METHOD FOR THE CHISEL-LESS FORMATION OF BOREHOLES FOR DEEP BORES AND CHISEL-LESS DRILLING SYSTEM FOR CARRYING OUT SAID METHOD

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ABSTRACT
The invention relates to a method for the chisel-less formation of boreholes for deep bores by means of high-pressure water jet cutting. A chisel-free drilling method that makes substantially continuous drilling operation possible is characterized, according to the invention, by a combination of the processes of high-pressure water jet cutting and high-frequency rock fragmentation. The invention also relates to a chisel-free drilling system for carrying out the method.
Fig. 3
METHOD FOR THE CHISEL-LESS FORMATION OF BOREHOLES FOR DEEP BORES AND CHISEL-LESS DRILLING SYSTEM FOR CARRYING OUT SAID METHOD

[0001] The invention relates to a method for the chisel-less formation of boreholes for deep bores by means of high pressure water jet cutting. Furthermore, the invention relates to a chisel-less drilling system for carrying out said method.

[0002] Boreholes for vertical deep bores, that is to say bores which are driven into the ground to a depth of more than 500 m, are formed in practice by the “rotary method”, in which the rock to be penetrated is comminuted with a scraping action by means of a rotating chisel and is continuously removed by a flushing fluid which is pumped downward through the drill rod.

[0003] In the case of very deep bores, use is generally made of a drilling turbine which is arranged directly above the drill bit. In this method, the drill rod adjoining the drill bit counter to the drilling direction does not rotate with the drill bit but rather serves only for advancing the bit and for supplying the flushing fluid.

[0004] Drill bits with diamond or sintered carbide edging have a durability of 70 to 100 hours in customary ground conditions. In order to exchange and refurbish the drill bit, the entire drill string then has to be pulled out of the borehole and dismantled in order subsequently to be lowered again into the borehole with the new drill bit. In the conventional deep drilling method, the drilling operation therefore proceeds discontinuously.

[0005] In order to prevent the borehole from caving in, the borehole has to be supported, which is carried out in the case of the conventional deep bores by casing. This is carried out in stages with a decreasing pipe diameter in such a manner that, for example, in the case of an oil well at a depth of 3000 m, first of all a pipe reaching to a depth of 5 m and having an outside diameter of 473 mm is introduced. After a drilling depth of 150 m, a pipe known as a casing with an outside diameter of 340 mm is pushed as far as the bottom of the bore and the intermediate space between borehole wall and casing is filled with a cement slurry. At a drilling depth of 1500 m and at the final depth of 3000 m, further casing is carried out with casings which each have a smaller outside diameter than the previous casing, and therefore the outside diameter of the final casing after the end depth is reached is only 140 mm.

[0006] Although this known deep drilling method has proven successful in practice, the costs for deep bores of this type are extremely high because of the discontinuous drilling and the constant refurbishing or reprovisioning of the drill bits and of the drill rod.

[0007] An alternative deep drilling method of the type in question is known, for example, from DE 10 2010 005 264 A1, in which the borehole is formed in a chisel-less manner by means of water jet cutting. The drill head for carrying out said known method is of annular design and has a multiplicity of water outlet nozzles arranged next to one another. With this said annular drill head, rather than comminuting the entire borehole diameter, only a rock ring is comminuted, in the manner of a core drilling machine. After a predetermined depth of 5 m or 10 m is reached, radially inwardly facing water outlet nozzles on the drill head are activated in order radially to cut free the drill core which is exposed along the lateral area thereof. The cut-free drill core is subsequently pulled upward out of the borehole. In this known method, the borehole is lined via partial segments each spanning an arc of 120°.

[0008] Even said chisel-less drilling method operates discontinuously since the cut-free drill cores each have to be removed from the borehole. Furthermore, the borehole has to have a very large minimum diameter in order to have the appropriate handling clearances for transporting the drill cores.

[0009] Taking this as the starting point, the invention is based on the object of providing a method for the chisel-less formation of boreholes, which makes substantially continuous drilling operation possible.

[0010] According to the invention, the achievement of this objective is characterized by a combination of the high pressure water jet cutting process with high frequency rock fragmentation.

[0011] High pressure water jet cutting is understood as meaning the cutting up or severing of the rock with one water jet or with a plurality of water jets under high pressure. Water jets of this type can have a pressure from 1000 bar. Pressures from 4000 to 6000 bar are preferably used. An abrasive agent can be added to the water in order to increase the cutting power, this preferably being carried out only at pressures from 3000 bar. Said water jets reach outlet speeds of up to 1000 m/s.

[0012] By means of the combination according to the invention of the high pressure water jet cutting with the high frequency rock fragmentation, it is possible to provide a drilling method which operates efficiently and continuously, wherein the high frequency rock fragmentation can be operated alternating with the high pressure water jet cutting or in parallel thereto in order to use the most effective possibility in each case of breaking open the rock layer to be penetrated.

[0013] In order to be able to adapt the high pressure water jet cutting process and the high frequency rock fragmentation process to each other in the best possible manner and to the conditions required in situ in the borehole, it is proposed by the invention that the pressures of the high pressure water jet cutting process and the frequencies of the high frequency rock fragmentation are variably adjustable.

[0014] According to an advantageous embodiment of the method according to the invention, the inner wall of the borehole is continuously lined with a reinforcement, for example a fiber-reinforced shotcrete. By means of this continuous lining of the borehole directly after drilling, the entire drilling operation becomes more efficient since interruptions as are required, for example, during the borehole casing known in practice can also be omitted here.

[0015] A drilling system according to the invention for carrying out the chisel-less drilling method according to the invention is characterized in that sonotrodes for transmitting high frequency vibrations are arranged in addition to the water outlet nozzles for the high pressure water jet cutting on the front end side of the drill head.

[0016] According to a preferred embodiment of the invention, it is proposed that the drill head, but at least an end plate of the drill head, which end plate is provided with the water outlet nozzles and the sonotrodes, is designed to be rotatable about the center axis, in order to ensure a uniform and substantially extensive processing over the entire borehole diameter of the rock to be penetrated.

[0017] With a practical embodiment for configuring the drilling system according to the invention, it is proposed that
at least one safety module and at least one borehole lining module are arranged behind the drill head in the drilling direction. Depending on the application, the individual assemblies can be arranged one behind another rigidly or so as to be movable relative to one another.

[0018] In order, in the event of a sudden rise in pressure in the borehole, for example by drilling into a gas bubble, firstly to prevent uncontrolled escape of the gas from the borehole and secondly to prevent the entire drilling system from being able to be pushed upward out of the borehole by means of the rise in pressure, the safety module has at least one locking element for the form-fitting closing of the inside diameter of the borehole, and clamping elements for the force-fitting securing of the drilling system in the borehole.

[0019] The borehole diameter can be closed in a form-fitting manner, for example, with an expander ring which closes the borehole in order then to be able to dissipate the positive pressure in a controlled manner via suitable pressure control valves. The clamping elements with which the entire drilling system can be interlocked in a force-fitting manner in the borehole are designed, according to the invention, for example as barbs which face radially upward and outward and fix the drilling system in the respective position in the borehole.

[0020] In order to secure the borehole and also in order to shield the borehole from groundwater-conducting layers, the borehole is continuously lined directly after the drilling. For this purpose, the borehole lining module according to the invention has spray nozzles for applying a curing medium, such as, for example, concrete, and a reinforcing fabric laying apparatus. In order to form said hybrid material serving for lining the borehole wall and consisting of a reinforcing fiber and a curing medium, use is preferably made of carbon fibers and concrete. According to the invention, the fiber structure can be discharged via a cone, via which the reinforcing fibers can be applied directly onto the borehole wall in order subsequently to be able to be wetted with the curing medium. Depending on requirements, the borehole can be lined with a single layer or with multiple layers.

[0021] Of course, as an alternative to the carbon fibers mentioned and the concrete as curing medium, use may also be made of other fiber materials and other curing media for lining the borehole.

[0022] The drilling system according to the invention, consisting of the drill head, the safety module and the borehole lining module, is advantageously supplied via flexible pipe and/or hose lines, via which the drilling system is connected to supply devices outside the borehole, wherein the pipe and/or hose lines serve for the supply and removal of the materials relevant to the drilling system and for the feeding in of the electric supply lines. Each individual line of said flexible pipe and/or hose lines is preferably designed here as an endless line which can be kept ready on drums.

[0023] Furthermore, it is proposed by the invention that the drive and the steering and control apparatus for the drill head are arranged directly on the drill head.

[0024] In order to make the drilling system according to the invention as independent as possible from supply stations arranged outside the borehole, according to a practical embodiment of the invention the pumps for the high pressure water jet cutting and for sucking off the flushing medium are arranged on the drill head and/or on the safety module.

[0025] In addition to the electric supply lines, the flexible pipe and/or hose lines, via which the drilling system is connected to supply devices outside the borehole, also contain data lines, for example a bus system, via which the drill head and/or the safety module and/or the borehole lining module are connected to a workplace outside the borehole.

[0026] According to the invention, via the data lines, in addition to the system parameters, such as, for example, feed speed and pumping pressure, all of the ambient parameters in the borehole, such as, for example, temperature, pressure, rock density and the like, can be determined via sensors coupled to the data lines and can be transmitted to the workplace in order to control the drilling system.

[0027] Finally, it is proposed by the invention that, in order to generate the high frequency pulses for the high frequency rock fragmentation, piezo elements which are each coupled to an amplifying unit consisting of a sonotrode and an amplitude transformer are arranged in the drill head.

[0028] Owing to the equipping of the drilling system with the piezo elements and sonotrodes in order to generate the high frequency pulses, it is possible, after the target drilling depth is reached, to break up the rock with the aid of high frequency rock fragmentation in the manner of fracking, but without using chemicals.

[0029] Further features and advantages of the invention emerge with reference to the associated drawings in which an exemplary embodiment of a chisel-less drilling system according to the invention is illustrated merely by way of example without restricting the invention to said exemplary embodiment. In the drawings:

[0030] FIG. 1 shows a schematic side view of a chisel-less drilling system according to the invention:

[0031] FIG. 2 shows a front view of the drill head according to FIG. 1, and

[0032] FIG. 3 shows a view according to FIG. 1, but showing the drilling system in a borehole.

[0033] FIG. 1 shows a drilling system 1 for vertical deep bores, which drilling system essentially consists of a drill head 2, a safety module 3 and a borehole lining module 4, wherein the individual assemblies 2, 3 and 4 are arranged one behind another rigidly or so as to be movable relative to one another, depending on the application.

[0034] Although vertical deep bores are mentioned, it is possible, with the method described below and the drilling system 1, also to direct the drilling course from the vertical into a horizontal course if this is required. However, the main drilling direction is the deep vertical bore.

[0035] As is apparent from the arrangement, illustrated in FIG. 3, of the drilling system 1 arranged in a borehole 5, the drilling system 1 consisting of the drill head 2, the safety module 3 and the borehole lining module 4 is supplied via flexible pipe and/or hose lines 6, via which the drilling system 1 is connected to supply devices 7 outside the borehole 5. The pipe and/or hose lines 6 which serve for the supply and removal of the materials relevant to the drilling system 1 and for the feeding in of the electric supply lines, the individual pipe and/or hose lines 6 are designed as an endless line which can be kept ready on drums.

[0036] The individual pipe and/or hose lines 6 are connected at certain distances to spacers and thus form a feed-in package which is guided into the borehole 5. In order to be able to absorb the tensile forces which occur because of the dead weight of the pipe and/or hose lines 6 and the weight of the drilling system 1, steel cables which are appropriately mounted outside the borehole 5 are preferably entrained. Furthermore, there is the possibility of securing floats to the
pipe and/or hose lines 6, said floats absorbing the tensile loading since the borehole 5 is underwater during the drilling operation.

[0037] As is apparent from FIG. 2, water outlet nozzles 8 for the high pressure water jet cutting and sonotrodes 9 for transmitting high frequency vibrations for the high frequency rock fragmentation are arranged on the front end side of the drill head 2.

[0038] In order to ensure uniform and substantially extensive processing over the entire borehole diameter of the rock to be penetrated, the entire drill head 2, but at least an end plate 10 of the drill head 2, which end plate is provided with the water outlet nozzles 8 and the sonotrodes 9, is designed so as to be rotatable about the center axis.

[0039] For the sucking up of the drilling mud arising during the drilling operation, the end plate 10 is provided with suction openings 17, via which the drilling mud can be sucked off and pumped out of the borehole 5 by the pipe and/or hose lines 6.

[0040] In order to generate the high frequency pulses for the high frequency rock fragmentation, piezo elements which are each coupled to an amplifying unit consisting of a sonotrode 9 and an amplitude transformer are arranged in the drill head 2. In order to protect the sonotrode 9 from wear, said sonotrodes are advantageously coated, for example with polycrystalline diamond.

[0041] The pumps for the high pressure water jet cutting and for sucking off the flushing medium are arranged on the drill head 2 and/or on the safety module 3. In order to increase the cutting action of the high pressure water jet, an abrasive agent, such as, for example, quartz sand, can be added to the water jet, the abrasive agent being supplied to the drill head 2 via the flexible pipe and/or hose lines 6 and being mixed with the water jet only in the water outlet nozzle 8 in order to keep the wear on the lines as low as possible. The abrasive agent can be added here continuously or else only from time to time.

[0042] By means of the combination of the high pressure water jet cutting with the high frequency rock fragmentation, and by means of the sheet-like design of the drill head 2 and the corresponding positioning of the water outlet nozzles 8 and sonotrodes 9, it is possible to carry out the drilling operation continuously, that is to say without interruptions for refurbishing a drill bit or for removing a cut-free drill core, as is required in the deep drilling methods known from the prior art.

[0043] In order to be able to use a continuously operating drilling method as efficiently as possible, it is advantageous if the borehole 5 can also be secured and lined substantially continuously.

[0044] In order to secure the borehole 5 and also in order to shield the borehole from groundwater-conducting layers, the borehole 5 is lined directly after drilling. For this purpose, the borehole lining module 4 according to the invention has spray nozzles 11 for applying a curing medium, such as, for example, concrete, and a reinforcing fabric laying apparatus 12.

[0045] Use is preferably made of carbon fibers and concrete in order to produce the hybrid material serving for lining the borehole wall, but other fiber materials and other curing media, such as, for example, plastics, are also usable for producing the hybrid material.

[0046] The reinforcing fabric laying apparatus 12 for discharging the fiber structure can take place, for example, via a cone, via which the reinforcing fiber can be applied directly onto the borehole wall in order subsequently to be able to be wetted with curing medium. Depending on the depth and geological conditions, the borehole 5 can be lined with one layer or with multiple layers. The curing time of the concrete can be accelerated by the addition of special additives. In deeper regions with a higher earth temperature, the curing time is reduced simply by the rise in temperature. The concrete supplied via the pipe and/or hose lines is mixed with the additives, which are likewise supplied via the pipe and/or hose lines 6, only at the borehole lining module 4, in order to avoid curing in the supply lines.

[0047] A finished borehole lining 18 is illustrated schematically in FIG. 3.

[0048] The safety module 3 serves, in the event of a sudden rise in pressure in the borehole 5, for example by drilling into a gas bubble, firstly to prevent uncontrolled escape of the gas from the borehole 5 and secondly to prevent the entire drilling system 1 from being able to be pushed upward out of the borehole 5 by the rise in pressure. For this purpose, the safety module 3 has at least one locking element 13 for the form-fitting closing of the inside diameter of the borehole and clamping elements 14 for the force-fitting securing of the drilling system 1 in the borehole 2.

[0049] The diameter of the borehole is closed in a form-fitting manner via the locking element 13, for example with an expander ring which closes the borehole 5, in order then to be able to dissipate the positive pressure in a controlled manner via suitable pressure control valves. The clamping elements 14 with which the entire drilling system 1 can interlock in a force-fitting manner in the borehole 5 are designed, for example, as barbs which face radially upward and outward and fix the drilling system 1 in the respective position in the borehole 5 as the need arises.

[0050] The drive and also the steering and control apparatus for the drill head 2 are arranged on the drill head 2. In the embodiment illustrated, the drive for the drill head 2 is designed as a crawler drive 15 arranged on the outer side of the drill head 2.

[0051] In addition to the electric supply lines, the flexible pipe and/or hose lines 6, via which the drilling system 1 is connected to supply devices 7 outside the borehole 5, also contains data lines, for example a bus system, via which the drill head 2 and/or the safety module 3 and/or the borehole lining module 4 are connected to a workplace 16 outside the borehole 5.

[0052] Via said data lines, in addition to the system parameters, such as, for example, feed speed and pumping pressure, all of the ambient parameters in the borehole 5, such as, for example, temperature, pressure, rock density and the like, can be determined via sensors coupled to the data lines and can be transmitted to the workplace 16 in order to control the drilling system 1.

[0053] The control of the drilling system 1 can be arranged on only one of the components of drill head 2, safety module 3 or borehole lining module 4, or else can be arranged distributed between a plurality of the components 2, 3 and 4.

[0054] Since, in particular, the drill head 2 has a larger outside diameter than the fully lined borehole 5, after the end of the drilling operation the entire drilling system 1 remains in the borehole 5 and, after the capping of the supply lines, can be used via the data lines which continue to exist, in order to exchange data with the workplace 16.

[0055] The drilling method which is described above and is usable for geothermal bores and for opening up natural gas or
oil deposits is distinguished in that a continuous drilling operation is made possible and, by dispensing with drill rods and the like, requires substantially less outlay on material than the drilling methods known from the prior art, which leads to significantly more favorable costs for forming a deep bore.

1. A method for the chisel-less formation of boreholes for deep bores by means of high pressure water jet cutting, characterized by a combination of the high pressure water jet cutting process with high frequency rock fragmentation.

2. The method as claimed in claim 1, characterized in that the high frequency rock fragmentation is used alternating with the high pressure water jet cutting or simultaneously with the high pressure water jet cutting.

3. The method as claimed in claim 1, characterized in that the pressures of the high pressure water jet cutting process and the frequencies of the high frequency rock fragmentation are variably adjustable.

4. The method as claimed in claim 1, characterized in that the wall of the borehole is continuously lined with a reinforcement.

5. A chisel-less drilling system for carrying out the method as claimed in claim 1 with a drill head provided with water outlet nozzles, characterized in that the sonotrodes for transmitting high frequency vibrations are arranged in addition to the water outlet nozzles for the high pressure water jet cutting on the front end side of the drill head.

6. The chisel-less drilling system as claimed in claim 5, characterized in that the drill head, but at least an end plate of the drill head, which end plate is provided with the water outlet nozzles and the sonotrodes, is designed to be rotatable about the center axis.

7. The chisel-less drilling system as claimed in claim 5, characterized in that at least one safety module and at least one borehole lining module are arranged behind the drill head in the drilling direction.

8. The chisel-less drilling system as claimed in claim 7, characterized in that the safety module has at least one locking element for the form-fitting closing of the inside diameter of the borehole, and clamping elements for the force-fitting securing of the drilling system in the borehole.

9. The chisel-less drilling system as claimed in claim 7, characterized in that the borehole lining module has spray nozzles for applying a curing medium, and a reinforcing fabric laying apparatus.

10. The chisel-less drilling system as claimed in claim 5, characterized in that the drill head, the safety module and the borehole lining module are connected to supply devices outside the borehole via flexible pipe and/or hose lines, wherein the pipe and/or hose lines serve for the supply and removal of the materials relating to the drilling system and for the feeding in of the electric supply lines.

11. The chisel-less drilling system as claimed in claim 5, characterized in that the drive and also the steering and control apparatus for the drill head are arranged on the drill head.

12. The chisel-less drilling system as claimed in claim 5, characterized in that the pumps for the high pressure water jet cutting and for sucking off the flushing medium are arranged on the drill head and/or on the safety module.

13. The chisel-less drilling system as claimed in claim 5, characterized in that the drill head and/or the safety module and/or the borehole lining module are connected to a workplace outside the borehole via data lines, for example a bus system.

14. The chisel-less drilling system as claimed in claim 13, characterized in that, via the data lines, in addition to the system parameters, such as, for example, feed speed and pumping pressure, all of the ambient parameters in the borehole, such as, for example, temperature, pressure, rock density and the like, can be determined via sensors coupled to the data lines and can be transmitted to the workplace in order to control the drilling system.

15. The chisel-less drilling system as claimed in claim 5, characterized in that, in order to generate the high frequency pulses for the high frequency rock fragmentation, piezo elements which are each coupled to an amplifying unit consisting of a sonotrode and an amplitude transformer are arranged in the drill head.

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