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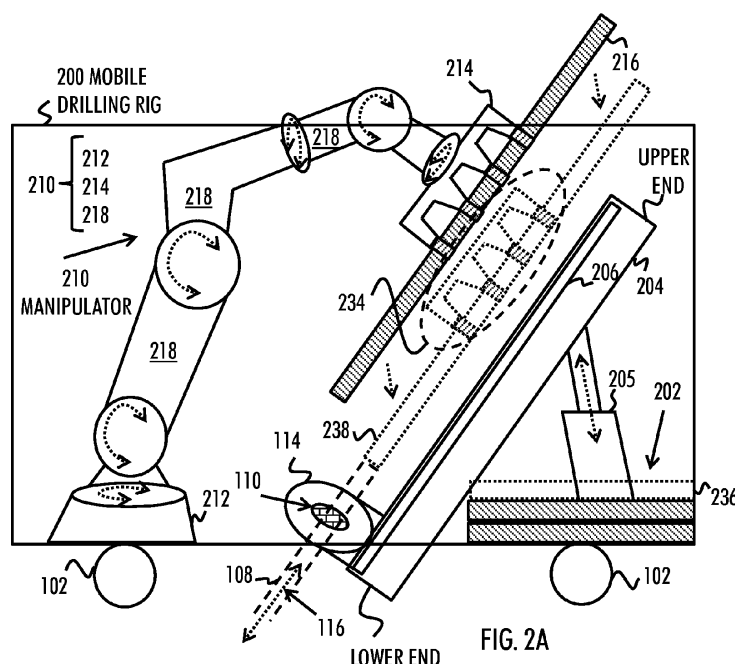
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(54) **Automatic drill rod handling**

(57) There is provided a manipulator (210) comprising a mounting base (212), a gripping unit (214) for gripping a drill rod (216), and a swivel arm (218) attached to the mounting base (212) and to the gripping unit (214), wherein the swivel arm (218) comprises a plurality of swivels (220 to 230) between the mounting base (212) and the gripping unit (214); wherein the swivel arm (218) is configured to automatically move the gripping unit (214) according to a programmed three-dimensional trajectory between a first position (232) and a second position (234),

wherein: in the first position (232), the gripping unit (214) is able to grip or release the drill rod (216) directly from/to a storage unit (202) for a plurality of drill rods, and in the second position (234), the gripping unit (214) is able to grip or release the drill rod (216) when the drill rod (216) is along a drilling axis (116) connected to a drill string (108) entering a borehole (110); and to automatically grip or release the drill rod (216) in the first position (232) or in the second position (234).



Description

Field

[0001] The invention relates generally to mining industry. More particularly, the invention relates to drill rod handling in a mobile drilling rig.

Background

[0002] Mobile drilling rigs may be used in production or exploration drilling so that the drill rods are fed to the borehole (drill hole) from inside the drilling rig. The plurality of connected drill rods fed to the borehole form a drill string (a.k.a. a rod string) entering beneath the surface of the ground. However, handling the drill rods in a small, closed space, such as in a mobile drilling rig, may be cumbersome.

Brief description of the invention

[0003] According to an aspect of the invention, there is provided an apparatus as specified in claim 1.

[0004] According to an aspect of the invention, there is provided a method as specified in claims 13.

[0005] According to an aspect of the invention, there is provided a computer program product as specified in claim 14.

[0006] According to an aspect of the invention, there is provided a computer-readable distribution medium carrying the above-mentioned computer program product.

[0007] According to an aspect of the invention, there is provided an apparatus comprising a processing system configured to cause the apparatus to perform any of the embodiments as described in the appended claims.

[0008] According to an aspect of the invention, there is provided an apparatus comprising means for performing any of the embodiments as described in the appended claims.

[0009] Embodiments of the invention are defined in the dependent claims.

List of drawings

[0010] In the following, the invention will be described in greater detail with reference to the embodiments and the accompanying drawings, in which

Figure 1 presents a prior art solution for handling drill rods.

Figure 2A shows a gripping unit approaching a second position, according to an embodiment;

Figure 2B shows the gripping unit approaching a first position, according to an embodiment;

Figure 3 shows the gripping unit, according to an embodiment;

Figure 4 shows screwing or unscrewing of a drill rod,

according to an embodiment;

Figure 5 illustrates a plurality of swivels of a swivel arm, according to an embodiment;

Figure 6 depicts a monitoring position, according to an embodiment;

Figure 7 illustrates safety position, according to an embodiment;

Figure 8 shows storing of drill rods and use of identifiers of the drill rods, according to an embodiment;

Figure 9 illustrates a controller of the manipulator, according to an embodiment;

Figure 10 shows the mobile drilling rig, according to an embodiment, and

Figure 11 shows a method, according to an embodiment.

Description of embodiments

[0011] The following embodiments are exemplary. Although the specification may refer to "an", "one", or "some" embodiment(s) in several locations of the text, this does not necessarily mean that each reference is made to the same embodiment(s), or that a particular feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

[0012] Drilling rigs may be used in exploration or production drilling. Many of the drilling rigs are large stationary platforms, such as oil drilling rigs. On the contrary, mobile drilling rigs 100 typically comprise wheels 102 or a crawler enabling movement of the drilling rig in the environment. Especially for exploration drilling, mobile drilling rigs 100 may be useful. However, such mobile drilling rigs 100 pose limits to the used drilling machinery. For example, the size of the mobile drilling rig 100, which is typically about 3 x 6 meters, limits the freedom of design of space usage. Further, the size poses limits to the used drilling machinery and other equipment in the drilling rig 100 (such as a space 104 used for storing the drill pipes). Further, the mounting or installation of the machinery to the drilling rig 100 may need special attention. Thus, the technical field of the mobile drilling rigs 100 is significantly different from the world of large, stationary drilling rigs. Thus, most of the prior art solutions with respect to, for example, vertical pipe handling operations in such stationary drilling rigs are unusable for the small and mobile drilling rigs 100.

[0013] One of the most time consuming work phases in drilling comprises adding or removing drill rods 106 to a drill string 108. The drill string 108, comprising a plurality of drill rods 106, penetrates the floor of the drilling rig and enters the borehole 110 beneath the surface of the ground 112 for the purposes of drilling the ground. A drill bit 109 is mounted on lower end of the drill string 108. The drill string 108 may be moved up and down along a drilling axis 116 with a drill string actuator unit 114. The drill string actuator unit 114 may also perform the rotating action of the drill bit, for example. Typically the drill rods

106 are 3 meters long and may weight up to, e.g., 35 kg. Thus, each time the drill string 108 is lowered for substantially 3 meters, a new drill rod 106 may need to be added to the upper part of the drill string 108. Alternatively, two drill rods connected to each other may be handled at once. The drills rods 106 are typically connected to each other via threads, as shown with inclined lines at the ends of the drill rods 106. In any case, there is a frequent need to add more drill rods 106 to the string.

[0014] Further, in the prior art rod handling machinery 118 is relatively simple. The machinery 118 may grip the manually provided individual drill pipes 106 with gripping elements, shown with blocks with right leaning diagonal lines, comprised in a rod placement structure 120. However, such machinery is not fully-automatic as the personnel of the rig needs to manually set/remove the drill rod to/from gripping elements of the rod handling machinery 118. This may cause a risk of injury and is not effective. Thus, at least some of the tasks in need of manual labor are shown with dashed arrows in Figure 1. It may also be that the drill pipe 106 is placed horizontally on the rod placement structure 120, which then pivots in the shown vertical position. Then the rod placement structure 120 rotates about a vertical mast 122 to place the drill rod 106 to the upper part of the drill string 108, as shown with dotted lines in Figure 1, or vice versa. In any case, the machinery 118 is located in immediate proximity of the drill string 108. This may cause problems from the point of view of the space usage in the mobile drilling rig 100. As one example of the problems related to the space usage, the prior art drill rod handling machinery 118 is located very close to the place where the samples from the ground are collected from the drill string 108 / borehole 110.

[0015] Figures 2A and 2B disclose a mobile drilling rig (MDR) 200 comprising a storage unit 202 inside the MDR 200 for storing a plurality of drill rods. These drill rods may be used in the drilling, for example, in making the drill string 108 longer by adding one or more drill rods to the drill string 108. It is beneficial to have such storage unit inside the MDR 200 because then they are easily transported along with the MDR 200 and, as the MDR 200 may have a roof, the drill rods/pipes may stay protected from varying weather conditions.

[0016] The MDR 200 may further comprise the drill string actuator unit 114 configured to actuate the drill string 108 entering the borehole 110 along the drilling axis 116 through the floor of the MDR 200. The drill string actuator unit 114 may move along the drilling axis 116 up and down. The movement may be provided by a drill string support structure 204 having a lower end and an upper end, and a chain 206, or alike, enabling the movement of the actuator unit 114, or some other drill string transport block, between the two ends. The inclination of the drill string support structure 204 and, thus, the angle of drill string 108 may be adjusted with the drill string adjustment structure 205, which may comprise a piston and a cylinder, for example, in order to change the incli-

nation of the support structure 204. In an embodiment, the drill string actuator unit 114 may comprise two parts, one that stays at the lower end and another which moves up and down for moving the drill string 108. The actuator unit 114 may comprise one or more gripping elements for gripping the drill string 108. The gripping element(s) may be jaws or fingers holding the drill string. Further, as said, the actuator unit 114 may also provide the rotation of the drill bit 109 at the lower end of the drill string 108.

[0017] In order to at least partially solve the problems presented above, the MDR 200 of Figures 2A and 2B further comprises a manipulator 210 for handling the drill rods. The manipulator 210 may comprise a mounting base 212 for mounting the manipulator 210 inside the MDR 200 to the MDR 200, a gripping unit 214 for gripping a drill rod 216, and a swivel arm 218 attached to the mounting base 212 and to the gripping unit 214, wherein the swivel arm 218 comprises a plurality of swivels 220 to 230 between the mounting base 212 and the gripping unit 214. Thus, the manipulator 210 has one arm which can be rotatably controlled with at least one of the plurality of swivels 220 to 230. The plurality of swivels 220 to 230 in the swivel arm 218 implies that the swivel arm 218 is made of a plurality of parts which turn independently. The parts form adjacent pairs which are connected to each other with a specific type of swivel. Turning of the parts may comprise rotation about the part's longitudinal axis or hinged movement about an axis which is in right angle with the longitudinal axis (i.e. a transversal axis). The rotation/turning of each of the swivels 220 to 230 are shown in the Figures with bidirectional dotted arrows. The plurality of swivels 220 to 230 may comprise at least one of the following: hinge joints, swivel joints, or pivot joints. The manipulator 210 may be made of steel or some other robust material. The plurality of swivels 220 to 230 may be hydraulic or electric driven, for example. The MDR 200, although not shown, may comprise a power source for the application of the manipulator 210 as well as any needed equipment, such as conduits, cables, hoses, tubes and valves, for enabling the control of the swivels 220 to 230.

[0018] Further, the manipulator 210 comprises, as shown in Figure 9, a control circuitry 902, such as at least one processor, and at least one memory 904 including a computer program code (PROG). The memory 904 may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. There may also be a user interface 908 comprising, for example, at least one keypad, a microphone, a touch display, a display, a speaker, etc. The user interface 908 may be used to control the manipulator 210 by the user personnel. The user personnel may locate in the MDR 200 in a reserved, protected space.

[0019] The at least one memory 904 and the computer

program code (PROG) may be configured, with the at least one processor 902, and more particularly, with a rod movement control circuitry 910, to control the swivels 220 to 230 (at least one of them) to cause the swivel arm 218 to automatically move the gripping unit 214 according to a programmed three-dimensional trajectory between a first position 232 (shown in Figure 2B) and a second position 234 (shown in Figure 2A). In the first position 232, the gripping unit 214 is able to grip or release the drill rod 216 directly from/to the storage unit 202, as shown in Figure 2B with a dotted rod shape 236. In the second position 234, the gripping unit 214 is able to grip or release the drill rod 216 when the drill rod 216 is connected to the drill string 108 and along the drilling axis 116, as shown in Figure 2A with a dotted rod shape 238. In the second position 234, the drill rod 216 forms an extension part of the drill string 108. The first and second positions 232, 234 of the gripping unit 214 are defined beforehand in a three-dimensional coordinate system XYZ of the MDR 200, as depicted in Figure 2B. The horizontal Y-axis is towards the paper.

[0020] Further, the gripping unit 214 may be controlled to automatically grip or release the drill rod 216 in the first position 232 or in the second position 234. Thus, advantageously, there is no manual work needed to move, grip and/or release the drill rod 216 from the storage unit 202 to the drill string 108, or vice versa. This may significantly increase the safety and efficiency of the drilling which takes place from inside the MDR 200. It should be noted that the lengths of the swivel arm parts between the swivels 220 to 230 are not in proportion between the Figures.

[0021] In an embodiment, the manipulator 210 may, for example, move the empty gripping unit 214 to the first position 232 associated with the storage unit 202 and grip one of the stored drill rods. Then the swivel arm 218 may move the gripped drill rod 216 according to the programmed trajectory inside the MDR 200 to the second position 234. In the second position 234, the gripped drill rod 216 may be attached to the drill string 108 to form a part of the drill string 108. Then, the drilling unit 214 may release the drill rod 216 which is attached to the drill string 108 as an extension part. Then, the swivel arm 218 may move to pick up another drill rod from the storage unit 202. This may be performed for as long as the drill string 108 reaches a desirable length. Further, in an embodiment, a drill rod 216 from the storage unit 202 may be added to the drill string 108 each time the controller 902 receives a command to do so from the user personnel via the user interface 908, for example.

[0022] In another embodiment, the manipulator 210 may, for example, move the empty gripping unit 214 to the second position 234 associated with the drill string 108 and grip the uppermost drill rod (or two uppermost drill rods, which are connected together) of the drill string 108. Then the uppermost drill rod 215 may be detached from the drill string 108 (as will be explained later). The swivel arm 218 may then move the gripped drill rod 216

according to the programmed trajectory inside the MDR 200 to the first position 232. In the first position 232, the gripped drill rod 216 may be released directly, without any manual work, to the storage unit 202. Next, the swivel arm 218 may move to pick up another drill rod from the drill string 108. This may be performed for as long as the drill string 108 no longer exists or is short enough according to current needs, for example. Further, in an embodiment, a drill rod 216 may be removed from the drill string 108 to the storage unit 202 by the swivel arm 218 each time the controller 902 receives a command to do so from the user personnel via the user interface 908, for example.

[0023] The drill string actuator unit 114 may be also controlled with the controller 902, and more particularly with a drill string actuator control circuitry 914, to co-operate in the process of adding or removing drill rods from the drill string. Such co-operation may comprise moving the drill string 108 up or down, so as to enable removing or adding of a drill rod in the second position 234.

[0024] In an embodiment, as shown in Figure 3, the gripping unit 214 comprises at least two pairs 300, 302 of jaws/fingers 304, 306. The drill rod 216 may be placed between the jaws 304, 306 of each pair 300, 302 in the first 232 and/or in the second position 234. Then, the at least one memory 904 and the computer program code may be configured, with the at least one processor 902, to move, in each pair 300, 302 of jaws 304, 306, the jaws 304, 306 towards each other in order to grip the drill rod 216 between the jaws 304, 306. The movement of the jaws 304, 306 may be performed with hydraulic power. Alternatively, the jaws 304, 306 in each pair 300, 302 may be moved away from each other to enable releasing the gripped drill rod 216. As shown in Figures 2A and 2B, there may be more than two pairs 300, 302 of jaws, such as three or four, in order to provide more reliable grip and stability to the gripped drill rod 216.

[0025] Figure 3 also shows one of the swivels 230 through which the gripping unit 214 is attached to the swivel arm 218. The shown swivel 230 provides for rotating the gripping unit 214 about the longitudinal axis of the attached part of the swivel arm 218, as will be described later.

[0026] In an embodiment, the drill rod 216 and the drill string 108 comprise screw threads at least at the connected parts for providing means for attaching the drill rod 216 and the drill string 108 together. Therefore, in this embodiment, as shown in Figures 4A to 4C, the at least one memory 904 and the computer program code are configured, with the at least one processor 902, to control the plurality of swivels 220 to 230 to cause the gripping unit 214 to automatically screw or unscrew the drill rod 216 and the drill string 108 in the second position 234.

[0027] Further, the drill string actuator unit 114 may be controlled to co-operate during the screwing or unscrewing. Such co-operation may in one embodiment denote preventing the drill string 108 from rotating during screw-

ing/unscrewing with a grip of the drill string 108, wherein the drill string actuator unit 114 may perform the gripping. In such case, as shown in Figures 4A to 4C, it is the drill rod 216 which may be rotated about the drilling axis 116 so as to perform the screwing/unscrewing. Figure 4A shows a 0 degrees starting position, for example. In Figure 4B, the drill rod 216 is turned 90 degrees and in Figure 4C the drill rod 216 is turned 180 degrees from the start position. Substantially in this position of Figure 4C, the gripping unit 214 may in release the drill rod 216 which may already/still be partly screwed to the drill string 108 (which is gripped by the actuator unit 114 below). Then, the gripping unit 214 may be moved back to the start position of Figure 4A, grip the drill rod 216 again and perform the process of Figures 4A to 4C again for as many times as it is needed to completely screw or unscrew the drill rod 216 to/from the drill string 108. This may be beneficial as then no manual labor is needed for the screwing or unscrewing purposes either.

[0028] The control of the swivels in this embodiment of Figure 4A to 4C may comprise controlling at least the swivel 228, as shown in Figure 4A to 4C. Further, as the drill rod 216 stays in the same location during the screwing (expect for rotating about its longitudinal axis), there may also be a need to control some of the swivels 222 and 224 to enable correct movement of the gripping unit 214 in the screwing/unscrewing. However, for the sake of simplicity, Figures 4A to 4C show only swivels 228 and 230.

[0029] In another embodiment, the co-operation of the drill string actuator unit 114 may comprise performing the screwing/unscrewing by a rotation of the drill string 108 caused by the actuator unit 114, while keeping the drill rod 216 still with the gripping unit 214.

[0030] In one embodiment, the mounting base 212 of the swivel arm 218 is fixedly mounted on the floor of the MDR 200. In another embodiment, the mounting location inside the MDR 200 may be a roof or a side wall, for example, in order to provide more space in the MDR 200 for user personnel. The mounting may be performed with nuts and bolts, for example, or by welding. When the mounting base 212 is fixedly mounted to the MDR 200, the end of the swivel arm 218 attached to the mounting base 218 stays still, whereas the other parts of the swivel arm 218 may move in a controllable manner in order to move the gripping unit 214. In another embodiment, the mounting base 212 is mounted to a unit which is movable with respect to the mounting location of the MDR 200. It may be for example, that the mounting base 212 is on top of a unit which may be slid along rails located on the floor/ceiling/wall of the MDR 200. This may provide even more possibilities for the space usage in the MDR 200.

[0031] In an embodiment, as shown for example in Figures 2A, 2B, the swivel arm 218 comprises six controlled swivels 220, 222, 224, 226, 228 to 230, each with an individual axis of rotation, for moving the gripping unit 214 according to the programmed three-dimensional trajectory. By controlling the amount of rotations of one or

more of the swivels 220 to 230, the swivel arm 218, and, thus, the gripping unit 214 attached to the other end of the swivel arm 218, may be moved along the programmed trajectory in the three-dimensional coordinate system XYZ of the MDR 200.

[0032] Let us take a closer look at the swivels 220 to 230 according to an embodiment with reference to Figure 5. In this embodiment, a first swivel 220 from the mounting base 212 enables rotation (of the swivel arm 218) about a first axis 500. In an embodiment, the first axis 500 is a longitudinal axis with respect to the at least one part of the swivel arm 218 which is attached to (e.g. rotate about) the first swivel 220. In an embodiment, this first axis 500 is a vertical (Z) axis 500 with respect to the XYZ coordinate system of the MDR 200.

[0033] A second 222 and a third swivel 224 from the mounting base 212 enable rotation of the swivel arm 218 about a second 502 and a third 504 axis, respectively, which are orthogonal to the first axis 500. In an embodiment, the second axis 502 is a transversal axis with respect to the parts of the swivel arm 218 which are attached to the second swivel 222. In an embodiment, the third axis 504 is a transversal axis with respect to the parts of the swivel arm 218 which are attached to the third swivel 224. That is, the second and the third axes 502, 504 may be on a horizontal XY-plane in the XYZ coordinate system of the MDR 200. The second 502 and the third 504 (and a fifth 508) axes are shown with a circle having a cross inside to represent a direction towards or out of the paper in the representation of Figure 5. These swivels 222, 224 (and 228) may be hinged swivels which may comprise, e.g., a shaft about which the two connected parts of the swivel arm 218 may rotate.

[0034] A fourth swivel 226 from the mounting base 212 enables rotation of the swivel arm 218 about a fourth axis 506 which is orthogonal to the second axis 502 and to the third axis 504. In an embodiment, the fourth axis 506 is a longitudinal axis with respect to the parts of the swivel arm 218 which are attached to the fourth swivel 226.

[0035] A fifth swivel 228 from the mounting base 212 enables rotation of the swivel arm 218 about a fifth axis 508 which is orthogonal to the fourth axis 506. In an embodiment, the fifth axis 508 is a transversal axis with respect to the parts of the swivel arm 218 which are attached to the fifth swivel 228.

[0036] Finally, a sixth swivel 230 from the mounting base 212 enables rotation about a sixth axis 510 which is orthogonal to the fifth axis 508. In an embodiment, the sixth axis 510 is a longitudinal axis with respect to the at least one part of the swivel arm 218 which is attached to the sixth swivel 230. It may be noted that on the other side of the sixth swivel 230 there may be the gripping unit 214.

[0037] Thus, such swivel arm 218 of the manipulator 210 provides for ease of control and a large variety in different positions of the swivel arm 218. This may significantly help in increasing the efficiency of the drill rod handling process.

[0038] In an embodiment, the MDR 200 further comprises at least one monitoring unit 600 to 604 for monitoring the physical condition of the drill rod 216. The monitoring unit(s) 600 to 604 may be mounted on a specific location in the MDR 200, such as to specific locations on the walls, floor, or roof. Thus, in order to enable the monitoring of the condition of the rod 216, the rod 216 needs to be brought to the specific location. This specific location to which the drill rod 216 needs to be brought may be preprogrammed in the processor 902 and in the memory 904. Thus, there may be a preprogrammed monitoring position 606 of the gripping unit 214 in which position the gripping unit 214 may hold the drill rod 216 during the monitoring. Alternatively, in one embodiment, the gripping unit 214 may release the drill rod 216 in the monitoring position 606. In such embodiment, there may be monitoring equipment which comprises not only the monitoring units 600 to 604 but also elements for gripping or holding the drill rod 216 during the measurement of the condition. It should be noted that the monitoring equipment or the gripping unit 214 may even move the drill rod 216 for the purposes of measurements. Such moving may comprise, for example, rotating the drill rod 216 about the longitudinal and/or transversal axis of the drill rod 216.

[0039] The monitoring unit 600 to 604 may monitor the condition of the rod 216 with machine vision, for example. The machine vision (marked with the dotted one-directional arrows in Figure 6) may examine the drill rod 216 and detect any breaks or cracks in surface of the rod 216. The material of the rod 216 may be steel, for example. There may also be monitoring units 600, 602 which see through the hollow rod 216 in longitudinal direction. These may detect any anomaly, such as breaks, in the inner wall of the hollow rod 216. It may also be that at least one of the monitoring units 600 to 604 applies illumination for better vision.

[0040] In another embodiment, the monitoring unit(s) 600 to 604 may apply sounds and echo-analysis for analyzing the condition of the drill rod 216. For example, if the transmitted sound is reflected back from a solid surface of the drill rod 216, the detected reflected sound (echo) is detected as normal. The normal echo and its marginals may be predetermined for each type and material of drill rods 216. However, when the echo is reflected from a break in the surface of the drill rod 216, the detected echo is different from the predetermined normal echo. As one further option, laser signals and distance measuring may be used to detect if the distance from the measuring units 604 to the surface of the drill rod 216 remains the same throughout the length of the pipe 216 or changes within acceptable margins. A change in the distance exceeding the acceptable margins may imply a crack or break in the rod 216 or a part which has become thin during use. Any anomaly, crack or break in the inner or outer walls of the rod 216 may imply that the condition of the rod 216 is poor. In one embodiment, there may be a predetermined threshold with respect to the number of

anomalies detected or with respect to the severity of the anomalies (such as a depth of a break in the wall of the rod 216). When the threshold is exceeded, the rod 216 is determined as non-usable. If the threshold is not exceeded, the rod 216 may be still used. The threshold may be detected on empirical or mathematical studies, for example.

[0041] Thus, in an embodiment, the at least one memory 904 and the computer program code are configured, with the at least one processor 902 and, more particularly, with a rod condition control circuitry 912, to control the plurality of swivels 220 to 230 to cause the swivel arm 218 to automatically move the drill rod 216 to a monitoring position 606 in which at least one monitoring unit 600 to 604 detects the physical condition of the drill rod 216. As said, the movement trajectory may be preprogrammed and comprise three-dimensional movements of the gripping unit 214 holding the drill rod 216 in the three-dimensional XYZ space inside the MDR 200. Further, in response to reception of information indicating that the physical condition of the drill rod 216 is below the predetermined threshold, the plurality of swivels 220 to 230 may be controlled to cause the swivel arm 218 to automatically move the drill rod 216 to a location reserved for non-usable drill rods. Such location may be predetermined and preprogrammed to the memory 904, for example, so that the swivel arm 218 may be automatically configured to move the drill rod to such location. This embodiment may significantly increase the efficiency and reliability of the drilling process as less drill rod condition-related problems occur.

[0042] In an embodiment, the gripping unit 214 holding the drill rod 216 is moved to the monitoring position 606 after the first position 232 and before the second position 234. Thus, after taking the drill rod 216 from the storage unit 202 and before bringing the gripped rod 216 to the drill string 108, the swivel arm 218 may move the gripping unit 214 to the monitoring position 606 for rod condition checking. If the rod 216 is not in adequate condition, the drill rod 216 is considered as non-usable and moved to the out-of-usage area. If the rod 216 is in adequate condition, the rod 216 is taken to the drill string 108 and may be used for drilling. This embodiment may have the benefit that the condition of the drill rod 216 is detected before it is added to the drill string 108 and, thus, no poor conditioned rods are added to the drill string 108.

[0043] In another embodiment, the gripping unit 214 holding the drill rod 216 is moved to the monitoring position 606 after the second position 234 and before the first position 232. This embodiment relates to emptying the drill string 108. After taking the drill rod 216 from the drill string 108 and before bringing the gripped rod 216 to the storage unit 202, the swivel arm 218 may move the gripping unit 214 to the monitoring position 606 for rod condition checking. If the rod 216 is not in adequate condition, the drill rod 216 is considered as non-usable and moved to the out-of-usage area. If the rod 216 is in adequate condition, the rod 216 is stored in the storage

unit 202 and may be used for drilling later on without a further check. This embodiment may have the benefit that the condition of the drill rod 216 is detected in good time and, in case new drill rods are needed (e.g. in case poor ones need to be replaced), the new drill rods may be inserted in the storage unit 202 in advance of the next drilling process (i.e. well before new drill rods are needed for further drilling).

[0044] In an embodiment, as shown in Figure 7, the at least one memory 904 and the computer program code are configured, with the at least one processor 902, to control the plurality of swivels 220-230 to cause the swivel arm 218 to retrieve/move/enter into a safety position 700 of the manipulator 210 for a time period reserved for removal of samples 706 from the drill string 108. In the safety position 700, any given point of the manipulator 210 is at least a guard distance 702 from the drill string 108. The safety position 700 of the manipulator 210 may be preprogrammed to the memory 904 so that the controller 902 may automatically move the swivel arm 218 and the gripping unit 214 to the safety position 700, which may be defined in the three-dimensional coordinate system XYZ of the MDR 200. In an embodiment, the manipulator 210 may be programmed to retrieve to and stay in the safety position 606 unless the manipulator 210 needs to perform any rod handling tasks. Thus, the safety position 606 may be regarded as a starting/ending position of the manipulator 210.

[0045] The guard distance 702 may correspond to an empirically derived distance needed by the user personnel to operate around the drill string 108 during the removal of the samples. In an embodiment, the guard distance 702 equals to substantially 1 meter or more. As known by a skilled person, the ground samples emerge upwards from the depth via the annulus between the borehole 110 and drill string 108, or within a hollow drill string 108 (as in, e.g., reverse circulation drilling). Further, as in diamond drilling, the ground samples may also be retrieved by using a retractable gripping tube which is lowered within the hollow drill string 108 and which grips a core tube locating close to the drill bit and comprises the ground sample. The core tube then is brought up together with the retractable gripping tube. Thus, the guard distance needed may be drilling type -specific and determined individually for each drilling type.

[0046] Therefore, the safety position 700 may as well be drilling type - specific and programmed individually for each drilling type. The controller 902 and the memory 904 may have knowledge for the safety positions with respect to a plurality of drilling types. These types may include diamond drilling, reverse circulation drilling, direct circulation drilling, etc. Thereafter, the controller 902 may select the to-be-used safety position on the basis of what the current type of drilling is.

[0047] In an embodiment, the manipulator 210 is fixedly mounted on the mobile drilling rig 200. Further, in this embodiment, the mounting base 212 of the manipulator 210 is at least the guard distance 702 away from

the location in which the drill string 108 enters the borehole 110. In an embodiment, as said, the guard distance 702 may be one meter or even more. This embodiment thus provides space for the user personnel if the user personnel need to be around the borehole 110. The swivel arm 218, which may be altogether 280 centimeters long while the swivels 220 to 230 are in positions which provide most length to the swivel arm 218, may provide enough extension for the manipulator 210 to still being able to perform all the rod handling tasks.

[0048] In addition, In an embodiment, the swivel arm 218 may comprise parts which may extend. For example, there may be two parts at least partially overlapping. The inner or outer part may then slide with respect to the other part so as to make the swivel arm longer or shorter, if needed.

[0049] In an embodiment the plurality of drill rods are stored in the storage unit 202 substantially horizontally with respect to a floor of the MDR 200. This provides a benefit according to which the height of the MDR 200, at least while moving, is not as high as if vertical storing of the drill rods was applied.

[0050] In an embodiment, as shown in Figure 8, each of the plurality of drill rods has an individual location in the storage unit 202. Figure 8 shows how the drill pipes may be stored in the storage unit 202. As a result, the at least one memory 904 and the computer program code are configured, with the at least one processor 902, to adjust the first position 232 of the programmed three-dimensional trajectory according to the individual location of the drill rod which is currently being moved or which is to be moved. The controller 902 may know the first position 232 of each drill rod 216 on the basis of machine vision, for example. The machine vision unit may be mounted in the gripping unit 214, for example.

[0051] However, in an embodiment, the first position 232 is kept the same for each drill rod 216. In this embodiment, the storage unit 202 may comprise structure, such as an inclined surface, which may be used for automatically causing a new pipe to be moved to the first position 232 due to gravity, for example. An inclination in other direction may be used for the process of emptying the drill string 108 to the storage unit 202. In yet one embodiment, the first position 232 may be adjusted according to whether the drill string 108 is to be extended or shortened.

[0052] In yet one embodiment, each drill rod comprises an identifier known by the controller 902, and the at least one memory 904 and the computer program code are configured, with the at least one processor 902, to cause the manipulator 210 to detect the identifier (ID) of the drill rod. For example, each drill rod may emit a specific ID which an ID detection unit of the manipulator 210 may detect. Such ID detection unit may be comprised in the gripping unit 214 for providing short distance between the drill rod emitting the ID and the ID detection unit. A possible technology for the ID reading may be radio frequency identification (RFID) -technique. In one embodi-

ment, a configuration known as an Active Reader Passive Tag (ARPT) is applied, in which an active reader (in the gripping unit 214) transmits interrogator signals and receives authentication replies from passive tags in the drill rods.

[0053] In another embodiment, the ID detection takes place via machine vision, near field communication, Bluetooth, for example. In any case, the manipulator 214 may obtain knowledge of the IDs of the drill rod(s) in the storage unit 202 or of the drill rod which is being gripped currently. Thereafter, the controller 902 may adjust the first position 232 of the three-dimensional trajectory on the basis of the detected identifier. In such embodiment, each drill rod may be taken to/from a specific location and the order in the drill storage unit 202 remains good throughout the process, which may expedite the drilling process.

[0054] Let us then take a look in how the life span of each drill rod 216 may be extended. It may be for example that a drill rod at a certain part of the drill string 108 is prone to damages. The controller 902 may identify which drill rods were in the drill string 108 and in which location of the drill string 108 during removal of drill rods from the drill string 108. The controller 902 may detect, e.g., the order of the drill rods in the drill string 108 which is a clear indication of the location of the removed drill rod in the drill string. Then each of the drill rods may be taken to a monitoring unit of Figure 6 for physical condition checking, or to some other type of physical condition checking. As a result, the controlled 902 may detect whether or not a drill rod in a specific location of the drill string 108 is more damaged than the other drill rods. Thus, by applying the drill rod condition checking, the part which is prone to damages in the drill string 108 may be more easily detected. As one possible consequence action, the controller 902 may avoid putting the same drill rod to that specific part of the drill string 108 repeatedly. In this manner, the life cycle of the drill rods may be extended.

[0055] Figure 10 shows the MDR 200 in a side view, wherein the MDR 200 comprises hinged stairs 1000A, 1000B and support members 1002A, 1002B laid down for the duration of drilling. A crawler 1004 may be for moving the MDR 200. The other elements, units, structures presented in Figure 10 have been explained earlier. The MDR 200 may be a closed space with floor, walls and at least partial roof. As shown, the storage unit 202 for the plurality of drill rods may be as large as the side wall of the MDR 200. This may be especially the case when the storage unit 202 stores a plurality of two rods connected together to make one pipe with a length of even 6 meters. The drill string support structure 204 may have been extended so as to support the drill string 108 after a new rod 216 has been added to the drill string 108. It is also shown how the angle between the drill string 108 and the surface of the ground is substantially 90 degrees. Such change in the inclination angle (from Figure 2A, for example) may have been caused by the change in the inclination of the drill string support struc-

ture 204.

[0056] There is also provided a method, as shown in Figure 11, for moving drill rods in the mobile drilling rig 200 between the first position 232 and the second position 234 with the manipulator 210, the method comprising: in step 1100, controlling the plurality of swivels 220 to 232 to cause the swivel arm 218 to automatically move the gripping unit 214 according to a programmed three-dimensional trajectory between the first position 232 and the second position 234; and, in step 1102, controlling the gripping unit 214 to automatically grip or release the drill rod in the first position 232 or in the second position 234.

[0057] In an embodiment, the manipulator 210 may be a stand-alone apparatus for moving drill rods between the first position 232 and the second position 234. In an embodiment, the manipulator 210 need not locate inside or be mounted to the MDR 200. In an embodiment, there need not be any MDR 200. In an embodiment, the first position 232 and the second position 234 are not inside any MDR 200. In an embodiment, the first position 232 and the second position 234 are reconfigurable. In an embodiment, the manipulator 210 is mounted, e.g. on a closed or open truck, such as on a platform of the truck. The storage unit 202 and/or the drill string actuator unit 114 may be located outside the truck, such as next to the truck on a separate vehicle, for example. In an embodiment, the storage unit 202 is on the truck with the manipulator 210, whereas the drilling actuator unit 114 is located outside the truck platform. In an embodiment, the manipulator 210, the storage unit 202 and the drill string actuator unit 114 are on the truck, which may have an open or closed platform/deck.

[0058] In an embodiment, the manipulator 210 may be used undergrounds, in a tunnel, for example. In such embodiment, the storage unit 202 and the drill string actuator unit 114 may be also located undergrounds.

[0059] In an embodiment, the length of the drill string 108 may be more than 100 meters. In an embodiment, the MDR 200 may be equipped with a steering unit for steering and moving the MDR 200. In an embodiment, the storage unit 202 may be open from the top.

[0060] As used in this application, the term 'circuitry' refers to all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) combinations of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal processor(s), software, and memory(ies) that work together to cause an apparatus to perform various functions, and (c) circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. This definition of 'circuitry' applies to all uses of this term in this application. As a further example, as used in this application, the term 'circuitry' would also cover an implementation of merely a processor (or multiple

processors) or a portion of a processor and its (or their) accompanying software and/or firmware. The term 'circuitry' would also cover, for example and if applicable to the particular element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular network device, or another network device.

[0061] The techniques and methods described herein may be implemented by various means. For example, these techniques may be implemented in hardware (one or more devices), firmware (one or more devices), software (one or more modules), or combinations thereof. For a hardware implementation, the apparatus(es) of embodiments may be implemented within one or more application-specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. For firmware or software, the implementation can be carried out through modules of at least one chip set (e.g. procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit and executed by processors. The memory unit may be implemented within the processor or externally to the processor. In the latter case, it can be communicatively coupled to the processor via various means, as is known in the art. Additionally, the components of the systems described herein may be rearranged and/or complemented by additional components in order to facilitate the achievements of the various aspects, etc., described with regard thereto, and they are not limited to the precise configurations set forth in the given figures, as will be appreciated by one skilled in the art.

[0062] Embodiments as described may also be carried out in the form of a computer process defined by a computer program. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. For example, the computer program may be stored on a computer program distribution medium readable by a computer or a processor. The computer program medium may be, for example but not limited to, a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. Coding of software for carrying out the embodiments as shown and described is well within the scope of a person of ordinary skill in the art.

[0063] Even though the invention has been described above with reference to an example according to the accompanying drawings, it is clear that the invention is not restricted thereto but can be modified in several ways within the scope of the appended claims. Therefore, all words and expressions should be interpreted broadly and

they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. Further, it is clear to a person skilled in the art that the described embodiments may, but are not required to, be combined with other embodiments in various ways.

10 Claims

1. A manipulator (210) comprising:

a mounting base (212) for mounting the manipulator (210);
a gripping unit (214) for gripping a drill rod (216);
a swivel arm (218) attached to the mounting base (212) and to the gripping unit (214), wherein the swivel arm (218) comprises at least six controlled swivels (220 to 230) between the mounting base (212) and the gripping unit (214), wherein each swivel (220 to 230) has an individual axis (500 to 510) of rotation for moving the gripping unit (214) according to a programmed three-dimensional trajectory;
at least one processor (902) and at least one memory (904) including a computer program code, wherein the at least one memory (904) and the computer program code are configured, with the at least one processor (902), to:

control the plurality of swivels (220 to 230) to cause the swivel arm (218) to automatically move the gripping unit (214) according to the programmed three-dimensional trajectory between a first position (232) and a second position (234), wherein:

in the first position (232), the gripping unit (214) is able to grip or release the drill rod (216) directly from/to a storage unit (202) for a plurality of drill rods, and

in the second position (234), the gripping unit (214) is able to grip or release the drill rod (216) when the drill rod (216) is along a drilling axis (116) connected to a drill string (108) entering a borehole (110); and

control the gripping unit (214) to automatically grip or release the drill rod (216) in the first position (232) or in the second position (234).

2. The manipulator (210) of claim 1, wherein the gripping unit (214) comprises at least two pair (300, 302) of jaws (304, 306), and the at least one memory (904) and the computer program code are configured, with the at least one processor (902), to:

move, in each pair (300, 302) of jaws (304, 306),

- the jaws (304, 306) towards each other in order to grip the drill rod (216) between the jaws (304, 306).
3. The manipulator (210) of any of claims 1 to 2, wherein the drill rod (216) and the drill string (108) comprise screw threads at the connected parts, and the at least one memory (904) and the computer program code are configured, with the at least one processor (902), to:
 - control the plurality of swivels (220 to 230) to cause the swivel arm (218) to automatically screw or unscrew the drill rod (216) and the drill string (108) in the second position (234);
 - control a drill string actuator unit (114) to cooperate during the screwing or unscrewing, wherein the drill string actuator unit (114) is configured to actuate the drill string (108).
 4. The manipulator (210) of any of claims 1 to 3, wherein:
 - a first swivel (220) from the mounting base (212) enables rotation about a first axis (500);
 - a second and a third swivel (222, 224) from the mounting base (212) enable rotation about a second and a third axis (502, 504), respectively, which are orthogonal to the first axis (500);
 - a fourth swivel (226) from the mounting base (212) enables rotation about a fourth axis (506) which is orthogonal to the second axis and to the third axis (502, 504);
 - a fifth swivel (228) from the mounting base (212) enables rotation about a fifth axis (508) which is orthogonal to the fourth axis (506); and
 - a sixth swivel (230) from the mounting base (212) enables rotation about a sixth axis (510) which is orthogonal to the fifth axis (508).
 5. The manipulator (210) of any of claims 1 to 4, wherein the at least one memory (904) and the computer program code are configured, with the at least one processor (902), to:
 - control the plurality of swivels (220 to 230) to cause the swivel arm (218) to automatically move the gripping unit (214) holding the drill rod (216) to a monitoring position (606) in which at least one monitoring unit (600 to 604) detects the physical condition of the drill rod (216); and
 - in response to reception of information indicating that the physical condition of the drill rod (216) is below a predetermined threshold, control the plurality of swivels (220 to 230) to cause the swivel arm (218) to automatically move the drill rod (216) to a location reserved for non-usable drill rods.
 6. The manipulator (210) of claim 5, wherein the gripping unit (214) is moved to the monitoring position (606) after the first position (232) and before the second position (234).
 7. The manipulator (210) of claim 5, wherein the gripping unit (214) is moved to the monitoring position (606) after the second position (234) and before the first position (232).
 8. The manipulator (210) of any of claims 1 to 7, wherein the at least one memory (904) and the computer program code are configured, with the at least one processor (902), to:
 - control the plurality of swivels (220 to 230) to cause the swivel arm (218) to move into a safety position (700) of the manipulator (210) for a time period reserved for removal of samples (700) from the drill string (108), wherein, in the safety position (700), any given point of the manipulator (210) is at least a guard distance (702) from the drill string (108).
 9. The manipulator (210) of claim 8, wherein the safety position (700) is drilling type-specific, and the at least one memory (904) and the computer program code are configured, with the at least one processor (902), to:
 - acquire knowledge of the safety positions with respect to a plurality of drilling types; and
 - select the to-be-used safety position (700) on the basis of what the current type of drilling is.
 10. The manipulator (210) of any of claims 1 to 9, wherein each drill rod (106) comprises an identifier known by the at least one processor (902), and the at least one memory (904) and the computer program code are configured, with the at least one processor (902), to:
 - cause the manipulator (210) to detect the identifier of the drill rod (106) which is currently being moved or which is to be moved, wherein the detection takes place with an identifier detecting unit comprised in the manipulator (210); and
 - adjust the first position of the three-dimensional trajectory on the basis of the detected identifier, wherein each drill rod (216) has an individual location in the storage unit (202).
 11. The manipulator (210) of any of claims 1 to 10, wherein each drill rod (106) comprises an identifier known by the at least one processor (902), and the at least one memory (904) and the computer program code are configured, with the at least one processor (902), to:

during removing of drill rods from the drill string (108), identify which drill rods were in the drill string (108) and in which locations of the drill string (108);

detect the physical condition of each of the drill rods which were in the drill string (108); and
detect whether or not a specific drill rod in a specific location of the drill string (108) is more damaged than the other drill rods.

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- 12.** The manipulator (210) of any of claims 1 to 11, wherein the manipulator (210) is mounted to a mobile drilling rig (200).

- 13.** A method for moving drill rods between a first position (232) and a second position (234) with a manipulator (210) comprising a mounting base (212) for mounting the manipulator (210), a gripping unit (214) for gripping a drill rod (216), and a swivel arm (218) attached to the mounting base (212) and to the gripping unit (214), wherein the swivel arm (218) comprises at least six controlled swivels (220 to 230) between the mounting base (212) and the gripping unit (214), wherein each swivel (220 to 230) has an individual axis (500 to 510) of rotation for moving the gripping unit (214) according to a programmed three-dimensional trajectory, the method comprising:

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controlling the plurality of swivels (220 to 230) to cause the swivel arm (218) to automatically move the gripping unit (214) according to the programmed three-dimensional trajectory between the first position (232) and a second position (234), wherein:

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in the first position (232), the gripping unit (214) is able to grip or release the drill rod (216) directly from/to a storage unit (202) for storing a plurality of drill rods; and
in the second position (234), the gripping unit (214) is able to grip or release the drill rod (216) when the drill rod (216) is along the drilling axis (116) connected to a drill string (108) entering a borehole (110); and
controlling the gripping unit (216) to automatically grip or release the drill rod (216) in the first position (232) or in the second position (234).

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- 14.** A computer program product embodied on a distribution medium readable by a computer and comprising program instructions which, when loaded into an apparatus, execute the method according to claim 13.

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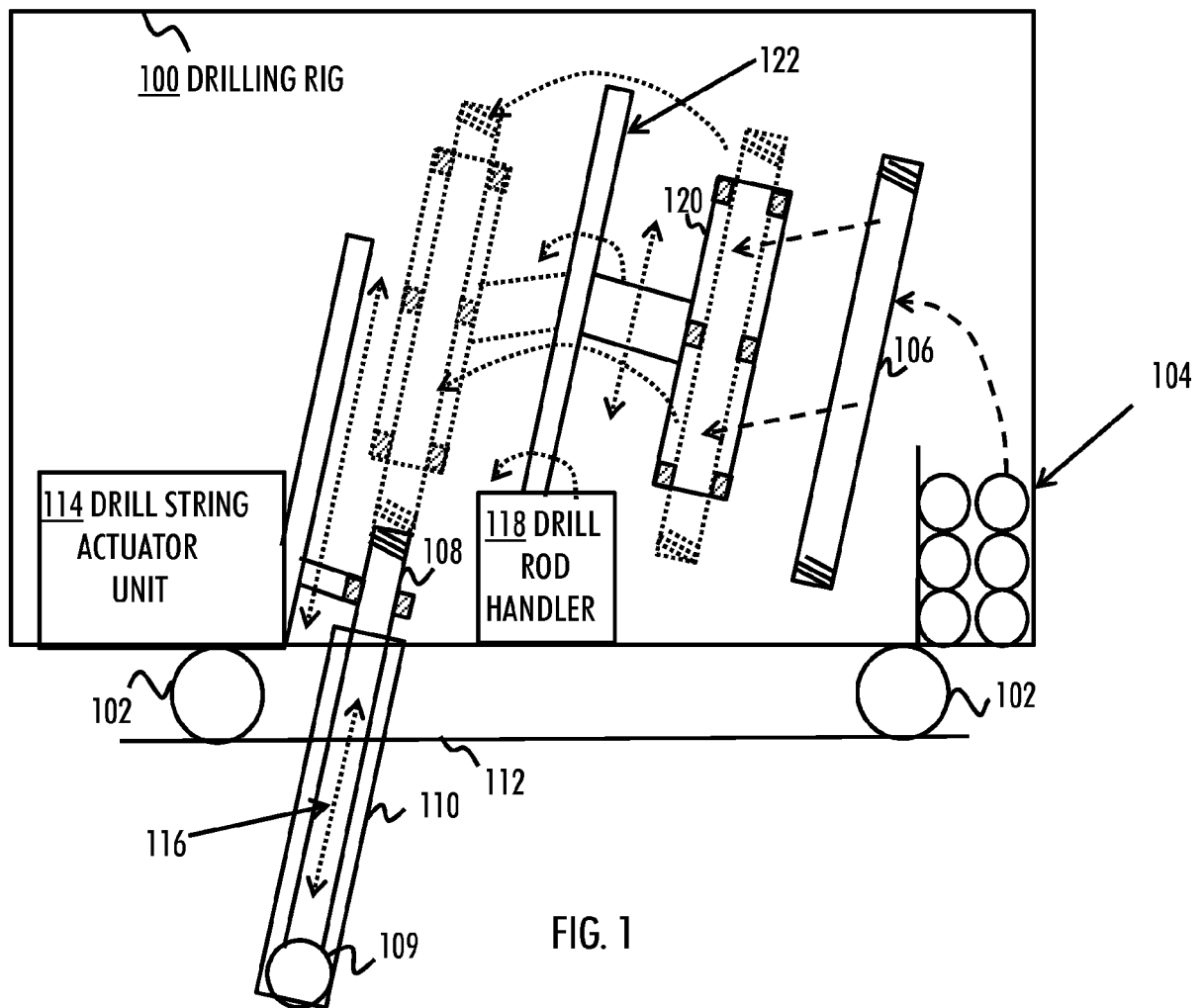


FIG. 1

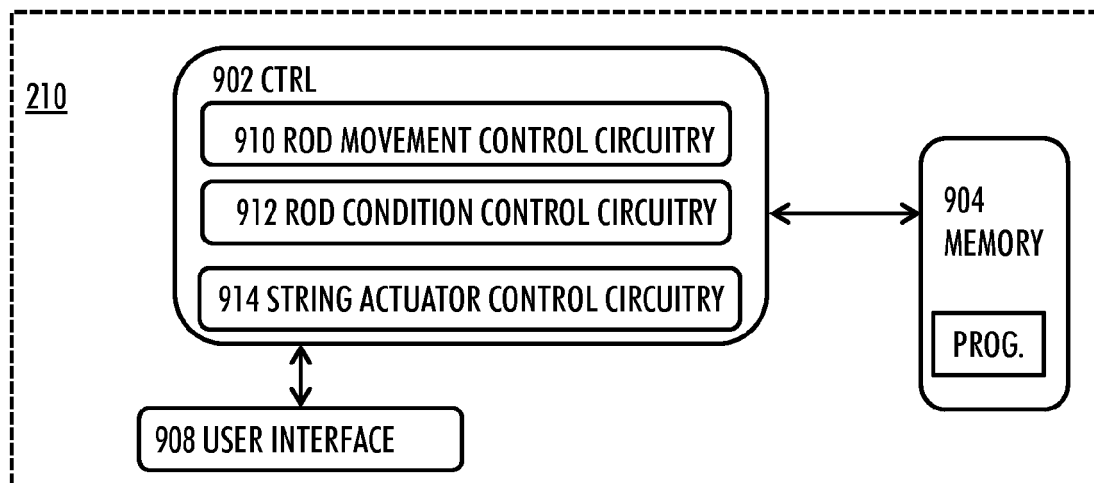
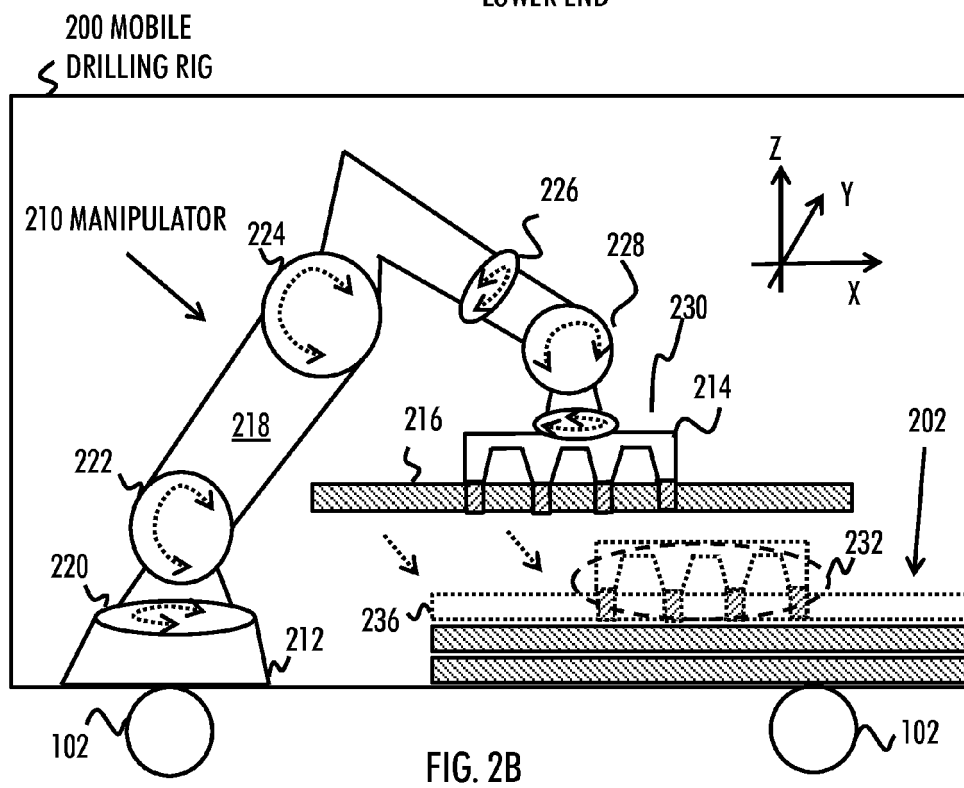
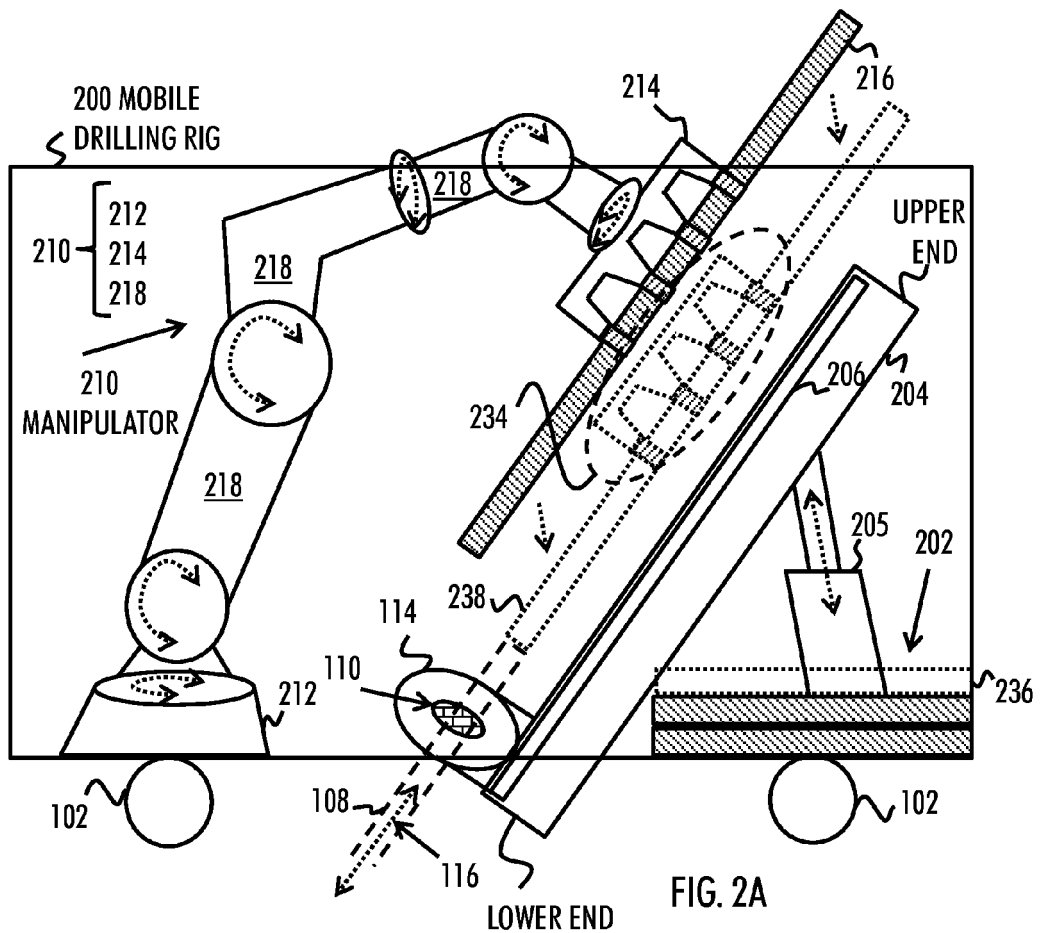
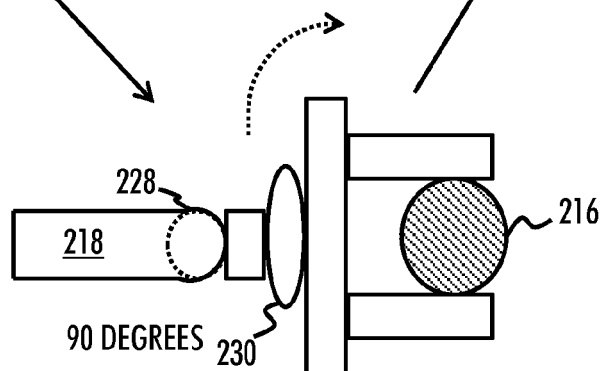
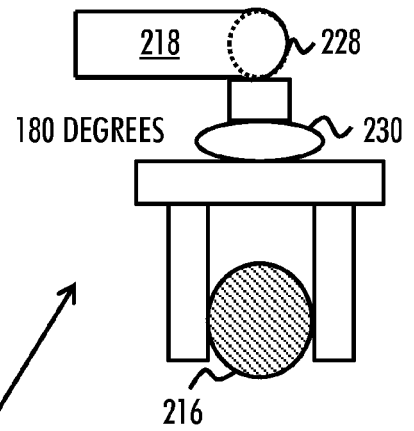
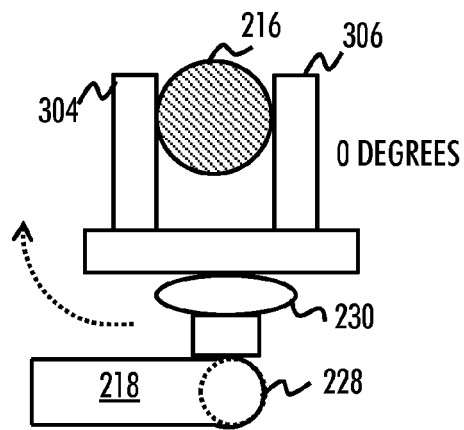
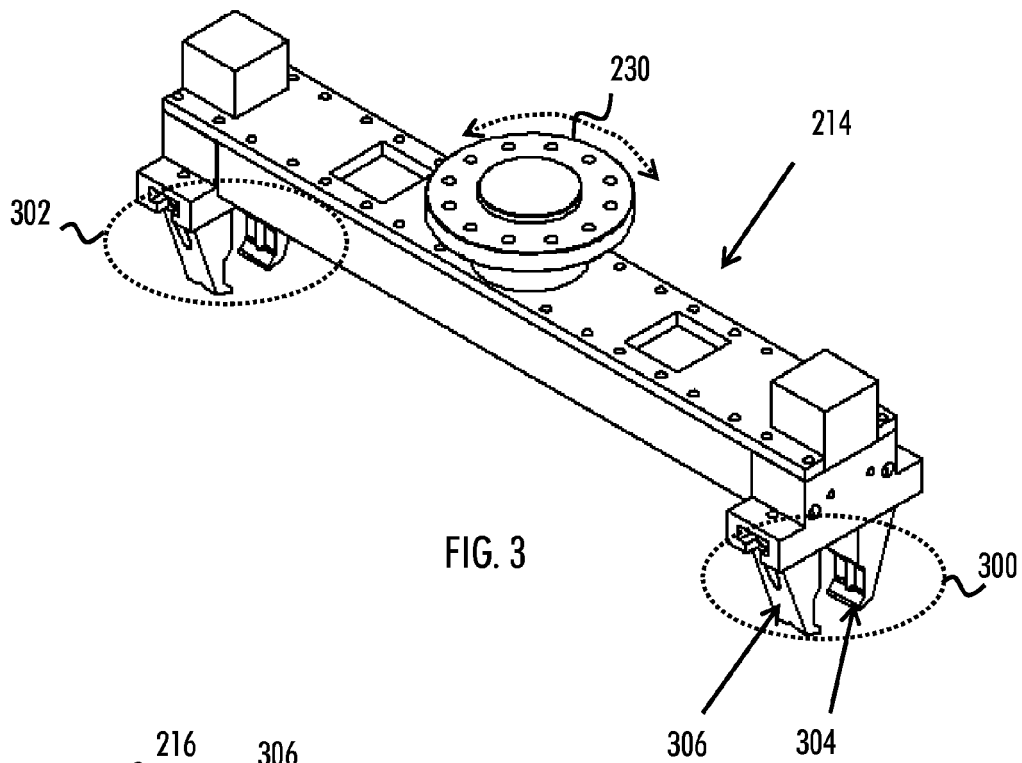
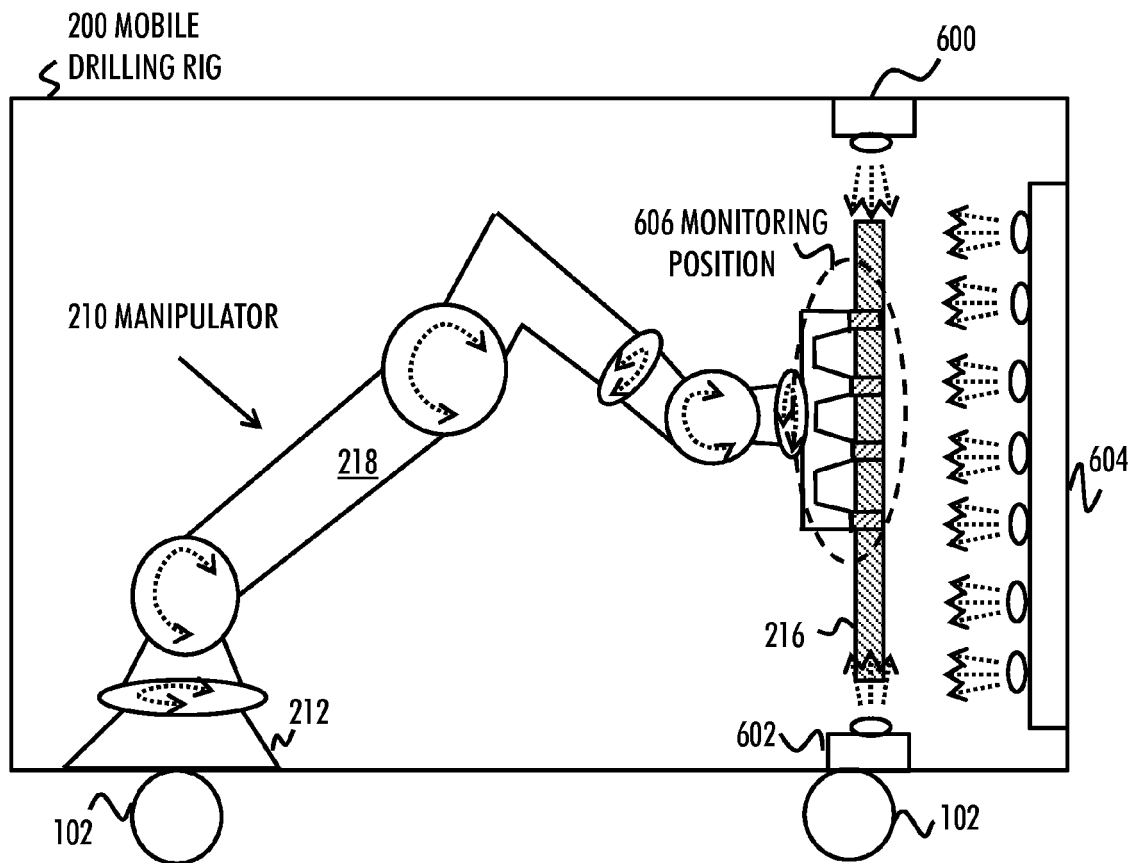
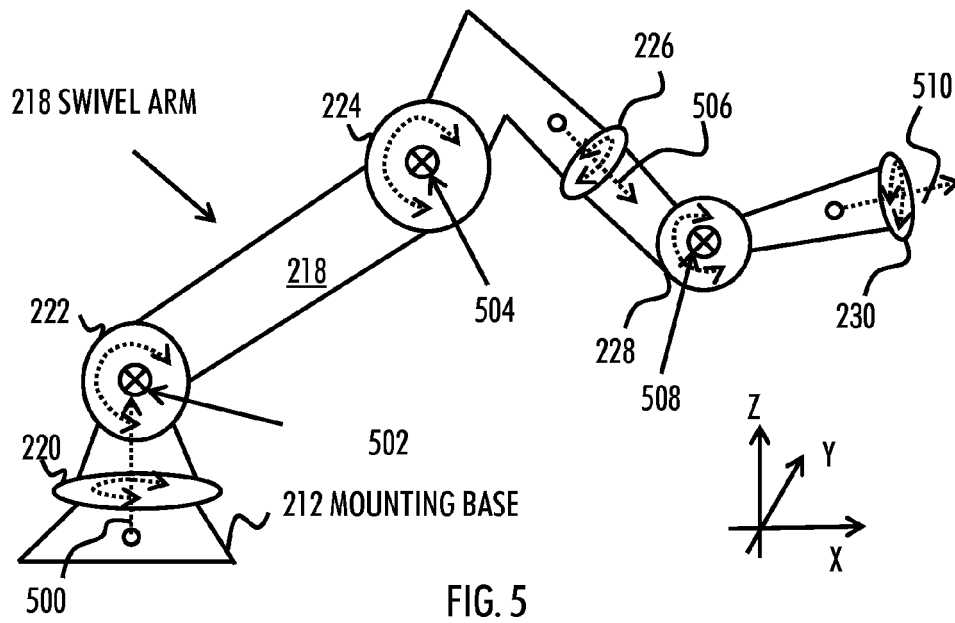


FIG. 9







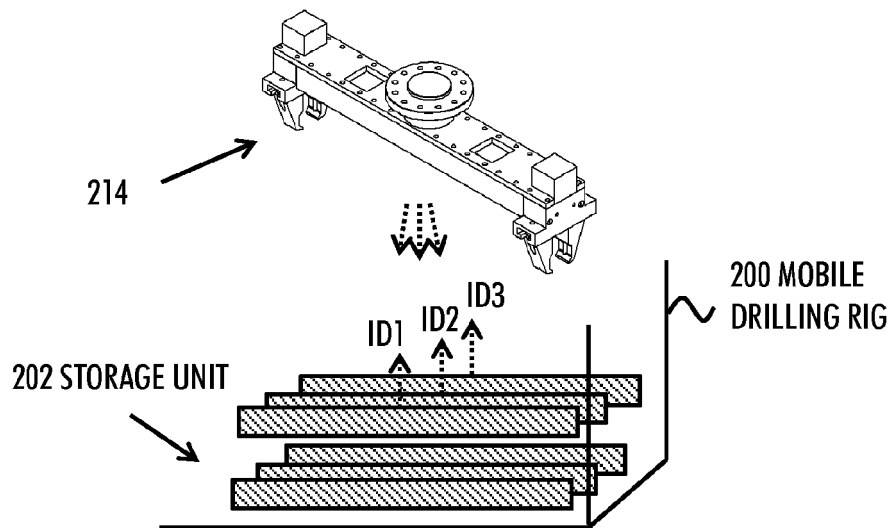
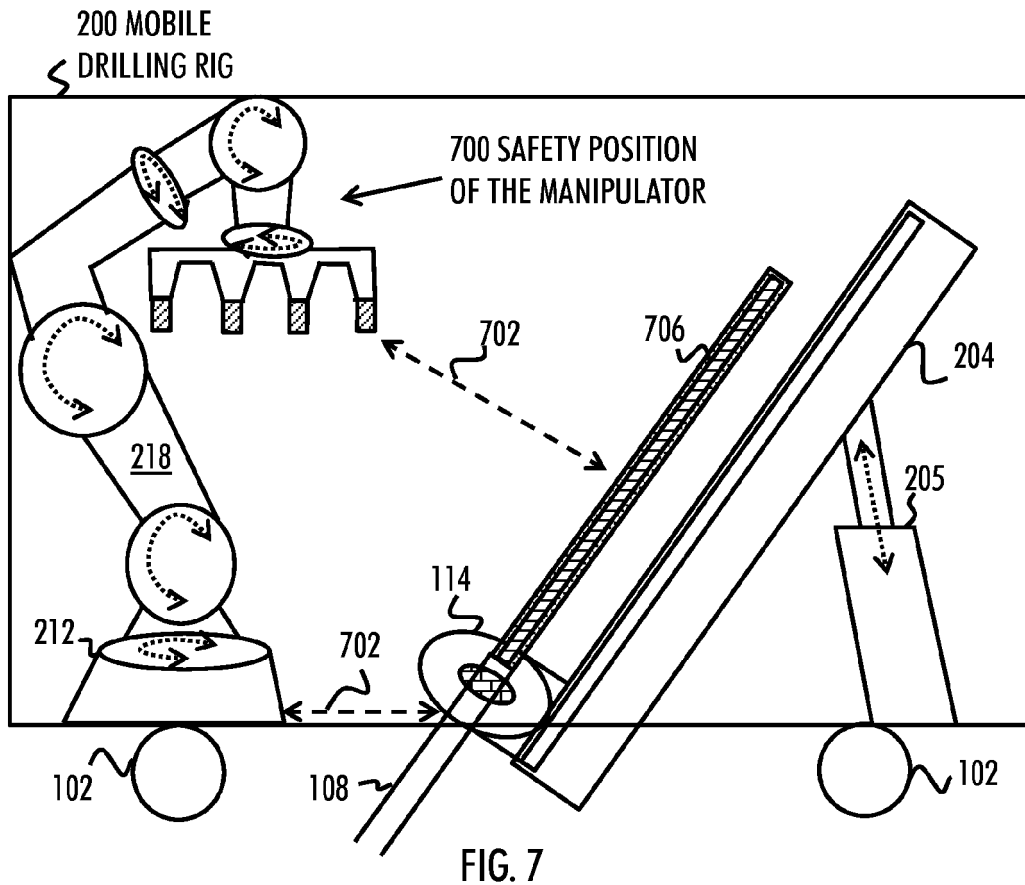


FIG. 8

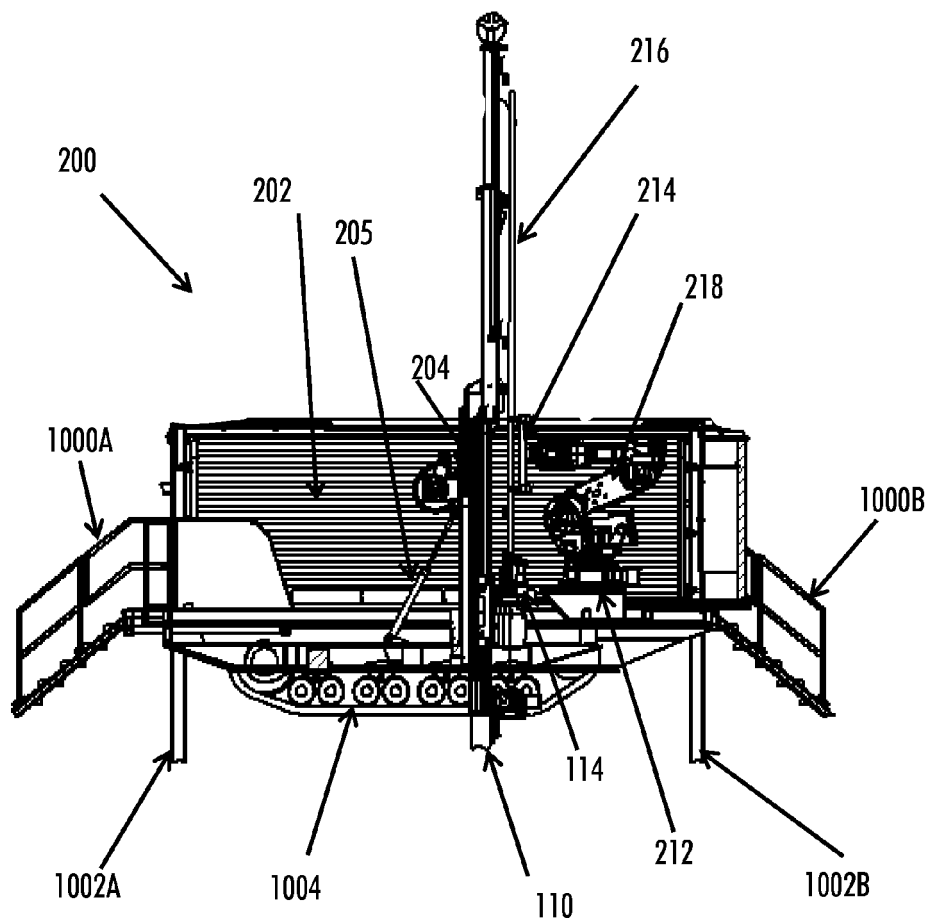


FIG. 10

1100 CONTROLLING THE PLURALITY OF SWIVELS TO CAUSE THE SWIVEL ARM TO AUTOMATICALLY MOVE THE GRIPPING UNIT ACCORDING TO THE PROGRAMMED THREE-DIMENSIONAL TRAJECTORY BETWEEN THE FIRST POSITION AND THE SECOND POSITION

1102 CONTROLLING THE GRIPPING UNIT TO AUTOMATICALLY GRIP OR RELEASE THE DRILL ROD IN THE FIRST POSITION OR IN THE SECOND POSITION

FIG. 11