engagement member of the central shaft of the impact clutch engages the reaction element of the engagement end of the drive shaft in the first direction;

the rotary device and the impact clutch impose decompression torque on the drive shaft in a second direction when the output of the rotary device control logic is the electrical output of the second polarity and the engagement member of the central shaft of the impact clutch engages the reaction element of the engagement end of the drive shaft in the second direction;

the compression device and the power rod move in a compression direction to compress the spring when the drive shaft rotates in the first direction;

the compression device and the power rod move in a decompression direction to decompress the spring when the drive shaft rotates in the second direction;

the spring imposes a spring torque through the power rod, ball screw, and drive shaft, the spring torque being opposite the compression torque, wherein the spring torque from the spring and compression torque from the rotary device and the impact clutch cause friction between the engagement member of the impact clutch and the reaction element of the

drive shaft that resists the drive shaft moving in the decompression direction with respect to the impact clutch; and

setting the state of the rotary device control logic to the no power state when the spring is imposing a spring torque on the impact clutch releases the friction between the engagement member of the impact clutch and the reaction element of the drive shaft and allows the power rod, ball screw, and drive shaft to move in the decompression direction.

14. The apparatus of claim 12 wherein the compression device and the power rod move in a decompression direction to decompress the spring when the drive shaft rotates in the second direction in the absence of gravity.

15. The apparatus of claim 7 wherein the spring comprises a wire coil and a jarring force provided by the apparatus is adjusted by selecting a spring constant factor selected from the group consisting of a wire material, the diameter of the wire, the diameter of the coil, the length of the spring, and the number of coils in the spring.

16. The apparatus of claim 12 wherein the engagement end of the drive shaft comprises:

a hollow columnar shell comprising an inner surface, and

wherein the reaction element is integral with the inner surface of the hollow columnar shell.

17. A method comprising:

a rotary device imposing torque in a first direction for a first period of time causing a screw to exert force in a compression direction, causing a spring to compress;

the rotary device not imposing torque for a second period of time, causing the spring to decompress at the beginning of the second period of time, causing the screw to move in a decompression direction opposite the compression direction; and

the rotary device imposing torque in a second direction opposite the first direction for a third period of time causing the screw to exert force in the decompression direction.

18. The method of claim 17 further comprising repeating the rotary device imposing rotary device imposing torque in the first direction for the first period of time, the rotary device not imposing torque

for the second period of time, and the rotary device imposing torque in the second direction opposite the first direction for the third period of time.

19. The method of claim 18 wherein an amplitude of the torque imposed for the first period of time is different from an amplitude of the torque imposed for the repetition of the first period of time.

20. The method of claim 17 wherein the rotary device imposing torque in the second direction opposite the first direction for the third period of time causes the screw to exert force in the decompression direction in the absence of gravity.

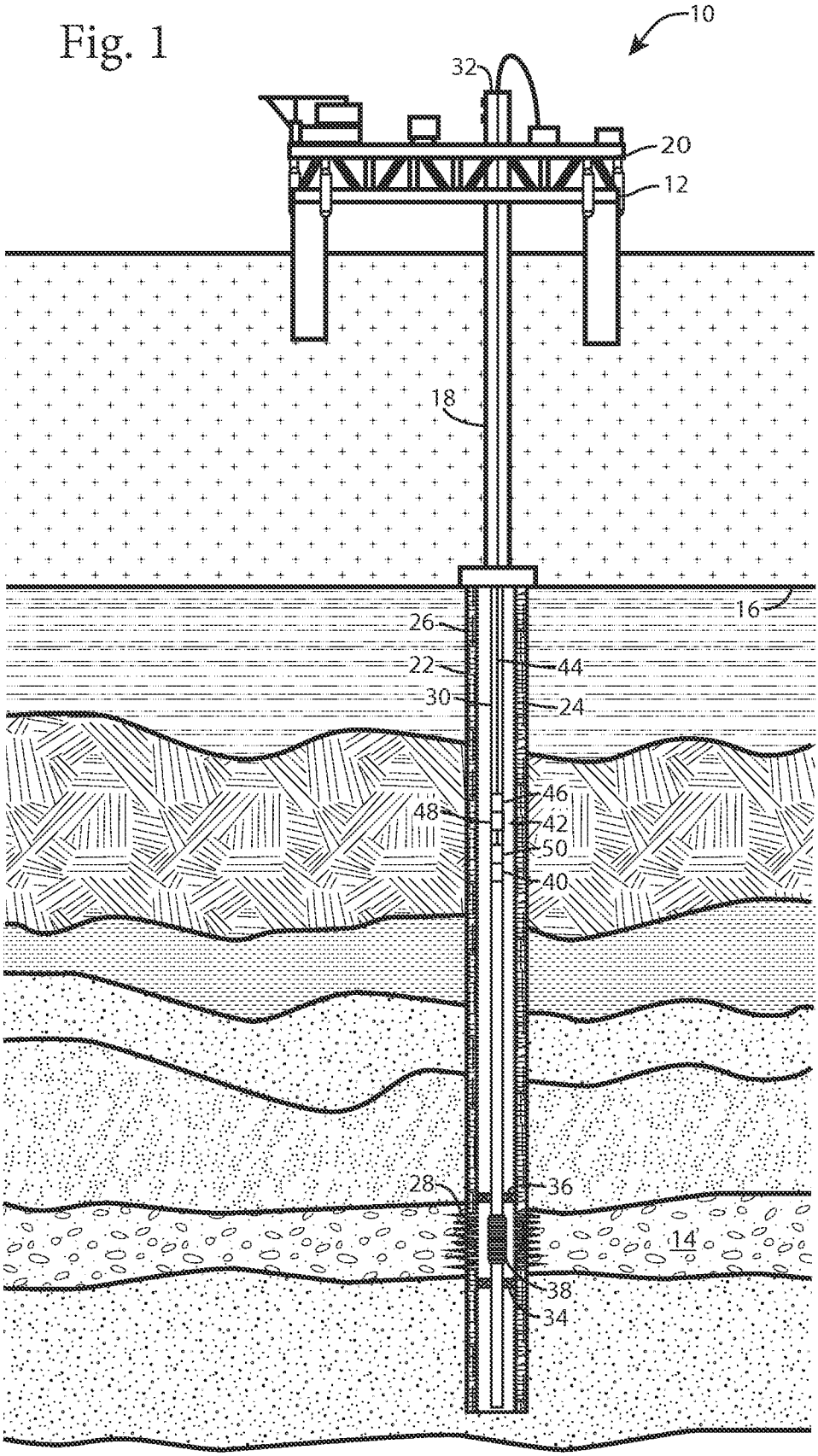
21. The method of claim 17 wherein the spring comprises a wire coil, further comprising adjusting a jarring force provided by the screw by selecting a spring constant factor selected from the group consisting of a wire material, the diameter of the wire, the diameter of the coil, the length of the spring, and the number of coils in the spring.

22. The method of claim 17 wherein the first period of time, the second period of time, and the third period of time are not all the same.

23. The method of claim 17 wherein the force exerted by the screw in the decompression direction comprises an impulse of force.

24. The method of claim 17 wherein the force exerted by the screw in the compression direction comprises a tensile force.

Fig. 1



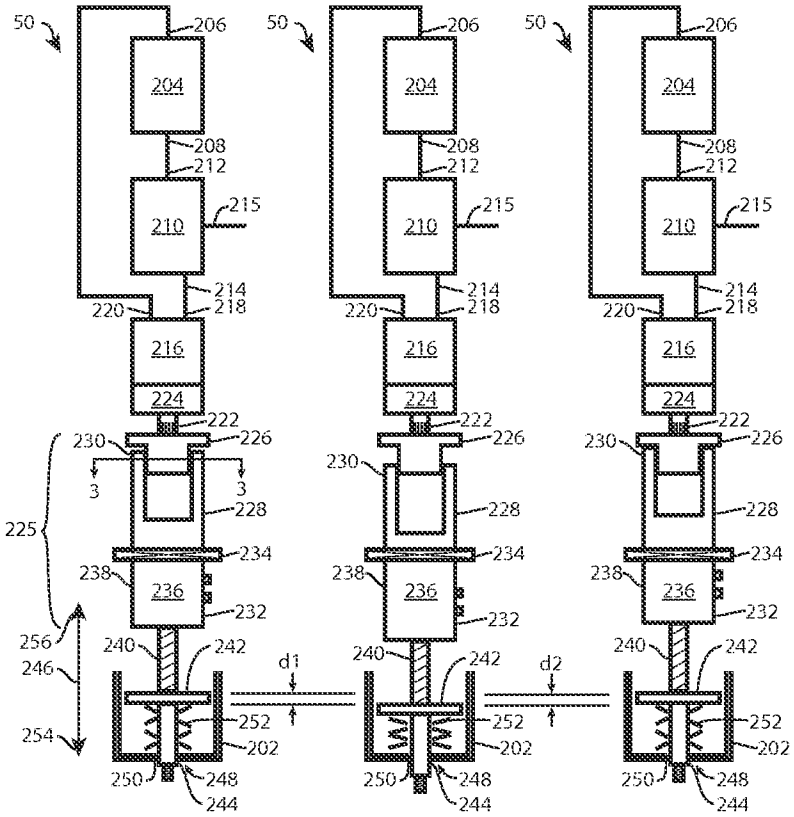


Fig. 2 Fig. 6 Fig. 7

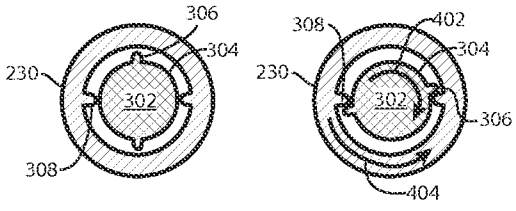


Fig. 3 Fig. 4 Fig. 5

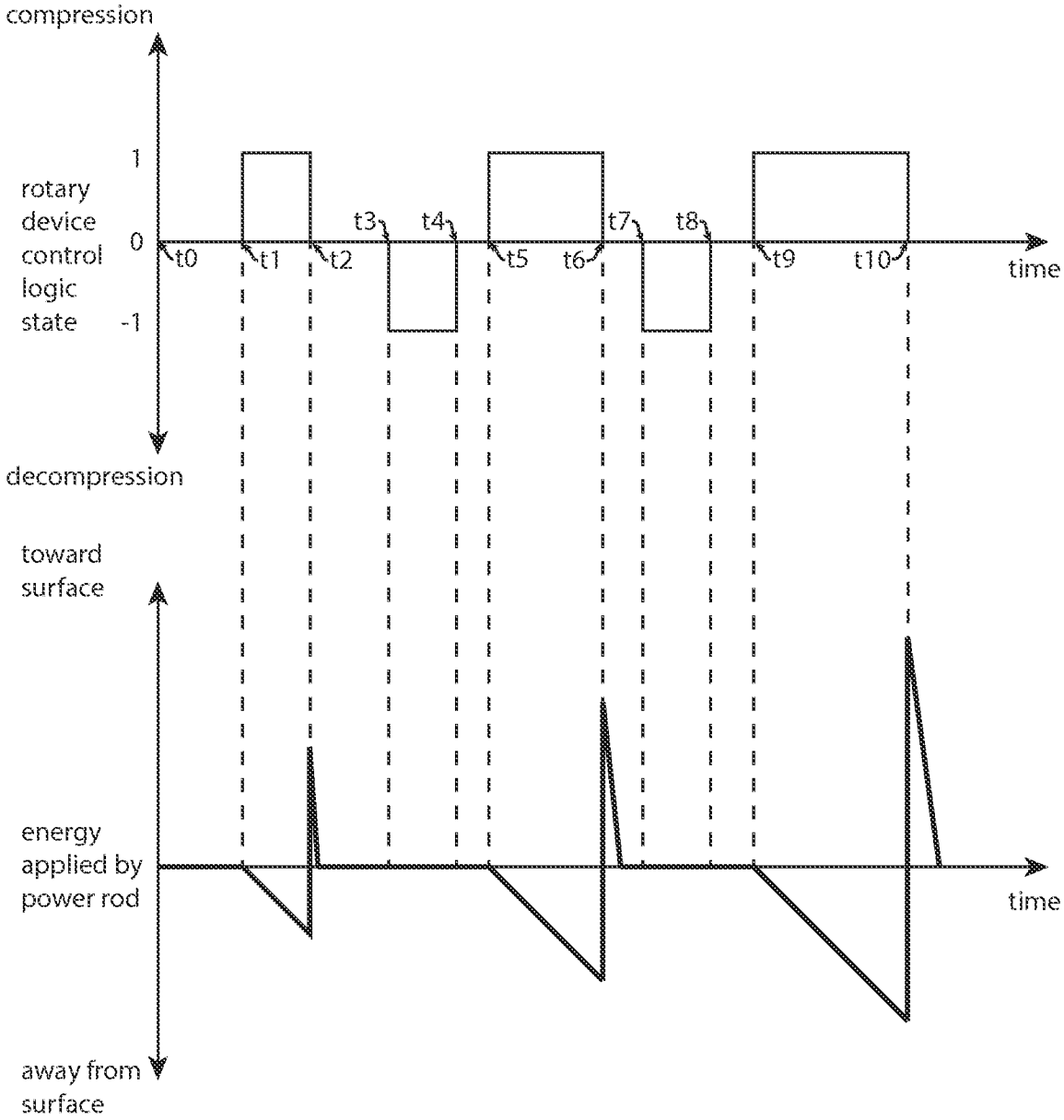

compression
1
rotary
device
control
logic
state
0
-1
t0
t1
t2
t3
t4
t5
t6
t7
t8
t9
t10
time
decompression
toward
surface
energy
applied by
power rod
time
away from
surface

Fig. 8

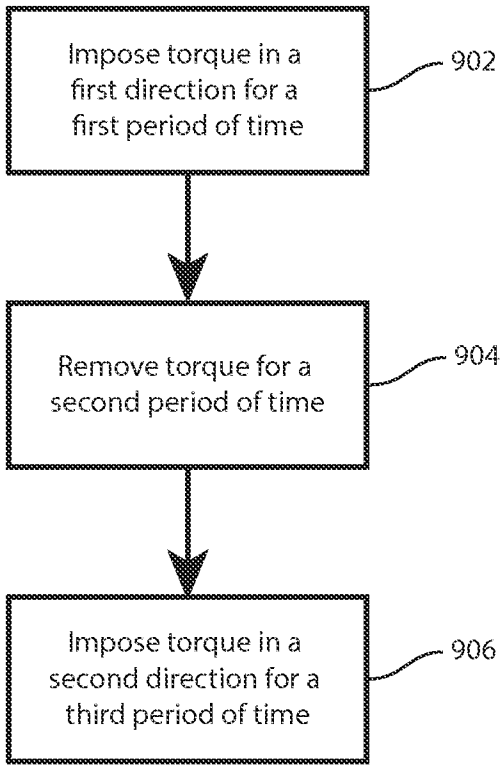

Impose torque in a first direction for a first period of time
902
Remove torque for a second period of time
904
Impose torque in a second direction for a third period of time
906

Fig. 9

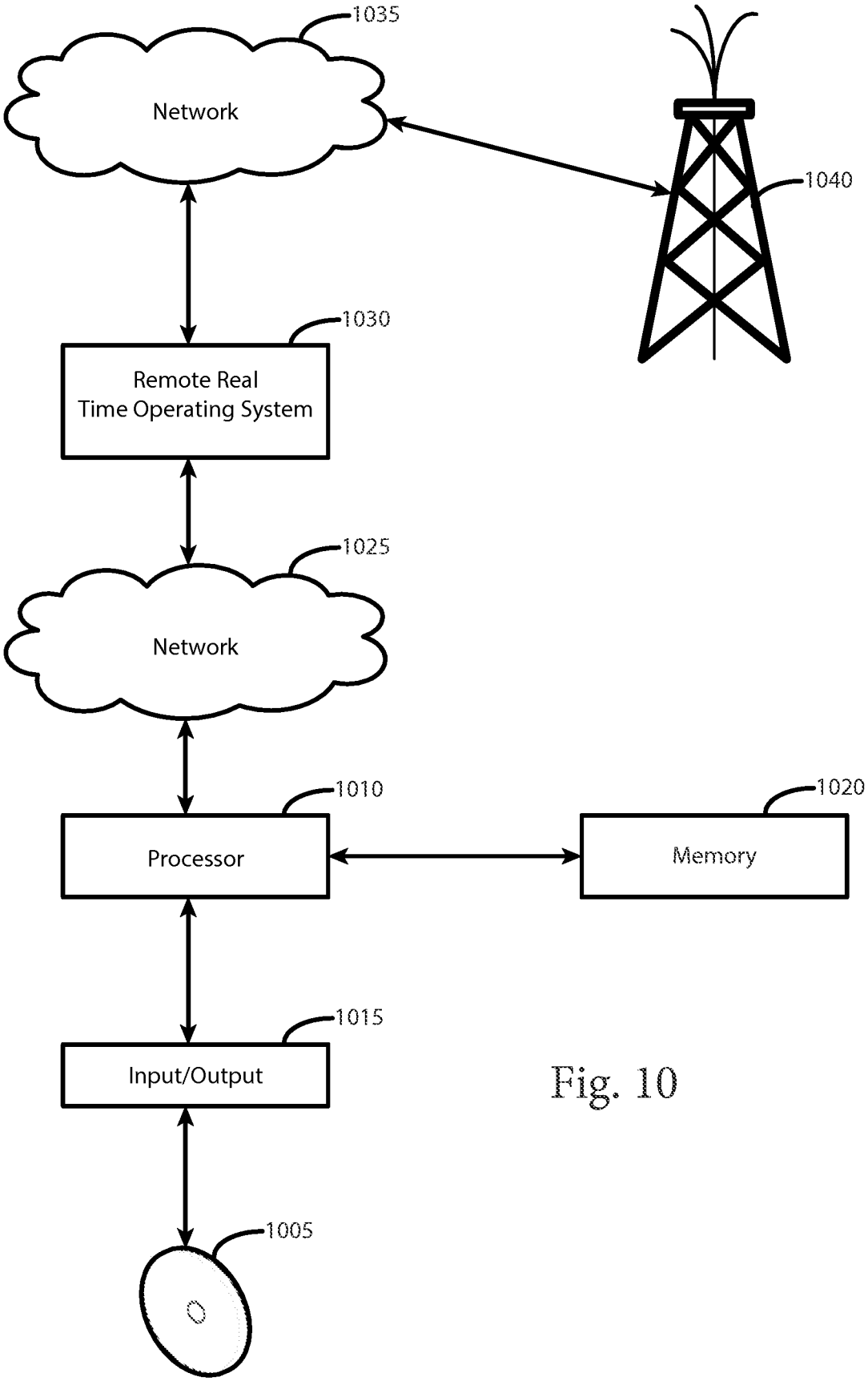

1035
Network
1040
1030
Remote Real
Time Operating System
1025
Network
1010
Processor
1020
Memory
1015
Input/Output
1005

Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/048786

A. CLASSIFICATION OF SUBJECT MATTER

E21B 31/107(2006.01)i, E21B 23/00(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 31/107; E21B 47/022; E21B 47/12; E21B 17/02; E21B 23/00

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: rotary, compression, torque, jarring, screw, spring, transmission

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007-0151732 A1 (CLEMENS et al.) 05 July 2007 See paragraphs [0010]-[0016], [0033]-[0044], [0056]-[0068], [0088]; and figures 2A-2C, 5-9.	1-11,17-24
A		12-16
Y	US 2013-0140029 A1 (SULLIVAN et al.) 06 June 2013 See paragraphs [0008], [0028], [0055], [0089]-[0099], [0135], [0147]; and figures 2, 10-13.	1-11,17-24
A	US 2011-0132597 A1 (HRADECKY, JASON A.) 09 June 2011 See paragraphs [0005], [0011]-[0013], [0019]-[0021]; and figures 1A-1D.	1-24
A	WO 2009-047708 A2 (SCHLUMBERGER CANADA LIMITED et al.) 16 April 2009 See paragraphs [0012], [0031]-[0032], [0042]-[0043], [0061]; and figures 2, 4, 11.	1-24
A	US 2008-0087424 A1 (MCLAUGHLIN, STUART) 17 April 2008 See paragraphs [0007], [0007]-[0018], [0020]-[0021]; and figures 1A-1C.	1-24

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 April 2015 (27.04.2015)	**28 April 2015 (28.04.2015)**

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

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Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/048786

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		CN 101408095 B	19/06/2013
		US 2009-0095490 A1	16/04/2009
		US 8499836 B2	06/08/2013
		WO 2009-047708 A3	09/07/2009
US 2008-0087424 A1	17/04/2008	US 7533724 B2	19/05/2009