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(54) DRILLING ROBOT WITH AN INFLATABLE SEGMENT

(57) A drilling robot 100 for drilling a vertical bore hole is claimed. The drilling robot 100 is in particularly electrically driven and comprises a drill head 2 and a first inflatable segment 11. The inflatable segment 11 is adapted to expand its volume in radial direction in an inflated state. Wherein in the inflated state, the first inflatable segment 11 is adapted to absorb a torque that occurs when driving the drill head 2.

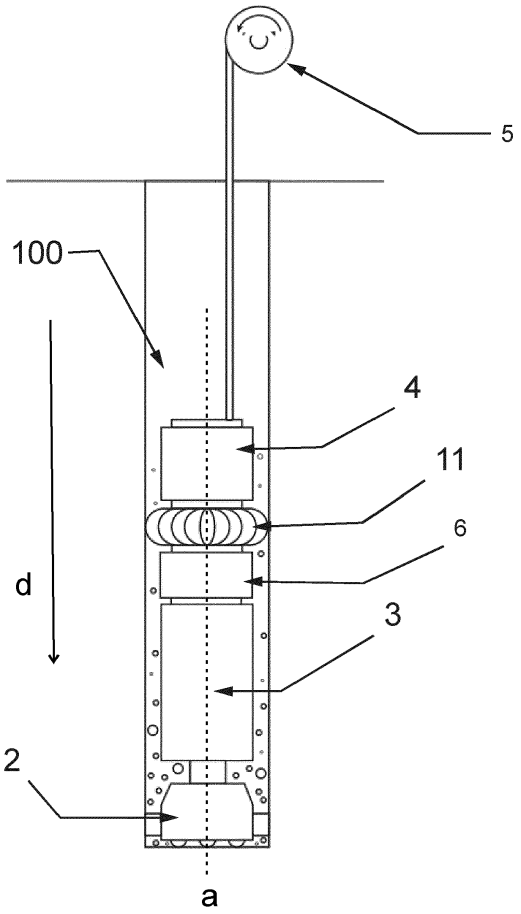

Fig. 1

EP 4 553 271 A1

Description

Technical Field

[0001] The invention refers in a first aspect to a drilling robot for drilling a vertical bore hole and in a second aspect to an inflatable unit for the drilling robot.

Background Art

[0002] Heat generation through geothermal energy plays a crucial role in worldwide successful heat transition. Boreholes for geothermal probes are traditionally drilled with a pneumatic hammer drill, wherein a compressor and a drill rig are arranged outside the borehole and the drill energy is transferred to the drill head inside the borehole via a drill pipe. Cuttings are flushed out of the borehole. Due to the water filled borehole, the pressure of the compressed air must increase along the depth of the borehole to actuate the pneumatic drill head. A very large compressor is needed to generate the necessary pressure and flow volume.

[0003] Such a drilling system requires a lot of space. The process is energy-intensive, expensive, imprecise, causes noise and massive damage to the landscape. As a result, many buildings cannot benefit from geothermal heat or are equipped with other heating systems.

[0004] Therefore, compact drilling robots are used to overcome the disadvantages of the described technology. Such drilling robots might be purely electrically driven.

[0005] Anyway, an electrically driven and compact drilling robot might generate a torque on the drill head which needs to be supported.

Disclosure of the Invention

[0006] The problem to be solved by the present invention is therefore to provide a drilling robot that is adapted to overcome the disadvantages of the prior art.

[0007] This problem is solved by a drilling robot according to a **first aspect** of the invention.

[0008] The drilling robot for drilling a vertical bore hole is in particular purely electrically driven. The drilling robot comprises a drill head and a first inflatable segment. The first inflatable segment is adapted to expand its volume in radial direction in an inflated state. In the inflated state, the first inflatable segment is adapted to absorb a torque that occurs when driving the drill head. This means that the inflatable segment is designed to handle the torque that occurs if the drill head is rotating to drill the bore hole.

[0009] In a further advantageous embodiment of the invention, the drilling robot comprises further a drilling system. The drilling system is arranged between the drill head and the first inflatable segment. Such an arrangement might be advantageous for electrically driven drilling robots. The heavy weight of the drive close to the drill head might move the robot forward in vertical direction by gravitational forces. Such an arrangement might be further advantageous in regard that the drilling system generates a torque moment and a hammer stroke directly close by the drill head.

[0010] In a further advantageous embodiment of the invention, the drilling system comprises a rotating system and a hammering system. The rotating system is adapted to rotate the drill head and the hammering system is adapted to hammer with the drill head.

[0011] Advantageously, the hammering system is adapted to operate according to an electro-pneumatic principle in order to generate an electro-pneumatic stroke.

[0012] In a further advantageous embodiment of the invention, the drilling robot comprises further a second inflatable segment. The second inflatable segment is also adapted to expand its volume in radial direction in an inflated state. In particular, the first and the second inflatable segment are arranged along a longitudinal axis of the drilling robot.

[0013] Advantageously, the drilling robot is further adapted to alternate the state of the first inflatable segment and the second inflatable segment from inflated to deflated. In the intended use of such a drilling robot, at least the first or the second inflatable segment is in an inflated state. This way, either the inflated first or the inflated second segment serves as the torque support on the bore wall. This means that with such an arrangement of the first and the second segment, the torque support on the bore wall is provided by either the first inflated segment or the second segment.

[0014] The arrangement with the first and the second segment allows the drilling robot to drill and move continuously, since always the first or the second segment acts as torque support and the forward movement of the drilling robot can be followed by alternating the inflation of the first and the second segment continuously.

[0015] In a further advantageous embodiment, the drilling robot comprises further a third inflatable segment. The third inflatable segment is adapted to expand its volume in radial direction in an inflated state. In particular, the third inflatable segment is arranged along the longitudinal axis of the drilling robot.

[0016] Advantageously, each of the first, the second and the third segment is further adapted to contract its axial length in axial direction of the longitudinal axis in an inflated state and to expand its axial length in a relaxed state. This means that in an inflated state, each of the first, second, and third segment is designed to reduce (or diminish) its axial length along the direction of the longitudinal axis, while in a relaxed state, they are designed to increase their axial length.

[0017] Advantageously, in the intended use of the drilling robot in a borehole along the vertical longitudinal axis, the first, second and third inflatable segments are arranged within the drilling robot or placed in the drilling unit in said order with the first inflatable segment directed in forward moving direction.

[0018] Advantageously, in the intended use of the drilling robot, to move the drilling robot from a first position to a second position, the drilling robot is adapted to inflate the first, the second and/or the third inflatable segment and thereby engage the drilling robot with the borehole at the first position. In particular, engage here means to direct the drilling robot to engage with the borehole to counteract a torque produced by the drilling head by drilling the borehole by means of the inflated segments. In particular, to engage the drilling robot with the borehole might also mean to activate the drilling robot that the first, second and/or third inflatable segments are inflated such that a torque of the drilling action of the robot is counteracted by at least one of the segments interacting respectively blocking the movement of the robot in the borehole.

[0019] Further advantageously, the drilling robot is adapted to subsequently relax the first and the second inflatable segment and thereby generate the advancing force to move the drilling robot to the second position and further subsequently inflate the first inflatable segment to frictionally engage the drilling robot in the borehole, respective with the inner surface of the borehole, at the second position.

[0020] In particular, frictionally engaged means that the first segment is designed to establish a frictional connection of the drilling robot with the inner surface of the borehole. In particular, the segment is therefore intended for frictionally coupling the drilling robot respectively the surface of the first segment of the drilling robot, with the inner surface of the borehole.

[0021] Further advantageously, the drilling robot is adapted to subsequently relax the third segment and thereby bring the first, second and third segment into a position to start the next move, by continuing to inflate the first, the second, and/or the third segment at the new first position that corresponds to the previous second position.

[0022] In a further advantageous embodiment, the first and the second inflatable segment are connected with an actuator. In particular such an actuator might be a single or double acting (hydraulic) cylinder. In particular, the actuator enables in particular a forward and/or a backward movement of the drilling robot, similar to a drilling robot comprising a third inflatable segment. Therefore, the actuator might replace the second inflatable segment in some embodiments of the drilling robot. In a further advantageous embodiment of the invention, the drilling robot comprises an energy reservoir to control the force acting on the drill head. In particular, the energy reservoir can be used to damp the drilling energy. In particular, the energy reservoir is arranged between the drilling system and the first inflatable element.

[0023] Further advantageously, the energy reservoir is an absorber, in particular a hydraulic cylinder or a spring element.

[0024] In a further advantageous embodiment of the invention, the at least first, second and third segment are all of the same type of segments.

[0025] In a further advantageous embodiment of the invention, for inflating the first, second and/or third segment, the respective first, second and/or third segment is filled with a fluid or gas.

[0026] In a further advantageous embodiment of the invention, the drilling robot comprises a medium-based, in particular water-based, very particular water-air-mix-based flushing system for flushing cuttings to the surface.

[0027] Advantageously, the first, second and/or third inflatable segment if there are any, are arranged around the flushing system respectively around a part of the flushing system. In particular, the flushing system might be a part of the drilling robot that is encircled by the first, second and/or third segment. This means that advantageously, the flushing-system flushes the cuttings or mud to the surface by flushing them internally through a pipe or similar through the drilling robot to the surface. The functionality of the first, second and third segment is not affected.

[0028] An advantageous flushing system is connected to a pump at the surface of the bore hole, to pump a flushing fluid into the flushing system and to pump cuttings out of the flushing system.

[0029] Further advantageously, the flushing system comprises at least one pathway, e.g. a pipe or tube, that allows to bring the flushing fluid, e.g. rinse water, or a power connection to the drill head to enable the flushing of cuttings right at the front of the drilling robot.

[0030] In particular, multiple pathways are integrated, e.g. one pathway for the flushing fluid and/or one for the power connection and/or one for bringing the cuttings or mud back to the surface. Thereby, the pathways are adapted such that they do not impede the functionality of the at least one inflatable segment.

[0031] Further advantageously, the pathways that are used for the flushing fluid might at the same time be used as pathways to inflate and deflate (relax) at least the first inflatable segment, and/or the second and/or the third inflatable segment, if there are any.

[0032] A **second aspect** of the invention refers to a inflatable unit for the drilling robot according to the first aspect of the invention and comprising at least a first inflatable segment. In addition, the inflatable unit comprises further a second and optionally even a third inflatable segment.

[0033] A flushing system is arranged within the inflatable unit such that the at least first inflatable segment surrounds the flushing system. In particular this means in other words, the flushing system is supposed to pass through the first inflatable segment without affecting the functionality of the first inflatable segment. The flushing system is adapted to transport cuttings from a bore hole to the surface of the bore hole via a drilling robot. The inflatable unit builds a part of the drilling robot, wherein the inflatable unit is adapted to absorb a torque that is generated by the drill head during the drilling of the bore hole.

[0034] Advantageously, a further aspect of the inven-

tion not claimed is a method to generate a torque support for the in particular electrically driven drilling robot for drilling a vertical bore hole. The drilling robot comprises a drill head and a first inflatable segment. The method comprises the steps of:

- inflating the inflatable segment to expand its volume in radial direction to absorb a torque that occurs when driving the drill head, and
- driving the drill head.

[0035] A further advantageous method moves the drilling robot from a first position to a second position. The drilling robot therefore comprises a second and a third inflatable segment. Each of the first, second and third segment is adapted to contract its axial length in axial direction of the longitudinal axis and to expand its volume in radial direction in an inflated state and to expand its axial length in a relaxed state.

[0036] Advantageously, the first, second and third inflatable segments are arranged within the drilling robot in said order with the first inflatable segment directed in forward moving direction. The method comprises advantageously the steps of:

- inflating the first, the second and the third inflatable segment and thereby engage the drilling robot with the borehole at the first position,
- relaxing the first and the second inflatable segment and thereby generating the advancing force to move the drilling robot to the second position,
- inflating the first inflatable segment to frictionally engage the drilling robot in the borehole at the second position, and
- relaxing the third inflatable element such that the drilling robot moves to the second position.

[0037] Other advantageous embodiments are listed in the dependent claims as well as in the description below.

Brief Description of the Drawings

[0038] The invention will be better understood and objects other than those set forth above will become apparent from the following detailed description thereof. Such description makes reference to the annexed drawings, wherein:

Fig. 1 shows a schematic drawing of an embodiment of the invention according to a first aspect of the invention;

Fig. 2 shows a schematic drawing of an embodiment of the invention according to a first aspect of the invention comprising further a second inflatable segment;

Fig. 3 shows a schematic drawing of an embodiment of the invention according to a first aspect of the invention comprising further a third inflatable segment;

Fig. 4a and b show schematic drawings of different embodiments of an inflatable unit comprising a flushing system according to a second aspect of the invention.

Modes for Carrying Out the Invention

[0039] Fig. 1 shows a schematic drawing of a drilling robot 100 for drilling a vertical bore hole. In the figure, the drilling robot is sitting in the vertical bore hole. The drilling robot 100 is in particular purely electrically driven. Advantageously, the drilling robot 100 comprises an electronic unit 4 that controls the electrically driven robot 100.

[0040] The drilling robot 100 comprises a drill head 2 and a first inflatable segment 11. The first inflatable segment 11 is adapted to expand its volume in radial direction in an inflated state. In the inflated state, the first inflatable segment 11 is adapted to absorb a torque that occurs when driving the drill head 2.

[0041] As visible on the picture, the drilling robot 100 in the intended use of the robot 100, when drilling a vertical bore hole, produces cuttings that need to be transferred to the surface. Therefore, the robot comprises a flushing system (not visible in Fig.1) that transports the cuttings to the surface. The flushing system is arranged such that it does not impede the functionality of the first inflating segment.

[0042] An advantageous flushing system 8 is connected to a pump at the surface of the bore hole, to pump a flushing fluid into the flushing system 8 and to pump cuttings out of the flushing system 8.

[0043] Further advantageously, the flushing system 8 comprises at least one pathway 81, e.g. a pipe or tube, that allows to bring the flushing fluid, e.g. rinse water, or a power connection to the drill head 2 to enable the flushing of cuttings right at the front of the drilling robot 100.

[0044] Further advantageously, the pathways 81 that are used for the flushing fluid might at the same time be used as pathways to inflate and deflate (relax) at least the first inflatable segment 11, and/or the second 12 and/or the third 13 inflatable segment, if there are any.

[0045] As visible in Fig. 1, the drilling system 3 is arranged between the drill head 2 and the first inflatable segment 11.

[0046] In a further advantageous embodiment of the invention, the drilling system 3 comprises a rotating system and a hammering system, wherein the rotating system is adapted to rotate the drill head 2 and wherein the hammering system is adapted to hammer with the drill head 2.

[0047] Advantageously, the drilling robot 100 as shown in Fig. 1 comprises an energy reservoir 6 to control the axial force at the drill head. Anyway, the drilling robot 100 would also work without the energy reservoir 6.

[0048] Further advantageously, the drilling robot 100 comprises a supply 5 for fluid, e.g. water, air pressure and/or power supply.

[0049] Fig. 2 shows a schematic of a drilling robot 100 comprising further a second inflatable segment 12. The second inflatable segment 12 is also adapted to expand its volume in radial direction in an inflated state. The first 11 and the second 12 inflatable segment are arranged along a longitudinal axis a of the drilling robot 100. In particular, the first 11 and the second 12 inflatable segment are arranged in said order in a forward moving direction d of the drilling robot 100.

[0050] In a further advantageous embodiment of the drilling robot 100, the robot 100 is adapted to alternate the state of the first inflatable segment 11 and the second inflatable segment 12 from inflated to deflated. At least the first 11 or the second 12 inflatable segment is in an inflated state. The respective first 11 or second 12 inflatable segment serves as the torque support on the bore wall.

[0051] The drilling robot 100 comprising the first 11 and the second 12 inflatable segment allows to continuously bore the bore hole, since while moving the robot 100 forward in the bore hole, the first 11 and second 12 inflatable segment are alternating inflated and deflated to follow the movement of the drilling robot 100 in the bore hole.

[0052] Advantageously, the first 11 and the second 12 inflatable segment are connected with an actuator 7. In particular such an actuator 7 might be a single or double acting cylinder. In particular, the actuator 7 enables a forward movement of the drilling robot 100, similar to a drilling robot 100 comprising a third inflatable segment 13. Therefore, the actuator 7 might replace the second inflatable segment 12 in some embodiments of the drilling robot 100.

[0053] In Fig. 2, both, the first 11 and the second 12 inflatable segment are in an inflated state.

[0054] **Fig. 3** shows a schematic figure of a drilling robot 100 comprising further a third inflatable segment 13 adapted to expand its volume in radial direction in an inflated state. The third inflatable segment 13 is arranged along the longitudinal axis a of the drilling robot 100.

[0055] The first 11, second 12 and third 13 inflatable segments are arranged on a longitudinal axis a in said order in forward moving direction d of the robot.

[0056] In the intended use of the drilling robot 100, to move the drilling robot 100 from a first position to a second position, the drilling robot 100 is adapted to inflate the first 11, the second 12 and the third 13 inflatable segment and thereby engage the drilling robot 100 with the borehole at the first position.

[0057] The drilling robot 100 is further adapted to subsequently relax the first 11 and the second 12 inflatable segment and thereby generate the advancing force to move the drilling robot 100 to the second position. Subsequently, the first inflatable segment 11 is inflated to frictionally engage the drilling robot 100 in the borehole at the second position.

[0058] In a further advantageous embodiment of the invention, the drilling robot 100 comprises optionally an energy reservoir 6 to control the movement of the drill head 2 in axial direction. Advantageously, the energy reservoir is arranged between the drilling system 3 and the first inflatable segment 11.

[0059] Advantageously, the energy reservoir is an absorber, in particular a hydraulic cylinder or a spring element.

[0060] As shown in Fig. 3, advantageously, the first 11, the second 12 and the third 13 segment are all of the same type of segments (here the second segment 12 is deflated and the first 11 and third 13 segments are inflated, which is why they look differently).

[0061] Advantageously, the first 11, the second 12, and the third 13 inflatable segment gets filled with gas or a fluid to become inflated.

[0062] In a further advantageous embodiment of the invention, the drilling robot 100 comprises a medium-based flushing system 8 for flushing cuttings to the surface.

[0063] The first inflatable segment 11 and the second inflatable segment 12 or the third inflatable segment 13, if there are any, are arranged around the flushing system 8.

[0064] **Fig. 4a and 4b** show a schematic drawing of different embodiments of an inflatable unit 101 for the drilling robot 100 according to the first aspect of the invention. The inflatable unit 101 comprises at least a first 11, in particular as shown in Fig. 4 also a second 12 and a third 13 inflatable segment. In addition, the inflatable unit 101 comprises further a flushing system 8, wherein the first 11, the second 12, and the third 13 inflatable segment, if there are any, are arranged around the flushing system. In particular, the flushing system 8 comprises at least one pathway 81 for a flushing fluid and/or a power connection. Fig. 4b shows an embodiment with two pathways 81, one pathway for a flushing fluid and one pathway for a power connection. In particular, the pathway 81 for the flushing fluid might also be used to inflate and/or deflate the first 11, second 12, and/or third inflatable segment 13.

Reference Table

[0065]

100	Drilling robot
11	First inflatable segment
12	Second inflatable segment
13	Third inflatable segment
2	Drill head
3	Drilling system
4	Electronic unit
5	Supply
6	Energy reservoir
7	Actuator
8	Flushing system
81	Pathway of flushing system

Claims

1. A drilling robot (100) for drilling a vertical bore hole, wherein the drilling robot (100) is in particular purely electrically driven and comprises:

   • a drill head (2),
   • a first inflatable segment (11) adapted to expand its volume in radial direction in an inflated state, and
   wherein in the inflated state, the first inflatable segment (11) is adapted to absorb a torque that occurs when driving the drill head (2).

2. The drilling robot (100) according to claim 1, comprising further a drilling system (3),
   wherein the drilling system (3) is arranged between the drill head (2) and the first inflatable segment (11).

3. The drilling robot (100) according to one of the preceding claims, wherein the drilling system (3) comprises a rotating system and a hammering system,
   wherein the rotating system is adapted to rotate the drill head (2) and wherein the hammering system is adapted to hammer with the drill head (2).

4. The drilling robot (100) according to any one of the preceding claims, comprising further a second inflatable segment (12) adapted to expand its volume in radial direction in an inflated state,
   wherein the first (11) and the second (12) inflatable segment are arranged along a longitudinal axis (a) of the drilling robot (100).

5. The drilling robot (100) according to claim 4, adapted to alternate the state of the first inflatable segment (11) and the second inflatable segment (12) from inflated to deflated, wherein at least the first (11) or the second (12) inflatable segment is in an inflated state,
   wherein the respective inflated first (11) or second (12) segment serves as the torque support on the bore wall.

6. The drilling robot (100) according to claim 4 or 5, comprising further a third inflatable segment (13) adapted to expand its volume in radial direction in an inflated state,
   wherein the third inflatable segment (13) is arranged along the longitudinal axis (a) of the drilling robot (100).

7. The drilling robot (100) according to claim 6, wherein each of the first (11), second (12) and third (13) segment is further adapted to contract its axial length in axial direction of the longitudinal axis (a) in an inflated state and to expand its axial length in a relaxed state,
   wherein the first (11), second (12), and third (13) inflatable segments are arranged within the drilling robot (100) in said order with the first inflatable segment (11) directed in forward moving direction (d) ,
   wherein in the intended use of the drilling robot (100), to move the drilling robot (100) from a first position to a second position, the drilling robot (100) is adapted to inflate the first (11), the second (12) and the third (13) inflatable segment and thereby engage the drilling robot (100) with the borehole at the first position,
   wherein the drilling robot (100) is further adapted to subsequently relax the first (11) and the second (12) inflatable segment and thereby generate the advancing force to move the drilling robot (100) to the second position and further subsequently inflate the first inflatable segment (11) to frictionally engage the drilling robot (100) in the borehole at the second position.

8. The drilling robot (100) according to one of the preceding claims, comprising an energy reservoir to control the force acting on the drill head (2),

   in particular, wherein the energy reservoir is arranged between the drilling system (3) and the first inflatable segment (11),
   in particular, wherein the energy reservoir is an absorber, in particular a hydraulic cylinder or a spring element.

9. The drilling robot (100) according to one of the preceding claims, wherein the at least first (11), second (12) and third (13) segment are all of the same type of segments.

10. The drilling robot (100) according to one of the preceding claims, wherein the diameter of at least the first inflatable segment (11), and/or the second (12) and/or the third (13) inflatable segment, if there are any, in a relaxed state is smaller than the diameter of the drill head (2).

11. The drilling robot (100) according to one of the preceding claims, wherein for inflating the respective at least first (11), second (12) or third (13) segment, the respective at least first (11), second (12) or third (13) segment is filled with a fluid or gas.

12. The drilling robot (100) according to one of the preceding claims comprising medium-based flushing system (8)for flushing cuttings to the surface,
   wherein the first inflatable segment (11) and the second (12) or third (13) inflatable segment if there are any, are arranged around the flushing system (8).

13. The drilling robot (100) according to claim 12, where-

in the flushing system (8) comprises at least one pathway (81) for a flushing fluid and/or a power connection.

14. The drilling robot (100) according to claim 13, wherein at least one pathway (81) is further adapted to provide the flushing fluid to inflate and deflate the at least first inflatable segment (11), and/or the second (12) and/or third (13) inflatable segment, if there are any.

15. Inflatable unit (101) for the drilling robot (100) according to claim 1 to 12, comprising at least a first (11), in particular also a second (12) and third (13) inflatable segment, and a flushing system (8), wherein the first (11), and the second (12) and third (13) inflatable segment if there are any, are arranged around the flushing system (8).

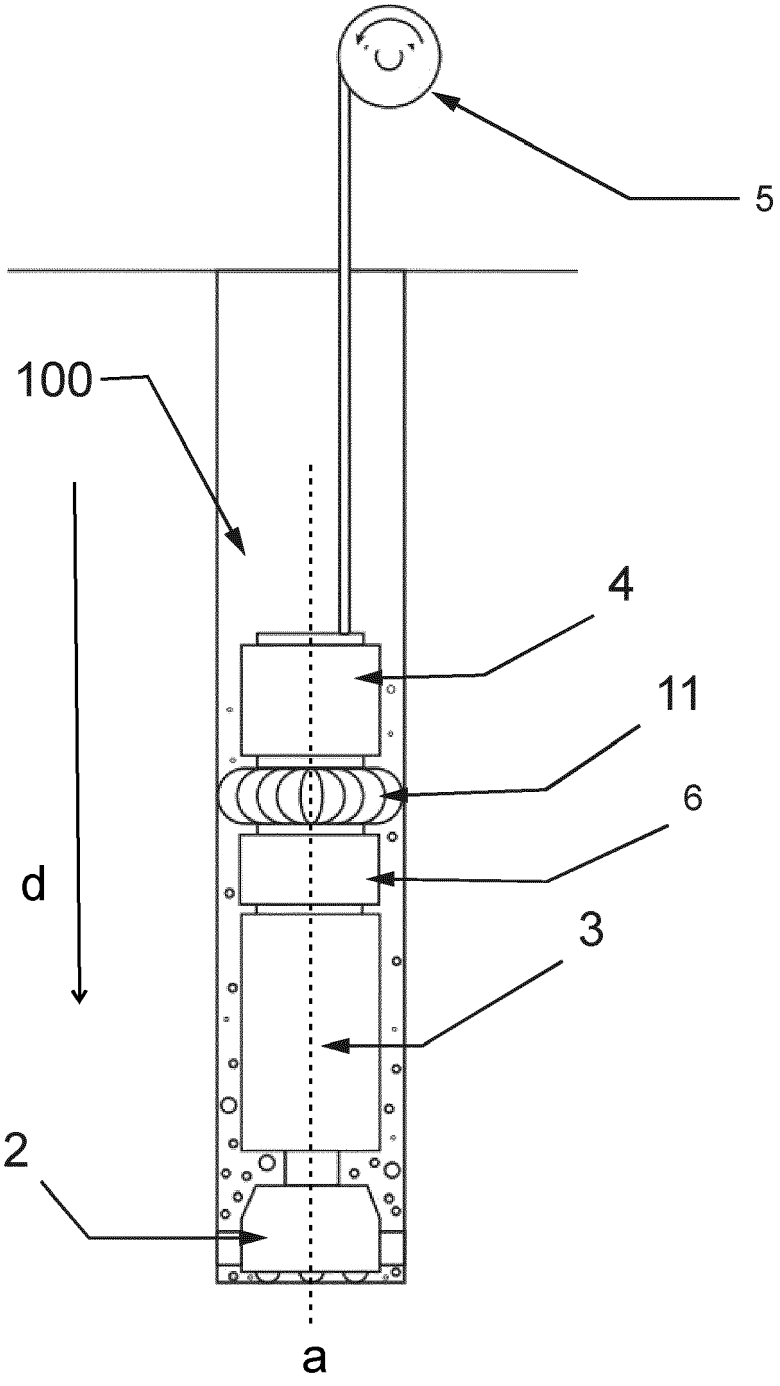

Fig. 1

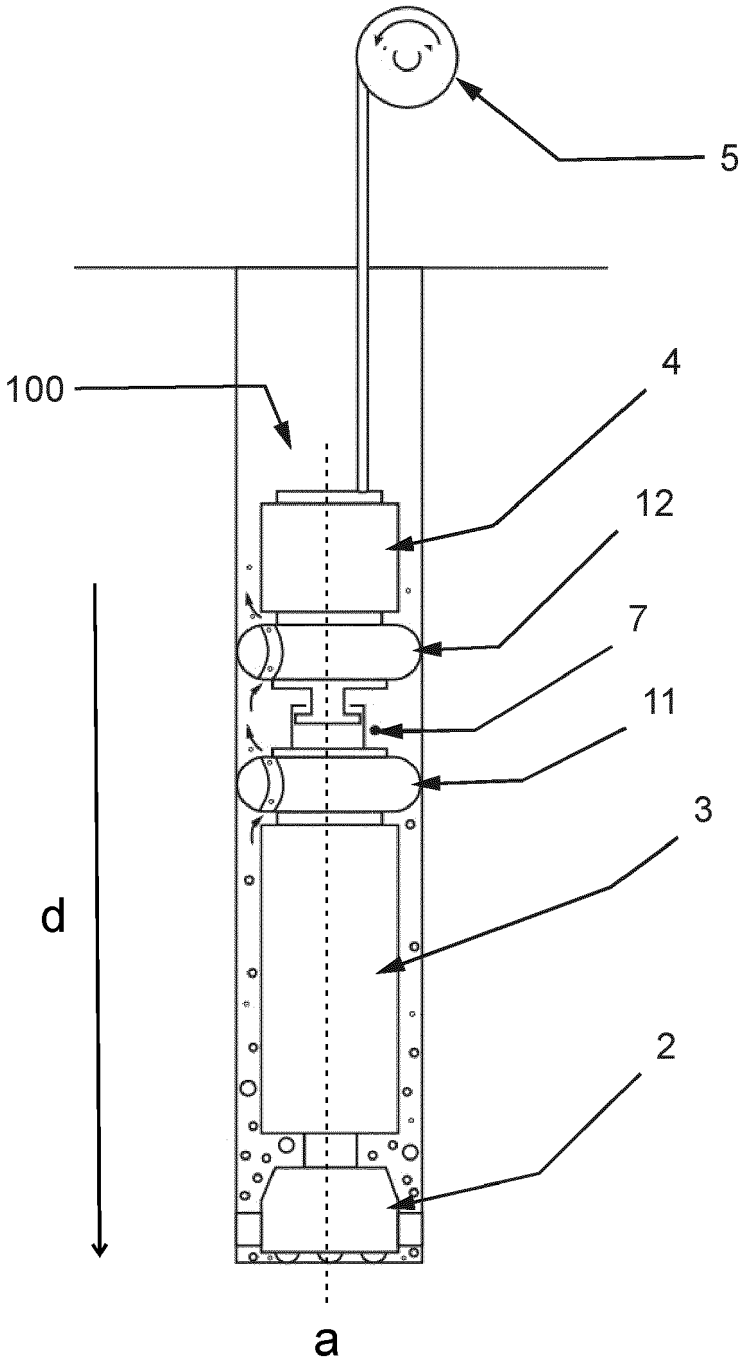

Fig. 2

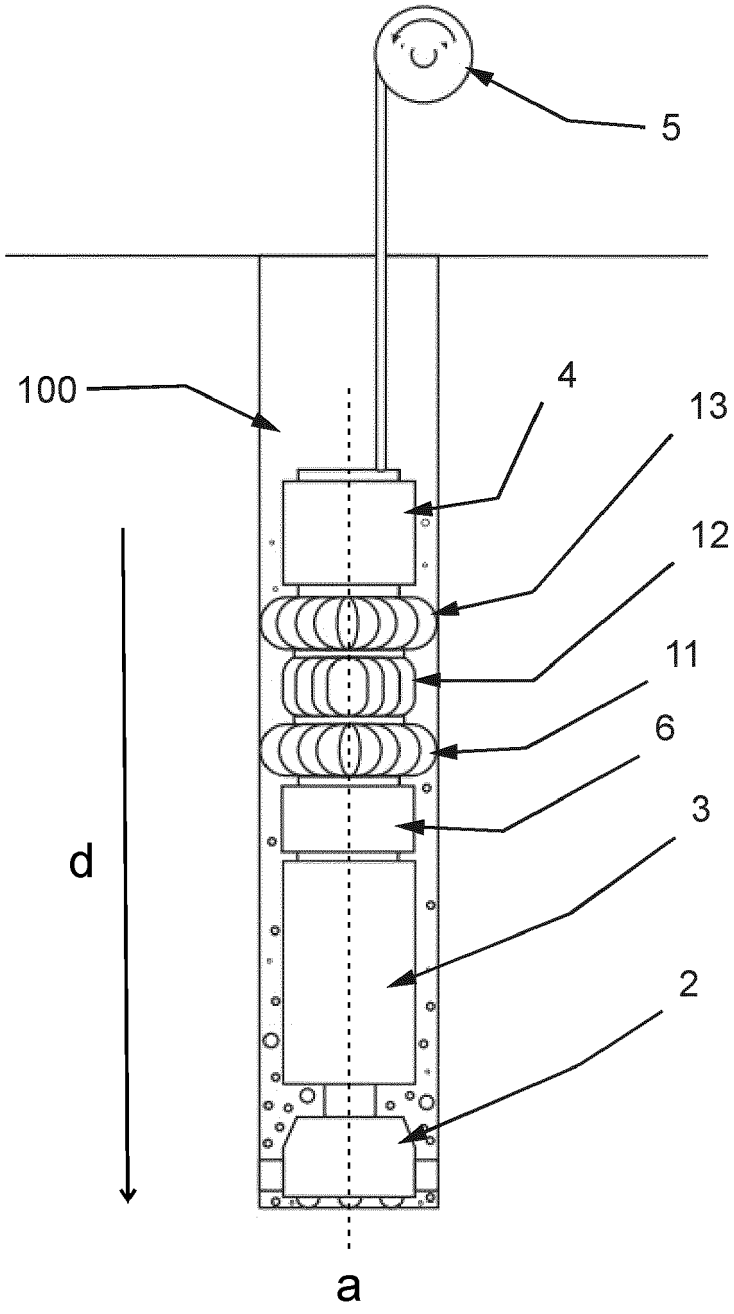

Fig. 3

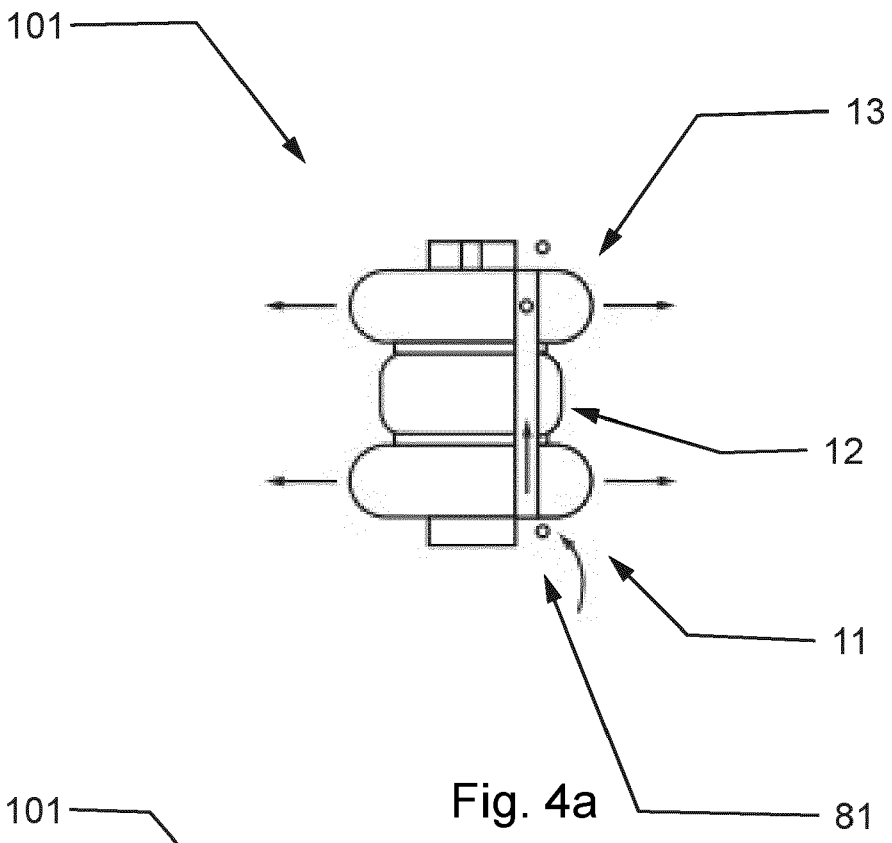

Fig. 4a

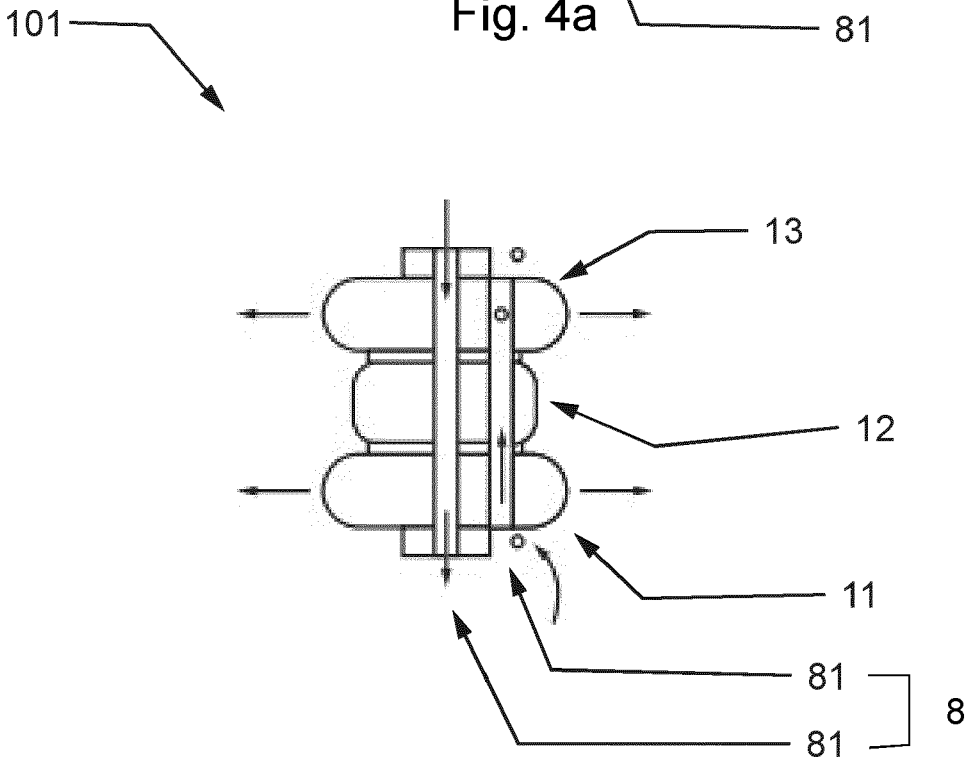

Fig. 4b

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 9221

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2003/034177 A1 (CHITWOOD JAMES E [US] ET AL) 20 February 2003 (2003-02-20) * paragraphs [0280], [0288] - [0298]; figures 5,6 * -----	1-15	INV. E21B7/02 E21B23/00 E21B23/01 E21B33/12
A	EP 0 110 182 A2 (ADVANCED DRILLING CORP [US]) 13 June 1984 (1984-06-13) * the whole document * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	12 April 2024	Simunec, Duro

CATEGORY OF CITED DOCUMENTS

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