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(54) Title: PERCUSSIVE DRILL, METHOD AND A DRILL RIG

(57) Abstract: A percussive drill (1) is provided. The percussive drill comprises an elongated drilling tool. The elongated drilling tool comprises an inner rod (4a) and an outer tube (4b). The inner rod (4a) comprises an impact-end (5) arranged for an impact with a piston (3). The percussive drill comprises a hydraulic supply (15) operative to repeatedly drive the piston (3) towards and away from the impact-end (5) of the inner rod (4a). The impact-end (5) is configured to be restricted in positions such as to range from a first position (11) along an axis (9), to a second position (12) along the axis (9). The percussive drill comprises a piston brake (16) for braking the piston (3), arranged such that, a set distance after the piston (3) reaches the first position (11), at a third position (13), the piston brake (16) initiates a braking of the motion of the piston (3).

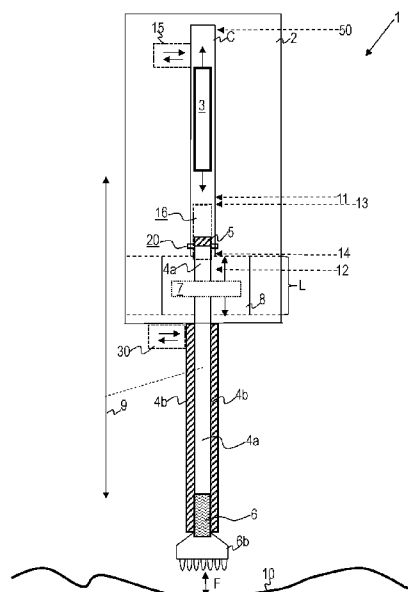


Fig. 1

PERCUSSIVE DRILL, METHOD AND A DRILL RIG

TECHNICAL FIELD

Embodiments herein relate to a percussive drill, a method for operating the
5 percussive drill. Furthermore, a drill rig comprising the percussive drill is provided herein.

BACKGROUND

Percussive drills may comprise a multi-layered drilling tool with an outer tube and an inner rod. To drill into the rock, the outer tube may perform a rotating action and the inner rod may be used to transfer a shock wave created by a hydraulic-driven piston wherein a
10 resulting force of the impact is transferred from the inner rod to a drill bit and the rotational torque from the outer tube subsequently into the rock. However, when there is no contact force between the percussive drill and the rock, striking the inner rod will instead deliver the resulting force to internal components of the drill, either by the inner rod impacting internal components of the drill, potentially damaging or breaking the drill. To avoid such a
15 problem, a hydraulic supply for the piston can be turned off when there is no contact force with a rock, and subsequently turned on when there is a contact force. While this avoids the inner rod damaging or breaking the drill, due to a high hydraulic power of driving the piston, turning on and off the hydraulics induces excessive wear to the hydraulic system and mechanical structure of a drill rig comprising the drill, leading to leakage in the
20 hydraulic system over time or fatigue breakage of the mechanical components. Furthermore, the hydraulic power for driving the piston is typically set to be optimal for drilling a firm rock foundation with a high contact force. This means that when drilling into a loose rock foundation where the drill has a low contact force with the rock, the hydraulic power designed for the firm rock foundation makes it difficult to handle for the drill.

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SUMMARY

An object of embodiments herein is to improve drilling efficiency while reducing wear and risk of damage.

According to a first aspect, a percussive drill is provided. The percussive drill
30 comprises a housing. The percussive drill comprises a piston comprised in a cylinder bore of the housing. The percussive drill comprises an elongated drilling tool comprised partly in the housing. The elongated drilling tool comprises an inner rod and an outer tube. The inner rod comprises an impact-end comprised in the housing. The impact-end is arranged

for an impact with the piston. The inner rod comprises a drill-end arranged exterior to the housing and arranged to be attached with a drill bit. The inner rod comprises a securing member arranged between the impact end and the drill-end. The securing member is arranged within a restricting section of the housing. The restricting section is arranged to
5 restrict a movement of the securing member such that the inner rod is arranged be moveable along an axis and restricted by a length of the restricting section, thereby causing a position of the impact-end to range from a first position along the axis, to a second position along the axis. In other words, the impact-end is configured to have a position ranging from the first position to the second position, along the axis. The
10 percussive drill comprises a hydraulic supply operative to repeatedly drive the piston towards and away from the impact-end of the inner rod. The percussive drill comprises a rotating device configured to apply a rotation on the drill end by rotating the outer tube. The percussive drill comprises a piston brake for braking the piston. The piston brake is arranged such that, a set distance after the piston reaches the first position, at a third
15 position, the piston brake initiates a braking of a motion of the piston.

Since the hydraulic supply is operative to repeatedly drives the piston towards and away from the impact end, and since the rotating device is configured to apply rotation to the drill end, the percussive drill allows for an efficient drilling operation using both rotation and percussive action.

20 Since the inner rod is moveable along the axis, the piston can strike the impact end at a strong force when the elongated tool has a contact force pressing the impact end to the first position, and when the contact force is low or non-existent, the piston brake will brake the piston such that the piston strikes the impact-end with a reduced force, or brakes the piston before it is able to strike the impact-end. Since the piston is braked, if
25 there is no contact force with a rock foundation, a resulting force of the piston to internal components instead of a force to the rock foundation is kept to a minimum or avoided completely, hence the piston brake reduces or avoids wear and damage to the internal components of the percussive drill. Since wear and damage to the internal components of the percussive drill is reduced or avoided, this allows the hydraulic supply to repeatedly
30 drives the piston even when the contact force is low or non-existent which further means that wear in the hydraulic system and mechanical components caused by turning on and off hydraulic power to the percussive drill is reduced, and hydraulic leakage or fatigue breakage can be avoided.

Furthermore, handling of drilling with low contact force with a rock foundation such
35 as loose rock formations is improved. This is since if the contact force is low, the impact-

end will be striking with a lower force due to the piston brake, which subsequently causes a lower drill force to the rock foundation.

In some example embodiments, the percussive drill is configured such that, when the position of the impact-end is at the first position, the piston is arranged to impact the impact-end with an intended force. In other words, the first position may be a default striking position when the elongated drilling tool has a contact force above a threshold with a rock foundation. The percussive drill may be configured to have a resulting drilling force to the rock foundation when the piston strikes the impact-end at the first position.

In some example embodiments, the percussive drill is configured such that, when the position of the impact-end is between the third position and the second position, the piston brake is arranged to brake the piston such that the piston does not impact the impact-end, or impacts the impact-end with a reduced force lower than a force generated when the piston impacts the impact-end at the first position.

This is since the piston is braked when reaching the third position, which means that the striking force to the inner rod is lower or if the piston is managed to be fully braked before reaching the inner rod, the piston will not strike the inner rod at all and instead be driven back by the hydraulic supply. In this way a resulting force caused by the piston brake when there is no contact force with rock foundation is reduced or removed completely, and as a result reduces wear and/or damage to the percussive drill and allows hydraulic supply to be turned on at all times.

In some example embodiments, the percussive drill is configured such that the piston is arranged to travel at most to a fourth position positioned between the first position and the second position, along the axis.

In this way, when there is no contact force with the rock foundation, the inner rod may have fallen due to gravity and/or be pushed to the second position. When this happens, the piston may not be able to reach the inner rod, since the piston can only travel to the fourth position, avoiding striking the inner rod. This means that the piston will be prevented from damaging internal components of the percussive drill caused by striking the inner rod at the second position.

In some example embodiments, the percussive drill is configured such that, the position of the impact-end along the axis is at least partly controlled by a contact force between the drill-bit and a rock foundation. In other words, the inner rod and the impact-end will be pushed along the axis based on how it is pressed towards the rock foundation.

In some example embodiments, the percussive drill is arranged to be attached to a feeding unit, the feeding unit being arranged to impose a force on the percussive drill along the axis, thereby increasing a contact force between the rock foundation and the drill bit.

5 In some example embodiments, the piston brake is a hydraulic piston brake.

In some example embodiments, the percussive drill is configured such that the piston brake is arranged to brake the motion of the piston by comprising a brake section, such that, when the piston travels via said brake section of the piston brake a pressure is applied to the piston and thereby braking the piston.

10 In some example embodiments, said brake section is arranged such that the piston is retarded by an oil pressure built up in an enclosed chamber of said brake section.

In some example embodiments, the piston brake is an active brake controlled by a control unit.

15 In some example embodiments, the piston brake comprises a valve and/or a magnet used for braking the piston, and wherein said control unit brakes the piston by actuating the valve and/or the magnet.

In some example embodiments, the percussive drill is configured such that, the restricting section is arranged to comprise an opening with a first width, in which opening the inner rod is provided, the first width being arranged to be wider than a second width of
20 the inner rod, to allow a movement of the inner rod through the opening, and wherein the first width is arranged to be narrower than a third width of the securing member, thereby restricting the movement of the securing member to be within the restricted section.

In some example embodiments, the percussive drill is configured such that, the piston brake is arranged in the housing, and positioned along the axis, and arranged
25 between the third position and the fourth position.

In some example embodiments, the percussive drill is configured such that the rotating device is operative to rotate the outer tube by pressure applied by a hydraulic supply.

30 In some example embodiments, the percussive drill is configured such that the inner rod comprises a set of rods, wherein the set of rods is arranged to transfer an impact from the piston and the impact end to the drill bit.

In some example embodiments, the percussive drill is operative to maintain a hydraulic power supplied by the hydraulic supply when a contact force between the drill-bit and a rock foundation is a below a threshold. In other words, the hydraulic supply can

always be turned on since the piston is braked such that the drill can still be managed accurately with low contact force.

According to a second aspect a method for operating a percussive drill according to the first aspect is provided. The method comprises repeatedly driving the piston towards
5 and away from the impact-end, such that, at a set distance after the piston reaches the first position, at a third position, the piston is braked by the piston brake for reducing a force of an impact between the piston and the impact-end. The piston is repeatedly driven by a hydraulic supply.

In this way it is possible to operate the percussive drill efficiently, with reduced or no
10 damage to the drill, allowing the hydraulic supply to repeatedly drive the piston towards and away from the impact-end without having to turn off the hydraulic supply when a contact force with rock foundation is low.

In some example embodiments, repeatedly driving the piston towards and away from the impact-end, comprises repeatedly driving the piston towards and away from the
15 impact-end when a contact force between the drill-bit and a rock foundation is a below a threshold. In other words, the piston is driven towards and away from the impact-end even when the contact force is low. In these example embodiments, the piston brake retards the piston to not impact the impact end, or to impact the impact end by a force below a threshold.

20 In some example embodiments, the method is performed with respect to any of the example embodiments discussed with respect to the first aspect.

According to a third aspect, a drill rig is provided. The drill rig comprises a percussive drill according to the first aspect.

In some example embodiments, the drill rig comprises a feeding unit arranged to
25 impose a force on the percussive drill along an axis, thereby increasing a contact force between the rock foundation and a drill bit of the percussive drill.

In some example embodiments, the feeding unit comprises a beam arranged to impose a force on the percussive drill along the axis.

Advantages and examples discussed with respect to any of the first, second, and
30 third aspects apply in a corresponding manner to all aspects respectively.

Further advantages and advantageous features of embodiments herein are disclosed in the following detailed description and in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Examples of embodiments herein are described in more detail with reference to attached drawings in which:

- Fig. 1 is a schematic block diagram illustrating an example percussive drill according to embodiments herein.
- Fig. 2 is a schematic block diagram illustrating an example percussive drill according to embodiments herein.
- Fig. 3 is a schematic block diagram illustrating an example percussive drill according to embodiments herein.
- Fig. 4 is a flow chart of an example method according to embodiments herein.
- Fig. 5 is a line diagram illustrating an example scenario according to embodiments herein.
- Fig. 6 is a line diagram illustrating an example scenario according to embodiments herein.
- Fig. 7 is an illustration of an example drill rig according to embodiments herein.
- Fig. 8 is an illustration of an example drill rig according to embodiments herein.

DETAILED DESCRIPTION

- Fig. 1 illustrates a **percussive drill 1** according to some embodiments herein. The percussive drill is operative to drill a **rock foundation 10**. The rock foundation 10 may for example be arranged in a quarry, pit, or underground mine. The percussive drill 1 may be a drill operative to drill the rock foundation using a combination of percussion and rotation.

The percussive drill 1 comprises a **housing 2**.

- The percussive drill 1 comprises a **piston 3** comprised in a **cylinder bore C** of the housing 2. The cylinder bore may be any suitable opening or chamber where a piston may be received and be moveable.

- The percussive drill 1 comprises an **elongated drilling tool 4a, 4b**. The elongated drilling tool is at least comprised partly in the housing 2. The elongated drilling tool comprises an **inner rod 4a** and an **outer tube 4b**.

The inner rod 4a comprises an **impact-end 5** comprised in the housing 2, e.g., the housing 2 encompasses the impact-end 5. The inner rod 4a is arranged for an impact with the piston 3. In other words, to perform a drilling operation with the percussive drill 1, the piston 3 is arranged to strike the impact-end 5.

The inner rod 4a comprises a **drill-end 6** arranged exterior to the housing 2 and arranged to be attached with a **drill bit 6b**. The drill-bit 6b may be any suitable drill bit arranged to be in contact with and drill into the rock foundation 10, e.g., when being supplied with an impact and rotation force by the inner rod 4a and the other tube 4b.

5 The inner rod 4a comprises a **securing member 7** arranged between the impact end and the drill-end 6. The securing member 7 is arranged within a restricting section 8 of the housing 2. The restricting section 8 is arranged to restrict a movement of the securing member 7 such that the inner rod 4a is arranged be moveable along an **axis 9** and restricted by a **length L** of the restricting section 8. In this way, a position of the
10 impact-end 5 is restricted to range from a **first position 11** along the axis 9, to a **second position 12** along the axis 9.

The percussive drill 1 comprises a **hydraulic supply 15** operative to repeatedly drive the piston 3 towards and away from the impact-end 5 of the inner rod 4a. The piston 3 may be operative to be repeatedly driven by the hydraulic supply 15, in an alternate
15 manner, towards an **end part 50** of the cylinder bore C, and subsequently towards the second position 12, passing through at least the first position and the third position 13, in an alternating order e.g., starting in any direction.

The hydraulic supply 15 may be configured to pump oil to push the piston 3 along the axis 9 in the cylinder bore C.

20 The hydraulic supply 15 may be configured to change direction of the provided oil pressure to periodically or repeatedly move the piston 3 back and forth such that the piston 3 is operative to strike the impact-end 5 at the first position 11.

The hydraulic supply 15 may be distributed such that the drill 1 has a valve for supplying the oil from a hydraulic pump, which hydraulic pump is located at a
25 corresponding drill rig, e.g., above the surface. In other words, the hydraulic supply 15 may be, or may comprise, a valve configured to supply oil pumped from a corresponding hydraulic pump. The valve may be able and/or may be configurable to change direction of the oil flow. The corresponding hydraulic pump may always supply an oil flow in a pumping direction to the valve. The valve may then direct the flow in at least two different
30 directions to push the piston 3 in different directions of the axis 9 in the cylinder bore C.

The outer tube 4b may encompass part of the inner rod 4a.

The outer tube 4b may be connected with the drill-end 6 such as to be operative to provide a rotation to the drill-end 6.

The percussive drill 1 comprises a **rotating device 30** configured to apply a rotation
35 on the drill end 6 by rotating the outer tube 4b.

The outer tube 4b may further be operative to rotate such that a rotation is provided to the drill-end 6, which would cause the drill bit 6b to rotate and be operative to drill into the rock foundation 10 with a rotation.

The percussive drill 1 may for example be configured such that the rotating device
5 30 is operative to rotate the outer tube 4b by pressure applied by a second hydraulic supply, e.g., the second hydraulic supply being independent from the hydraulic supply 15.

The percussive drill 1 comprises a **piston brake 16** for braking the piston 3, and arranged such that, a set distance after the piston 3 reaches the first position 11, at a
10 **third position 13**, the piston brake 16 initiates a braking of the motion of the piston 3. The third position 13 may be any suitable distance from the first position towards the second position along the axis 9. A consequence is that the piston 3 is operative to be braked when reaching the third position 13, i.e., between the third position 13 and the second position 12. When positioned at the first position 11 and in the distance between the first position 11 and the third position 13, the piston 3 is operative to be driven by the hydraulic
15 supply at a maximum or intended speed such as to strike the impact-end 5 with an intended force. Since the piston 3 is operative to be braked when the piston reaches the third position 13, the piston 3 will be operative to either be braked completely before striking the impact-end 5, or to strike the impact-end 5 at a reduced force lower than the intended force.

20 In some example embodiments, the percussive drill 1 is configured such that, the position of the impact-end 5 along the axis 9 is at least partly controlled by a **contact force F** between the drill-bit 6b and a rock foundation 10.

Since the inner rod 4a is arranged be moveable along the axis 9, the contact force F between the drill bit 6b and the rock foundation 10, e.g., as well as due to gravitational pull
25 and/or kinematic forces applied to the inner rod 4a, may determine the position of the impact-end 5. This means that when the drill bit 6b is directed downwards and pressed towards the rock foundation 10 with the contact force F above a threshold, the impact-end may move along the axis 9 to be positioned at the first position 11. When the contact force F is low, the inner rod 4a, and consequently the impact-end 5 may move along the axis
30 towards the second position 12, e.g., due to gravitational pull and/or kinematic forces applied to the inner rod 4a, such that the impact-end 5 may move to be positioned between the first position 11 and the second position 12, typically between the third position 13 and the second position 12, which means that when the piston 3 is arranged to strike the inner rod 4a, the piston 3 may be braked by the piston brake 6 to

In some example embodiments, the percussive drill 1 is configured such that, when the position of the impact-end 5 is at the first position 11, the piston 3 is arranged to impact the impact-end 5 with a intended force. In other words, the piston 3 is operative to be driven by the hydraulic supply 15 with a configured hydraulic power, causing the piston 5 to impact the intended force.

In some example embodiments, the percussive drill 1 is configured such that, when the position of the impact-end 5 is between the third position 13 and the second position 12, the piston brake 16 is arranged to brake the piston 3 such that the piston 3 does not impact the impact-end 5, or impacts the impact-end 5 with a reduced force lower than a 10 force generated when the piston 3 impacts the impact-end 5 at the first position 11. In other words, the piston 3 may be braked by the piston brake 16 such that the piston can stop before reaching the impact-end 5, or strikes the impact-end 5 with a lower force than the intended force.

In some example embodiments, the percussive drill 1 is configured such that the 15 piston 3 is arranged to travel at most to a **fourth position 14** positioned between the first position 11 and the second position 12, along the axis 9. In this way, when there is no contact force F , i.e., the contact force F is zero, the impact-end 5 may move along the axis 9 to be positioned at the second position 12, e.g., due to gravitational pull and/or kinematic forces applied to the inner rod 4a, and since the piston 3 is restricted to the 20 fourth position 14, the piston will not reach the impact-end 5 at all, thereby not risking damaging the percussive drill 1 by striking the impact-end 5 at the second position 12.

To summarize example relationships of the positions along the axis 9:

- The first position 11 may be at a top most position of the axis 9, when the percussive drill 1 is directed downwards i.e., in a vertical position or in a vertical 25 position with an angle, and e.g., being configured to drill the rock foundation 10.
- Along the axis 9, at a distance from the first position 11, the third position 13 is located.
- Between the third position 13 and the second position 12, the fourth position may be located.
- 30 - The distances between the first, second, third, and fourth positions 11, 12, 13, 14 may be configured in any suitable manner.

In some example embodiments, the piston brake 16 is a hydraulic piston brake.

In some example embodiments, the piston brake 16 is an active brake controlled by a control unit. Additionally or alternatively or in combination to, the piston brake 16 is a 35 passive mechanically driven brake. In other words, the piston brake 16 may be designed

in any suitable manner as long as the percussive drill is operative to brake the movement of the piston 3 along the axis 9, such that a striking force of the piston 3 to the impact-end can be reduced or mitigated when there is a low or no contact force F , and the impact-end 5 is between the third position 13 and the second position 12, or position at the position 12.

In some example embodiments, the percussive drill 1 is configured such that the piston brake 16 is arranged to brake the motion of the piston 3 by comprising a brake section, such that, when the piston 3 travels via said brake section of the piston brake 16 a pressure is applied to the piston 3 and thereby braking the piston. In other words, dimensions of the space of the brake section may cause a retardation of the piston 3, which retardation may brake the piston 3 at an increasing or maintained force as the piston 3 passes the brake section, e.g., located at or overlapping the third position 13 along the axis 9.

In some example embodiments, said brake section is arranged such that the piston 3 is retarded by an oil pressure built up in an enclosed chamber 20 of said brake section.

As an example, the brake section comprises any one or more out of: a braking recess, a slit, and a equalizing chamber, e.g., respectively arranged to provide a pressure to the piston 3 as it passes through the brake section and thereby retarding the piston 3.

In some example embodiments, the piston brake 16 comprises a valve used for controlling the braking of the piston 3, e.g., the valve may control an oil pressure which brakes the piston 3. In these embodiments, the control unit may brake the piston 3 by actuating the valve. Additionally or alternatively, the piston brake 16 may comprise a magnet used for braking of the piston 3, e.g., the magnet may retard the piston 3 by creating a magnetic field which slows the speed of the piston 3 when the piston passes through said magnetic field. In these embodiments, the control unit may brake the piston 3 by actuating the magnet.

In some example embodiments, the piston brake 16 comprises a valve and/or a magnet used for braking the piston 3, and wherein said control unit brakes the piston 3 by actuating the valve and/or the magnet.

In some example embodiments, the percussive drill 1 is configured such that, the restricting section 8 is arranged to comprise an opening with a first width, in which opening the inner rod 4a is provided. In these example embodiments, the first width is arranged to be wider than a second width of the inner rod 4a. In this way, a movement of the inner rod 4a is allowed through the opening. In other words, the inner rod 4a may be received in the opening. The first width may be arranged to be narrower than a third width

of the securing member 7. In this way, the movement of the securing member 7 is restricted to be within the restricted section 8. In other words, the restricting section 8 may be configured to restrict the movement of the securing member 7 along the axis 9, e.g., such that the impact-end 5 is operative to move from the first position 11 to the second position 12, along the axis 9, based on the contact force F.

In some example embodiments, the percussive drill 1 is configured such that, the piston brake 16 is arranged in the housing 2, and positioned along the axis 9, and arranged between the third position 13 and the fourth position 14. However, the piston brake 16 may further be positioned in any suitable position such that it can brake the piston 3 when it reaches the third position 13.

In some example embodiments, the percussive drill 1 is operative to maintain a hydraulic power supplied by the hydraulic supply 15 when a contact force F between the drill-bit 6b and a rock foundation 10 is a below a threshold. In other words, this means that the percussive drill 1 may operate independently on the contact force F, since the operation of the hydraulic supply will not cause the piston 3 to damage the percussive drill 1. In this way, wear caused by turning on and off the hydraulic power is avoided.

Fig. 2 illustrates an example embodiment of the percussive drill 1. In this example, the inner rod 4a may be partitioned into a **set of rods 40a**. In other words, in some example embodiments, the percussive drill 1 is configured such that the inner rod 4a comprises a set of rods 40. The set of rods 40 may be arranged to transfer an impact from the piston 3 and the impact end 5 to the drill bit 6b. This means that the piston 3 is operative to strike the impact-end 5, e.g., as described with reference to Fig. 1, and the set of rods 40a of the inner rod 4a will interact to provide a percussive force to the drill bit 6b. Using the partitioned set of rods 40a may be beneficial since the length of the inner rod 4a can be varied dynamically based on need and the rods will still behave similar to as if they were a longer rod.

In a corresponding manner, the outer tube 4b may in some embodiments be partitioned into a **set of outer tubes 40b**. The set of outer tubes 40b may be connected such that the adjacent outer tubes 40b provides rotation to each other and finally to the drill bit 6b. The rotation may be initiated by the rotation device 30 in any suitable manner. Using a partitioned set of outer tubes 40b may be beneficial since the length of the outer tube 40b can be varied dynamically based on a desired drill depth.

Fig. 3 illustrates an example embodiment of the percussive drill 1. In this example scenario, it is illustrated that any suitable unit, such as a **feeding unit 300**, may be arranged with the percussive drill to provide an external feeding force to increase the

contact force F when needed. In other words, in some example embodiments, the percussive drill 1 is arranged to be attached to the feeding unit 300. The feeding unit 300 may be arranged to impose a **force 301** on the percussive drill 1 along the axis 9, thereby increasing the contact force F between the rock foundation 10 and the drill bit 6b.

5 **Fig. 4** illustrates a flow chart of an example method for operating the percussive drill 1 according to any example embodiments herein. The method may be performed by a control unit or performed by any other suitable means. When the method is performed by a control unit, the method may comprise using said control unit to control any suitable controllable entity of above discussed example embodiments.

10 The method may comprise the following actions, which actions may be taken in any suitable order, and/or concurrently.

Action 401.

The method comprises, by the hydraulic supply 15, e.g., by actuating the hydraulic supply 15, repeatedly driving the piston 3 towards and away from the impact-end 5, such
15 that a set distance after the piston 3 reaches the first position 11, at a third position 13, the piston is braked by the piston brake 16 for reducing a force of an impact between the piston 3 and the impact-end 5.

Repeatedly driving the piston 3 towards and away from the impact-end 5, may comprise repeatedly driving the piston 3 towards and away from the impact-end 5, when a
20 contact force F between the drill-bit 6b and a rock foundation 10 is a below a threshold.

Action 402.

The method may comprise controlling the piston brake 16, e.g., when the piston brake 16 comprises an actively controlled piston brake. For example, when the piston brake 16 comprises a valve and/or magnet used for braking the piston 3, the method may
25 comprise controlling the magnet and/or valve to initiate a brake of the piston 3 by actuating the valve and/or the magnet.

Controlling the piston brake 16 may be performed in response to obtaining sensor input or other control parameters indicating that the piston has or is expected to have reached the third position 13.

30 **Action 403.**

The method may comprise controlling the hydraulic supply 15 for driving the piston 3. Controlling the hydraulic supply 15 may comprise controlling the hydraulic supply to maintain a hydraulic power supplied by the hydraulic supply 15. The hydraulic power may be maintained when the contact force F between the drill-bit 6b and the rock foundation
35 10 is a below a threshold and/or independent of the contact force F . In other words,

controlling the hydraulic supply 15 may comprise refraining from reducing or turning of the hydraulic supply 15 as a response to a change in the contact force F .

Fig. 5 illustrates a **first periodic function 500** of positions the piston 3 over time. The **Y-axis 501** represents a position of the piston 3 along the axis 9. In this example scenario, there is no contact force F between the rock foundation 10 and the drill bit 6b. This means that the impact end 5 is in the example scenario positioned at the second position 12. It can be observed that the piston 3 is braked after passing the third position 13. The piston 3 will be braked such that it does not continue towards the second position 12, and instead may eventually turn back towards the end-position 50, e.g., when the hydraulic supply alternates a pressure driving the piston 3.

Fig. 6 illustrates a **second periodic function 600** of positions the piston 3 over time. The **Y-axis 601** represents a position of the piston 3 along the axis 9. In this example scenario, there is a low contact force F between the rock foundation 10 and the drill bit 6b, e.g., within a predefined interval. This means that the impact end 5 is in the example scenario positioned at an **impact position 602**, located between the third position 13 and the second position 12 along the axis 9.

It can be observed that the piston 3 is braked after passing the third position 13. The piston 3 will be braked such that it will have a slower motion when it reaches the impact position 602 during a **first time 603**. The piston 3 will impact the impact-end 5 which will transfer its force to the drill bit 6b causing a force onto the rock foundation 10. The piston 3 may then eventually turn back towards the end-position 50, e.g., when the hydraulic supply alternates a pressure driving the piston 3. These series of events may further repeat as the piston 3 is driven towards and away from the impact-end, to further impact the impact-end 5 at **second time 604**.

Fig. 7 illustrates a **drill rig 700** according to an example scenario. The drill rig 700 may be a machine configured to drill the rock foundation 10. The drill rig 700 may comprise the percussive drill 1. The drill rig 700 may comprise a **first feed beam 701** for imposing a force to the percussive drill 1, e.g., to increase the contact force F between the rock foundation 10 and the drill bit 6b.

The drill rig 700 may comprise a rod handling device 702, such as for handling the set of rods 40a.

Fig. 8 illustrates a **drill rig 800** according to an example scenario. The drill rig 800 may be an alternative view of the drill rig 700. The drill rig 800 may be a machine configured to drill the rock foundation 10. The drill rig 800 may comprise the percussive drill 1. The drill rig 800 may comprise a **second feed beam 801** for imposing a force to

the percussive drill 1, e.g., to increase the contact force F between the rock foundation 10 and the drill bit 6b. The drill rig 800 may comprise a rod handling device 802, e.g., for handling the set of rods 40a.

The drill rig 700, 800, e.g., according to any of the examples in Figs. 7-8, may
5 further comprise the feeding unit 300 illustrated in Fig. 3. The feeding unit 300 may be arranged to impose the force 301 on the percussive drill 1 along the axis 9, thereby increasing the contact force F between the rock foundation 10 and the drill bit 6b of the percussive drill 1. The feeding 300 unit may comprise a beam arranged to impose a force on the percussive drill 1 along the axis 9, e.g., the first feed beam 701 or the second feed
10 beam 702.

CLAIMS

1. A percussive drill (1) comprising:
- a housing (2),
 - a piston (3) comprised in a cylinder bore (C) of the housing (2),
 - 5 - an elongated drilling tool comprised partly in the housing (2), the elongated drilling tool comprising an inner rod (4a) and an outer tube (4b), wherein the inner rod (4a) comprises:
 - an impact-end (5) comprised in the housing (2), arranged for an impact with the piston (3), and
 - 10 ○ a drill-end (6) arranged exterior to the housing (2) and arranged to be attached with a drill bit (6b),
 - a securing member arranged between the impact end and the drill-end (6), wherein the securing member (7) is arranged within a restricting section (8) of the housing (2), the restricting section (8) being arranged to restrict a movement of the securing member (7) such that the inner rod (4a) is arranged be moveable along an axis (9) and restricted by a length (L) of the restricting section (8), thereby causing a position of the impact-end (5) to range from a first position (11) along the axis (9), to a second position (12) along the axis (9), and
 - 15
 - 20 - a hydraulic supply (15) operative to repeatedly drive the piston (3) towards and away from the impact-end (5) of the inner rod (4a),
 - a rotating device (30) configured to apply a rotation on the drill end (6) by the outer tube (4b), and
 - 25 - a piston brake (16) for braking the piston (3), and arranged such that, a set distance after the piston (3) reaches the first position (11), at a third position (13), the piston brake (16) initiates a braking of the motion of the piston (3).
- 30 2. The percussive drill (1) according to claim 1, wherein the percussive drill (1) is configured such that, when the position of the impact-end (5) is at the first position (11), the piston (3) is arranged to impact the impact-end (5) with a intended force.
- 35 3. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is configured such that, when the position of the impact-end (5) is

between the third position (13) and the second position (12), the piston brake (16) is arranged to brake the piston (3) such that the piston (3) does not impact the impact-end (5), or impacts the impact-end (5) with a reduced force lower than a force generated when the piston (3) impacts the impact-end (5) at the first position (11).

5

4. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is configured such that the piston (3) is arranged to travel at most to a fourth position (14) positioned between the first position (11) and the second position (12), along the axis (9).

10

5. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is configured such that, the position of the impact-end (5) along the axis (9) is at least partly controlled by a contact force (F) between the drill-bit (6b) and a rock foundation (10).

15

6. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is arranged to be attached to a feeding unit (300), the feeding unit (300) being arranged to impose a force (301) on the percussive drill (1) along the axis (9), thereby increasing a contact force (F) between the rock foundation (10) and the drill bit (6b).

20

7. The percussive drill (1) according to any preceding claim, wherein the piston brake (16) is a hydraulic piston brake.

25

8. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is configured such that the piston brake (16) is arranged to brake the motion of the piston (3) by comprising a brake section, such that, when the piston (3) travels via said brake section of the piston brake (16) a pressure is applied to the piston (3) and thereby braking the piston.

30

9. The percussive drill (1) according to claim 8, wherein said brake section is arranged such that the piston (3) is retarded by an oil pressure built up in an enclosed chamber (20) of said brake section.

10. The percussive drill (1) according to any one of claims 1-7, wherein the piston brake (16) is an active brake controlled by a control unit.

5 11. The percussive drill (1) according to claim 10, wherein the piston brake (16) comprises a valve and/or a magnet used for braking the piston (3), and wherein said control unit brakes the piston (3) by actuating the valve and/or the magnet.

10 12. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is configured such that, the restricting section (8) is arranged to comprise an opening with a first width, in which opening the inner rod (4a) is provided, the first width being arranged to be wider than a second width of the inner rod (4a), to allow a movement of the inner rod (4a) through the opening, and wherein the first width is arranged to be narrower than a third width of the securing member (7), thereby restricting the movement of the securing member (7) to be
15 within the restricted section (8).

13. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is configured such that, the piston brake (16) is arranged in the housing (2), and positioned along the axis (9), and arranged between the third
20 position (13) and the fourth position (14).

14. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is configured such that the rotating device (30) is operative to rotate the outer tube (4b) by pressure applied by a hydraulic supply.
25

15. The percussive drill (1) according to any preceding claim, wherein the percussive drill (1) is configured such that the inner rod (4a) comprises a set of rods (40), wherein the set of rods (40) is arranged to transfer an impact from the piston (3) and the impact end (5) to the drill bit (6b).
30

16. The percussive drill (1) according to any preceding claim wherein the percussive drill is operative to maintain a hydraulic power supplied by the hydraulic supply (15) when a contact force (F) between the drill-bit (6b) and a rock foundation (10) is a below a threshold.
35

14. A method (400) for operating a percussive drill (1) according to claim 1, the method comprising:

- by the hydraulic supply (15), repeatedly driving (401) the piston (3) towards and away from the impact-end (5), such that a set distance after the piston (3) reaches the first position (11), at a third position (13), the piston is braked by the piston brake (16) for reducing a force of an impact between the piston (3) and the impact-end (5).

18. The method (400) according to claim 14, wherein repeatedly driving (401) the piston (3) towards and away from the impact-end (5), comprises repeatedly (401) driving the piston (3) towards and away from the impact-end (5), when a contact force (F) between the drill-bit (6b) and a rock foundation (10) is below a threshold, and wherein the piston brake (16) retards the piston (3) to not impact the impact end (5), or to impact the impact end (5) by a force below a threshold.

19. The method (400) according to any one of claims 14-18, wherein the percussive drill (1) is configured according to any one of claims 2-16.

20. A drill rig (700, 800) comprising a percussive drill (1) according to any one of the claims 1-16.

21. The drill rig (700, 800) according to claim 20 further comprising a feeding unit (300) being arranged to impose a force (301) on the percussive drill (1) along an axis (9), thereby increasing a contact force (F) between the rock foundation (10) and a drill bit (6b) of the percussive drill (1).

22. The drill rig (700, 800) according to claim 21, wherein the feeding unit comprises a beam (701, 801) arranged to impose a force on the percussive drill (1) along the axis (9).

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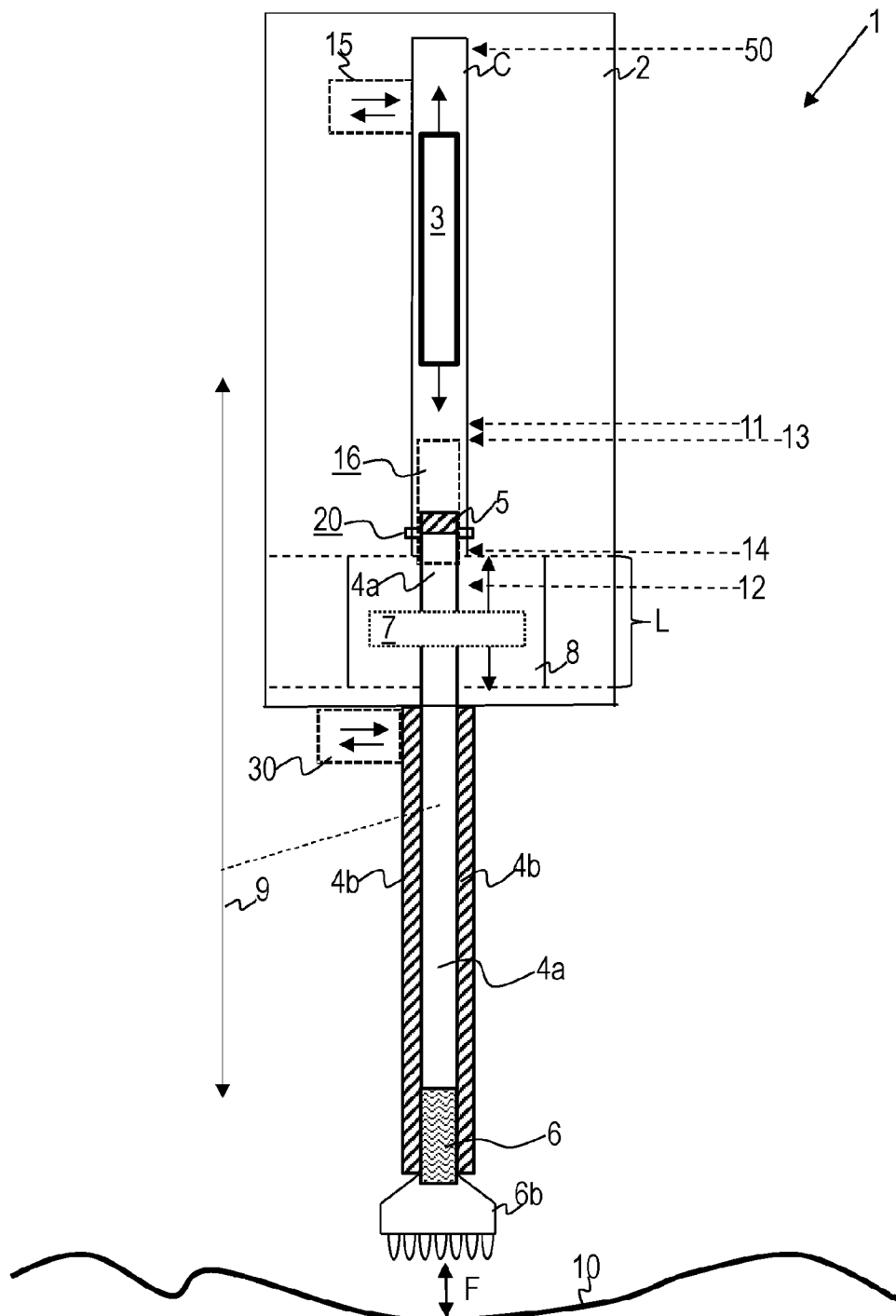


Fig. 1

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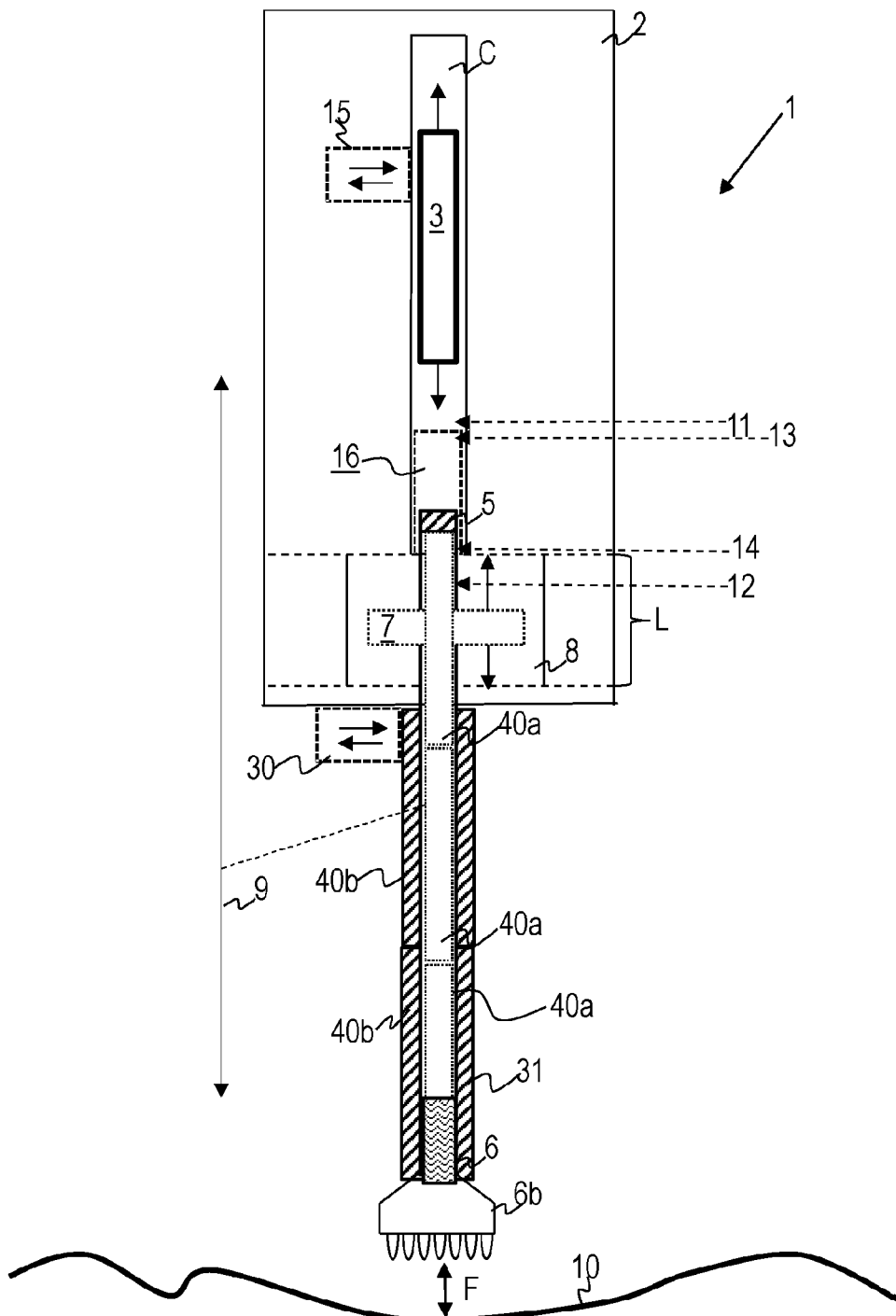


Fig. 2

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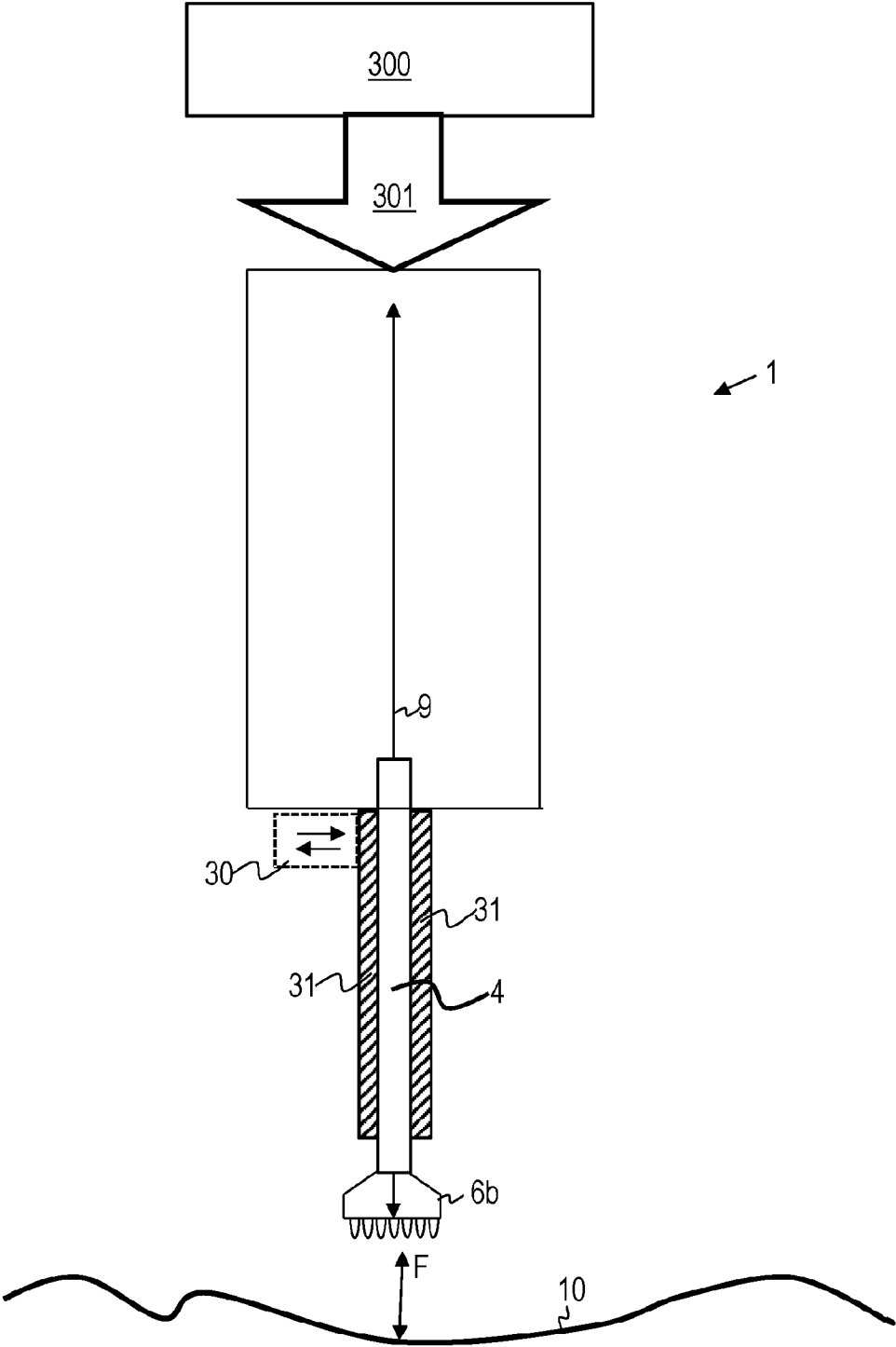


Fig. 3

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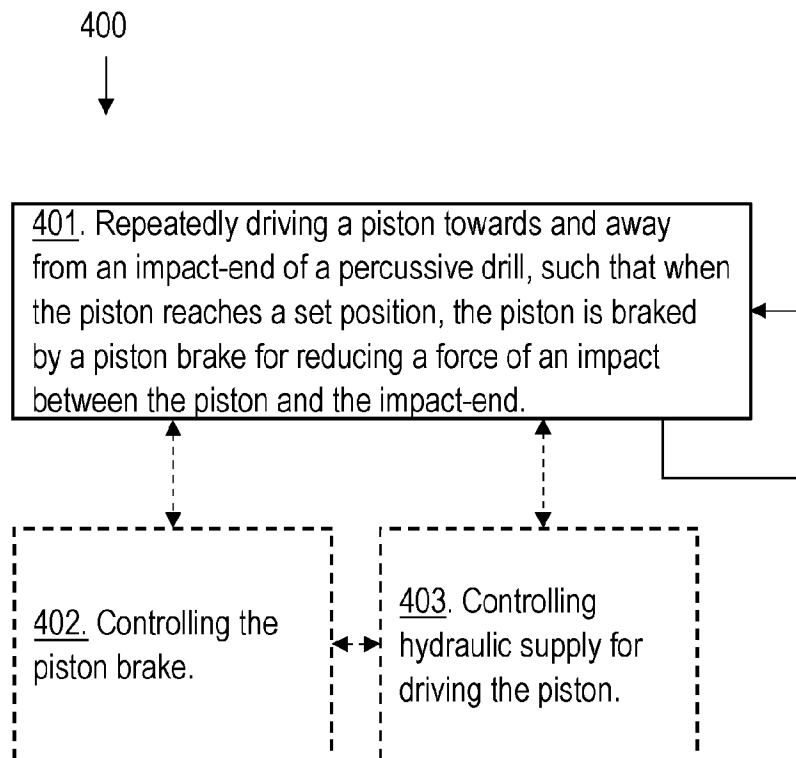


Fig. 4

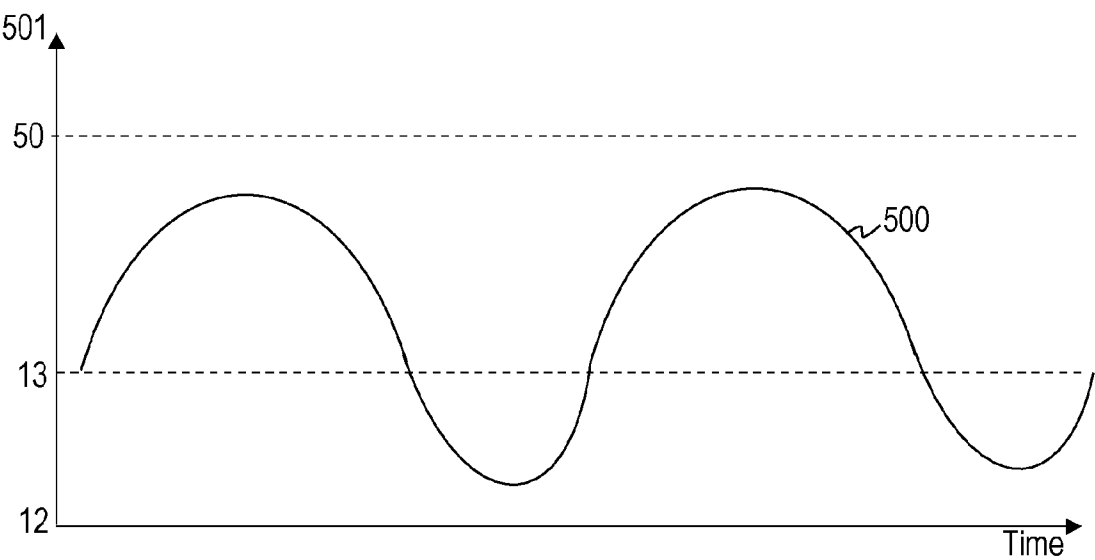


Fig. 5

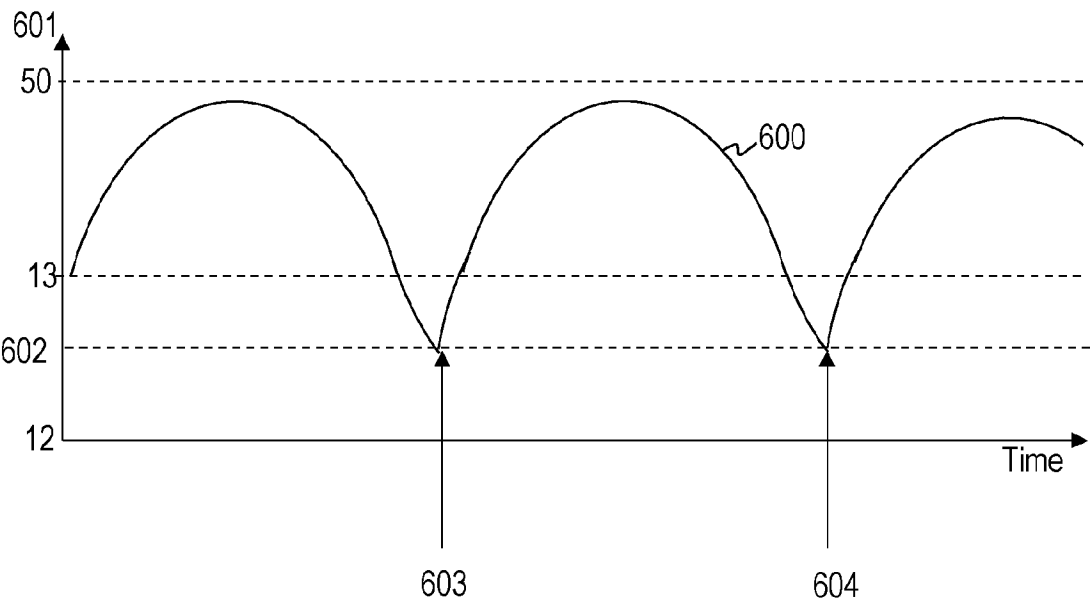


Fig. 6

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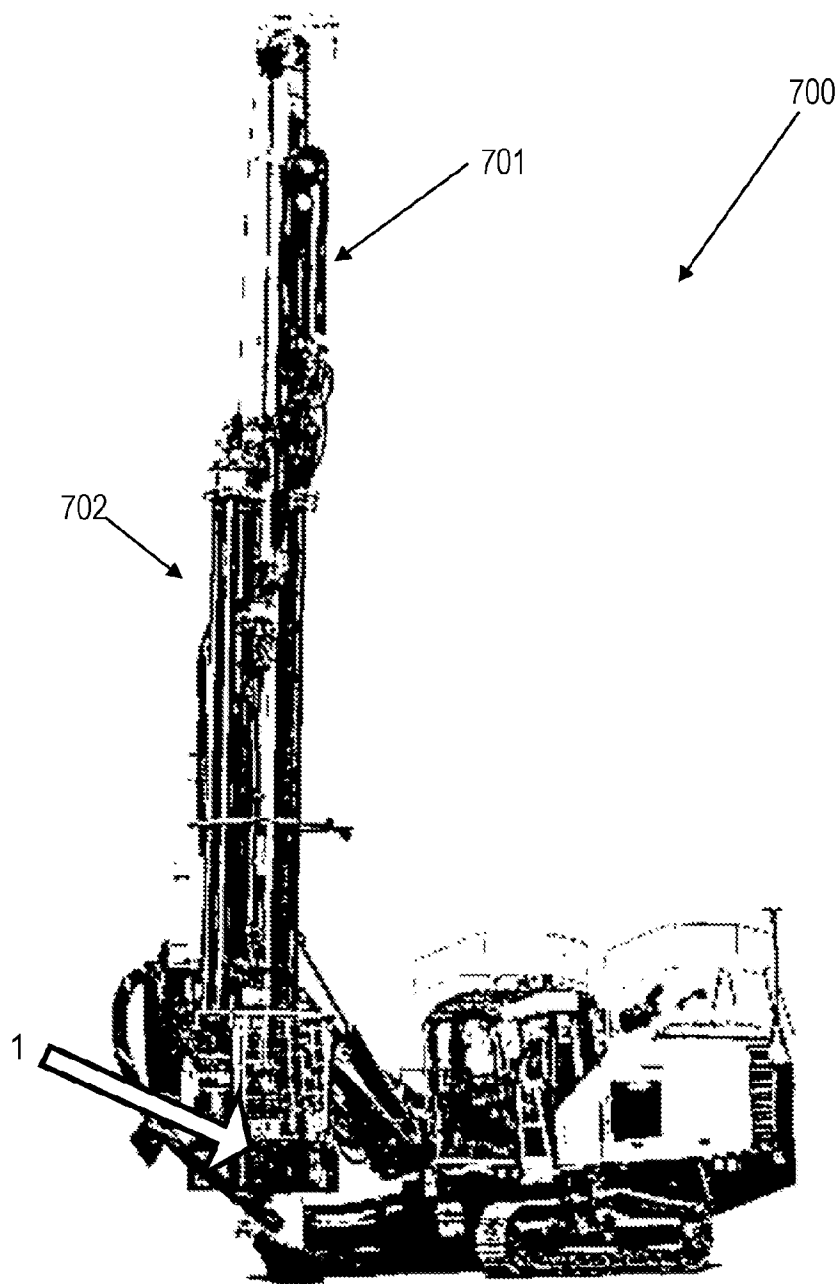


Fig. 7

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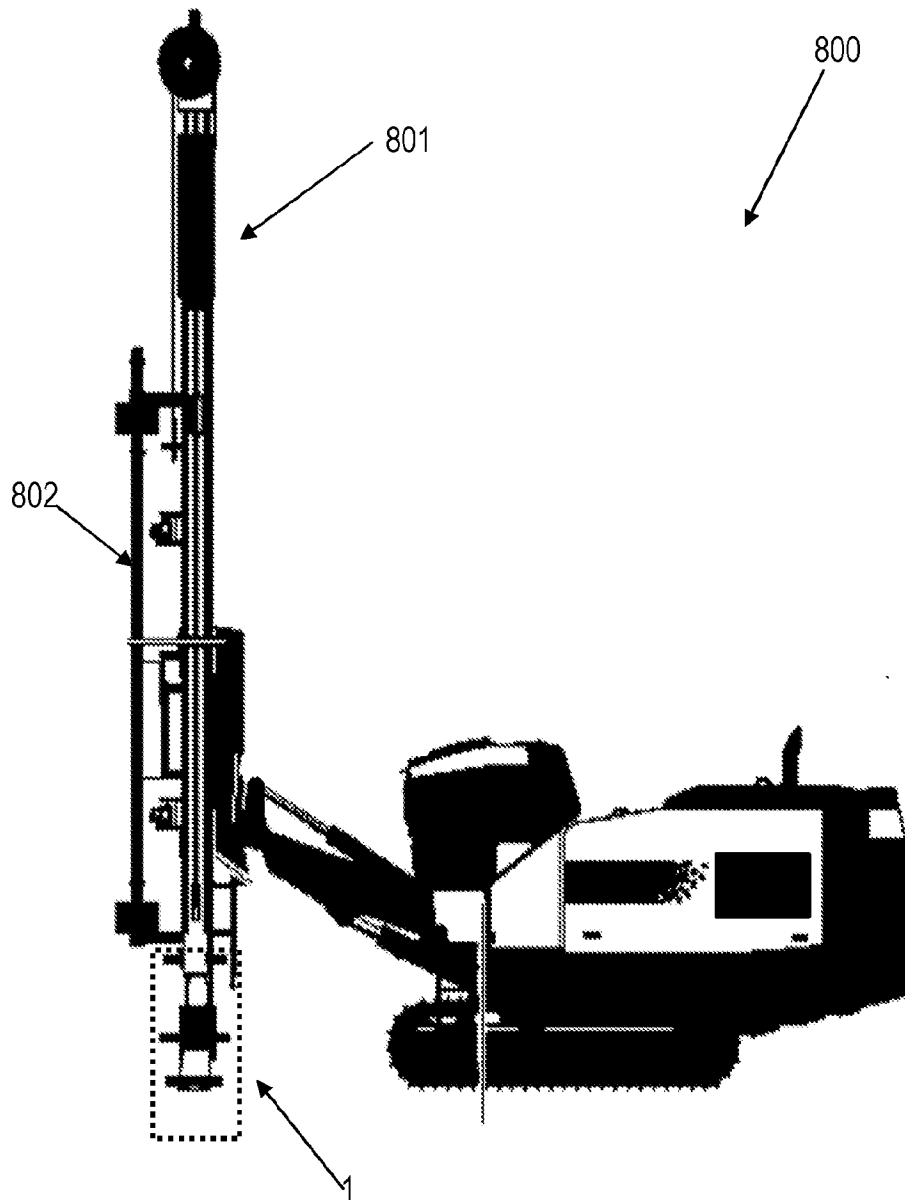


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2023/051306

A. CLASSIFICATION OF SUBJECT MATTER INV. E21B6/04 E21B1/24 ADD.		
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		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2022/274242 A1 (CHEYLUS FRANÇOIS-XAVIER [FR] ET AL) 1 September 2022 (2022-09-01) paragraph [0114] - paragraph [0115]; figure 1 -----	1 - 22
A	WO 2014/084772 A1 (ATLAS COPCO ROCK DRILLS AB [SE]) 5 June 2014 (2014-06-05) paragraph [0053] -----	1 - 22
A	US 2023/294260 A1 (KOSKIMAKI ANTTI [FI] ET AL) 21 September 2023 (2023-09-21) figure 4 -----	1 - 22
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 21 May 2024		Date of mailing of the international search report 31/05/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Ott, Stéphane

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SE2023/051306

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2022274242 A1	01-09-2022	AU 2022201360 A1 CA 3149908 A1 CN 115070959 A EP 4053374 A1 FR 3120248 A1 JP 2022133251 A KR 20220123594 A US 2022274242 A1 ZA 202202359 B	15-09-2022 01-09-2022 20-09-2022 07-09-2022 02-09-2022 13-09-2022 08-09-2022 01-09-2022 26-10-2022
WO 2014084772 A1	05-06-2014	AU 2013352655 A1 CA 2889508 A1 CN 104812986 A EP 2925949 A1 ES 2660879 T3 JP 6304835 B2 JP 2015535496 A NO 2925949 T3 SE 1251341 A1 US 2015290788 A1 WO 2014084772 A1 ZA 201504600 B	18-06-2015 05-06-2014 29-07-2015 07-10-2015 26-03-2018 04-04-2018 14-12-2015 05-05-2018 29-05-2014 15-10-2015 05-06-2014 26-07-2017
US 2023294260 A1	21-09-2023	AU 2021286164 A1 CA 3177676 A1 CL 2022003319 A1 CN 115867714 A EP 3919717 A1 FI 3919717 T3 JP 2023528339 A KR 20230017182 A PE 20230104 A1 US 2023294260 A1 WO 2021245065 A1	19-01-2023 09-12-2021 03-03-2023 28-03-2023 08-12-2021 15-05-2023 04-07-2023 03-02-2023 19-01-2023 21-09-2023 09-12-2021