Title: METHOD FOR CONTROLLING DRILLING UNIT OF ROCK DRILLING RIG, AND ROCK DRILLING RIG

Abstract: When excavating a rock cavern one round at a time by a rock drilling rig (1) comprising at least one drilling boom (3) and at least one drilling unit (4) arranged in the drilling boom (3), holes (21) of a round are drilled in accordance with a drilling pattern (14) designed for the round. In order to drill each single hole (21), the drilling unit (4) is controlled into a rotating angle (Φ) which carries out a location (21') and direction determined for the particular hole (21) in the drilling pattern (14) designed for the particular round. The rotating angle (Φ) of the drilling unit (4) to be used for drilling the hole (21) is determined on the basis of the rotating angle (Φ) of the drilling unit (4) carried out in connection with the drilling of one or more previously drilled holes (21).

(1) International Application Published Under the Patent Cooperation Treaty (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 June 2012 (07.06.2012)

(51) International Patent Classification:
E21B 7/02 (2006.01) E21B 44/00 (2006.01)

(21) International Application Number:
PCT/FI2011/00101

(22) International Filing Date:
16 November 2011 (16.11.2011)

(25) Filing Language:
Finnish

(26) Publication Language:
English

(30) Priority Data:
20106255 FI 29 November 2010 (29.11.2010) FI

(71) Applicant (for all designated States except US): SANDVIK MINING AND CONSTRUCTION OY [FI/FI]; Pihtisulunkatu 9, FI-33330 Tampere (FI).

(72) Inventor; and

(75) Inventor/Applicant (for US only): PUURA, Jussi [FI/FI]; c/o Sandvik Mining and Construction Oy, Pihtisulunkatu 9, FI-33330 Tampere (FI).

(74) Agent: KOLSTER OY AB; Iso Roobertinkatu 23, P.O. Box 148, FI-00121 Helsinki (FI).


(54) Title: METHOD FOR CONTROLLING DRILLING UNIT OF ROCK DRILLING RIG, AND ROCK DRILLING RIG

1. Starting drilling of hole

2. Distributing, among booms, location and rotating angle data associated with previously drilled holes

3. Calculating distances between hole to be drilled and previously drilled holes

4. Arranging calculated distances in order of magnitude

5. Determining rotating angle associated with hole to be drilled

6. Storing rotating angle of drilling unit carried out in drilling of drilled hole

FIG. 4

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

—— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(H))
Method for controlling drilling unit of rock drilling rig, and rock drilling rig

Background of the invention

[0001] The invention relates to a method for controlling at least one drilling unit arranged in at least one drilling boom of a rock drilling rig when excavating a rock cavern one round at a time, the method comprising drilling holes of a round in accordance with a drilling pattern designed for the round, controlling, in order to drill each single hole, the drilling unit into a rotating angle which carries out a location and direction determined in the drilling pattern of the particular round for the particular hole, and storing the rotating angle of the drilling unit carried out during the drilling of each hole of the round.

[0002] The invention further relates to a rock drilling rig comprising a movable carrier, at least one drilling boom, at least one drilling unit arranged in the drilling boom, the drilling unit comprising a feed beam and a rock drill, the rock drill being arranged to be movable on the feed beam by means of a feed device, a rotating mechanism for rotating the drilling unit into a rotating angle, at least one storage unit configured to store a drilling pattern to be used for drilling a round to be excavated for a rock cavern, at least one control unit configured, via the rotating mechanism, to control the drilling unit into a rotating angle which carries out a location and direction determined for a hole in the drilling pattern of the round, and at least one storage unit configured to store the rotating angle of the drilling unit carried out in the drilling of each hole of the round to be excavated.

[0003] Tunnels, underground storage halls and other rock caverns are excavated in rounds, i.e. one round at a time, in other words, by employing a so-called drill-and-blast method, such that holes are drilled at a face of a rock cavern and then, after drilling, charged and blasted. Thus, one blast serves to break off rock material from the rock in an amount equal to that of one round.

[0004] For excavating a rock cavern, a plan is made in advance and information is determined about the rock type, for instance. Usually, the orderer of the rock cavern also sets different quality requirements on the cavern to be excavated. For each round, a drilling pattern is designed as office work and delivered to the rock drilling rig for drilling holes in the rock so as to generate a desired round. The drilling pattern includes at least the locations of the holes to be drilled and their directions and lengths or alternative start and end points of the holes to be drilled. Further, the drilling pattern designer may also determine
in the drilling pattern a rotating angle of the drilling unit for each hole of a round, such an angle being generally also referred to as a "roll-over" or a "roll-over angle". By choosing the rotating angle correctly, it can be better ensured that the drilling boom or the drilling unit does not collide with the walls, ceiling or floor of the rock cavern during the drilling of the holes, and that a drill rod of the rock drill of the drilling unit is visible to the operator of the rock drilling rig during the drilling of a hole, and that the drilling unit does not collide with the drilling boom of the rock drilling rig during the drilling of holes which, with respect to the rock drilling rig, come close to a point where the drilling unit is supported against the drilling boom, either.

[0005] However, the rotating angles of the drilling unit determined by the drilling pattern designer in the drilling pattern are quite seldom useful in a drilling situation in practice. This may be for instance because the designer of the drilling pattern does not see the practical situation in the rock cavern or even necessarily know the size of the rock drilling rig to be used for drilling a particular round. Consequently, the designer of the drilling pattern is not in practice capable of determining the rotating angles of the drilling unit for all holes such that it would be possible to drill all the holes by employing the particular rotating angles of the drill unit suggested by the designer of the drilling pattern without the operator of the rock drilling rig having to control the drilling unit into a new rotating angle with respect to no hole at all. Problems arise particularly at the edges of a rock cavern if the rotating angle of the drilling unit determined in the drilling pattern is such that the drilling unit tries to turn into a position wherein it comes into contact with the edge of the rock cavern, and also in the central part of the rock cavern, where a cut hole is drilled, if the rotating angle of the drilling unit determined in the drilling pattern is such that the drilling unit tries to turn into a position where it collides with the drilling boom of the rock drilling rig. In addition to these, another problematic situation arises when the rotating angle of the drilling unit given in the drilling pattern is such that the drilling unit tries to turn into a position where the drilling boom prevents the operator of the rock drilling rig from seeing the drill rod of the rock drill provided in the drilling unit when, in practice, the operator of the rock drilling rig wishes to see the drill rod for the purpose of monitoring the drilling and its advance as well as the condition of the drill rod, and for detecting possible water flowing out of the hole. Presently, in order to avoid all the aforementioned situations, the operator of the rock drilling rig has to monitor the operation of an
automatic drilling cycle of the rock drilling rig very carefully and, when necessary, control the drilling unit into a new rotating angle upon starting the drilling of at least some holes, which slows down the drilling cycle and its advance.

**Brief description of the invention**

[0006] An object of the invention is to provide a solution which enables the reliability and speed of advance of the operation of an automatic drilling cycle to be increased.

[0007] The method according to the invention is characterized by determining the rotating angle of the drilling unit to be used for drilling a hole on the basis of the rotating angle of the drilling unit carried out in connection with the drilling of one or more previously drilled holes.

[0008] The rock drilling rig according to the invention is characterized in that the control unit is configured to determine the rotating angle of the drilling unit to be used for drilling a hole on the basis of the rotating angle of the drilling unit carried out in connection with the drilling of one or more previously drilled holes.

[0009] When excavating a rock cavern one round at a time by a rock drilling rig comprising at least one drilling boom and at least one drilling unit arranged in the drilling boom, holes of a round are drilled in accordance with a drilling pattern designed for the round. In order to drill each single hole, the drilling unit is controlled into a rotating angle which carries out a location and direction determined for the particular hole in the drilling pattern designed for the particular round. The rotating angle of the drilling unit to be used for drilling the hole is determined on the basis of the rotating angle of the drilling unit carried out in connection with the drilling of one or more previously drilled holes.

[0010] The solution thus utilizes values of the rotating angles of the drilling unit carried out in connection with previously drilled holes when determining the rotating angle of the drilling unit to be used in connection with drilling a hole to be drilled next. The previously drilled holes may thus be only previously drilled holes of the same round being presently excavated, or they may also be holes drilled in connection with already previously excavated rounds. The determination of a rotating angle of the drilling unit to be used for drilling holes is thus based on the rotating angles of the drilling unit actually carried out in connection with the previously drilled holes, which enables a situation to be achieved very quickly wherein a vast majority or even almost all of the holes of
a round may be drilled by using the rotating angle of the drilling unit determined by the disclosed solution. In such a case, the operator of the rock drilling rig very seldom needs to participate in choosing the rotating angle to be used for drilling a hole. This makes a round quicker to drill, and it releases the capacity of the operator of the rock drilling rig for monitoring the drilling and the condition of the drilling equipment.

[0011] According to an embodiment, when determining the rotating angle of the drilling unit to be used for drilling a hole, the method comprises choosing, as initial data for the determination, location data about the hole and data about the rotating angle of the drilling unit associated with those already drilled holes which were drilled by the drilling unit arranged in the same drilling boom as the drilling unit to be used for drilling the hole to be drilled, determining a distance between the already drilled holes chosen in the previous step and the hole to be drilled, and choosing, on the basis of the distance between the already drilled holes and the hole to be drilled, one or more already drilled holes on the basis of whose rotating angle of the drilling unit carried out in the drilling thereof the rotating angle of the drilling unit to be used for drilling the hole to be drilled is determined, and determining, on the basis of the rotating angle of the drilling unit carried out in the drilling of the one or more already drilled holes, the rotating angle of the drilling unit to be used for drilling the hole to be drilled.

[0012] When the rotating angle of the drilling unit to be used for drilling the hole to be drilled is determined on the basis of the rotating angles carried out in the drilling of the already drilled holes located at a certain distance from the hole to be drilled, the value of the rotating angle of the drilling unit given by the determination is very accurate, since the determination of the rotating angle utilizes data associated with a limited number of previously drilled holes.

[0013] According to a second embodiment, the method comprises determining the rotating angle of the drilling unit to be used for drilling the hole to be drilled to correspond with the rotating angle of the drilling unit carried out in the drilling of an already drilled hole closest to the hole to be drilled. In this embodiment, the determination of the rotating angle is very simple, and it is very likely that the value of the rotating angle of the drilling unit used in the drilling of the distance-wise closest already drilled hole is very suitable for use in the drilling of the next hole to be drilled.
According to a third embodiment, the method comprises determining the rotating angle of the drilling unit to be used for drilling the hole to be drilled to correspond, by a predetermined quantity, with a mean value of the rotating angles of the drilling unit carried out in the drilling of the distance-wise closest already drilled holes. In such a case, the value of the rotating angle of the drilling unit used in connection with one, already drilled hole does not have too great importance for the rotating angle of the hole being presently drilled, which is advantageous if, for some reason, the value of the rotating angle of the drilling unit used in connection with the already drilled hole is completely unsuitable for use as the value of the rotating angle of the drilling unit in connection with the hole being presently drilled.

Brief description of the figures

The invention is now described in closer detail in connection with preferred embodiments and with reference to the accompanying drawings, in which:

Figure 1 is a schematic side view showing a rock drilling rig.
Figures 2a and 2b are schematic side views showing some rotating mechanisms which may be used for turning a drilling unit into a correct position for a drilling event, and Figures 2c and 2d schematically show a rotating angle of a drilling unit as seen from behind the drilling unit,
Figure 3 is a diagram schematically showing holes and a rotating angle of a drilling unit carried out in connection with drilling of each hole,
Figure 4 is a flow diagram schematically showing a method for determining a rotating angle of a drilling unit to be used for drilling a single hole of a round to be drilled,
Figures 5a and 5b schematically show a detail in determination of a rotating angle of a drilling unit to be used for drilling a single hole of a round to be drilled,
Figure 6 schematically shows another detail in determination of a rotating angle of a drilling unit to be used for drilling a single hole of a round to be drilled, and
Figures 7 to 10 schematically show examples relating to a use of the method according to Figure 4.
Detailed description of the invention

[0016] Figure 1 is a schematic side view showing a rock drilling rig 1 which may be used for excavating a rock cavern. The rock drilling rig 1 according to Figure 1 comprises a movable carrier 2, two drilling booms 3, and drilling units 4 arranged in the drilling booms 3. As distinct from Figure 1, the rock drilling rig 1 may be provided with only one drilling boom 3, or the number of drilling booms 3 may even be more than two. The drilling unit 4, which is shown larger in Figure 2, comprises a feed beam 5 and, arranged thereon, a rock drill 6 which may be moved with respect to the feed beam 5 by a feed device 22 shown schematically in Figures 1 and 2. The drilling unit 4 further comprises a tool 7, such as a drill rod, enabling impact pulses given by a percussion device, which for the sake of clarity is not shown, of the rock drill 6 to be transmitted to a rock 8 to be drilled. The rock drilling rig 1 further comprises at least one control unit 9 configured to control actuators of the rock drilling rig 1 for controlling operation of the drilling boom 3 and the drilling unit 4, for instance. The control unit 9 may be a computer or a corresponding device, and it may comprise a user interface, including a display device, as well as control means, such as a keyboard or a joystick, for communicating commands and information to the control unit 9.

[0017] In Figure 1, the drilling unit 4 is arranged in the drilling boom 3 of the rock drilling rig 1, in connection with the end of the drilling boom 3, by means of a rotating mechanism 10. Figures 2a and 2b show schematic examples of some possible rotating mechanisms 10. The rotating mechanisms 10 according to Figures 2a and 2b are provided with a rotating unit 11 which, in the embodiment of Figures 2a and 2b, includes a rotating joint 11' or a roll-over joint 11 and an actuator, such as a hydraulic motor, which, for the sake of clarity, is not shown in the figures, enabling a rotating motion to be produced in the rotating joint 11'. The rotating unit 11 or the rotating joint 11' has a rotating axis A, or, in other words, the rotating unit 11 or the rotating joint 11' defines the rotating axis A, which is substantially parallel with the feed beam 5 of the drilling unit 4 and around which the drilling unit 4 is arranged to turn or rotate as a consequence of the rotating motion of the rotating unit 11 or the rotating joint 11' in a manner schematically shown by arrow A', in which case the value of the rotating angle Φ describes the quantity of rotating of the drilling unit 4 around the rotating axis A. The rotating axis A is shown in Figures 2a and 2b schematically in broken line.
[0018] In the embodiments shown in Figures 2a and 2b, the rotating mechanism 10 further comprises a turning unit 12 including a turning joint 12', and an actuator, which, for the sake of clarity, is not shown in the figures, for turning the drilling unit 4 sideways around an axis B in the direction shown by arrow B'. In addition, in the embodiments shown in Figures 2a and 2b, the rotating mechanism 10 further comprises a second turning unit 13 including a second turning joint 13', and an actuator, which, for the sake of clarity, is not shown in the figures, for turning the drilling unit 4 sideways around an axis C, which, for the sake of clarity, is not shown in the figures, for turning the drilling unit 4 along an axis perpendicular to the surface of the paper in Figures 2a and 2b, in the direction shown by arrow C.

[0019] The rotating mechanisms 10 shown in Figures 2a and 2b are only some feasible examples of rotating mechanisms that enable the drilling unit 4 to be rotated around the aforementioned rotating axis A. Thus, in connection with the solution disclosed in this description, any other rotating mechanism may also be used which enables at least said rotating of the drilling unit 4 around the rotating axis A to be achieved.

[0020] Figures 2c and 2d schematically show a rotating angle \( \Phi \) of the drilling unit 4 as seen from behind the drilling unit 4. In Figure 2c, the drilling unit 4 has rotated around the rotating axis A of the drilling unit 4 to the left with respect to a vertical axis corresponding with the vertical position of the drilling unit 4 and indicated by a value of 0 degree of the rotating angle \( \Phi \). The rotating direction shown in Figure 2c has been determined to be a rotating direction corresponding with a negative rotating angle. In Figure 2d, the drilling unit 4, in turn, has rotated around the rotating axis A of the drilling unit 4 to the right with respect to a vertical axis corresponding with the vertical position of the drilling unit 4 and indicated by a value of 0 degree of the rotating angle \( \Phi \). The rotating direction shown in Figure 2d has been determined to be a rotating direction corresponding with a positive rotating angle. However, the connection between the rotating angle \( \Phi \) and the rotating direction of the drilling unit 4 may also be determined in some other way which differs from that shown in Figures 2c and 2d.

[0021] Typically, for the drilling of holes of each round for a rock cavern, a drilling pattern 14 is provided which determines the locations, directions and lengths of the holes to be drilled or, alternatively, start and end points of the holes in a coordinate system of the drilling pattern. Typically, a drilling
pattern is made outside a drilling site, e.g. in an office 15, wherein the drilling pattern 14 may be stored on a memory member, such as a memory stick or a diskette, provided therein, or it may be transferred directly via a data transfer connection 16 to a storage unit 17 provided in the rock drilling rig 1. The storage unit 17 may either be included in the control unit 9, or it may be a storage unit located outside the control unit 9 and communicating with the control unit 9. The drilling pattern 14 may also be amended either at or outside the drilling site. The preparation of the drilling pattern 14 is a computer-aided process, and usually iterative in nature. A design program is run on a computer 18, and a designer 19 operates interactively with the design program, entering necessary data, making selections as well as controlling the design process. During the design process, the already designed parts of the drilling pattern may yet be iteratively amended so as to achieve a better end result. In the drilling pattern 14, the designer 14 may also determine for each hole his or her suggestion concerning the roll-over angle Φ or the rotating angle Φ to be used in the drilling of a hole.

[0022] After the drilling pattern 14 is made, it may be stored in the storage unit 17 of the rock drilling rig 1 and implemented in the control unit 9. The holes designed in the drilling pattern 14 are then drilled into the rock 8, charged and blasted. A quantity of rock equal to that of a desired round is broken off the rock 8 and transported elsewhere. Next, new holes are drilled for the next round, in accordance with a new drilling pattern 14.

[0023] Figure 3 schematically shows a diagram 20 or a rotating angle diagram 20 wherein the locations of holes 21 carried out in a drilled round are indicated by circles 21′, while directional lines 21″ extending from the circles 21″ indicate the rotating angle Φ of the drilling unit 4 carried out during the drilling of each hole 21. When a round which corresponds with the rotating angle pattern 20 shown in Figure 3 was drilled, a rock drilling rig 1 provided with two drilling booms 3 has been used, whereby the locations 21′ of the holes 21 indicated in thin lines in Figure 3 and the directional lines 21″ corresponding with the rotating angles Φ of the drilling unit 4 carried out are holes 21 drilled by the drilling unit 4 arranged in a first drilling boom 3 of the rock drilling rig 1, while the locations 21′ of the holes 21 indicated in thick lines and the directional lines 21″ corresponding with the rotating angles Φ of the drilling unit 4 carried out are holes 21 drilled by the drilling unit 4 arranged in a second drilling boom 3 of the rock drilling rig 1. The rotating angles Φ of the drilling unit 4 cor-
responding with the directional lines 21 of the rotating angle diagram 20 shown in Figure 3 are, during or after drilling the round, stored in a storage unit provided in the rock drilling rig 1, which storage unit may be the same as the storage unit 17 previously described in this description and Figure 1, or the storage unit may be e.g. a storage unit which communicates with the control unit 9 and is only used for storing the rotating angles Φ carried out in connection with the drilling of the holes 21. Data about the location 21' of each hole 21 may also be stored in connection with data indicating the rotating angle Φ of the drilling unit 4 carried out in connection with the corresponding hole 21 if the data about the rotating angle Φ of the drilling unit 4 carried out in connection with the hole 21 are not otherwise linked, e.g. via the drilling pattern 14, with the data indicating the location 21' of the corresponding hole 21.

[0024] Figure 4 is a flow diagram schematically showing a method or a calculation algorithm for determining a rotating angle Φ of a drilling unit 4 to be used for drilling a single hole 21 of a round to be drilled next. In Figure 4, a starting phase or an initial situation of drilling the hole 21 is indicated by a phase number one. In this starting phase, data about the locations 21' of the holes 21 drilled in connection with previous rounds and the rotating angles Φ of the drilling unit 4 carried out during the drilling of the particular holes 21 is collected from the storage unit 17 into a temporary working storage or another suitable memory provided in the control unit 9, for instance. Said data may also comprise the location data about the holes 21 associated with the holes 21 already previously drilled during the drilling of the same round and the data about the rotating angles Φ of the drilling unit 4 carried out during the drilling of the particular holes 21. Location data about a hole 21 refers to a starting location of the hole 21 in the drilling of each round. Said data may comprise data about the locations 21' and the rotating angles Φ that have been carried out of the holes 21 of all rounds that have already been drilled, or data only about the locations 21' and the rotating angles Φ that have been carried out of the holes 21 of e.g. 3 to 5 rounds that have been drilled most recently. In the drilling of the holes 21 of the first round for a rock cavern, the rotating angles Φ of the drilling unit 4 separately suggested by the designer 19 in the drilling pattern 14 may be used, or the operator of the rock drilling rig 1 may control the drilling unit 4 into a desired rotating angle Φ when starting the drilling of at least some or even all of the holes 21.
In the next phase of the drilling of the hole 21, i.e. in phase 2 of the diagram in Figure 4, data about the locations 21' of the holes 21 and the rotating angles $\Phi$ of the drilling unit 4 associated therewith that relate to the drilling boom 3 by whose drilling unit 4 the hole 21 is to be drilled are separated from the data collected in the starting phase.

In the next phase of the drilling of the hole 21, i.e. in phase 3 of the diagram in Figure 4, a distance between the location 21' of each hole 21 chosen in phase 2 and the location of the hole 21 to be drilled next is determined in the control unit 9. The distance may be determined by taking into account the distance between the previously drilled holes 21 and the hole 21 to be drilled next on the two-dimensional plane at the face of the rock cavern where the hole 21 to be drilled next is located. In this case, the previously drilled holes 21 are thus projected onto the same two-dimensional plane as the hole 21 to be drilled next. It is also feasible that when determining the distance, the distance in a three-dimensional space between the locations 21' of the previously drilled holes 21 and the hole 21 to be drilled next is taken into account also in the direction of progression of excavation of the rock cavern e.g. such that with respect to the round being drilled, the distances between the locations 21' of the holes 21 drilled in connection with the very previous round and the hole 21 to be drilled next is considered more important than the distances between the locations 21' of the holes 21 drilled in connection with the already previously excavated rounds and the location of the hole 21 to be drilled next.

In the next phase of the drilling of the hole 21, i.e. in phase 4 of the diagram in Figure 4, the distances calculated in phase 3 may be arranged in the order of magnitude.

In the next phase of the drilling of the hole 21, i.e. in phase 5 of the diagram in Figure 4, the rotating angle $\Phi$ of the drilling unit 4 associated with the hole 21 to be drilled is determined on the basis of the rotating angle $\Phi$ of the drilling unit 4 carried out in connection with one or more previously drilled holes 21. The rotating angle $\Phi$ of the drilling unit 4 associated with the hole 21 to be drilled may be determined or calculated in many different ways.

An alternative is to use directly the rotating angle $\Phi$ of the drilling unit 4 carried out in the drilling of the already drilled hole 21 distance-wise closest to the hole 21 to be drilled.
[0030] A second alternative is to determine the rotating angle $\Phi$ of the drilling unit 4 to be used in the drilling of the hole 21 to correspond with a mean value $\Phi_{\text{mean}}$ of the rotating angles $\Phi$ of the drilling unit 4 carried out in the drilling of a predetermined number of, e.g. two or more, such as 3 to 5, distance-wise closest already drilled holes 21.

[0031] A third alternative is to use, for drilling the hole 21 to be drilled, a value of the rotating angle $\Phi$ of the drilling unit 4 which corresponds with a mean value $\Phi_{\text{mean}}$ of the rotating angles $\Phi$ of the drilling unit 4 carried out in connection with the drilling of the already drilled holes 21 residing at no more than a certain distance, such as at a distance of no more than one metre, from the hole 21 to be drilled next, or, if no previously drilled hole resides at said distance of e.g. no more than one metre, to use the rotating angle $\Phi$ of the drilling unit 4 carried out in connection with the drilling of the closest previously drilled hole 21.

[0032] In the determination of the rotating angle $\Phi$ of the drilling unit 4 associated with the hole 21 to be drilled next, it may also be taken into account how the location of the rock drilling rig 1 varies with respect to the origin or zero point of the drilling pattern 14 used for drilling the round when drilling successive rounds of the rock cavern. Figure 5a schematically shows a situation wherein the origin OR1 of an imaginary coordinate system associated with the dimensions of the rock drilling rig 1 and attached to the rock drilling rig 1 resides at the same point as, or congruently with, the origin OR2 of the coordinate system of the drilling pattern 14. The origin OR1 of the coordinate system associated with the rock drilling rig 1 may reside e.g. in a joint of the rock drilling rig 1 which connects the drilling booms 3 with the rock drilling rig 1, as schematically shown in Figure 1.

[0033] In the situation shown in Figure 5b, the rock drilling rig 1 is located in a rock cavern to be excavated in such a position wherein the location of the origin OR1 of the coordinate system associated with the rock drilling rig 1 differs from the location of the origin OR2 of the drilling pattern 14. This difference between the location of the origin OR1 of the rock drilling rig 1 and the location of the origin OR2 of the drilling pattern 14 may preferably be taken into account when determining the rotating angle to be used in the drilling of the hole 21 to be drilled next e.g. in the following manner. First, when the value of the rotating angle $\Phi$ of the drilling unit 4 carried out in the drilling of the drilled hole 21 is stored, subtracting from said value of the rotating angle $\Phi$ a
proportion or quantity or value which results from the difference between the location of the origin OR1 of the rock drilling rig 1 and the location of the origin OR2 of the drilling pattern 14. Further, when the drilling of the hole 21 to be drilled next is started utilizing the value of the rotating angle Φ of the drilling unit 4 determined as disclosed above, adding to the value of the particular rotating angle Φ a proportion or quantity or value which corresponds with the difference between the location of the origin OR1 of the rock drilling rig 1 and the location of the origin OR2 of the drilling pattern 14.

[0034] In the manner disclosed in the previous paragraph, it is thus possible to compensate for the variation in the location of the rock drilling rig 1 with respect to the origin OR2 of the drilling pattern 14. The necessary calculation may be performed in the control unit 9, for instance. When making said compensation, the coordinates of the origin OR1 of the rock drilling rig 1 are projected onto the same plane as that of the coordinate system of the drilling pattern 14. In the previous paragraph, the values of the rotating angles Φ of the drilling unit 4 carried out in the drilling of the holes 21 were attached to the origin OR2 of the drilling pattern 14. Alternatively, the values of the rotating angles Φ of the drilling unit 4 carried out in the drilling of the holes 21 could be attached or determined also with respect to the origin OR1 of the coordinate system associated with the rock drilling rig 1, in which case in connection with excavation of each round, data about the location of the origin OR1 of the rock drilling rig 1 with respect to the origin OR2 of the drilling pattern 14 is also stored so as to enable the difference between the location of the origin OR1 of the rock drilling rig 1 and the location of the origin OR2 of the drilling pattern 14 to be taken into account when determining the rotating angle Φ of the drilling unit 4 to be used in connection with the hole 21 to be drilled next.

[0035] In the next phase of drilling the hole 21, i.e. in phase 6 of the diagram in Figure 4, the rotating angle Φ of the drilling unit 4 used in connection with the drilling of the hole 21 is stored in the storage unit 17. The rotating angle Φ of the drilling unit 4 used in the drilling of the hole 21 may be stored simultaneously, after drilling the round, in connection with storing the rotating angles Φ of the drilling unit 4 used in connection with the drilling of the other holes 21 of the same round, in which case the rotating angles Φ of the drilling unit 4 carried out and associated with all the holes 21 of the round are stored simultaneously after drilling the round. Preferably, the value of the rotating angle Φ of the drilling unit 4 carried out in the drilling of a single hole 21 of the
round is stored immediately during or after the drilling of the hole 21, in which case the particular value carried out may be used for determining the rotating angle $\Phi$ of the drilling unit 4 to be used already in the drilling of the hole 21 to be drilled next in the same round.

[0036] Thus, the method utilizes the values of the rotating angles $\Phi$ of the drilling unit 4 carried out in connection with the already previously drilled holes 21 for determining the value of the rotating angle $\Phi$ of the drilling unit 4 to be used in the drilling of the next hole 21.

[0037] The value of the rotating angle $\Phi$ of the drilling unit 4 to be used for the drilling of the hole 21 may be determined e.g. in degrees or another corresponding numerical value or another appropriate value. In such a case, for instance, if the value of the rotating angle $\Phi$ of the drilling unit 4 associated with one previous hole 21 is 34 degrees while the value of the rotating angle $\Phi$ of the drilling unit 4 associated with another previous hole is 40 degrees, their mean value is 37 degrees if the value of the rotating angle $\Phi$ of the drilling unit 4 to be used for drilling the next hole 21 is determined on the basis of the values of the rotating angles $\Phi$ of the drilling unit 4 carried out in connection with two previously drilled holes 21.

[0038] However, a problem in the aforementioned manner of calculation arises when the value of the rotating angle $\Phi$ of the drilling unit 4 associated with one previous hole 21 is 170 degrees while the value of the rotating angle $\Phi$ of the drilling unit 4 associated with another previous hole 21 is -170 degrees, whereby, in view of the above, their mean value would be 0 degree when, however, the desired result would be either 180 degrees or -180 degrees. This situation is illustrated in Figure 6 wherein the value of the rotating angle $\Phi$ of the drilling unit 4 indicated by arrow $\Phi$ 1 is 170 degrees while the value of the rotating angle $\Phi$ of the drilling unit 4 indicated by arrow $\Phi$ 2 is -170 degrees, in which case their mean value is 0 degree, as indicated by arrow $\Phi$ 3, rather than 180 degrees or -180 degrees, as it should be, as indicated by arrow $\Phi$ 4.

[0039] This problem may be avoided by dividing, in potential calculation of a mean value, the values of each single rotating angle $\Phi$ first into a vertical component $\Phi_{\text{sin}} = \sin(\Phi \pi/180^\circ)$ and a horizontal component $\Phi_{\text{cos}} = \sin(\Phi \pi/180^\circ)$, wherein $\pi$ is thus pi, i.e. mathematical Archimedes' constant or Ludolph's number. Next, mean values $\Phi_{\text{sin\_mean}}$ of the vertical components and the mean values $\Phi_{\text{cos\_mean}}$ of the horizontal components of the rotat-
ing angles $\Phi$ of the drilling unit 4 carried out are calculated separately. The final mean value $\Phi_{\text{mean}}$ of the rotating angles $\Phi$ of the drilling unit 4 to be used for drilling a hole is obtained on the basis of the aforementioned mean value of the vertical components and the aforementioned mean value of the horizontal components, from formula $\Phi_{\text{mean}} = \text{atan2}(\Phi_{\text{cos_mean}}, \Phi_{\text{sin_mean}})$, whereby in the aforementioned example, the value of the rotating angle $\Phi$ of the drilling unit 4 to be used in the drilling of the hole 21 is 180 degrees or -180 degrees, as indicated by arrow $\Phi_4$.

[0040] In the previous example, the determination of the rotating angle $\Phi$ of the drilling unit 4 to be used in the drilling of the hole 21 to be drilled next is shown to be performed by utilizing the control unit 9 provided in the rock drilling rig 1 and the storage unit 17. However, it is possible that the determination of the rotating angle $\Phi$ of the drilling unit 4 to be used in the drilling of the hole 21 to be drilled next is performed e.g. by the computer 18 in the office 15 or by another computer outside the drilling site, in which case the necessary data about the rotating angles $\Phi$ of the drilling unit 4 carried out in connection with the drilling of the already drilled holes 21 is communicated to the particular computer via the data transfer connection 16. In such a case, again via the data transfer connection 16, data about the rotating angle $\Phi$ of the drilling unit 4 to be used in the drilling of the hole 21 to be drilled next is then communicated to the control unit 4 of the rock drilling rig 1 either from the computer 18 in the office 15 or from another computer. It is also possible that the values of the rotating angles $\Phi$ of the drilling unit 4 that have been determined on the basis of the values of the rotating angles $\Phi$ of the drilling unit 4 carried out in the drilling of the previous holes 21 and that are to be used for drilling the holes 21 of a round to be drilled next are incorporated into the drilling pattern 14 of the round to be drilled next.

[0041] Figures 7 to 10 schematically show an example of a relation between the rotating angles $\Phi$ of the drilling unit 4 determined by the method according to Figure 4 and the rotating angles $\Phi$ of the drilling unit 4 carried out in the drilling of the already drilled holes 21 and used for the determination. In the example of Figures 7 to 10, a rock drilling rig provided with two drilling booms 3, each having one drilling unit 4, is used as the rock drilling rig 1.

[0042] Figure 7 shows, by employing circles drawn in thin line, the locations 21' of the holes 21 designated as residing within the coverage area or operation area of a first boom 3 of the rock drilling rig 1 and, by employing
directional lines 21" drawn in thin line, the rotating angles Φ of the drilling unit 4 determined by the aforementioned method for the particular holes 21. Said rotating angles Φ are thus suggestions about those rotating angles Φ of the drilling unit 4 suggested by the aforementioned method for use in the drilling of the holes 21 of the round. A thick line designates those previously drilled holes 21 and the rotating angles Φ of the drilling unit 4 carried out that were used for determining the rotating angles Φ of the drilling unit 4 designated in said thin lines. In the case shown in Figure 7 there was one previously drilled round. Figure 8, in turn, shows a pattern corresponding with Figure 6 in a situation wherein there were three previously drilled rounds. Figures 9 and 10 show a corresponding example concerning the coverage area or operation area of a second drilling boom 3 of the rock drilling rig 1. It can be seen in Figures 7 to 10 how already after three excavated rounds, the suggestions designated in thin line about the values of the rotating angles Φ of the drilling unit 4 to be used in connection with the holes 21 of the round to be drilled next are already very much in accordance with the rotating angles Φ that were carried out.

[0043] The disclosed solution thus utilizes the values of the rotating angles Φ of the drilling unit 4 carried out in connection with the previously drilled holes 21 when determining the rotating angle Φ of the drilling unit 4 to be used in connection with the drilling the hole 21 to be drilled next. Since the determination of the rotating angle Φ of the drilling unit 4 to be used in the drilling of the holes 21 is based on the actual rotating angles Φ of the drilling unit 4 carried out in connection with the previously drilled holes 21, a situation is very quickly achieved wherein a vast majority of the holes 21 of a round may be drilled by using a rotating angle Φ of the drilling unit 4 determined by the disclosed solution such that the operator of the rock drilling rig 1 seldom has to participate in choosing the rotating angle Φ of the drilling unit 4 to be used in the drilling of the hole 21. This makes the round quicker to drill, and it releases the capacity of the operator of the rock drilling rig 1 for monitoring the drilling and the condition of the drilling equipment. Thus, the solution also takes into account the real drilling situation prevalent in the rock cavern as well as the size and type of the rock drilling rig actually being used for the drilling. Since the determination of the rotating angle Φ of the drilling unit 4 may be implemented automatically e.g. in the control unit 9 of the rock drilling rig 1 or by the computer 15 in the office 15, the designer 19 of the drilling pattern 14 no longer has to determine the rotating angles Φ of the drilling unit 4, possibly except
for the rotating angles $\Phi$ of the drilling unit 4 associated with the holes 21 of
the first round of a rock cavern, whereby the capacity of the designer 19 of the
drilling pattern 14 may also be released for other tasks.

[0044] It will be obvious to a person skilled in the art that as technology advances, the basic idea of the invention may be implemented in many different ways. The invention and its embodiments are thus not restricted to the examples described above but may vary within the scope of the claims.
Claims

1. A method for controlling at least one drilling unit (4) arranged in at least one drilling boom (3) of a rock drilling rig (1) when excavating a rock cavern one round at a time, the method comprising

- drilling holes of a round in accordance with a drilling pattern (14) designed for the round,
- controlling, in order to drill each single hole (21), the drilling unit (4) into a rotating angle (Φ) which carries out a location (21') and direction determined in the drilling pattern (14) of the particular round for the particular hole (21), and
- storing the rotating angle (Φ) of the drilling unit (4) carried out during the drilling of each hole (21) of the round,

characterized by

- determining the rotating angle (Φ) of the drilling unit (4) to be used for drilling the hole (21) on the basis of the rotating angle (Φ) of the drilling unit (4) carried out in connection with the drilling of one or more previously drilled holes (21).

2. A method as claimed in claim 1, characterized by determining the rotating angle (Φ) of the drilling unit (4) to be used for drilling the hole (21) on the basis of the rotating angle (Φ) of the drilling unit (4) carried out in connection with the drilling of one or more holes (21) of one or more previously drilled rounds.

3. A method as claimed in claim 1 or 2, characterized by when determining the rotating angle (Φ) of the drilling unit (4) to be used for drilling the hole (21),

- choosing, as initial data for the determination, location data (21') about the hole (21) and data about the rotating angle (Φ) of the drilling unit (4) associated with those already drilled holes (21) which were drilled by the drilling unit (4) arranged in the same drilling boom (3) as the drilling unit (4) to be used for drilling the hole (21) to be drilled,
- determining a distance between the already drilled holes (21) chosen in the previous step and the hole (21) to be drilled, and
- choosing, on the basis of the distance between the already drilled holes (21) and the hole (21) to be drilled, one or more already drilled holes (21) on the basis of whose rotating angle (Φ) of the drilling unit (4) carried out in the
drilling thereof the rotating angle ($\Phi$) of the drilling unit (4) to be used for drilling the hole (21) to be drilled is determined, and
determining, on the basis of the rotating angle ($\Phi$) of the drilling unit (4) carried out in the drilling of the one or more already drilled holes (21), the rotating angle ($\Phi$) of the drilling unit (4) to be used for drilling the hole (21) to be drilled.

4. A method as claimed in claim 3, characterized by determining the rotating angle ($\Phi$) of the drilling unit (4) to be used for drilling the hole (21) to be drilled to correspond with the rotating angle ($\Phi$) of the drilling unit (4) carried out in the drilling of an already drilled hole (21) closest to the hole (21) to be drilled.

5. A method as claimed in claim 3, characterized by determining the rotating angle ($\Phi$) of the drilling unit (4) to be used for drilling the hole (21) to be drilled to correspond with a mean value ($\Phi_{\text{mean}}$) of the rotating angles ($\Phi$) of the drilling unit (4) carried out in the drilling of a predetermined number of distance-wise closest already drilled holes (21).

6. A method as claimed in claim 3, characterized by determining the rotating angle ($\Phi$) of the drilling unit (4) to be used for drilling the hole (21) to be drilled to correspond with a mean value ($\Omega_{\text{mean}}$) of the rotating angles ($\Omega$) of the drilling unit (4) carried out in the drilling of already drilled holes (21) residing at no more than a predetermined distance, or, if no already drilled hole (21) resides at said no more than a predetermined distance, determining the rotating angle ($\Phi$) of the drilling unit (4) to be used for drilling the hole (21) to be drilled to correspond with the rotating angle ($\Phi$) of the drilling unit (4) carried out in the drilling of the closest already drilled hole (21).

7. A method as claimed in claim 5 or 6, characterized by determining the mean value ($\delta_{\text{mean}}$) of the rotating angles ($\delta$) of the drilling unit (4) carried out in the drilling of the already drilled holes (21) by dividing the value of each rotating angle ($\delta$) into a vertical component ($\delta\sin$) and a horizontal component ($\delta\cos$), by determining a mean value ($\Phi_{\delta\sin_{\text{mean}}}$) of the vertical components ($\delta\sin$) and a mean value ($\Phi_{\cos_{\text{mean}}}$) of the horizontal components ($\Phi\cos$), and by determining the rotating angle ($\Phi$) of the drilling unit (4) to be used for drilling the hole (21) on the basis of the mean value ($\Phi_{\delta\sin_{\text{mean}}}$) of the vertical components ($\delta\sin$) and the mean value ($\Phi_{\cos_{\text{mean}}}$) of the horizontal components ($\Phi\cos$).
8. A method as claimed in claim 7, characterized by determining the rotating angle (Φ) of the drilling unit (4) to be used for drilling the hole (21) on the basis of the mean value (Φ_{sin\_mean}) of the vertical component (Osin) and the mean value (Φ_{cos\_mean}) of the horizontal component (Φ_{cos}) by employing a calculation formula

\[ Φ_{\text{mean}} = \text{atan2}(Φ_{\text{cos\_mean}}, Φ_{\text{sm\_mean}}) \]

9. A method as claimed in any one of the preceding claims, characterized by determining the rotating angle (Φ) of the drilling unit (4) to be used for drilling the hole (21) with respect to the origin (OR1) of a coordinate system attached to the rock drilling rig (1).

10. A rock drilling rig (1), comprising:

- a movable carrier (2),
- at least one drilling boom (3),
- at least one drilling unit (4) arranged in the drilling boom (3), the drilling unit (4) comprising a feed beam (5) and a rock drill (6), the rock drill (6) being arranged to be movable on the feed beam (5) by means of a feed device (22),
- a rotating mechanism (10) for rotating the drilling unit (4) into a rotating angle (Φ),
- at least one storage unit (17) configured to store a drilling pattern (14) to be used for drilling a round to be excavated for a rock cavern,
- at least one control unit (9) configured, via the rotating mechanism (10), to control the drilling unit (4) into a rotating angle (Φ) which carries out a location (21') and direction determined for a hole (21) in the drilling pattern (14) of the round, and
- at least one storage unit (17) configured to store the rotating angle of the drilling unit (4) carried out in the drilling of each hole (21) of the round to be excavated,

characterized in that

the control unit (9) is configured to determine the rotating angle (Φ) of the drilling unit (4) to be used for drilling the hole (21) on the basis of the rotating angle (Φ) of the drilling unit (4) carried out in connection with the drilling of one or more previously drilled holes (21).

11. A rock drilling rig (1) as claimed in claim 10, characterized in that the control unit (9) is configured to determine the rotating angle (Φ) of the drilling unit (4) to be used for drilling the hole (21) on the basis of the
rotating angle \((\Phi)\) of the drilling unit (4) carried out in connection with the drilling of one or more holes \((21)\) of one or more previously drilled rounds.

12. A rock drilling rig \((1)\) as claimed in claim 10 or 11, characterized in that the control unit \((9)\) of the rock drilling rig \((1)\) is configured to determine the rotating angle \((\Phi)\) of the drilling unit \((4)\) to be used for drilling the hole \((21)\)

by choosing, from the storage unit \((17)\), as initial data for the determination, location data \((21')\) about the hole \((21)\) and data about the rotating angle \((\Phi)\) of the drilling unit \((4)\) associated with those already drilled holes \((21)\) which were drilled by the drilling unit \((4)\) arranged in the same drilling boom \((3)\) as the drilling unit \((4)\) to be used for drilling the hole \((21)\) to be drilled,

by determining a distance between the already drilled holes \((21)\) chosen in the previous step and the hole \((21)\) to be drilled, and

by choosing, on the basis of the distance between the already drilled holes \((21)\) and the hole \((21)\) to be drilled, one or more already drilled holes \((21)\) on the basis of whose rotating angle \((\Phi)\) of the drilling unit \((4)\) carried out in the drilling thereof the rotating angle \((\Phi)\) of the drilling unit \((4)\) to be used for drilling the hole \((24)\) to be drilled is determined, and

by determining, on the basis of the rotating angle \((\Phi)\) of the drilling unit \((4)\) carried out in the drilling of the one or more already drilled holes \((21)\), the rotating angle \((\Phi)\) of the drilling unit \((4)\) to be used for drilling the hole \((21)\) to be drilled.

13. A rock drilling rig \((1)\) as claimed in claim 12, characterized in that the control unit \((9)\) of the rock drilling rig \((1)\) is configured to determine the rotating angle \((\Phi)\) of the drilling unit \((4)\) to be used for drilling the hole \((21)\) to be drilled to correspond with the rotating angle \((\Phi)\) of the drilling unit \((4)\) carried out in the drilling of an already drilled hole \((21)\) closest to the hole \((21)\) to be drilled.

14. A rock drilling rig \((1)\) as claimed in claim 12, characterized in that the control unit \((9)\) of the rock drilling rig \((1)\) is configured to determine the rotating angle \((\Phi)\) of the drilling unit \((4)\) to be used for drilling the hole \((21)\) to be drilled to correspond with a mean value \((\Phi_{\text{mean}})\) of the rotating angles \((\Phi)\) of the drilling unit \((4)\) carried out in the drilling of a predetermined number of distance-wise closest already drilled holes \((21)\).

15. A rock drilling rig \((1)\) as claimed in claim 12, characterized in that the control unit \((9)\) of the rock drilling rig \((1)\) is configured to de-
etermine the rotating angle \((\Phi)\) of the drilling unit (4) to be used for drilling the hole (21) to be drilled to correspond with a mean value \((\Phi_{\text{mean}})\) of the rotating angles \((\Phi)\) of the drilling unit (4) carried out in the drilling of already drilled holes (21) residing at no more than a predetermined distance, or, if no already drilled hole (21) resides at said no more than a predetermined distance, to determine the rotating angle \((\Phi)\) of the drilling unit (4) to be used for drilling the hole (21) to be drilled to correspond with the rotating angle \((\Phi)\) of the drilling unit (4) carried out in the drilling of the closest already drilled hole (21).

16. A rock drilling rig (1) as claimed in claim 14 or 15, characterized in that the control unit (9) of the rock drilling rig (1) is configured to determine the mean value \((\Phi_{\text{mean}})\) of the rotating angles \((\Phi)\) of the drilling unit (4) carried out in the drilling of the already drilled holes (21) by dividing the value of each rotating angle \((\Phi)\) into a vertical component \((\Phi_{\text{vertical}})\) and a horizontal component \((\Phi_{\text{horizontal}})\), by determining the mean value \((\Phi_{\text{mean}})\) of the vertical components \((\Phi_{\text{vertical}})\) and the mean value \((\Phi_{\text{horizontal}})\) of the horizontal components \((\Phi_{\text{horizontal}})\), and by determining the rotating angle \((\Phi)\) of the drilling unit (4) to be used for drilling the hole (21) on the basis of the mean value \((\Phi_{\text{mean}})\) of the vertical components \((\Phi_{\text{vertical}})\) and the mean value \((\Phi_{\text{horizontal}})\) of the horizontal components \((\Phi_{\text{horizontal}})\).

17. A rock drilling rig (1) as claimed in claim 16, characterized in that the control unit (9) of the rock drilling rig (1) is configured to determine the rotating angle \((\Phi)\) of the drilling unit (4) to be used for drilling the hole (21) on the basis of the mean value \((\Phi_{\text{mean}})\) of the vertical component \((\Phi_{\text{vertical}})\) and the mean value \((\Phi_{\text{horizontal}})\) of the horizontal component \((\Phi_{\text{horizontal}})\) by employing a calculation formula \(\Phi_{\text{mean}} = \text{atan2}(\Phi_{\text{horizontal}}, \Phi_{\text{vertical}})\).

18. A rock drilling rig (1) as claimed in any one of claims 10 to 17, characterized in that the control unit (9) of the rock drilling rig (1) is configured to determine the rotating angle \((\Phi)\) of the drilling unit (4) to be used for drilling the hole (21) with respect to the origin (OR1) of a coordinate system attached to the rock drilling rig (1).
1. Starting drilling of hole

2. Distributing, among booms, location and rotating angle data associated with previously drilled holes

3. Calculating distances between hole to be drilled and previously drilled holes

4. Arranging calculated distances in order of magnitude

5. Determining rotating angle associated with hole to be drilled

6. Storing rotating angle of drilling unit carried out in drilling of drilled hole

FIG. 4
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
See extra sheet
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)
IPC: E21 B, E21 C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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  "E" earlier application or patent but published on or after the international filing date
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Date of the actual completion of the international search 24 January 2012 (24.01.2012)
Date of mailing of the international search report 09 February 2012 (09.02.2012)

Name and mailing address of the ISA/FI
National Board of Patents and Registration of Finland
P.O. Box 1160, FI-00101 HELSINKI, Finland
Facsimile No. +358 9 6939 5328

Authorized officer
Marko Keranen
Telephone No. +358 9 6939 500

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### International Search Report

**Information on patent family members**

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