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- (54) **Title:** MECHANICALLY ASSISTED FRACTURE INITIATION

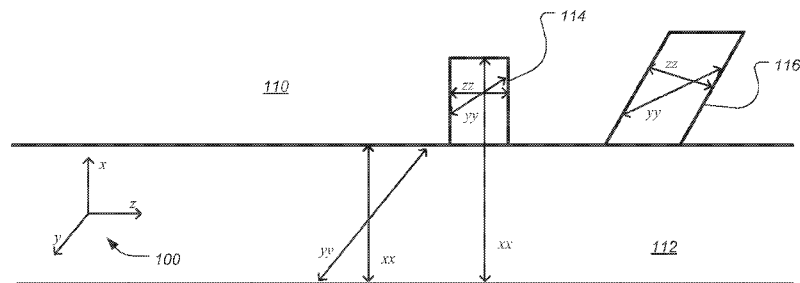


Fig. 1

- (57) **Abstract:** Systems and methods are described for controlling the location where a fracture initiates and the fracture direction at the initiation point. A mechanical device is positioned in a main wellbore or partially or fully in a side hole off of the main wellbore. The mechanical device is actuated so as to contact the formation walls and induce stress in the formation. According to some embodiments, fractures are also initiated using the mechanical device. A hydraulic fracturing process is then carried out to fracture and/or propagate fractures in locations and/or directions according to the actuation of the mechanical device.

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MECHANICALLY ASSISTED FRACTURE INITIATION

Field

[0001] The subject disclosure generally relates to reservoir fracturing. More particularly, the subject disclosure relates to an apparatus and method for controlling the location where a fracture initiates and the fracture direction at the initiation point.

Background

[0002] Hydraulic fracturing (HF) is performed in many hydrocarbon bearing formations to enhance production level. This is particularly useful for reservoirs having low permeability such as shale gas, shale oil, and tight reservoirs. During hydraulic fracturing, a relatively large volume of fluid, typically water with some additives, is injected at a pressure high enough to exceed the mechanical integrity of the rock and fracture it. Some of the energy used in a fracturing operation is used to induce fractures and the remainder is used to propagate the fractures.

[0003] Conventionally, a well is drilled into the formation. This is followed by a set of logging measurements that provide petrophysical and geomechanical information about the reservoir rock as a function of depth. Based on log information, a desired depth zone is chosen to be fractured and it is common to hydraulically isolate this zone from the remaining part of the well by placing mechanical packers on the two limits of the zone, and sealing-off the zone. This is followed by pumping fracturing fluid into the zone to fracture the rock. With this conventional approach, the pumped fluid exerts radial force to the formation and initiates fracture(s) in the formation away from the borehole. The fracture position will be between the two packers; however the location of the fracture cannot be controlled. This is because the formation is already under stress and the fracture starts at a depth (albeit within the zone) where minimum energy is needed. The position (and direction) of the fracture is controlled by the stress distribution in the rock formation. It is common to use perforations to create weak points in the formation and help fracture initiation, but this may not always be successful as there is no control on the amount of stress exerted on the formation.

Summary

[0004] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

[0005] According to some embodiments, a system is described for inducing fractures in a subterranean rock formation surrounding a wellbore. The system includes: an expandable mechanical device configured to make physical contact with rock surfaces on the subterranean rock formation and to apply force on the rock surfaces thereby inducing stress in the subterranean rock formation; and a hydraulic fracturing sub-system configured to isolate a subterranean zone including the mechanical device and to pump fluid into the isolated zone thereby inducing further stress in the rock formation such that fractures are induced and/or propagated in the formation. The induced and/or propagated fractures are in a location and/or direction that are based on the force applied from the expandable mechanical device.

[0006] According to some embodiments, a method is described for inducing fractures in a subterranean rock formation surrounding a wellbore. The method includes: positioning an expandable mechanical device in the wellbore; expanding the mechanical device so as to make physical contact with rock surfaces on the subterranean rock formation; further expanding the mechanical device so as to induce stress in the subterranean rock formation; and pumping hydraulic fluid into an isolated zone of the wellbore including the expandable mechanical device so as to induce and/or propagate fractures in the formation in a location and/or direction that is based in part on the force applied from the expandable mechanical device.

[0007] The subject disclosure describes mechanical devices and methods that can be used to help initiate fracturing a reservoir and doing so in a preset depth and initial direction.

[0008] According to some embodiments, mechanical devices are inserted into a reservoir and attached to the formation. The devices have an expansion mechanism to increase the size of the device. Once the size of the device becomes larger than the distance between opposing

walls, any further diameter increase induces a stress in the rock formation. The device can be engineered to induce sufficient stress to cause (micro) cracks in the rock. The cracks so produced will act so as to initialize a hydraulic fracturing process and will be the starting point for a fully developed fracture.

[0009] According to some further embodiments, the stress can be reduced to a low enough level that cracks are not generated but the stress is present as a result of the mechanical device and acts to facilitate fracturing the rock at that location.

[0010] According to some further embodiments, the mechanical device is engineered to cause stress in a desired direction. The initial direction of a fracture is controlled and facilitated with these mechanical devices.

[0011] The mechanical devices of the subject disclosure function when they are in contact with the formation. Sensing devices are added to the mechanical device to measure properties such as pressure, temperature, mechanical stress directions, etc.

[0012] It is desirable to control the location where the fracture initiates, the fracture direction at the initiation point, and the fracture direction as it propagates away from the borehole. The subject disclosure describes an apparatus and method for controlling the location where the fracture initiates and the fracture direction at the initiation point.

[0013] According to some embodiments, the device can be configured to expand in a rapid accelerative manner thereby inducing a degree of shock to the wellbore wall. This will further induce micro-cracks in the rock and in a direction appropriate for fracture initiation.

[0014] Further features and advantages of the subject disclosure will become more readily apparent from the following detailed description when taken in conjunction with the accompanying drawings.

Brief Description of the Figures

[0015] FIG. 1 illustrates a horizontal well with two side holes to aid in fracture initiation, according to some embodiments;

[0016] FIGS. 2-1 and 2-2 are side views illustrating an anchor device used for inducing stress and/or initiating fractures, according to some embodiments;

[0017] FIGS. 3-1 and 3-2 illustrate side views of a device for inducing stress and/or initiating fractures, according to some other embodiments;

[0018] FIGS. 4-1 and 4-2 show side and end views, respectively, of a symmetrical nut used in a device for inducing stress and/or initiating fractures, according to some embodiments.

[0019] FIGS. 4-3 and 4-4, show side and end views, respectively, of an asymmetrical nut used in a device for inducing stress and/or initiating fractures, according to some embodiments

[0020] FIG. 5 is a side view of a radial expander devices used to induce stress and/or initiate fractures, according to some embodiments;

[0021] FIG. 6 is a side view of a radial expander devices used to induce stress and/or initiate fractures, according to some other embodiments;

[0022] FIG. 7 shows examples of T-expanders being used to apply stress in side holes, according to some embodiments;

[0023] FIG. 8 shows example expanders in the main borehole capable of applying stress in the main borehole or in a side hole, according to some embodiments;

[0024] FIG. 9 is a flowchart showing aspects of a hydraulic fracturing process that includes mechanical expander devices used to induce stress and/or initiate fractures, according to some other embodiments;

[0025] FIGS. 10-1 and 10-2 show aspect of an expander used to apply stress in a formation having a greatly reduced contact tip, according to some embodiments; and

[0026] FIG. 11 shows details of the shape of spacers according to some embodiments.

Detailed Description

[0027] The particulars shown herein are by way of example and for purposes of illustrative discussion of the embodiments of the subject disclosure and are presented in the cause of

providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the subject disclosure. In this regard, no attempt is made to show structural details in more detail than is useful for the fundamental understanding of the subject disclosure, the description taken with the drawings making apparent to those skilled in the art how the several forms of the subject disclosure may be embodied in practice. Furthermore, like reference numbers and designations in the various drawings indicate like elements.

[0028] FIG. 1 illustrates a section of a horizontal well with two side holes to aid in fracture initiation, according to some embodiments. Although a horizontal well 112 is shown, the embodiments described herein can be applied to vertical or deviated wells according to some embodiments. Two example side holes 114 and 116 are shown. The side holes have a length comparable to the diameter of the main borehole 112 and are intended to help fracture initiation. According to some embodiments, the side holes may be the perforations, although in the example shown in FIG. 1 the side holes 114 and 116 are drilled. The side hole 114 is drilled perpendicular to the z -direction, as shown by coordinate system 100. Note that the z -direction is parallel with the longitudinal axis of the main wellbore 112. The side hole 114 is shown along the x -direction but other side holes can exist which may be along the y -direction or any direction between these two directions. The side hole 116 is drilled at a slanted angle relative to the borehole axis (which is in the z -direction). The double-sided arrows in FIG. 1 define stress directions within the borehole and inside the side holes. Considering a 3×3 stress tensor in a coordinate system 100 aligned within the wellbore 112, the diagonal stresses (xx , yy , and zz) are shown in FIG. 1. The off-diagonal stress directions are not shown for clarity, but they can be visualized having FIG. 1 and the coordinate system 100 defined in it. The side holes 114 and 116 help introduce stress to the formation in the zz direction, which is normally not possible along the axis of the well.

[0029] In FIG. 1, the stress directions are relative to the borehole direction. However, the geo-stresses have their own directions that define the stress frame of reference of the formation. According to some embodiments, matrix algebra can be used to transform stresses from one frame of reference to those in the other, if needed.

[0030] According to some embodiments, logging tools such as borehole imaging (e.g. FMI Fullbore Formation MicroImager, provided by Schlumberger™) and sonic logging tools are used to help determine the stress directions. When a borehole is drilled in the formation, the drilling induced stresses perturb the space around the borehole (the damaged zone) leading to a stress distribution that may be different from the natural geo-stresses. One of the reasons for drilling the side holes, according to some embodiments, is to bypass the damage zone which allows desired stresses to be applied at a location closer to the formation that is controlled by the geo-stresses. The side holes also make it possible to apply stress in the well direction (zz) which cannot be done very effectively by operating in the main well.

[0031] According to some embodiments, a side hole is drilled perpendicular to or at a predetermined angle relative to the direction of the main well bore to a depth which is comparable to the diameter of the main well, such as the case shown in FIG. 1. The side hole is made deep enough that the stress variation caused by the well drilling operation is by-passed, or at least reduced. A mechanical device is then inserted inside the hole. The mechanical device is designed to apply stress to the hole wall and initiate a mini (local) fracture, or at least, induce stress in the formation and keep the stress active so that when the hydraulic fracturing fluid is pumped into the well, the presence of this added stress helps to initiate the fracture at that point. As a result, the fracture will initiate at the location where the mechanical device is placed (a predetermined depth). In addition, some or all of the energy that is normally used to initiate the fracture in a normal fracturing operation is saved. According to some embodiments, the side hole(s) are created using a perforation tool.

[0032] According to some further embodiments, a small drill bit (smaller than the drill bit used to drill the well) is used along with a drill motor to drill the side hole. Commercial logging tools are available to perform this operation such as the Cased Hole Dynamics Tester (CHDT) tool offered by Schlumberger™. According to some embodiments the side holes are drilled using a side wall coring tool. In such cases, the cut core may be brought to the surface and used for other studies.

[0033] According to some embodiments, the mechanical device is chosen to have an appropriate diameter for insertion into the newly drilled side hole. Once at the desired location

and orientation, the device is expanded to make contact with the borehole wall and then further expanded to apply stress to the formation.

[0034] According to some embodiments, a class of mechanical devices known as an anchor is used to provide radial stress. Anchors are mechanical devices that fit into a hole, and are expanded to make contact with the hole wall. These devices are used for attaching objects on a surface. The attached objects apply a pull on the anchor; however, the radial force prevents the anchor from moving axially. For the application according to some of the embodiments described herein, there is no axial pull, and the radial force is used instead to induce stress on the formation and facilitate fracture initiation. The anchors are available commercially, for example, from Concrete Fastening System in Cleveland, OH. Anchors vary in design but as long as they are an appropriate size to fit into the side hole and are made mechanically strong to induce the desired level of stress they may be used for the applications described herein.

[0035] Anchors are designed such that the expansion is typically caused by turning a bolt that moves the inner parts of the device relative to each other which causes the diameter to increase. FIGS. 2-1 and 2-2 are side views illustrating an anchor device used for inducing stress and/or initiating fractures, according to some embodiments. The anchor device 200 includes a plurality of rods each having two or more pieces that are hinged together and to the body of the anchor. Two rods 212 and 222 are visible in the side views of FIGS. 2-1 and 2-2, but more may be present. Each of the rods (e.g. 212 and 222) is made of three smaller rods. Each of the rods (e.g. 212 and 222) is attached to the end pieces 226 and 228 via hinges. One of the ends, in this case end piece 228 is not threaded (has a through hole) and remains fixed while the other end piece 226 is threaded and can be moved by turning the bolt 229 in the direction that shortens the length of the rods 212 and 222, causing the hinges 224 and 225 to move out and away from the central axis of the device 200. The expansion in this example can be caused by turning the bolt 229, which pulls the end piece 226 and reduces the distance from 226 to 228. FIG. 2-2 shows the same anchor 200 where the bolt 229 has been tightened to some extent causing the rods 212 and 222 to expand as described. In using a device such as anchor 200 shown in FIGS. 2-1 and 2-2, the device 200 in its non-expanded state (as shown in FIG. 2-1) is inserted in the side hole (such as side holes 114 and/or 116 in FIG. 1) and oriented to the desired direction, with the bolt

head accessible from the main well and can be turned to expand the anchor. The anchor is then expanded in place and the expanded rods (222 and 212) exert radial stress to the formation (e.g. formation 110 in FIG. 1).

[0036] According to some embodiments, the mechanical devices described herein are also equipped with one or more sensors. Sensors 250 and 252 shown in FIGS. 2-1 and 2-2, for example, can be stress measuring sensors that are placed on the part of the mechanical device that touches the formation. According to some embodiments, the sensors 250 and 252 are designed to measure the stress in three orthogonal directions (e.g. in x -, y -, and z -directions). In this way, the stress variation can be monitored as a function of time and in particular before and after the fracture initiation. According to some embodiments, sensors 250 and 252 can be powered by batteries (not shown) and data can be saved in memory (not shown) for future download. According to some other embodiments, the sensors 250 and/or 252 can include other types of measurement devices such as to measure temperature, pressure, acoustic, and/or flow. In this way, further details as to the mechanism of fracturing can be studied. According to some embodiments, the data from the sensors 250 and 252 are transmitted wirelessly to the surface during the fracturing operation and the data is monitored to optimize the fracturing process in real time.

[0037] FIGS. 3-1 and 3-2 illustrate side views of a device for inducing stress and/or initiating fractures, according to some other embodiments. A bolt 332 is attached to a nut 334, which is used to expand the device 300. The device has two or more rods of which two 316 and 336 are visible in FIGS. 3-1 and 3-2. The rods are attached at one end via hinges to end piece 338, while the other end of each rod is loosely held together (not shown in FIGS. 3-1 and 3-2) before the expansion. The expansion is caused by the shape of nut 334 which is designed to be of a higher diameter at one end. When the nut 334 is moved into the space between the rods 316 and 336, as a result of tightening bolt 332, it causes the rods 316 and 336 to expand by moving away from each other. The expansion increases as the nut 334 approaches the end piece 338. An expanded form of the device 300 is shown in FIG. 3-2. According to some embodiments, one or more sensors 250 and/or 252 are included such as described with respect to FIGS. 2-1 and 2-2, *supra*.

[0038] In the design shown in FIGS. 3-1 and 3-2, the nut 334 may or may not be circularly symmetric. If the nut 334 is symmetric, it has no preferred orientation, and as a result it can expand the rods to the same extent and induce stress on the wall of the side hole in a non-preferential way.

[0039] According to some embodiments, the expansion nut can be asymmetric. FIGS. 4-1 and 4-2 show side and end views, respectively, of a symmetrical nut 334, according to some embodiments. FIGS. 4-3 and 4-4, show side and end views, respectively, of an asymmetrical nut 444, according to some embodiments. The asymmetrical nut 444 has been designed to have a higher expansion capability in a selected direction causing the induced stress to be higher in that direction. This embodiment is useful in causing fracture initiation in one preferred direction. Also shown in FIGS. 4-2 and 4-4 are cross sections of rods 316 and 336 as well as rods 416 and 436. As can be seen from FIG. 4-4, the asymmetry in the shape of nut 444 will cause greater expansion, and therefore greater induced stress, by rods 316 and 336 than by rods 416 and 436.

[0040] The anchors described above in FIGS. 2-1, 2-2, 3-1, 3-2, 4-1, 4-2, 4-3 and 4-4 can be applied to the side hole 114 of FIG. 1, causing stresses in the yy or zz (or any combination thereof) directions as seen in FIG. 1. When applied to the side hole 116, the anchor can be applied inline with the axis of the side hole, which causes the stress direction to not align with the borehole defined axis system thereby creating off-diagonal elements. According to some embodiments, a tilted direction (as opposed to inline) may be adapted for the anchor (or by using other devices described herein below) if desired.

[0041] According to some embodiments, the stress can be induced within the borehole. In a non-limiting example, the anchors of FIGS. 2-1, 2-2, 3-1, 3-2, 4-1, 4-2, 4-3 and 4-4 can be made proportionally larger so that they can operate in the main borehole. In such cases, the anchor designs described above can be used to induce the desired stress in a radial direction perpendicular to the axis of the well, rather than to the side hole. These anchors can also be used to apply force in one particular radial direction by limiting the number of rods to two, or by limiting the rod expansion to a selected sub set of rods, for example, by using the asymmetric nuts of FIGS. 4-3 and 4-4.

[0042] According to some embodiments, another class of mechanical device that may be used is a radial expander. These devices can be used to induce stress in a direction perpendicular to the borehole (or the side hole) wall. FIG. 5 is a side view of a radial expander devices used to induce stress and/or initiate fractures, according to some embodiments. The expander device 500 is made of a bolt 552 and a nut 554. The total length of this device 500 can be varied by turning the nut 554 in a clockwise direction to reduce the length of the device or a counter clockwise direction to increase the length of the device. A suitably long radial expander can be held perpendicular to the borehole axis and the nut 554 can be turned clockwise to increase the device length causing it to contact the borehole wall. The tightening can be continued leading to induced stress on the borehole wall. According to some embodiments, one or more sensors 250 and/or 252 are included such as described with respect to FIGS. 2-1 and 2-2, *supra*.

[0043] A feature of the radial expander is that it can be mounted on the borehole wall on one side and the deep end of a side hole 114 on the other end, as in the case of expander 502 depicted in FIG. 8, *infra*. The radial extender of FIG. 5 is turned to set and apply stress to the formation. The turning motion is in a plane perpendicular to the long axis of the expander; the plane of turn is perpendicular to the expansion direction. The embodiments using this type of expander are particularly well suited to main borehole applications where there is good access to the expander, making it practical to turn one of the two sides and set the expander in place.

[0044] FIG. 6 is a side view of a radial expander devices used to induce stress and/or initiate fractures, according to some other embodiments. The radial T-expander 600 is similar to expander 500 of FIG. 5, except that it is expanded by turning a nut at a plane that is parallel to the direction of expansion. As depicted in FIG. 6, the T-expander is “T” shaped. In these embodiments, the turning motion is transferred to the two parts of the expander through a 90° joint. The two nut parts 614 and 624 are used to press on the formation and apply the stress. These two nut parts are pushed in or out when the two screws 612 and 622 are turned. These screws are attached to gears 610 and 620 which are engaged to a gear 618. The gear 618 turns as a result of rotating the nut 602. The nut 602 is used to set the device in place. As the nut 602 is turned, its rotational motion is transferred to the rotational motion of screws 612 and 622 which in turn move the parts 614 and 624 closer together or away from each other, depending on the

direction of rotation of nut 602. One of the design parameters of the T-expander is the gear ratio between gear 618 and gears 610 and 620. A smaller gear 618 can be turned easier, with less torque, than a larger gear 618. The penalty of course is the number of turns but a smaller gear 618 can be used to apply a relatively larger force on the formation wall. According to some embodiments, one or more sensors 250 and/or 252 are included such as described with respect to FIGS. 2-1 and 2-2, *supra*.

[0045] FIG. 7 shows examples of T-expanders being used to apply stress in side holes, according to some embodiments. In the implementation of FIG. 7, the nut 602 of T-expander 600 is accessible easier from the borehole 112 and can be turned to achieve the desired stress on the formation 110. In another example, another T-expander 650 is being deployed in side hole 116 to apply stress and/or initiate fractures at the location and in the direction shown.

[0046] FIG. 8 shows example expanders in the main borehole applying stress in the main borehole or in a side hole, according to some embodiments. In the case of FIG. 8, an expander 500 is deployed as shown for applying stress on the main borehole 112 as shown. According to some embodiments, a longer sized expander 502 is shown with one end on the wall of the main borehole 112 and the other end on the deep end of a side hole 114 as shown. In yet another example, a T-expander 600 is being deployed in the main borehole 112.

[0047] According to some other embodiments, one or more spacers can be used to reduce the length requirement for the mechanical device. Shown in FIG. 8, another T-expander 810 is used for applying pressure to the side hole 116 and main hole 112 at the same time, similar to the application shown that uses radial expander 502. In this case, however, a shorter T-expander 810, along with spacers 660 and 662 are used to achieve the objective. The T-expander 810 does not have to be long enough to span the total distance rather the spacers 660 and 662 are used in conjunction with it to increase its effective length. The effective length can be made even longer if greater numbers of spacers are used. FIG. 11 shows further detail of the shape of spacers 660 and 662, according to some embodiments.

[0048] According to other embodiments, spacers such as shown in FIG. 11 can be combined with other types of expanders. For example, using the design of the hydraulic jack used in many

applications, the gear system used in T-expander can be replaced with a hydraulic piston similar to what is done with a conventional hydraulic jack. The new expander can be called H-expander where H refers to its hydraulic mode of activation. Some of the hydraulic jacks have telescopic extensions allowing them to expand to more than twice their length. According to some embodiments, the H-expanders are used with any of the features described herein with respect to T-expanders. A conventional hydraulic jack used in automobile applications, is designed such that one side expands. The same type of asymmetric expansion can be used for the H- or T-expanders described herein. In this case, the nut 602 of the T-expander, and corresponding nut for the H-expander will be at the same distance from the borehole wall which simplifies the design of the nut driver needed to implement the expanders.

[0049] In a further embodiment of an H-expander, the hydraulic fluid can be replaced by a slow burn charge that is activated by a detonator or electrical impulse. This slow burn charge expands a fluid or gas, allowing the device to accelerate to the borehole surface thus imparting a force and a shock to induce micro-fractures in the rock.

[0050] In a further embodiment of an H-expander, the hydraulic circuit can be designed so as to impart a vibrational force on the wall of the borehole, in a similar fashion to a jack-hammer. This will further enhance the cracking of the rock.

[0051] A further embodiment of an H-expander allows for the placement of a reactive fluid – an oxidizer, acid or chelating agent – that can be pumped out of the mechanical or hydraulic device in a predetermined manner and direction. The direction of this flow of reactive fluid can create weakpoints in the rock by dissolving or reacting with the rock grains to create chemically weakened zones that either further evolve into micro-cracks or sufficiently reduce the rock mechanical strength allowing for easier fracture initiation.

[0052] According to some embodiments, the contact surface between the mechanical device and the borehole wall can be tuned to achieve different outcomes. For example, if the contact surface is wide, as shown in FIGS. 2-1, 2-2, and 5-8, the induced stress by the mechanical device is less likely to cause a failure in the formation. With this approach relatively large stress levels can be induced in the formation in preparation for the subsequent hydraulic fracturing operation.

FIGS. 10-1 and 10-2 show aspect of an expander used to apply stress in a formation having a greatly reduced contact tip, according to some embodiments. The contact surface of rod 1094 is made into a sharp chisel point 1010. The T-expander 1002 has a wide surface 1092 on one side which can be used as the base contact with the borehole wall. It also has a sharp surface 1010, mounted to end piece 1014 which is a chisel like structure and with appropriate amount of force can penetrate into the rock and create a mini-fracture. FIG. 10-2 shows the top view of the sharp surface 1010. In this case, application of the mechanical device leads to a relatively short fracture in the formation even before the hydraulic fracturing operation has started. The relatively short fracture will act as the initiation point for the final hydraulic fracture.

[0053] FIG. 9 is a flowchart showing aspects of a hydraulic fracturing process that includes mechanical expander devices used to induce stress and/or initiate fractures, according to some other embodiments. In block 910, a side hole is drilled perpendicular to or at a predetermined angle relative to the direction of the main well bore to a depth which is comparable to the diameter of the main well, such as the case shown in FIG. 1. The side hole(s) are made deep enough that the stress variation caused by the well drilling operation is by-passed, or at least reduced. According to some embodiments, a small drill bit (smaller than the drill bit used to drill the well) is used along with a drill motor to drill the side hole. Commercial logging tools are available to perform this operation such as the Cased Hole Dynamics Tester (CHDT) tool offered by SCHLUMBERGER™. According to some embodiments the side holes are drilled using a side well coring tool. In such cases, the cut core may be brought to the surface and used for other studies. According to some embodiment, no side hole is drilled in block 910, and the mechanical device is positioned to apply stress and/or induce fractures within the main borehole.

[0054] In block 912, a mechanical device is then inserted inside the borehole. A mechanical device is chosen to have an appropriate diameter for insertion into the newly drilled side hole. Once at the desired location and orientation, in block 914 the device is expanded to make contact with the borehole wall and/or side hole wall. The mechanical device is designed to apply stress to the hole wall and initiate a mini (local) fracture, or at least, induce stress in the formation and keep the stress active so that when the hydraulic fracturing fluid is pumped into the well, the presence of this added stress helps to initiate the fracture at that point. As a result, the fracture

will initiate at the location where the mechanical device is placed (a pre-determined depth). In addition, some or all the energy that is normally used to initiate the fracture in a normal fracturing operation is saved. According to some embodiments, no side hole is drilled in block 910, and the mechanical device is positioned to apply stress and/or induce fractures within the main borehole.

[0055] In block 916, if the mechanical device includes one or more sensors such as sensors 250 and 252 shown in FIGS. 2-1 and 2-1, those sensors are used to measure the stress in three orthogonal directions (e.g. in x-, y-, and z-directions), and or make other types of measurements (e.g. temperature, pressure, acoustic, and/or flow). According to some embodiments, one or more of the measurements are taken during the expansion process of the mechanical device and/or during the hydraulic fracturing process of block 918. The measurements are recorded in the device and/or transmitted to another tool or the surface for analysis. In the case where data from the sensors 250 and 252 are transmitted during the fracturing process the data is monitored in real-time so as to optimize the fracturing process in real-time.

[0056] In block 918, the hydraulic fracturing process is carried out. A zone that includes the location of the mechanical device is hydraulically isolated using packers. According to some embodiments, at least one of the packers (the one farther away from uphole) is positioned prior to the mechanical expansion (block 914) such that the fluid can be pumped into the isolated zone soon after the expansion of the mechanical device. According to some embodiments, the mechanical device remains in place while the fracturing fluid is pumped into the well. Following the completion of the hydraulic fracturing, in block 920, the mechanical device is contracted and removed.

[0057] Although a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from this invention. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail

employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words 'means for' together with an associated function.

Claims

What is claimed is:

1. A system for inducing fractures in a subterranean rock formation surrounding a wellbore, the system comprising:

an expandable mechanical device configured to make physical contact with two or more rock surfaces on the subterranean rock formation and to apply force on the two or more rock surfaces thereby inducing stress in the subterranean rock formation; and

a hydraulic fracturing sub-system configured to isolate a subterranean zone including the mechanical device and to pump fluid into the isolated zone thereby inducing further stress in the rock formation such that one or more fractures are induced and/or propagated in the formation, wherein the one or more fractures are in a location and or direction that is based in part on the force applied from the expandable mechanical device.

2. A system according to claim 1, wherein the force applied on the two or more rock surfaces is in a direction that is not perpendicular to a central axis of the wellbore.

3. A system according to claim 1, wherein the force applied on the two or more rock surfaces initiates a first fracture which is thereafter propagated by the pumped fluid from the hydraulic fracturing sub-system.

4. A system according to claim 1, wherein the expandable mechanical device is further configured so as to be at least partially positionable in a side hole formed off of the wellbore, wherein at least one of the two or more rock surfaces are in the side hole.

5. A system according to claim 4, further comprising a drilling sub-system configured to form the side hole using a drilling process.

6. A system according to claim 4, wherein the side hole has a central axis perpendicular to a central longitudinal axis of the wellbore.

7. A system according to claim 4, wherein the side hole has a central axis that is not perpendicular to a central longitudinal axis of the wellbore.

8. A system according to claim 1, wherein the expandable mechanical device is further configured such that actuation of the device causes a first end piece to move towards a second end piece thereby causing two or more rods to move away from a central longitudinal axis of the device, and wherein at least portions of the two or more rods are configured to contact the two or more rock surfaces.

9. A system according to claim 8, wherein the two or more rods includes a first pair of rods and a second pair of rods, and the mechanical device is further configured to expand asymmetrically such that the first pair of rods move away from the central axis of the device at a greater rate than the second pair of rods.

10. A system according to claim 1, wherein the expandable mechanical device is further configured such that actuation of the device causes a first end piece to move away from a second end piece in a direction parallel to a central longitudinal axis of the device, and wherein the first and second end pieces are configured to contact the two or more rock surfaces.

11. A system according to claim 10, wherein the actuation is caused by turning a nut in a direction about the central longitudinal axis of the device.

12. A system according to claim 10, wherein the actuation is caused by turning a nut in a direction about a secondary axis that is perpendicular to the central longitudinal axis of the device.

13. A system according to claim 1, wherein the expandable mechanical device includes one or more sensors for measuring one or more parameters while deployed in the wellbore.

14. A system according to claim 13, wherein the one or more parameters includes stress in three orthogonal directions.

15. A system according to claim 13, wherein the one or more parameters is selected from a group consisting of temperature, pressure, acoustic, and fluid flow.

16. A system according to claim 13, wherein the expandable mechanical device is further configured to store measurements from the one or more sensors.

17. A system according to claim 13, wherein the expandable mechanical device is further configured to transmit measurements from the one or more sensors directly or indirectly to a surface analysis system.

18. A system according to claim 1, wherein the expandable mechanical device forces fluid into a hydraulic cylinder for expansion.

19. A system according to claim 1, wherein the expandable mechanical device includes one or more non-expandable spacers positioned between the two or more rock surfaces on the subterranean rock formation.

20. A system according to claim 1, wherein the mechanical device is further configured with a sharp edge for making physical contact with at least one of the rock surfaces so as to initiate a fracture in the at least one of the rock surface.

21. A method for inducing fractures in a subterranean rock formation surrounding a wellbore, the method comprising:

- positioning an expandable mechanical device in the wellbore;
- expanding the mechanical device so as to make physical contact with two or more rock surfaces on the subterranean rock formation;
- further expanding the mechanical device so as to induce stress in the subterranean rock formation; and
- pumping hydraulic fluid into an isolated zone of the wellbore including the expandable mechanical device so as to induce and/or propagate one or more fractures in the formation, wherein the one or more fractures are in a location and/or direction that is based in part on the force applied from the expandable mechanical device.

22. A method according to claim 21, further comprising forming a side hole off of the wellbore, wherein the expandable mechanical device is positioned at least partially in the side hole and at least one of the two or more rock surfaces is in the side hole.

23. A method according to claim 22, wherein the side hole is formed using a drilling process.

24. A method according to claim 22, wherein the side hole has a central axis perpendicular to a central longitudinal axis of the wellbore.

25. A method according to claim 22, wherein the side hole has a central axis that is not perpendicular to a central longitudinal axis of the wellbore.

26. A method according to claim 22, wherein the force applied on the two or more rock surfaces is in a direction that is not perpendicular to a central axis of the wellbore.

27. A method according to claim 21, wherein the expanding and the further expanding include actuating the mechanical device such that a first end piece moves towards a second end piece along a central longitudinal axis of the device thereby causing two or more rods to move away from the central longitudinal axis of device, and wherein at least portions of the two or more rods make contact with the two or more formation rock surfaces.

28. A method according to claim 27, wherein the two or more rods includes a first pair of rods and a second pair of rods, and the expanding is asymmetric such that the first pair of rods move away from the central axis of the device at a greater rate than the second pair of rods.

29. A method according to claim 21, wherein the expanding and the further expanding include actuating the mechanical device such that a first end piece moves away from a second end piece in a direction parallel to a central longitudinal axis of the device, and wherein the first and second end pieces make contact with the two or more formation rock surfaces.

30. A method for mechanically inducing fractures in a subterranean rock formation surrounding a wellbore, the method comprising:

- positioning an expandable mechanical device in the wellbore;
- expanding the mechanical device so as to make physical contact with two or more rock surfaces on the subterranean rock formation;
- further expanding the mechanical device so as to initiate one or more fractures in the subterranean rock formation; and
- pumping hydraulic fluid into an isolated zone of the wellbore including the expandable mechanical device so as to further propagate the one or more fractures in the formation.

31. A method according to claim 30, further comprising forming a side hole off of the wellbore, wherein the expandable mechanical device is positioned at least partially in the side hole.

32. A method according to claim 30, wherein said further expanding includes providing an acceleration of the mechanical device towards at least one of the two or more rock surfaces so as to impart a shock to the subterranean rock formation thereby facilitating the initiation of the one or more fractures in the subterranean rock formation.

33. A method according to claim 30, wherein said further expanding includes vibrating part of the mechanical device so as to impart vibrational energy into the subterranean rock formation thereby facilitating the initiation of the one or more fractures in the subterranean rock formation.

34. A method according to claim 30, further comprising introducing chemically reactive fluids so as to selectively weaken the subterranean rock formation in specific directions thereby facilitating the initiation of the one or more fractures in the subterranean rock formation.

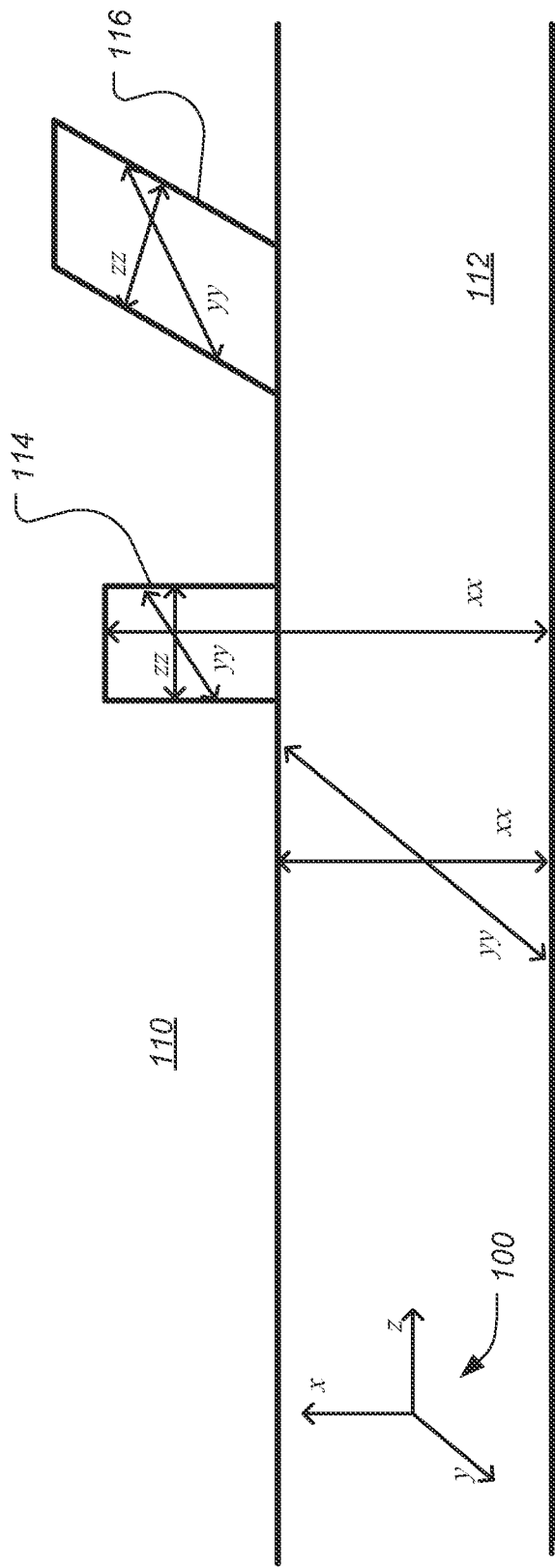


Fig. 1

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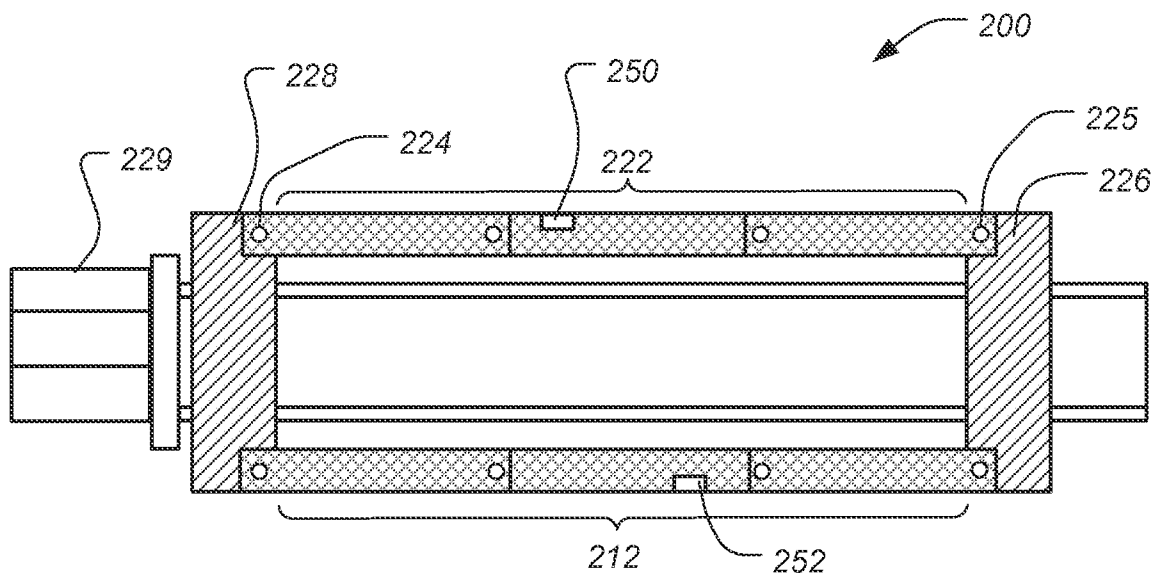


Fig. 2-1

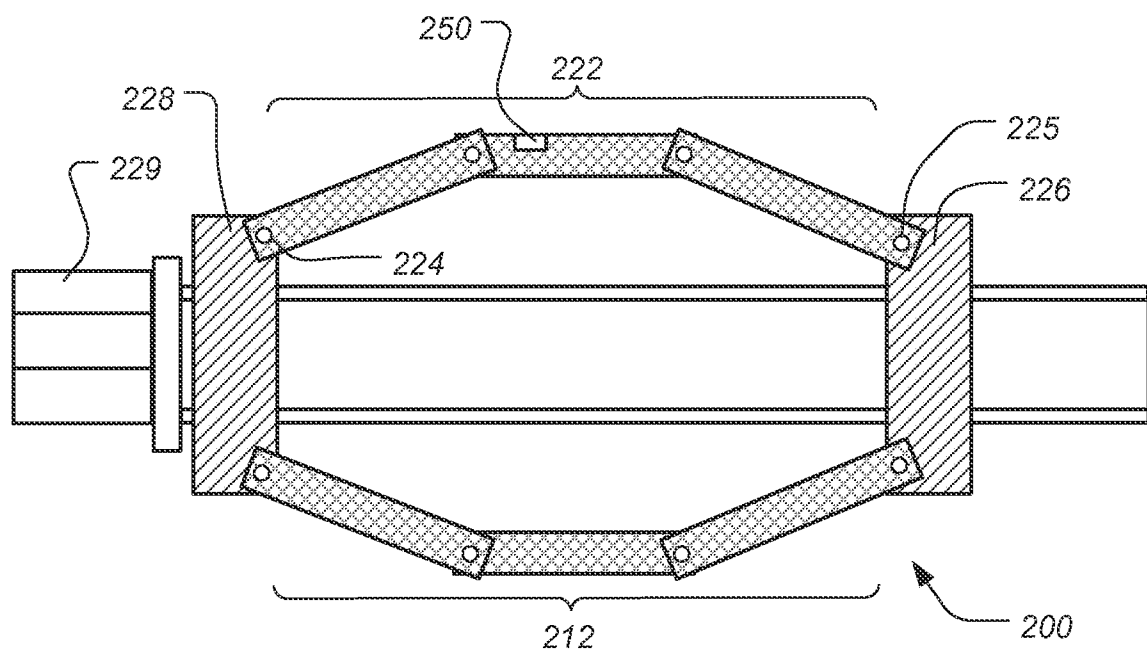
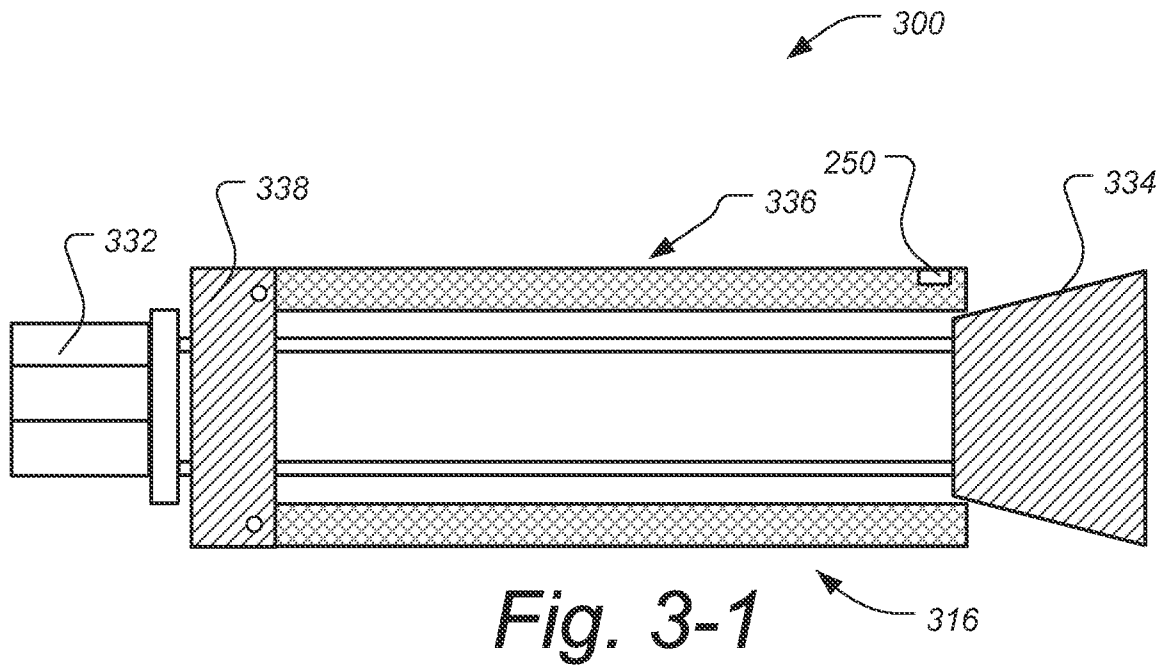
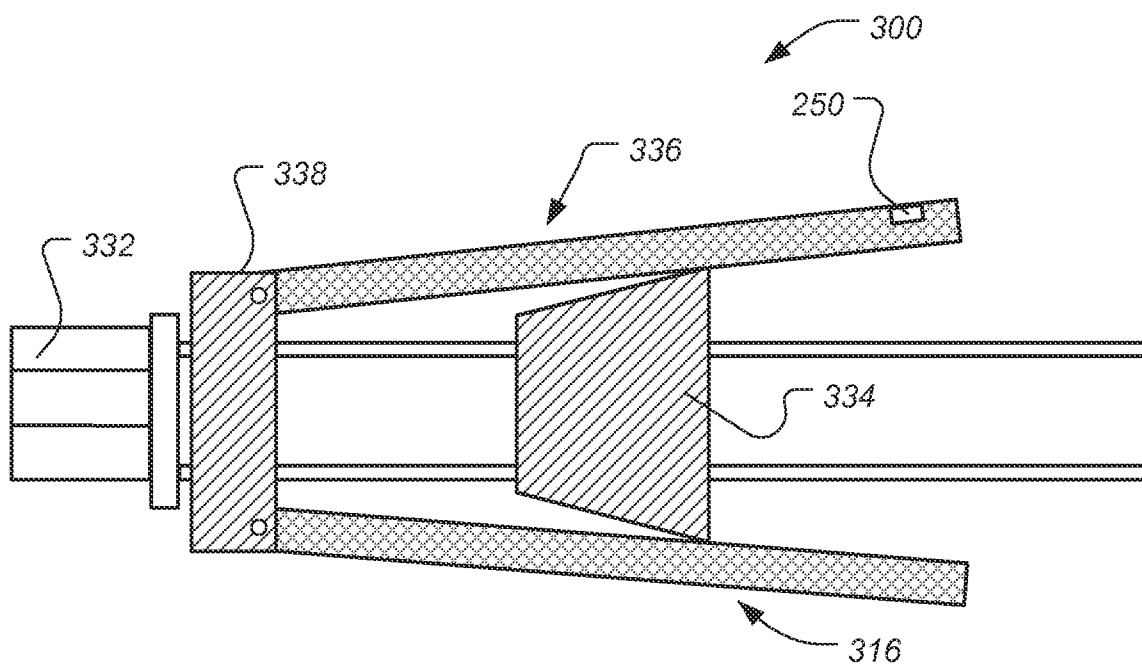


Fig. 2-2

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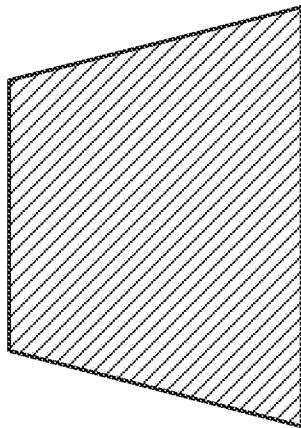


Fig. 4-1

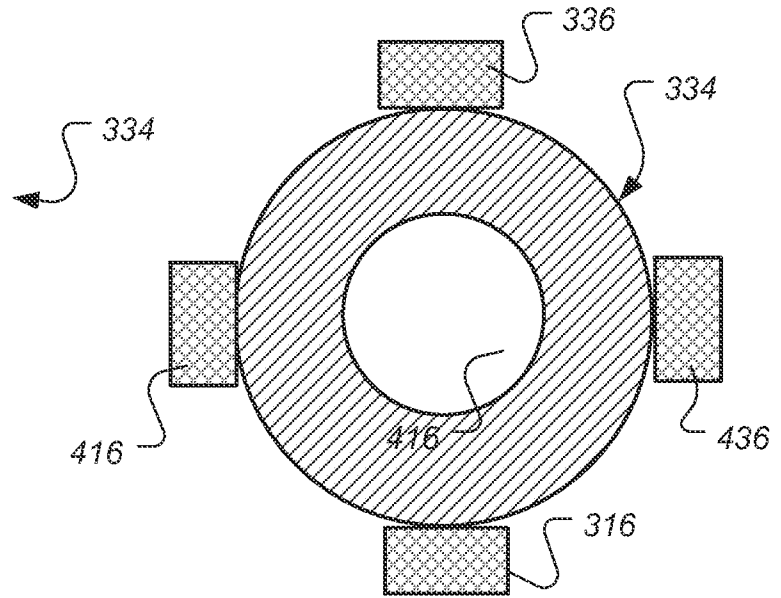


Fig. 4-2

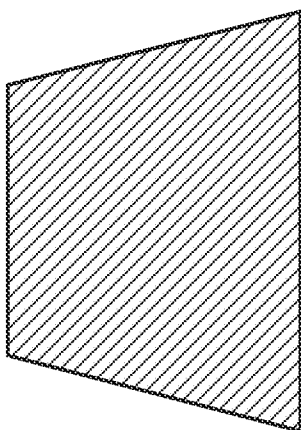


Fig. 4-3

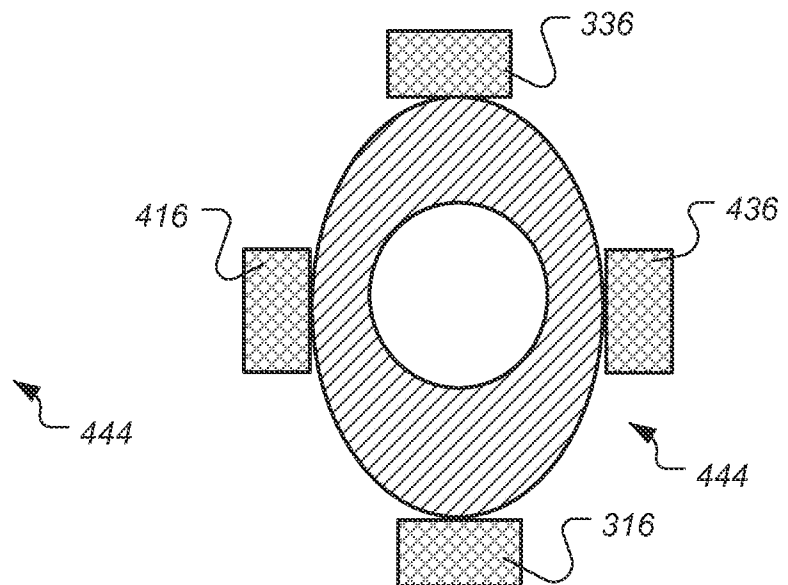
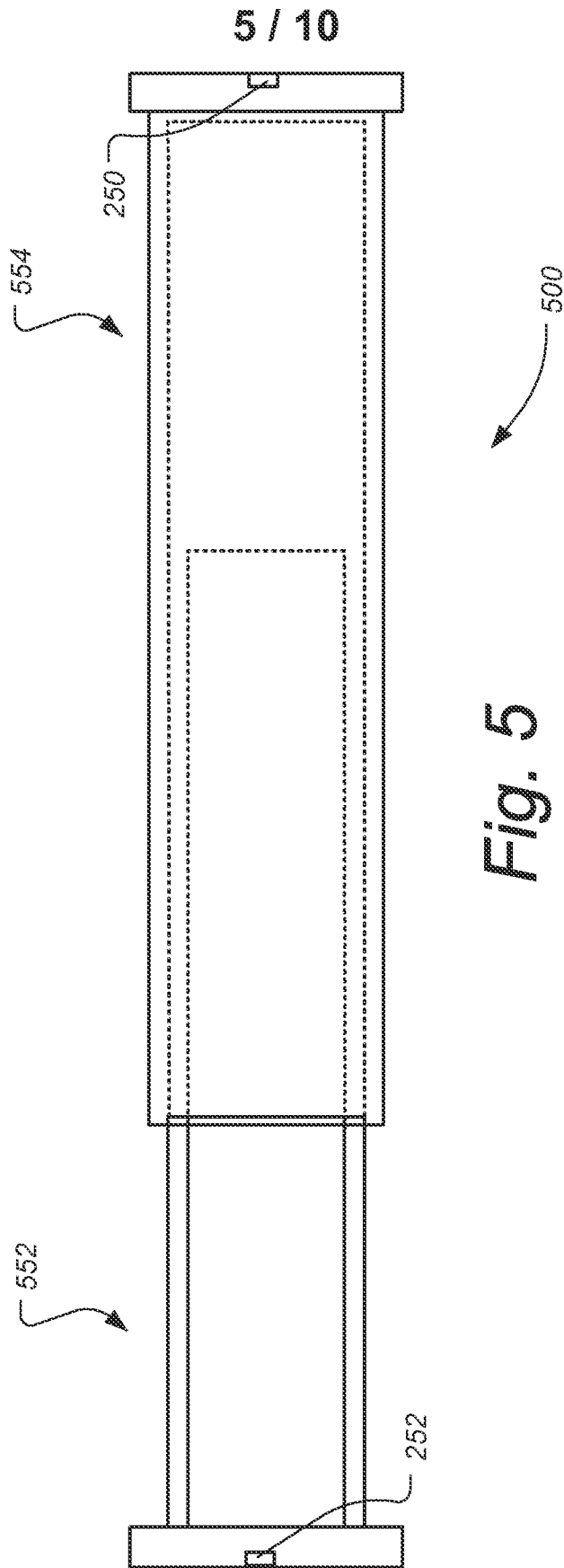


Fig. 4-4



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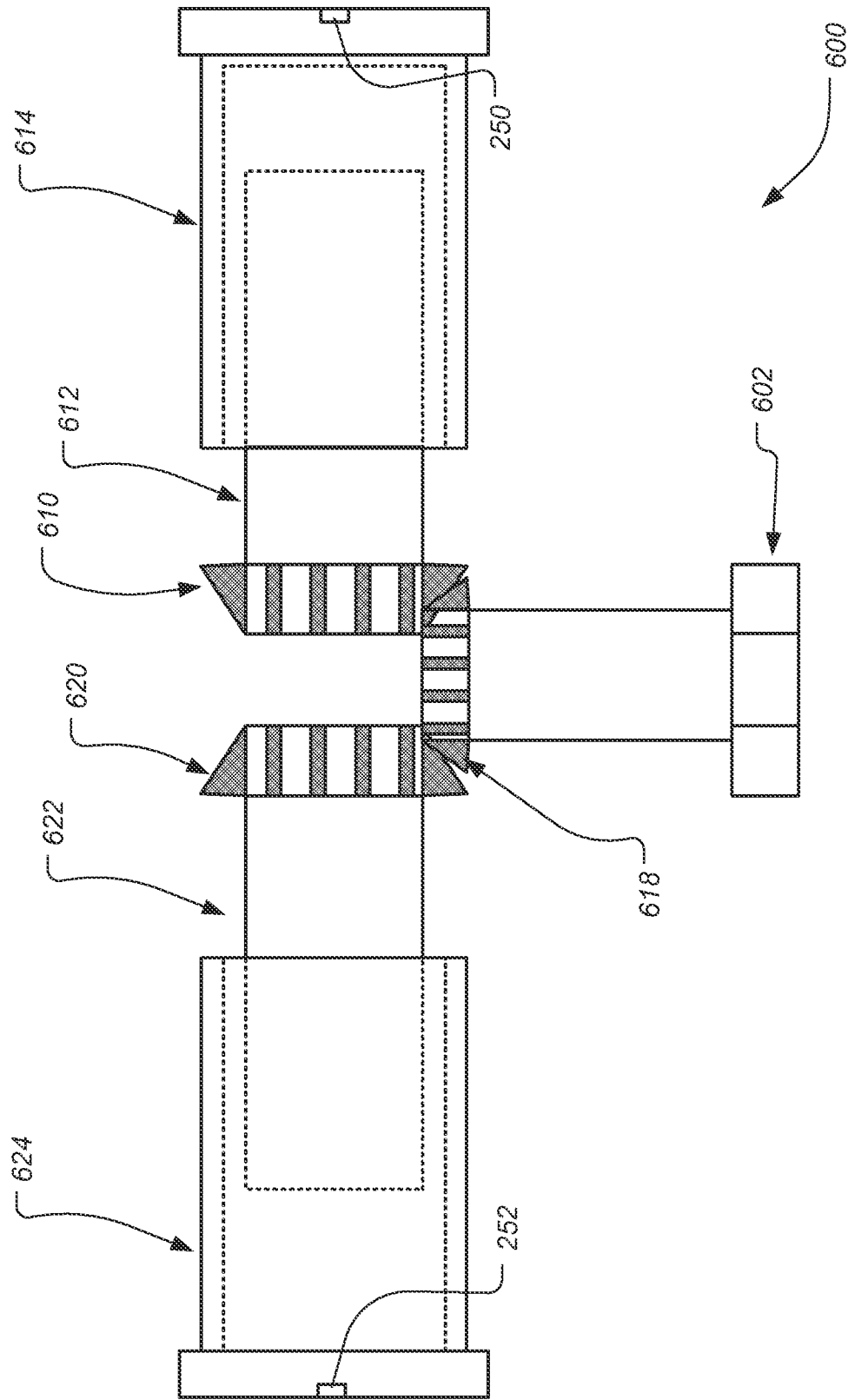


Fig. 6

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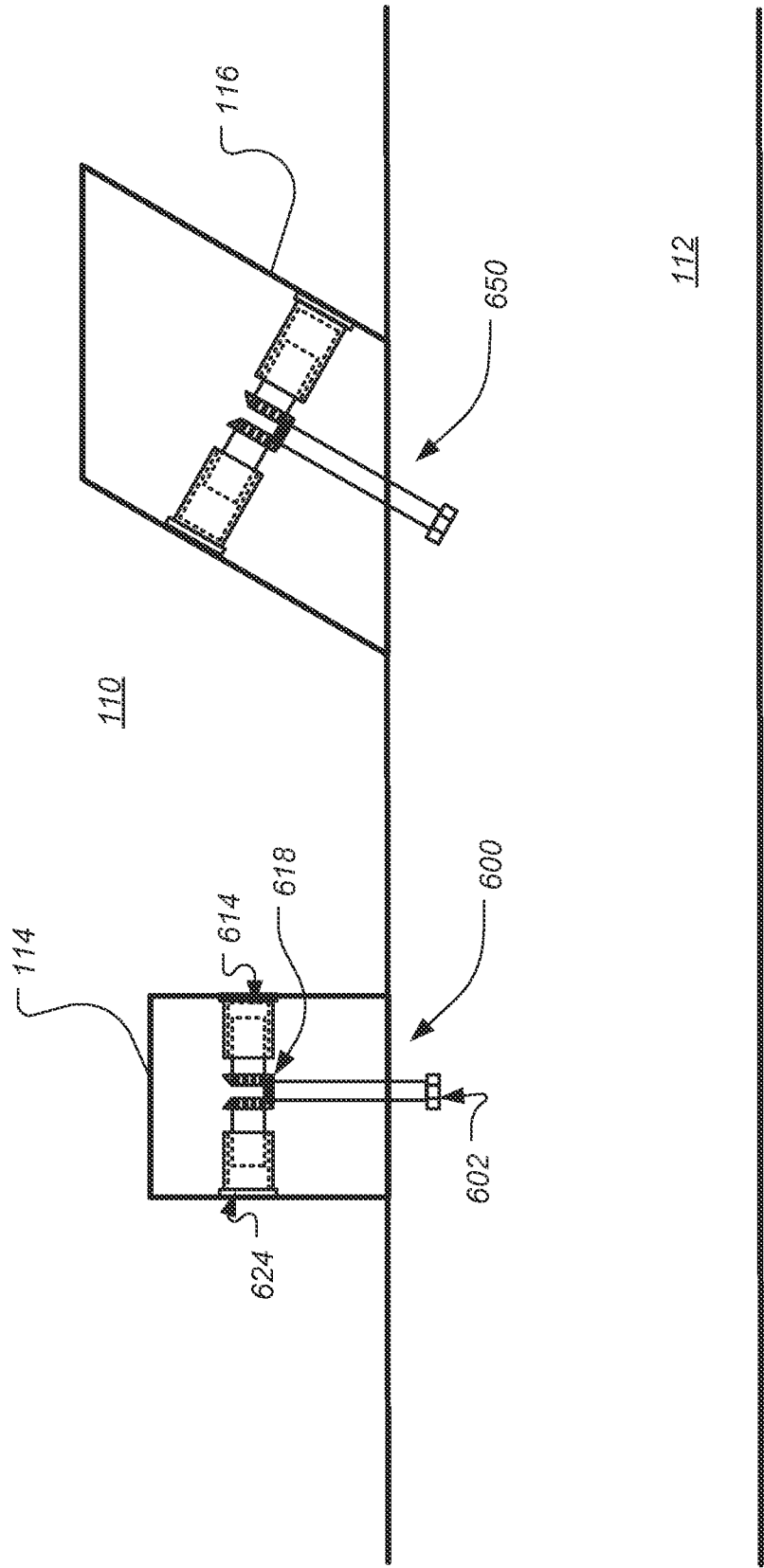


Fig. 7

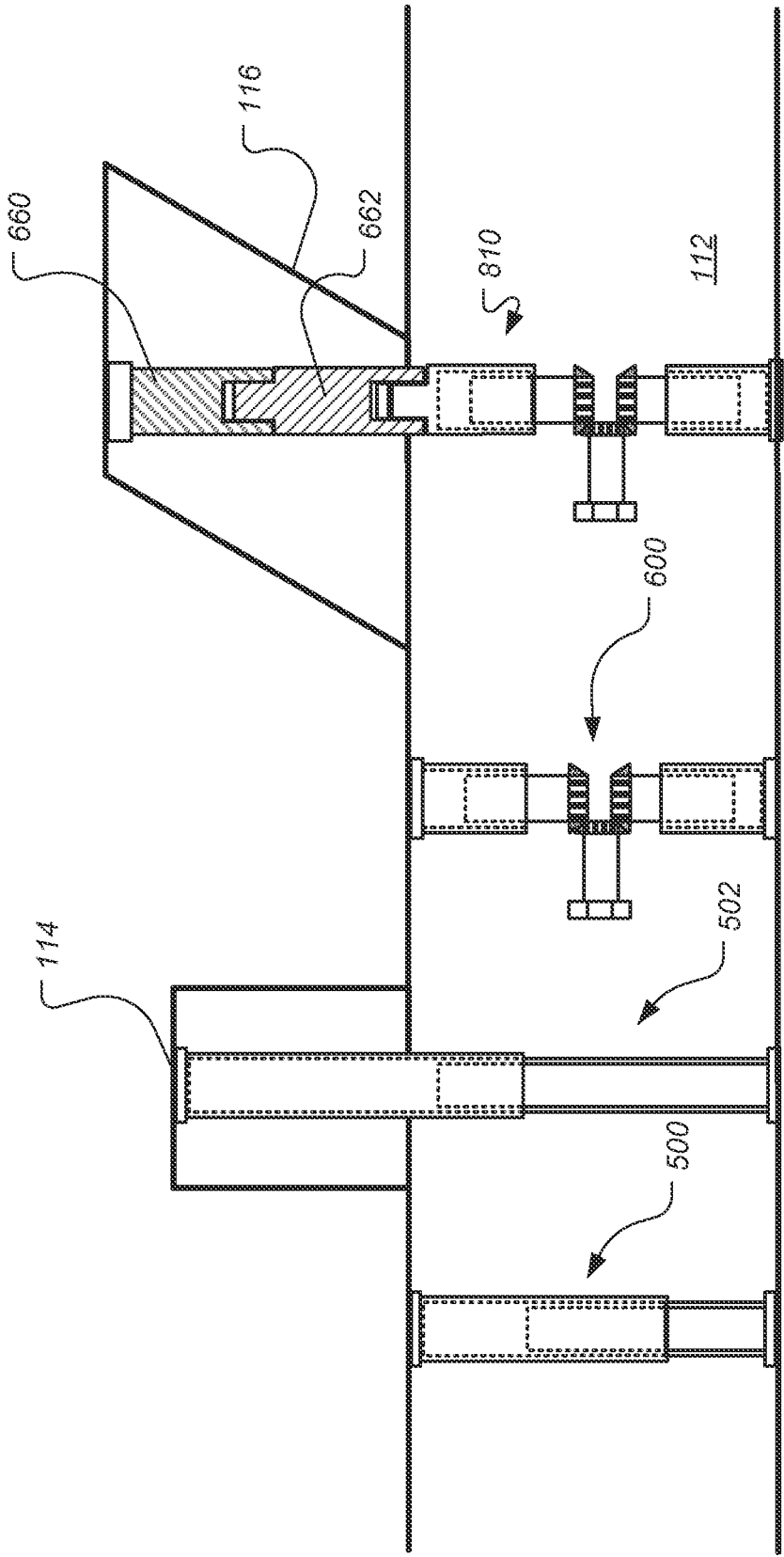
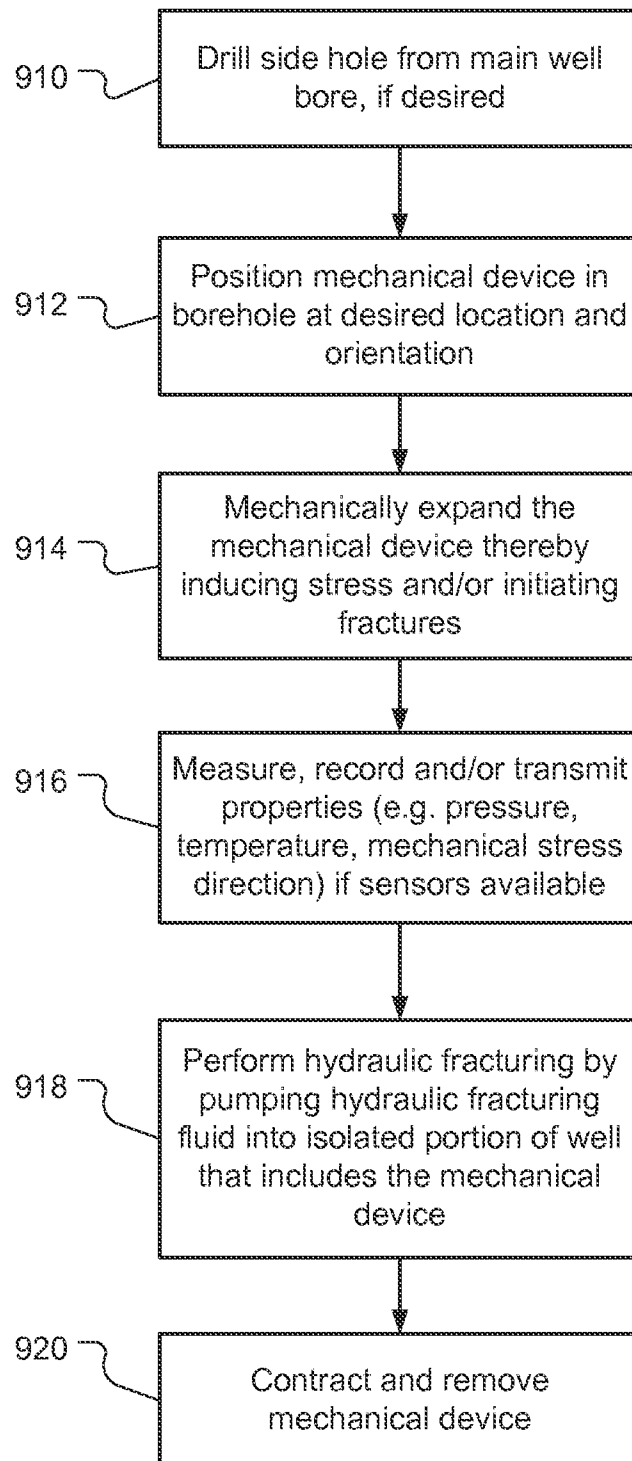


Fig. 8

9 / 10***Fig. 9***

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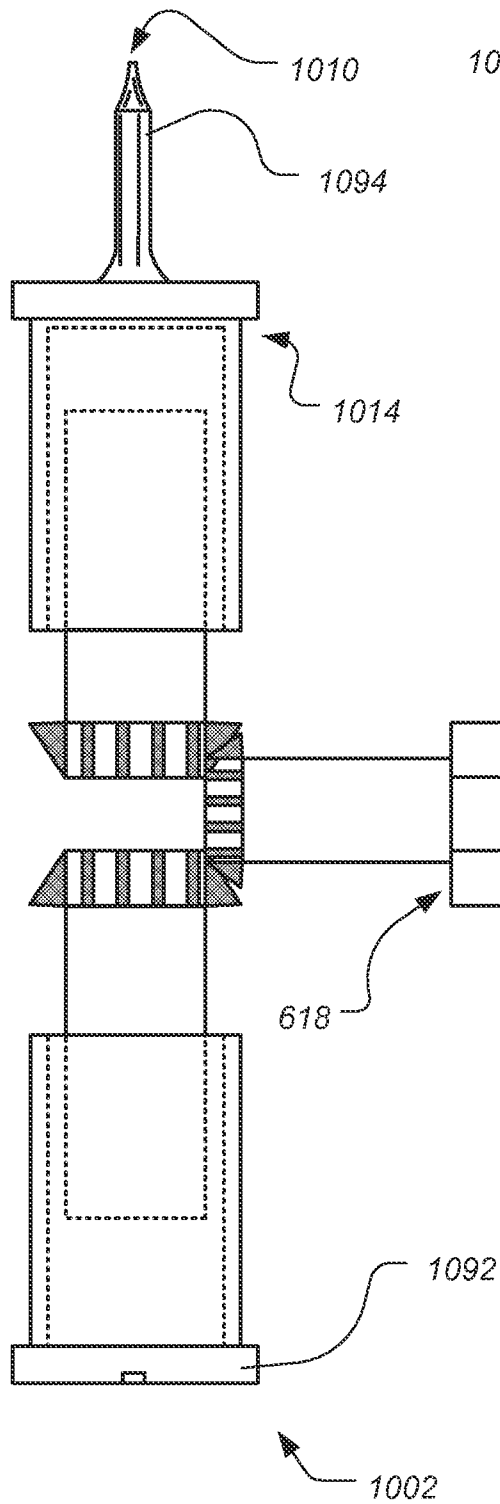


Fig. 10-1

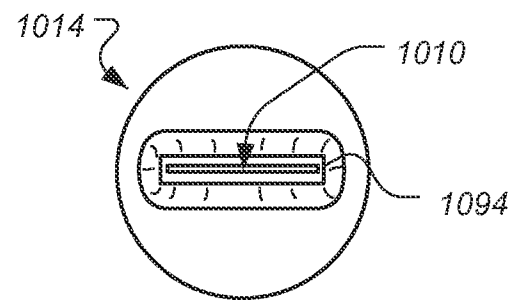


Fig. 10-2

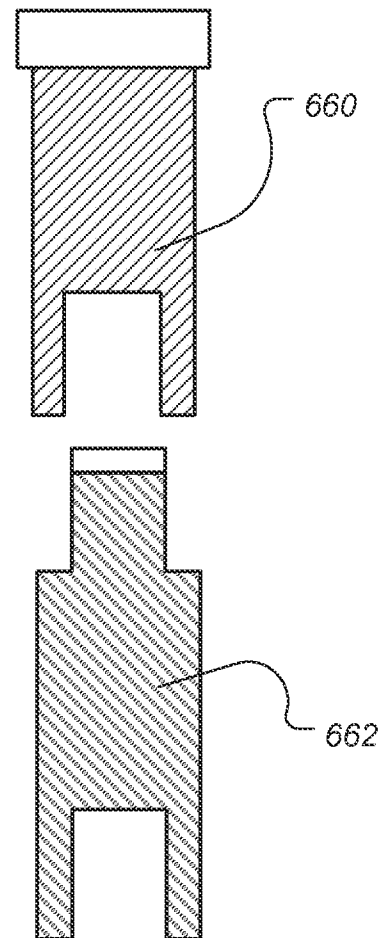


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/064557**A. CLASSIFICATION OF SUBJECT MATTER****E21B 43/26(2006.01)i, E21B 28/00(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 43/26; E21B 29/08; E21B 47/00; E21B 49/00; G01N 33/24; E21B 28/00

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: expand, rock, force, road, bolt, nut, side hole

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6176313 B1 (COENEN et al.) 23 January 2001 See column 4, line 6 - column 6, line 54; claims 1, 12; and figures 1-7.	1, 18, 21, 30
Y		13-17
A		2-12, 19-20, 22-29, 31-34
Y	US 4149409 A (SERATA, SHOSEI) 17 April 1979 See column 4, lines 7-25, column 6, line 44 - column 7, line 9 and figures 13-17.	13-17
A	US 2009-0266548 A1 (OLSEN et al.) 29 October 2009 See paragraphs [0015]-[0036] and figures 1-5.	1-34
A	US 5576485 A (SERATA, SHOSEI) 19 November 1996 See column 2, line 10 - column 3, line 21 and figures 1-12.	1-34
A	US 2009-0166040 A1 (CAVENDER et al.) 02 July 2009 See abstract; paragraphs [0005]-[0008]; and figures 5-8.	1-34



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

27 January 2014 (27.01.2014)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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