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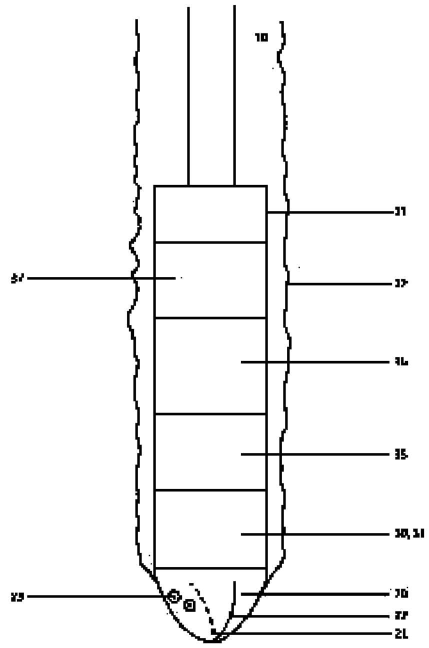
(54) Title **A method for energy efficient and fast rotary drilling in inhomogeneous and/or hard rock formations**

(57) Abstract

It is described a rotary drilling system (10) for drilling a borehole (12) in inhomogeneous and/or hard rock formations. The system (10) comprising: a rotary drill bit (20; 50), and at least two electrodes (21, 22, 23, 51, 52, 53) arranged for pulsing between said electrodes of at least one high voltage electro pulse (41), wherein said at least one high voltage electro pulse (41) is generated in response to a detected resistance on the drill bit (20) from a rock formation (40) in front of the drill bit (20) while rotating, in order to create small/micro-cracks (45) in the rock formation (40).



A method for energy efficient and fast rotary drilling in inhomogeneous and/or hard rock formations

INTRODUCTION

The present invention concerns a rotary drilling system and a method for drilling a borehole in inhomogeneous and/or hard rock formations.

BACKGROUND OF THE INVENTION

Rotary drilling is generally used today for drilling of deep wells for e.g. oil, gas, mining and geothermal energy exploration and excavation. In the resent year, PDC (Polycrystalline Diamond Compact) bits have been the fastest developing drilling bit technology, delivered in a large variety of different shapes and sizes, mainly optimized to rock types and well diameter size. Whenever possible it is the preferred bit choice for any drilling. For high temperature and/or high pressure environments they also have a clear benefit to many other drill bit concepts due to no moving parts. However, a major disadvantage by PDC bits is their inability to drill efficiently in inhomogeneous (soft-hard) rock formations, due to large wear from dysfunctional vibrations (bit impact wear) and abrasive wear. Due to similar stability issues, they have neither been suited for large well diameters. When drilling in rock formations, the friction between the drill bit under rotation and the rock formation will vary also depending on the rock properties, e.g. hardness, porosity etc. This friction is experienced as a resistance on the drill bit by the rock formation. Drilling in inhomogeneous or hard rock formation results in highly varying resistances experienced by the drill bit during drilling. A PDC bit tends to create stick-slip, caused when cutters teeth are stalling in hard rock due to excessive depth of cut when coming from a softer to a harder rock formation. The consequent vibrations are potentially severe when the drill string has accumulated enough torque to break the cutters loose and the drill string up-winds. Stick-slip is the root cause of many costly and time consuming problems in drilling operations; vibration related equipment failure, drill string failure, bit impact damage and slow rate of penetration (ROP). These technical obstacles are being progressively addressed, e.g. by new bit designs, new hybrid bit designs, shock-absorbers above the bit (mechanical decrease of bit torque), or addition of a torsional impact hammer function to the bit in order to provide additional torsional energy to assist in fracturing the formation. Similar problems may more or less also be experienced by other rotary drill bits as e.g. roller cone bits, hybrid roller cone - PDC bits, and cutter disks in rotary tunnel excavators.
Drilling by an electro pulse boring (EPB) method is well known and has been described by e.g. V. F. Vajor et. al. in "Physics Vol. 4" of Tomsk Polytechnic University (Russia) 1996.

Different solutions for EPB drilling methods and equipment are given in US 7,784,563, US 7,530,460 and US 8,109,345, including combinations of electrodes for electro pulsing with mechanical cutters on the drill-head. However, in the mentioned patents, the electro pulse boring (EPB) is set to be the main excavation method throughout the drilling processes, either by general fracturing (making cutter bits) of the rock in front of the drill head or by fracturing the surrounding rock material to facilitate drilling in the direction of the directed electric energy.

SUMMARY OF THE INVENTION

The invention solves or at least alleviates the problems by the prior art drilling systems.

In a first aspect, the present invention relates to a rotary drilling system for drilling a borehole in inhomogeneous and/or hard rock formations. The system comprises a rotary drill bit. Furthermore, the system comprises at least two electrodes. Said electrodes are arranged for pulsing therebetween of at least one high voltage electro pulse. Said at least one high voltage electro pulse is generated in response to a detected resistance on the drill bit from a rock formation in front of the drill bit while rotating, in order to create small/micro-cracks in the rock formation.

The electrodes may be incorporated in the rotary drill bit. The at least one high voltage electro pulse may be generated when the detected resistance of the drill bit exceeds a predetermined limit under rotary drilling. The predetermined resistance limit under rotation is determined based on a number of parameters e.g. the hardness of the rock formation, the drilling equipment and the drill bit, and may vary when pre-detected devices are used. The rotary drilling system may further comprise at least one sensor arranged in the drill bit for detecting the resistance on the drill bit from the rock formation. Alternatively, at least one sensor may be arranged in the drilling system for detecting the resistance on the drill bit from the rock formation. In a further embodiment, the rotary drilling system may further comprise a radar or sonar for pre-detecting the resistance on the drill bit from the rock formation.
Further, an electro pulse device may be connected to said electrodes and adapted for generating said at least one high voltage electro pulse. A sensing device may be arranged for detecting the resistance to a drill bit from the rock formation in front of the drill bit under rotary drilling. The system may include an electronic switch for electro pulsing. The system may further include at least one of: a capacitor, a rectifier and a transformer of low to high voltage and/or current. The system may further include an electro pulse device for

controlling and generation of the high voltage electrode pulses. The electronic switch may form part of the electro pulse device. The electro pulse device may further comprise at least one of: a capacitor, a rectifier and a transformer of low to high voltage and/or current.

The rotary drilling system may further comprise an electrical source comprising at least one of: a battery pack or batteries, a mud driven generator, water driven generator, a compressed air generator, a rotary drill string driven generator, and cables to surface. The rotary drilling system may comprise a drilling assembly. The rotary drill bit may be arranged in the drilling assembly. In an embodiment, the electro pulse device may be arranged in the drilling assembly. The drill bit may further comprise at least one of: teeth, scrapers and cutter disks, and wherein said at least two electrodes are incorporated in at least one of: the drill bit itself, the teeth, the scrapers and the cutter disks.
The system may be adapted for tunneling, and the drill bit may then be a rotary tunnel excavator.

In a further aspect, the invention provides a rotary drilling method for drilling a borehole in inhomogeneous and/or hard rock formations. The method comprising rotary drilling of a borehole using a rotary drill bit, pulsing between at least two electrodes of at least one high voltage electro pulse, wherein said at least one high voltage electro pulse is generated in response to a resistance on the drill bit from a rock formation in front of the drill bit while rotating, creating small/micro-cracks in the rock formation.

The at least two electrodes may be incorporated in the drill bit. The method may further comprise generating said at least one high voltage electro pulse when the detected resistance on the drill bit exceeds a predetermined limit under rotary drilling. The detected resistance may be in the form of a detected torque on the drill bit from the rock formation. Detection of the resistance may be pre-detected using a suited detecting device in the drill bit or drilling assembly. The generation of said at least one high voltage electro pulse may be performed or initiated when the detected resistance on the drill bit exceeds a predetermined limit under rotary drilling, or by a signal from the device pre-detecting resistance. The predetermined resistance limit or torque limit under rotary drilling may be determined based on a number for factors, e.g. rock formation hardness, the equipment and drill bit used, and may vary by pre-detecting the resistance from rock formation. Said at least one high voltage electro pulse may have a value of about 100 kV or more.

The method may further comprise excavating the small/micro-cracked rock lattice or matrix. The method may further be adapted for tunneling, and the drill bit may then be a rotary tunnel excavator.

In general, the present invention provides a technology system that "softens up" the rock in front of a rotary drill bit by formation of small/micro-cracks in the rock lattice when the resistance on the drill bit or drill bit teeth/cutters exceeds, or are to exceed, a given limit while rotary drilling. The rock in front of the rotary drill bit is "softened up" by one or more short-duration, high voltage electro pulse(s) given through separate electrodes in the rotary drill bit, causing small/micro-cracks in the rock formation between and/or around the electrodes. The small/micro-cracks in the rock lattice will avoid stick slip, high torque and abrasive wear of any rotary drill bit, while keeping an even and high rate of penetration. By "softening up" the rock formation with the high voltage electro pulse(s) when needed, the drill bit is experiencing almost the same resistance from the rock formation all the time during drilling, regardless of the properties of the rock formation. This enables maintaining a constant or little varying rotational speed of the drill bit resulting. This results in an efficient drilling process also reducing risks for damage on drilling equipment.
The "soften up" of the rock formation in front of the rotary drill bit in the present invention may only be activated when needed based on the detected resistance on the drill bit.
The electro pulsing in the present invention is only used for forming small/micro-cracks in the rock formation in front of the drill bit and not for cracking of the rock formation for rock bits. Cracking of the rock formation for rock bits are used when drilling with an electro pulse method as the main drilling method. The present invention, which activates the high voltage electro pulse(s) only when needed based on the detected resistance on the drill bit, keeps the total energy demand to a fraction of what is usually needed for either the rotary drilling bit technology or electro pulsing drilling used separately.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a rotary drilling system according to an embodiment of the present invention,

Fig. 2-4 are showing steps of the principle for "softening up" the rock in front of a rotary drill bit by small cracks/micro-cracks according to the present invention,

Fig. 5 illustrates another rotary drilling system according to another embodiment of the present invention.

DETAILED DESCRIPTION

In the following description, details are set forth to provide an understanding of the present invention. However, it will be understood by those of ordinary skill in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiment may be possible.

The present invention provides a system and a method for softening up the rock formation in front of a rotary drill bit by creation of small/micro-cracks in the rock lattice or matrix when the resistance on the drill bit is to, or exceeds a predetermined limit while rotary drilling. This enables efficient drilling with approximately constant rotational speed on the drill bit as the resistance experienced by the drill bit due to friction between the rotating drill bit and the rock formation is maintained about a same level throughout the drilling process.

A rotary drilling system 10 according to an embodiment of the present invention, is shown in FIG. 1.The system 10 comprises a drilling assembly 11 used to form a borehole 12, e.g. a wellbore. The wellbore may be drilled in any direction but usually, but not restricted thereto, from a surface into any desired formation. The drilling assembly 11 may be based on any standard rotary drilling technology. The rotary drilling assembly 11 and the rotary drilling system 10 may be selected from any known rotary drilling system and support systems including any known equipment, methods, and procedures known to anyone skilled in the art of rotary drilling.

In front of the drilling assembly 11 there is a rotary drill bit 20. At least two electrodes are arranged for pulsing between said electrodes of at least one high voltage electro pulse (41). The at least two electrodes (21, 22, 23) may be incorporated in the rotary drill bit (20). The body of rotary drill bit (20) may also in itself be an electrode. The at least one high voltage electro pulse (41) (illustrated in Figure 2) is generated in response to a detected resistance on the drill bit (20) from a rock formation (40) in front of the drill bit (20) while rotating. The at least one high voltage electro pulse (41) creates small/micro-cracks (45) in the rock formation (40). The at least one high voltage electro pulse (41) is generated when the detected resistance on the drill bit (20) under rotary drilling exceeds a predetermined limit. The predetermined resistance limit under rotation is determined based on a number of parameters e.g. the hardness of the rock formation to be drilled, the drilling equipment used and the drill bit used.

The rotary drill bit 20 may be provided with drill bit teeth 21 and/or scrapers 22 for excavation of the rock formation in front of the drill bit 20. The bit teeth 21 or scrapers 22 on the drill bit 20 may also in an embodiment include the at least one electrodes 21, 22 for high voltage electro pulsing. The drill bit 20 may also include separate electrodes 23 or be an electrode in itself. The electrodes 21, 22 and/or 23 may be of any suited material and placed at any suited place on the drill bit 20 in order to efficiently "soften up" (create small/micro-cracks in) the rock in front of the drill bit 20 by pulsing of high voltage current between the at least two electrodes 21, 22, 23 and/or the drill bit itself. The voltage used for the pulsing between said at least two electrodes 21, 22, 23 and/or the drill bit itself, may be of any high voltage. The at least one high voltage electro pulse may have a value of about 100 kV or more. Drill bit 20 may contain any device for injection of insulating drilling fluid for the electro pulsing, if needed. Other drill-bits, equipped with or without the present invention with drill-bit 20 in assembly 11 may be used in other places along the drilling assembly system 10, as e.g. reamers for widening the borehole 12.

Electrical connections to the electrodes 21, 22, 23, and or the drill bit 20 itself, may be incorporated in the drill bit 20 in any suitable way. The electrical connections may further be connected to an electric switch 35 in the drilling assembly 11 by any suitable means. The electric switch 35 for electro pulsing may be of any kind e.g. an electronic switch or a mechanical switch, generating high voltage electric pulses at given value and frequency. The switch 35 will only be operating when needed for the drilling purposes. The switch 35 may be engaged or triggered in response to the measured or pre-detected resistance on the drill bit (20) from a rock formation (40), from the resistance sensing device 30 or detecting device 31.The resistance on the drill bit (20) from a rock formation (40) may be detected by a resistance sensing device (30), or pre-detected by a detecting device (31). The resistance sensing device 30 measures the resistance (force) on the drill bit 20 from the rock formation in front of the drill bit 20, while the drill bit 20 is rotating. The resistance sensing device 30 may e.g. be in the form of a mechanical (e.g. spring compression), electronic or any combinations thereof sensor(s) arranged in the drill bit itself, or as a mechanical or electronic torque sensing device detecting the torque on the drill bit 20 arranged in the drilling assembly 11. The resistance sensing device 30 may be arranged on the drill bit 20, directly behind the drill bit 20, or in other places on the drilling assembly 11, or rotary drilling system 10. The resistance sensing device 30 may also be of any other suitable kind. When the resistance sensing device 30 detects a resistance experienced by the drill bit 20 due to the rock formation in front of the drill bit, exceeding a the predetermined value/limit , the switch 35 is triggered or engaged, and the electro pulsing between the electrodes 21, 22, 23, and or the drill bit 20 itself, starts. The at least one high voltage electro pulse 40 is generated in response to the detected torque on the drill bit 20.

Resistance to drill bit 20 may alternatively, or in parallel to resistance device 30, be pre-detected by a detecting device 31. When pre-detecting resistance from the rock formation 40 in front of the drill bit 20 exceeds a predetermined value/limit, electro pulses 41 between the electrodes 21, 22, 23 and /or the drill bit 20 itself, may be engaged by electronic switch 35 shortly before or simultaneously as the rotary drill bit 20 engage harder rock formation. The detecting device 31 may be of any suited kind (e.g. radar or sonar), and may detect rock properties in front of the drill bit 20 by any suited means, e.g. by acoustic or electronic signals or by electric resistance between electrodes 21, 22 and/or 23, and may be integrated in drill bit 20, directly behind the drill bit 20, or in any other places on the drilling assembly 11.
The resistance sensing device 30 and/or detecting device 31, and the electronic switch 35 may be arranged together as an integrated unit.

The high voltage electro pulses supplied to the electrodes 21, 22, 23 and or the drill bit 20 itself, through switch 35 may e.g. be energized from a capacitor(s) 36 in the drilling assembly 11. Energy may be supplied to the capacitor(s) 36 by an internal energy supply in the drilling assembly 11 or trough electric cables from the surface of the borehole 12. The drilling assembly 11 may also include a rectifier or transformer of low to high voltage and/or current. The internal energy supply may be provided by an electrical source 37, including but not limited to e.g. batteries or a battery pack. The batteries/battery pack 37 may also include or be substituted by e.g. any of a mud driven generator, a water driven generator, a compressed air generator, or a rotary drill string generator.
In an embodiment a high voltage electro pulse device may comprise the switch 35 for controlling and/or initiating the high voltage electro pulsing. The high voltage electro pulse device may further comprise at least one of: the capacitor 36, rectifier and transformer of low to high voltage and/or current. All or some parts of the high voltage electro pulse device can be arranged in the drilling assembly 11.

In principle, the electro pulse devices 21, 22, 23, 30, 31, 35, 36, and 37 in the drilling assembly 11 of the present invention operate independently of any other parts or operations of the rotary drilling system 10 when needed for efficient drilling. In any failure of the electro pulse functions in the system of the present invention, the remaining rotary drilling system of the drilling assembly system 10 will perform drilling as efficient as an equal rotary drilling system without the present invention.

The principle of "soften up" the rock in front of a rotary drill bit by small/micro-cracks in the rock lattice when the torque of the drill bit teeth/cutters, detected by sensing device 30, exceeds a given limit/value while drilling are illustrated in FIG. 2, FIG. 3, and FIG. 4. Reference numbers referred to below, but not shown in FIG. 2, FIG. 3, and FIG. 4, are shown in FIG. 1. FIG. 2 illustrates that the cutter teeth 21 or scrapers 22 of the drill bit 20 hit a hard rock formation 40, resulting in a resistance experienced by the cutter teeth 21 or scrapers 22 from the rock formation that exceeds the limit for the sensing device 30. The sensing device 30, thus engages the switch 35. One or more short high voltage electro pulse(s) 41 is/are then generated through the rock matrix 40 as illustrated in Figure 2. After the electro pulse(s), the lattice of the rock formation 40 will contain internal small/micro-cracks 45 as illustrated in Fig. 3. The force from the teeth 21 or scrapers 22 in the drill bit 20 that is now required to excavate the rock matrix 40, which now contain small/micro-cracks 45, will be less than the predetermined limit set for the sensing device 30. The small/micro-cracked rock lattice 40 will then be excavated as shown in Fig. 4. When the rock lattice with small/micro-cracks has been excavated, the electro pulse process may be reinitiated as the teeth 21 or scrapers 22 of the drill bit 20 again hit hard rock formation 40 resulting in a detected resistance above the predetermined value for the formation to be drilled, as illustrated in FIG. 2. During drilling, high voltage electro pulses will be generated when resistance values above the predetermined limit are sensed by the sensors or sensing device 30. This enables efficient drilling with approximately constant rotational speed on the drill bit as the resistance experienced by the drill bit due to friction between the rotating drill bit and the rock formation is maintained about a same level throughout the drilling process. How often the high voltage electro pulses are generated, depends e.g. on the predetermined limit set and the properties of the rock formation.

The principle of "soften up" the rock in front of a rotary drill bit by small/micro-cracks in the rock lattice when expected increased resistance from rock formation 40 to the drill bit teeth/cutters is pre-detected by detecting device 31, exceeds a given limit/value while drilling are also illustrated in FIG. 2, FIG. 3, and FIG. 4. Reference numbers referred to below, but not shown in FIG. 2, FIG. 3, and FIG. 4, are shown in FIG. 1. FIG. 2 illustrates that the cutter teeth 21 or scrapers 22 of the drill bit 20 is about to hit a hard rock formation 40. The detecting device 31, thus engages the switch 35. One or more short high voltage electro pulse(s) 41 is/are then generated through the rock matrix 40 as illustrated in Figure 2. After the electro pulse(s), the lattice of the rock formation 40 will contain internal small/micro-cracks 45 as illustrated in Fig. 3. The force from the teeth 21 or scrapers 22 in the drill bit 20 that is now required to excavate the rock matrix 40, which now contain small/micro-cracks 45, will be less than the predetermined limit set for the detecting device 31. The small/micro-cracked rock lattice 40 will then be excavated as shown in Fig. 4. When the rock lattice with small/micro-cracks has been excavated, the electro pulse process may be reinitiated as the teeth 21 or scrapers 22 of the drill bit 20 again are about to hit hard rock formation 40 having a resistance above the predetermined value for the formation to be drilled, as illustrated in FIG. 2. During drilling, high voltage electro pulses may be generated when pre-detected resistance values are above the predetermined limits sensed by detecting device 31.This enables efficient drilling with approximately constant rotational speed on the drill bit as the resistance experienced by the drill bit due to friction between the rotating drill bit and the rock formation is maintained about a same level throughout the drilling process. How often the high voltage electro pulses are generated, depends e.g. on the predetermined limits set from the drilling equipment and the properties of the rock formation.

The amount of electric current needed for drilling a given amount of hard rock formation as illustrated in FIG. 2 is depending on the properties of the rock lattice 40. This amount of electric current is estimated to be considerably less than when drilled by electro pulse drilling as the main drilling method. The use of electro pulsing in the present invention only provides formation of small/micro-cracks in a rock lattice upon mechanical drilling/excavation and it does not require large cracks that chip off large bits from the rock lattice as required when using single electro pulse methods for excavating a borehole. The amount of electric current is estimated to be in the order of 50% or less. A considerable reduction of the amount of electric current/energy may e.g. enable drilling assemblies having internal energy supplies lasting the entire life time of the drill bit itself.

The principle of the present invention may in a similar way be used in any other system for rotary drilling of inhomogeneous and/or hard rock formations. An example, but not restricted thereto, is for tunneling as shown in FIG. 5. Electrodes may be incorporated in cutter disks 51 and/or scrapers 52, as separate electrodes 53, and/or as the drill head of 50 itself, in a rotary tunnel excavator 50. The electro pulses are only triggered when needed due to the detected resistance (may be measured or pre-detected) from the rock formation on the cutter disks 51 or scrapers 52 at rotation of the rotary tunnel excavator 50. Electro pulsing is provided by the electrodes in a similar manner as explained for the embodiment shown in FIG. 1, and illustrated in Figures 2, 3 and 4. Small/micro-cracks are thus formed in the rock formation prior to excavation by the cutter disks 51 or scrapers 52.

The present invention concerns also a method for rotary drilling of a borehole 12 in inhomogeneous or hard rock formations. A rotary drill bit 20 us used for rotary drilling of the borehole 12. During drilling a resistance on the drill bit from the formation is detected. When the detected resistance exceeds a predetermined value, at least one high voltage electro pulse 41 is generated between the at least two electrodes creating small/micro-cracks 45 in the rock formation 40. Monitoring of the resistance during drilling may be performed continuously, almost continuously or at specific intervals.
Thea least two electrodes 21, 22, 23, 51, 52, 53 may be incorporated in the drill bit 20. One of the electrodes may also be the drill bit itself. The rotary drill bit can also be a rotary tunnel excavator 50 as shown in fig. 5. Detecting the resistance may be performed by detecting a torque on the drill bit 20 from the rock formation. In an alternative embodiment, detecting the resistance may be performed by a radar or sonar pre-detecting the resistance on the drill bit 20 from the rock formation 40.

The drill bit, which is rotating at its intended rotational speed during the measurement and high voltage pulse generation procedure, excavates the small/micro-cracked rock lattice or matrix 40. When the measured or pre-detected resistance again exceeds the predetermined value, this again results in the generation of the at least one high voltage electro pulse 41. Monitoring of the resistance during drilling and pulsing high voltage electro pulses 41 only when needed, ensures that the drill bit experiences about the same resistance/force from the formation at all times during drilling. This considerably improves and simplifies drilling in inhomogeneous and/or hard rock formations, at the same time as the energy consumption is considerably reduced.

The present invention may be used by any rotary drilling method in inhomogeneous and hard rock formations. Primary use is drilling of wellbores for oil, gas, mining and geothermal exploration and excavation, and any tunneling with rotary equipment for mining or any infrastructures, like but not restricted to, for hydro power, electric cables, roads, train, and water.

Although a variety of examples and other information was used to explain aspects within the scope of the appended claims, no limitation of the claims should be implied based on particular features or arrangements in such examples, as one of ordinary skill would be able to use these examples to derive a wide variety of implementations. Further and although some subject matter may have been described in language specific to examples of structural features and/or method steps, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to these described features or acts. For example, such functionality can be distributed differently or performed in components other than those identified herein. Rather, the described features and steps are disclosed as examples of components of systems and methods within the scope of the appended claims.

CLAIMS

1. A rotary drilling system (10) for drilling a borehole (12) in inhomogeneous and/or hard rock formations, the system (10) comprising:

a rotary drill bit (20; 50), and

at least two electrodes (21, 22, 23, 51, 52, 53) arranged for pulsing between said electrodes of at least one high voltage electro pulse (41),

wherein said at least one high voltage electro pulse (41) is generated in response to a detected resistance on the drill bit (20) from a rock formation (40) in front of the drill bit (20) while drilling, in order to create small-cracks/micro-cracks (45) in the rock formation (40).

2. The rotary drilling system (10) according to claim 1, further comprising at least one sensor arranged in the drill bit for detecting the resistance on the drill bit (20) from the rock formation (40).

3. The rotary drilling system (10) according to claim 1, further comprising at least one sensor arranged in the drilling system for detecting the resistance on the drill bit (20) from the rock formation (40).

4. The rotary drilling system (10) according to claim 1, further comprising a radar or sonar (31) for pre-detecting the resistance on the drill bit (20) from the rock formation (40).

5. The rotary drilling system (10) according to one of claims 1-4, wherein said at least one high voltage electro pulse (41) is generated when the detected resistance on the drill bit (20) exceeds a predetermined limit under drilling.

6. The rotary drilling system (10) according to claim 1, wherein the detected resistance is in the form of a detected torque on the drill bit (20) from the rock formation (40).

7. The rotary drilling system (10) according to claim 6, wherein said at least one high voltage electro pulse (41) is generated when the detected torque on the drill bit (20) exceeds a predetermined torque limit under rotary drilling.

8. The rotary drilling system (10) according to one of claims 1-7, wherein at least two electrodes (21, 22, 23, 51, 52, 53) are incorporated in the drill bit (20).

9. The rotary drilling system (10) according to any one of the claims 1 to 8, further comprising an electro pulse device connected to said electrodes and adapted for generating said at least one high voltage electro pulse (41).

10. The rotary drilling system (10) according to any one of the claims 1 to 9, further comprising a torque sensing device (30) arranged for detecting the drill bit (20) torque from the rock formation (40) in front of the drill bit (20) under drilling.

11. The rotary drilling system (10) according to any one of the claims 1 to 10, further comprising an electronic switch (35) for electro pulsing.

12. The rotary drilling system (10) according to any one of the claims 1 to 11, wherein the electro pulse device comprises at least one of: a capacitor (36), a rectifier and a transformer of low to high voltage and/or current.

13. The rotary drilling system (10) according to any one of the claims 1 to 10, wherein the system (10) further comprises an electrical source comprising at least one of: a battery pack or batteries (37), a mud driven generator, a water driven generator, a compressed air driven generator, a rotary drill string driven generator, and cables to surface.

14. The rotary drilling system (10) according to any one of the claims 1 to 13, further comprising a drilling assembly (11).

15. The rotary drilling system (10) according to claim 14, wherein the rotary drill bit (20) is arranged in the drilling assembly (11).

16. The rotary drilling system (10) according to claim 14 or claim 15, wherein the electro pulse device is arranged in the drilling assembly (11).

17. The rotary drilling system (10) according to any one of the claims 1 to 16, wherein the drill bit (20) comprises at least one of: teeth (21), scrapers (22; 52) and cutter disks (51), and wherein said at least two electrodes (21, 22, 23, 51, 52, 53) are incorporated in at least one of: the drill bit (20) itself, the teeth (21), the scrapers (22; 52) and the cutter disks (51).

18. The rotary drilling system (10) according to any one of the claims 1 to 17, wherein the system (10) is adapted for tunneling, and the drill bit is a rotary tunnel excavator (50).

19. A method for rotary drilling of a borehole (12) in inhomogeneous and/or hard rock formations, comprising:

- rotary drilling a borehole (12) using a rotary drill bit (20; 50),
- pulsing between at least two electrodes (21, 22, 23, 51, 52, 53) of at least one high voltage electro pulse (41), wherein said at least one high voltage electro pulse (41) is generated in response to a detected resistance on the drill bit (20) from a rock formation (40) in front of the drill bit (20) while rotating, creating small cracks/micro-cracks (45) in the rock formation (40).

20. Method according to claim 19, further comprising generating said at least one high voltage electro pulse (41) when the detected resistance on the drill bit (20) exceeds a predetermined limit under rotary drilling.

21. Method according to claim 19, further comprising detecting the resistance by detecting a torque on the drill bit (20) from the rock formation (40).

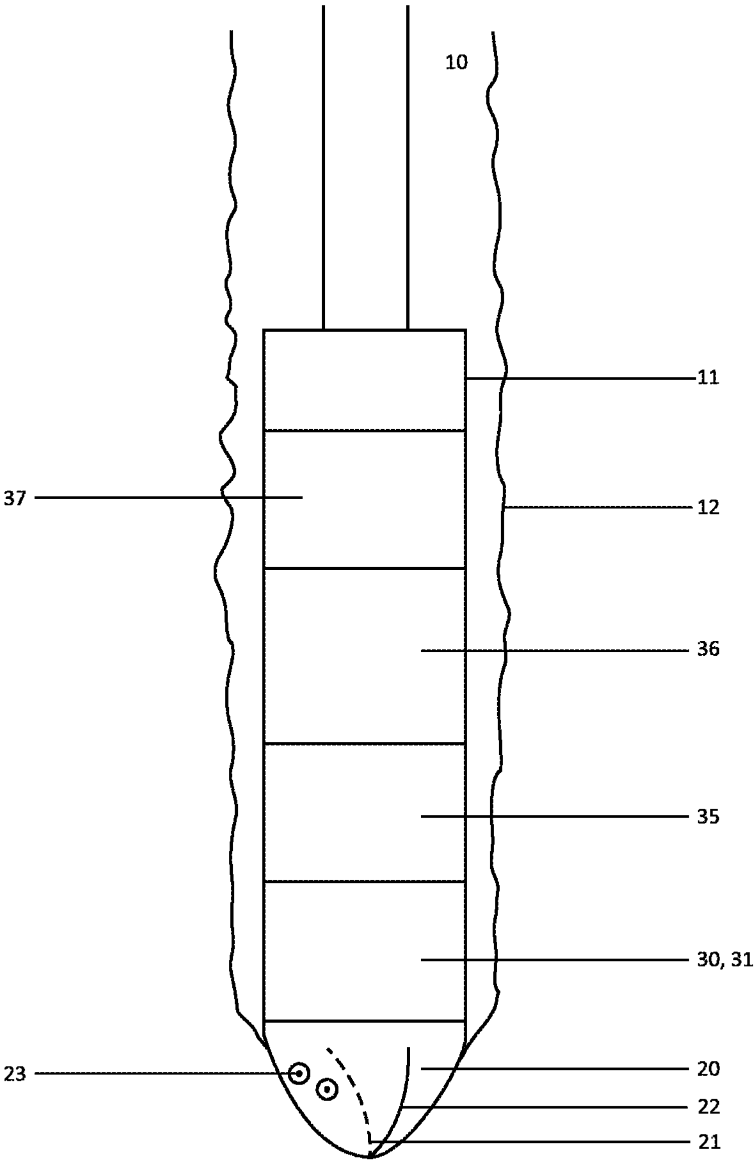
22. Method according to claim 19, further comprising detecting by using a radar or sonar for pre-detecting the resistance on the drill bit (20) from the rock formation (40).

23. The rotary drilling method according to one of claims 19-22, wherein at least two electrodes (21, 22, 23, 51, 52, 53) are incorporated in the drill bit (20).

24. The rotary drilling method according to any one of the claims 19-23, further comprising excavating the micro-cracked rock lattice or matrix (40).

25. The rotary drilling method according to any one of the claims 19-24, wherein the method is adapted for tunneling, and the drill bit is a rotary tunnel excavator (50).

Fig. 1



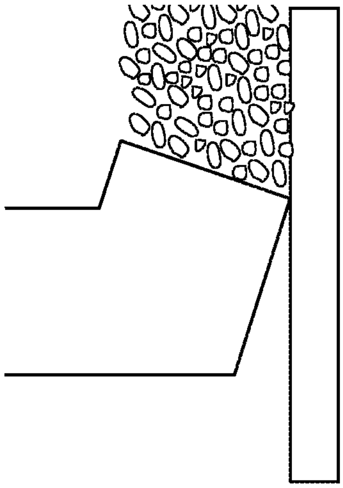


Fig. 4

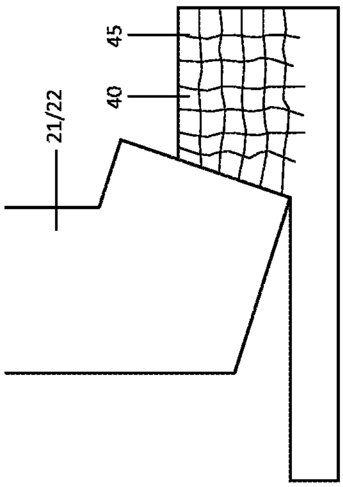


Fig. 3

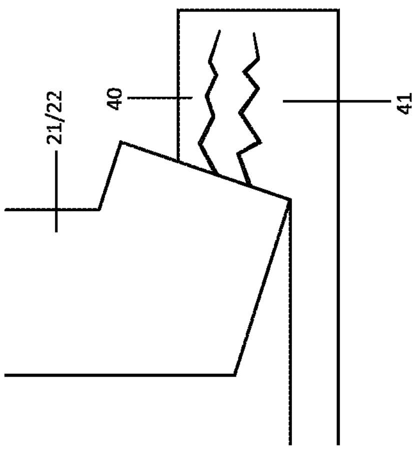


Fig. 2

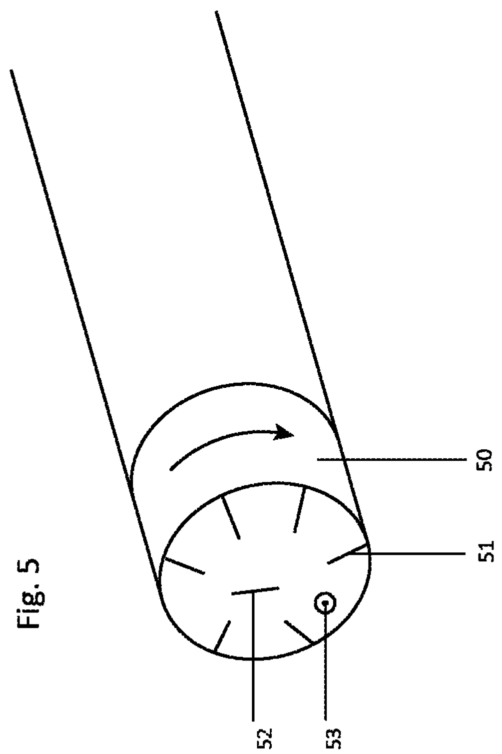


Fig. 5