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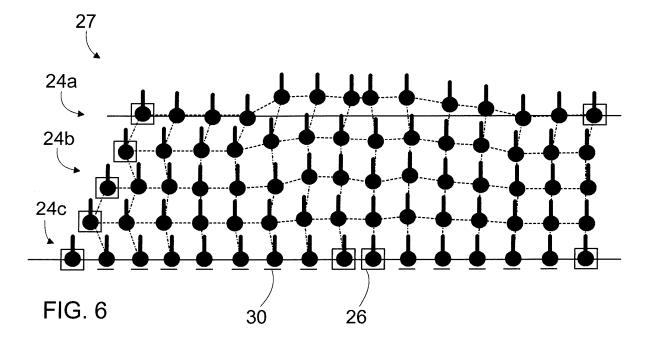
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### (54) Apparatus and method for designing and modifying drilling pattern for bench drilling

(57) The invention relates to an apparatus for creating and modifying a drilling pattern for drilling a vertical bench, to a method of drilling a vertical bench round and

to a computer program product. An initial drilling pattern is modified and at least one property of at least one other drill hole is modified in order to even out the made change.



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#### Background of the invention

**[0001]** The invention relates to an apparatus for designing and modifying a drilling pattern intended for vertical bench drilling. The produced drilling pattern comprises at least determined positions of drill holes for a desired area to be drilled by means of one or more rock drilling rigs.

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**[0002]** The invention further relates to a method of drilling pattern a vertical bench round of a bench, and to a software product for executing the disclosed method and solution.

**[0003]** The field of the invention is defined more specifically in the preambles of the independent claims.

[0004] Bench blasting is the most common blasting work. Bench blasting is used in open pit mines and quarries. The method is also implemented widely at different construction sites. Typically the bench is provided with substantially vertical blast holes utilizing vertical bench drilling. Then vertical or close to vertical drill holes in one or several rows are charged and blasted towards a free surface of a bench. In bench excavation method rock material is detached in several successive bench rounds in horizontal plane. Thus, the excavation proceeds in several successive rounds in the horizontal planes and in several successive horizontal planes from up to down. Positioning of drill holes is a demanding task and requires skilled workers. In order to facilitate work of operators of rock drilling rigs, drilling patterns made in advance may be utilized. However, it has been noted that present solutions have some disadvantages.

### Brief description of the invention

**[0005]** An object of the invention is to provide a novel and improved apparatus, method and software for assisting drilling procedure of a vertical bench.

**[0006]** The apparatus according to the invention is characterized in that the apparatus is configured to: receive updated control data relating to at least one parameter of the initial drilling pattern; modify at least one drill hole of the initial drilling pattern in accordance with the received control data, whereby at least one drill hole is deviated from the initial drilling pattern; even out the executed deviation by causing changes to at least one other drill hole of the initial drilling pattern; and update the initial drilling pattern.

[0007] The method according to the invention is characterized by indicating by means of the drilling tool a modification of at least one drill hole of the initial drilling pattern; providing the control unit with the indication data; executing the modification of the initial drilling pattern by means of the control unit; and changing at least one property of at least one other drill hole in order to even out the performed modification indicated by the drilling tool.

[0008] The software product according to the invention

is characterized in that the computer program product comprises program code means configured to execute the steps and procedures disclosed in the independent claims when being run on a computer or a data processing device.

[0009] An idea of the disclosed solution is that the apparatus creates an initial drilling pattern for bench drilling based on received data. The initial drilling pattern comprises one or more drill hole rows and several vertical drill holes in each row. Blasting technical data, such as a specific charging, is taken into consideration when positioning the drill holes to their initial positions. An additional updated data is received by the apparatus and the initial drilling pattern is modified in accordance with the received data. Thus, one or more drill holes are modified. The executed modification causes changes to several other drill holes of the initial drilling pattern in order to even out the made changes in the drilling pattern. Thus, the initially formed drilling pattern may be modified dynamically.

[0010] An advantage of the disclosed solution is that work of an operator may be facilitated and a less skilled operator is required for the bench drilling when the disclosed system assisting work of the operator is utilized. The same applies also to work of a designer when a drilling pattern is designed as office work external to a rock drilling rig. Also, when implementing the disclosed solution, the actual drilling phase may be faster, since no unnecessary drill holes are being drilled. Further, the excavation may be safer because the drill holes are not drilled too close to a free face of the bench causing fly rock. Thus, a so called rock throw problem may be avoided, but still, the rock material may be detached properly. Further, quality of the blasting may be improved, since the detached rock blocks have desired size i.e. rock fragmentation size is as required whereby further processing is facilitated. In addition, the disclosed solution allows keeping shapes of the successive benches as desired. [0011] According to an embodiment, the blasting tech-

nical data comprises specific charging.

[0012] According to an embodiment, the blasting tech-

nical data comprises predetermined spacing.

[0013] According to an embodiment, the blasting tech-

[0013] According to an embodiment, the blasting technical data comprises predetermined burden.

**[0014]** According to an embodiment, the apparatus is configured to implement same blasting technical rules for all drill holes of the drilling pattern.

**[0015]** According to an embodiment, the apparatus is configured to implement same specific charging for all drill holes of the drilling pattern.

[0016] According to an embodiment, the blasting technical data determines properties of rock fragmentation. Then a closely spaced round with small diameter drill holes provides better fragmentation than a round of widely spaced large diameter drill holes provided that the same specific charge is used. Thus, the spacing and the burden may be predetermined.

[0017] According to an embodiment, the apparatus is

provided with blasting technical data. Based on blasting technical rules and data, basic spacing and burden are defined for an initial drilling pattern. However, in the modified drilling pattern it is allowed to deviate from basic spacing and burden determined by blasting technical parameters.

[0018] According to an embodiment, the apparatus executing drilling pattern creation and amendments is located in a rock drilling rig. The rock drilling rig may comprise one or more control units provided with needed processing means for implementing the disclosed measures for placing drill holes to a drilling pattern and allowing amendments to the drilling pattern. The on-board control unit may comprise one or more display devices and one or more input means allowing interaction between an operator of the rock drilling rig and a computer program being executed in the processing means. By means of the input means measuring data from on-board and external measuring devices may be input to the system, as well as data elements comprising design or blasting data on the bench under operation.

[0019] According to an embodiment, the apparatus executing drilling pattern creation and amendments is located external to a rock drilling rig. One or more control devices, such as design computers may be implemented for executing the disclosed measures for placing drill holes to a drilling pattern and allowing amendments to the drilling pattern. In this embodiment measurement and detection data on position and direction of a drilling tool of a rock drilling rig may be transmitted to the external control device. Additionally, data on realized drill holes may be gathered during drilling and the gathered data may be transmitted to the external control device to be utilized therein when creating a drilling pattern and amending it. The created and modified drilling pattern may be transmitted via wireless data connection to a control unit on-board the rock drilling rig, or it may be stored to a data storage and may be loaded to the onboard control unit.

**[0020]** According to an embodiment, one or more external control devices are configured to design in assistance with a designer a drilling plan on the basis of base data of a bench to be drilled. The predesigned drilling pattern is then transmitted to one or more control devices onboard a rock drilling rig. The predesigned drilling pattern may be modified at a work site as is disclosed in this patent application.

**[0021]** According to an embodiment, the drilling pattern is modified automatically in response to realized drill holes being already drilled. The control system may comprise an algorithm or computer program product which executes automatically calculations for the modifying steps and places one or more drill holes optimally to the drilling pattern or suggests optimal positions for the drill holes.

**[0022]** According to an embodiment, the apparatus is configured to modify the drilling pattern automatically in response to received measuring data, input data and

control parameters. Modifications to the drilling pattern may be done continuously during the execution of the drilling pattern. Thus, the drilling pattern may be updated automatically and continuously or at least nearly continuously. Then, factors influencing to the drilling may be taken care properly and without unnecessary delays.

[0023] According to an embodiment, the drilling pattern is modified in accordance with measuring data received from a positioning system of the rock drilling rig. The positioning system may comprise a satellite navigation system determining position and direction of a rock drilling unit and a drilling tool, for example. Thanks to this embodiment no dedicated drill hole measuring devices or sensors are needed. Thus, a rock drilling rig and a rock drilling unit may be simpler and operation may be faster. [0024] According to an embodiment, the apparatus is configured to determine positions of start points of one or more drill holes on the basis of principles disclosed in this application.

**[0025]** According to an embodiment, the apparatus is configured to determine positions of end points of one or more drill holes on the basis of principles disclosed in this application.

**[0026]** According to an embodiment, the apparatus is configured to determine directions of one or more drill holes on the basis of principles disclosed in this application.

**[0027]** According to an embodiment, the apparatus is configured to determine lengths of one or more drill holes on the basis of principles disclosed in this application.

**[0028]** According to an embodiment, the apparatus is configured to determine one or more drill hole positions when creating new drill holes or replacing drill holes. The apparatus may automatically place the drill hole or it may inform the detected position to an operator. The apparatus may determine start and end points for the drill holes. Alternatively it may determine either start or end points and also direction and length.

[0029] According to an embodiment, the apparatus is configured to create and modify a drilling pattern comprising one single drill hole row, which comprises at least two vertical drill holes. The drill hole row is substantially in the same direction as a face of a bench. The drilling pattern may be placed at a predetermined distance from the face of the bench. Positions of the drill holes may be moved two-dimensionally. Thus, the drill holes may be moved in a longitudinal direction of the row and also in transverse direction. Thereby the created or modified row may deviate from a straight line.

**[0030]** According to an embodiment, the apparatus is configured to create and modify a drilling pattern comprising at least two drill hole rows. Each of the rows comprises at least two vertical drill holes. Such drilling pattern is designed for a so called multiple-row blasting. The drill hole rows are substantially in the same direction as a face of a bench. The drilling pattern may be placed so that a first row is at a predetermined distance from the face of the bench. Positions of the drill holes may be

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moved two-dimensionally. Thus, the drill holes may be moved in a longitudinal direction of the row and also in transverse direction. Thereby the created or modified row may deviate from a straight line. Positions of drill holes in one drill hole row affect to positions of one or more other drill holes in one or more other drill hole rows. An advantage of use of the drill hole rows is that inserting charges and arranging detonators is easier and faster.

[0031] According to an embodiment, the apparatus is configured to create and modify a drilling pattern having a grid-like configuration. The drilling pattern has two or more drill hole rows and two or more drill holes placed in each row. Drill holes of adjacent rows may be initially located at same positions in the rows, or alternatively, drill holes of adjacent rows may initially be located at different positions so that the drill holes in adjacent rows have an offset. Size of the offset may be half of a basic spacing used in the initial drilling pattern.

[0032] According to an embodiment, the drilling pattern comprises at least three drill hole rows each row comprising several vertical drill holes. Typically the drilling pattern comprises at least five rows. The number of rows may be five to ten. Positions of the drill holes may be moved two-dimensionally. Thus, the drill holes may be moved in a longitudinal direction of the row and also in a transverse direction. Thus, the created or modified row may deviate from a straight line. Positions of drill holes in one drill hole row affects to position of one or more other drill holes in one or more other drill hole rows. The apparatus may be configured to even out change of the drill hole by automatically modifying properties of other drill holes in two or more rows. If, for example, a first row is amended, the amendment may be even out in intermediate rows between the first row and a last row, whereby the last row may be kept unchanged. When the drilling pattern comprises several rows, for example five rows, it is possible to define the last row together with one or more rows closest to the last row to be fixed, whereby the amendments have no influence to them. In another example, one or more drill holes in a middle section of the drilling pattern are modified, whereby at least all neighboring drill holes in the intermediate rows are also modified in order to even out the made change. The system allows the first row and the last row to be kept unchanged. Thus, it is possible to determine for the system one or more fixed elements, which are not amended when the drilling pattern is modified.

[0033] According to an embodiment, the apparatus allows creating and modifying of a drilling pattern comprising several drill hole rows each row comprising several vertical drill holes. A first row is closest to a face of a bench and the shape of the first row is modified according to the realized shape of face of the bench. A last row of the drilling pattern is straight or substantially straight. Thanks to the straight last row the shape of the bench may be kept straight, which facilitates forthcoming drilling of a next bench round.

[0034] According to an embodiment, the apparatus al-

lows creating and modifying of a drilling pattern comprising several drill hole rows each row comprising several vertical drill holes. Shape of the drilling pattern is substantially rectangular. Typically width of the drilling pattern is greater than depth. The rows may be straight and spacing between the drill holes may be constant in the initial drilling pattern. The apparatus may be provided with such simplified initial drilling pattern, which may be used as a starting point for drilling pattern design and modification measures. The initial drilling pattern may be modified as it is disclosed in this application. The simplified initial drilling pattern may be especially utilized in an on-board control device.

**[0035]** According to an embodiment, the apparatus allows creating and modifying procedures of a drilling pattern wherein a last drill hole row has a desired shape deviating from a straight line. The last row is located at a greatest distance from a face of a bench. The shape of the last row may be V- or U -shaped, for example. The shape of the last row may be modified manually in a manner disclosed in this application or alternatively the apparatus may retrieve a data element, wherein a predesigned shape is determined.

[0036] According to an embodiment, the apparatus allows determining one or more fixed elements, such as fixed drill holes, reference points or boarder elements for a drilling pattern. The fixed element may prevent execution of modifications or it may limit allowable modifications of the drilling pattern. Desired drill holes may be locked so that they keep their properties despite of changes in neighboring drill holes and drill hole rows. Further, the reference points may be indicated to the system by means of a drilling tool and the defined reference points may be implemented to limit an area where the modifications are possible. Further, a first drill hole row, a last drill hole row, or both may be defined to serve as the fixed elements. Then, modifications made in a middle section of the drilling pattern have no influence to the first and last rows, which may keep their desired shapes. In addition, any other drill hole row than the first or last row may be defined to a fixed element.

**[0037]** According to an embodiment, the apparatus allows an area of influence to be determined and implemented for modifying process of a drilling pattern. The area of influence may be indicated on a display device by means of a control device, or by means of any other input device of a control system. Alternatively, the area of influence may be indicated by means of a drilling tool, in which case the position of the tool is determined by means of an instrumented drilling unit. Modifying a drill hole may then affect to several other drill holes which are located inside the determined area of influence.

[0038] According to an embodiment, the apparatus allows determining one or more drill holes of a drilling pattern to be independent drill holes, which have no influence to properties of other drill holes. Thus, the independent drill holes do not affect to positions of other drill holes and to spacing, for example. The independent drill

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hole may be an additional drill hole determined by an operator when executing the drilling pattern. Alternatively a designer of a drilling pattern may place one or more independent additional drill holes in the drilling pattern. The apparatus disclosed in this patent application does not take into account the defined independent drill hole when performing the disclosed adjusting measures.

**[0039]** According to an embodiment, a shape of a free face of a bench is determined. The face of the bench is seldom straight because rock material is detached by blasting. The face may comprise notches and protrusions, and it may be slanting too. The realized face of the bench may be determined before drill holes locating closest to the outer edge are drilled. The disclosed apparatus, control unit or control system is configured to take the determined face shape and profile into consideration when creating a drilling pattern and modifying the drilling pattern.

[0040] According to an embodiment, a shape of a face of a bench is determined by positioning a drilling tool of a rock drilling unit in accordance with the realized face of the bench. The drilling tool may then be positioned close to the outermost edge of the bench, and the position of the drilling tool, such as a drill bit, is determined by means of measuring devices of the rock drilling rig. Thus, the drilling tool may serve as an indicating element or instrument for indicating a shape of the outermost edge. The disclosed apparatus is configured to create and modify a drilling pattern in response to the determined face of the bench. An outermost drill hole row may be placed and drilled at a desired distance from the detected face of the bench.

[0041] According to an embodiment, a face of a bench is determined by positioning a drilling tool of a rock drilling unit in accordance with the face of the bench. The drilling tool may be positioned to a desired start point of a drill hole to be drilled, wherein the start point is located at a distance from an outermost edge of the bench. Thus, an outermost drill hole line may be indicated for the control system by positioning the drilling tool to the desired start points. Drilling may be executed at the start points after positioning. The position of the drilling tool, such as a drill bit, is determined by means of measuring devices of the rock drilling rig. Thus, the drilling tool may be utilized for two purposes, indicating and drilling. The disclosed apparatus is configured to create and modify a drilling pattern in response to the determined face of the bench.

[0042] According to an embodiment, the apparatus is configured to receive input data relating to position and direction of a drilling tool and is configured to use the data for creating and amending a drilling pattern. The drilling tool may be positioned manually by means of the operator. The position of the drill bit may be determined in a control unit on the basis of measuring data received from one or more sensors or measuring devices of the rock drilling rig. The rock drilling rig may be instrumented, which means that one or more sensors may be located in a boom and in the rock drilling unit. Alternatively or in

addition to, the rock drilling unit may be provided with one or more satellite measuring devices for determining the position of the drilling tool. Thus, a satellite navigation system of the rock drilling rig may provide needed measuring data accurately and without use of any complicated separate measuring sensors and devices.

[0043] According to an embodiment, a shape of a face of a bench is determined by means of one or more measuring devices external to the rock drilling rig. The external measuring device may be a bench scanner. The shape of the bench may be determined by means of photogrammetric methods. The shape of the bench may be scanned and the scanning data may be processed in order to create a 3D model of the bench. The 3D model may comprise point cloud data wherein the points are provided with coordinate data, i.e. x, y, z coordinates. The shape of the bench determined by the bench scanning process may be used when positioning outermost drill holes of a drilling pattern. Alternatively, the shape of the bench may be determined using different digital photography and image processing methods. A control unit of a rock drilling rig may be provided with the determined bench scanning data and the on-board control unit may implement the data of the realized face of the bench by creating of modifying automatically an optimized drilling pattern before executing the drilling. Alternatively, the control unit may automatically present assisting control information for an operator of the rock drilling in order to facilitate creation and modification procedure of a drilling pattern, or assisting placing of a predesigned drilling pattern correctly in response to the realized face of the bench.

**[0044]** According to an embodiment, a shape of a bottom plane of a bench is determined. The bottom plane is substantially horizontal and end points of drill holes are located on the surface bottom plane. The data on the bottom plane is taken into consideration when creating and modifying a drilling plan of the bench. The bottom plane may be slanted whereby drill hole lengths may be modified based on that information. Further, the bottom plane may be provided with notches, whereby it may be desirable to place end points of the drill holes close to edges of the notches. The notches may be shafts, channels or grooves, for example.

**[0045]** According to an embodiment shape or quality of an upper surface may also cause a need to amend positions of one or more single start points so that drilling may be executed. The shape of the upper surface of the bench may be detected visually by the operator of it may be scanned or photographed.

**[0046]** According to an embodiment, the apparatus is configured to take into consideration data on already drilled realized neighboring drill holes when determining positions of one or more yet undrilled drill holes. During drilling measuring data may be gathered and based on the gathered data changes may be made to one or more properties of one or more drill holes.

**[0047]** According to an embodiment, the apparatus is configured to take into consideration data on a previously

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drilled and blasted bench located above the current bench under operation. The system may utilize drilling data of the previous bench plane. Then, the drill holes of the currently operated bench may be positioned so that their start points are positioned at positions different than positions of end points of the previous bench plane. This embodiment ensures that new drill holes are not drilled to locations where the rock material is already damaged due the drilling and blasting of the previous bench. Thanks to this, collapse of upper end portions of the drill holes may be avoided and charging may be executed without problems. Further, the embodiment may improve safety when it is ensured that no drilling is executed to positions where charging material of the previous blasting could possibly be located.

**[0048]** According to an embodiment, the apparatus is configured to take into consideration data on measured vibration induced by already drilled and blasted drill holes when determining positions of one or more yet undrilled drill holes. Thanks to this, drill holes may be placed in positions allowing suitable amount of charge material and inducing acceptable levels of vibration in surrounding rock.

[0049] According to an embodiment, the apparatus is configured to place a preplanned drilling pattern at a work site on the basis of principles disclosed in this patent application. The drilling pattern may be positioned in response to data on realized shape of the bench. The shape of the bench may be determined by scanning or indicating the shape by means of a drilling tool, as it is disclosed in this patent application. The apparatus may compare the detected shape of the bench to shape of the preplanned drilling pattern and may automatically position the whole drilling pattern to a position where the shapes match best. Alternatively, the apparatus may inform the operator of the need for reposition of the drilling pattern on a display device, for example, and may also assist the operator to relocate the drilling pattern. In addition to, the apparatus may modify the preplanned drilling pattern by relocating one or more drill holes and by changing their directions. Alternatively, the apparatus may inform the operator of the need to modify the drilling pattern, and it may assist the operator in the execution.

[0050] According to an embodiment, the apparatus is configured to indicate for the operator closest distances between a free face of a bench and designed drill holes, which are located in a first drill hole row. Shape and location of the free face of the bench may be determined by scanning, for example. The closest distances may be shown on a display device. The system may also give a warning message in case any of the drill holes is closer to the free face as it is allowed. Alternatively, the system may automatically move the whole drilling pattern so that the closest distance is always greater than a preset limit value. Thanks to this embodiment, drilling of drill holes too close to the free face of the bench may be avoided. Then, no fly rock situations exist when blasting the bench. [0051] According to an embodiment, drilling of a bench

is executed by means of two or more rock drilling rigs. The rock drilling rigs may be in data communication with each other and with one or more external control devices. The disclosed apparatus may be located in one of the rock drilling rigs or external to them. The apparatus is configured to receive drilling data from the rock drilling rigs and is configured to take the received data into consideration when modifying a drilling pattern being shared with the several rock drilling rigs. Thus, the shared drilling pattern may be updated and modified in accordance with the received drill hole data. Alternatively, the drilling pattern may be divided to several partial drilling patterns, the number of the partial patterns corresponding to the number of the rock drilling rigs operating at the same work site. One or more of the partial drilling patterns may be updated and modified in accordance with received drill hole data. If for example realized drill holes deviate from a first partial drilling pattern, the deviation may cause modifications to a second partial drilling pattern. Similarly, if the first partial drilling pattern is modified by the control system or the operator, the modification may again cause modifications to a second partial drilling pattern. Thanks to this embodiment, the apparatus may update the one or more drilling patterns dynamically.

[0052] According to an embodiment, the drilling pattern is created in a computer-assisted manner by using a specific design computer or control unit of a rock drilling rig. The drilling pattern may be created so that no basic or initial drilling pattern is utilized as a base for the design. The designer or operator may place a drill hole in accordance with one or more reference objects and the design program may suggest positions of other drill holes or place the neighboring holes automatically in accordance with predetermined criteria.

[0053] According to an embodiment, the drilling pattern is created in a computer-assisted manner by using a specific design computer or control unit of a rock drilling rig. The drilling pattern may be created so that an initial or basic drilling pattern is utilized as a base for the design. The initial drilling pattern may be a simplified base pattern, or it may be a predesigned drilling pattern, which may be already utilized in drilling one or more benches and may be retrieved from a memory device. A new drilling pattern may be created by amending the initial drilling pattern by moving positions of the drill holes, changing inclinations of the drill holes, removing or adding one or more drill holes, adding or removing drill hole rows, or amending any other parameters and properties of the drill holes.

[0054] According to an embodiment, the apparatus is configured to determine position and shape of a free face of a bench. The face of the bench may be scanned or it may be determined by using an instrumented boom and drilling unit. These measures are disclosed elsewhere in this patent application. Since the apparatus is aware of the position of an edge of the bench, this information may be utilized in monitoring position of a carrier of a rock drilling rig relative to the edge. The system may produce

an alarm for the operator if the carrier is driven close to the edge of the bench. One or more limit distances may be given for the monitoring system, and if the carrier is moved to distance closer than the limit value, then the operator is informed or the carrier is stopped by the monitoring system. An advantage of this embodiment is that risk of falling rock drilling rig may be decreased

**[0055]** In this patent application vertical drill holes of a vertical bench drilling mean drill holes being vertical or close to vertical. Thus, the drill holes may be slightly inclined, for example 10 - 200. However, such vertical drill holes clearly differ from horizontal drill holes.

**[0056]** The above disclosed embodiments can be combined in order to form suitable solutions provided with necessary features.

#### Brief description of the figures

**[0057]** Some embodiments are described in more detail in the accompanying drawings, in which

Figure 1 is a schematic side view showing a rock drilling rig suitable for bench drilling,

Figure 2 is a schematic view showing a bench and a rock drilling rig drilling vertical drill holes for a bench round.

Figure 3 is a schematic top view showing a bench and a drilling area provided with several drill holes arranged in drill hole rows,

Figure 4a is a schematic view of a drill hole row before modifications, and Figure 4b shows the same row after being modified,

Figure 5a is a schematic view of an initial drilling pattern and Figure 5b shows the drilling pattern after being modified,

Figure 6 is a schematic view of a drilling pattern wherein a first drill hole row is modified in accordance with a face of a bench and the changes made to the positions of the drill holes have also caused changes to positions of neighbouring drill holes,

Figure 7 is a schematic view of a drilling pattern, which is partly realized and positions of several other drill holes are being influenced by the realized drill holes,

Figure 8 is a schematic view of a display device, wherein is indicated for an operator distances between drill holes of a first drill hole row and a detected realized face of a bench,

Figure 9a is a schematic view of a curved drilling pattern, which is in an incorrect position relative to a realized face of a bench, and Figure 9b shows the situation after the system has positioned the drilling pattern correctly by implementing detected bench face data.

Figure 10 is a schematic view of a work site wherein several rock drilling rigs are drilling a same bench, whereby data relating to drilling patterns is shared with several control units,

Figure 11 is a schematic view of bench drilling wherein an initial direction of some drill holes are amended and the made amendment is gradually changed back to the desired initial inclination, and

Figure 12 is a schematic view of a bench and a bottom plane of the bench provided with a shaft and a slanting portion.

**[0058]** For the sake of clarity, the figures show some embodiments of the disclosed solution in a simplified manner. In the figures, like reference numerals identify like elements.

#### Detailed description of some embodiments

[0059] Figure 1 shows a rock drilling rig 1 comprising a movable carrier 2, one or more drilling booms 3 and drilling units 4 arranged in the drilling booms 3. The drilling unit 4 comprises a feed beam 5 on which a rock drilling machine 6 can be moved by means of a feed device. Further, the drilling unit 4 comprises a tool 7 with which the impact pulses given by the percussion device of the rock drilling machine are transmitted to the rock to be drilled. The rock drilling rig 1 further comprises at least one control unit 8 arranged to control actuators of the rock drilling rig 1, for example. The on-board control unit 8 may be a computer, processing device or a corresponding device, and it may comprise a user interface with a display device 9 as well as control means for giving commands and information to the control unit 8. The control unit 8 may be one computer equipped with appropriate software, or an entity consisting of a plurality of computers.

[0060] A drilling pattern for assisting the drilling may be designed in an office 10 or somewhere else external to the rock drilling rig 1 by means of a design computer 11. The predesigned drilling pattern may be loaded to the control unit 8 of the rock drilling rig 1 and implemented. Alternatively, no predesigned complete drilling pattern is needed. Instead the drilling pattern may be generated during the drilling process taking into account already realized drill holes. One or more basic data elements 12, such as blasting technical rules and data, may be defined in advance and they may be taken into consideration when creating and modifying a drilling pattern. The set data may be input to the control unit 8 or it may be stored to one or more memory devices so that it can be retrieved by the control unit 8. The operator 13 of the rock drilling rig 1 controls the drilling interactively with the control unit 8.

**[0061]** Figure 1 further discloses that measuring or sensing means 14 may be arranged to determine current position and direction of the tool 7. Needed sensor means 14 may locate in the boom 3. Thus, the rock drilling rig 1 and the boom 3 may be instrumented. Alternatively the sensing may be executed remotely. The rock drilling rig 1 may be provided with a satellite based navigation and positioning system 15. Then, the boom 3 and the rock

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drilling unit 4 may be provided with one or more receivers 16 for receiving signals from several satellites 17. The sensing data is provided to the control unit 8, which may execute needed calculations.

**[0062]** In Figure 1 a bench 18 and a face 19 of the bench 18 are shown. Drill holes 20 are drilled in vertical direction for a round 21 of a bench 18. As it is mentioned earlier in this patent application, the drill holes 20 may be inclined but are still considered to be substantially vertical.

[0063] Figure 2 shows a principle of a bench excavation. Several successive bench rounds 21 a, 21 b are formed in a same bench plane. A rock drilling rig 1 may drill several drill holes 20 to an upper surface of a bench 18. The drill hole 20 have a length L, direction D, start point S and end point B, which define position of the drill hole. Furthermore, blasting technical data and rules may be determined for the bench round 21. The blasting technical data may determine a specific charge to be used for the bench round 21. The blasting technical data and rules may concern all the drill holes 20 of the bench 18. The blasting technical data and rule may determine spacing between drill holes and burden V between adjacent drill hole rows.

**[0064]** Realized face 19a of the bench 18 may be determined and utilized in drilling control and drilling pattern creation and modification. The face 19 may scanned by using an external bench scanner 22. Scanning results may be transmitted to an on-board control unit and to an external control unit.

**[0065]** In Figure 2 it is further shown drill hole end points 23 of another bench round located above the current bench plane. The previous bench above and the positions of the end points 23 may be taken into consideration by the system when determining drill hole positions of a new drilling pattern.

**[0066]** Figure 3 shows a rock drilling rig 1 on a bench 18. A shape of a face 19 of the bench 18 may be indicated for the system by positioning a drilling tool 7 in accordance with the realized face profile. Since the rock drilling rig 1 is provided with suitable measuring and positioning system the position and direction of the drilling tool 7 is always known and may be recorded. This feature may be implemented in a manner disclosed earlier in this patent application.

**[0067]** Figure 3 further shows that between drill hole rows 24 is burden V and between drill holes 20 is spacing E. The burden and spacing may be determined by blasting technical rules and data. A specific charging affects to both of them, for example.

[0068] Figure 4a shows a drill hole row 24 before modifications. Several drill holes 20 are defined for the drill hole row at equal spacing E. In Figure 4b, one drill hole 20a is moved in the row 24 to left, as it is illustrated by means of an arrow 25. Then the system may automatically determine new positions for several drill holes 20. An area of influence of modifications may be limited. Figure 4b shows that extreme drill holes may be fixed so

that they are not modified. Around a hole symbol may be a square 26 indicating that the drill hole is fixed and may not be moved in the row 24. As can be seen, positions of the other drill holes between the outermost drill holes are being modified in the row 24. Thereby the system allows deviations of the original spacing E defined by blasting technical matters. Figure 4b further discloses that the system may even out the made modification by moving several other drill holes. In Figure 4b the modification and smoothing processes are implemented in one dimension, namely in the direction of the row 24.

[0069] Figure 5a discloses a grid-like initial drilling pattern 27a and Figure 5b shows a modified drilling pattern 27b. The drilling pattern 27 defines a drilling area 28 and comprises several drill hole rows 24a - 24c provided with several vertical drill holes 20. A control unit of a rock drilling rig may be provided the simplified initial drilling pattern 27a, which may be modified by an operator. In Figure 5b a realized face 19a of a bench is shown. The initial drilling pattern 27a may be placed to a suitable position taking into account the face 19a. Shape of the face 19a may not be even whereby one or several drill holes in a first drill hole row 24a needs to be amended. Figure 5b shows initial positions 29 of modified drill holes. The modifications may also cause changes to other drill holes located in successive drill hole lines. In Figure 5b the modification has cause change in an intermediate row 24b. Thus, the modification of the drilling pattern may be made two-dimensionally. The system also allows deviations from basic spacing values defined for the bench round.

**[0070]** Figure 5b further shows that the drilling pattern 27 may be provided with fixed drill holes or elements. This is indicated in Figure 5b by placing squares 26 around selected drill hole symbols, or lines 30 under the symbols. The square 26 means that the marked drill hole may not be modified two dimensionally, and the line 30 means that the drill hole may be moved only one dimensionally in the row. Since the last drill hole row 24c is fixed by using the squares 26, modifications are allowed only in rows 24a and 24b.

**[0071]** Figure 6 shows a drilling pattern 27 wherein a first drill hole row 24a is modified in accordance with a face of a bench. As can be seen, changes made to the positions of the drill holes in the first row 24a have caused changes to positions of neighbouring drill holes in other rows 24b, except in a last row 24c. Figure 6 shows that the drill hole positions may be amended two-dimensionally, that spacing may after the modification deviate from a basic spacing defined by blasting technical rules, and further that the system may even out the made changes taking into account the fixed elements.

**[0072]** Figure 7 shows a drilling pattern 27, which is partly realized and positions of several other drill holes are being influenced by the realized drill holes. In Figure 7 the realized drill holes are shown as black circles and designed drill holes, which are not yet drilled, are shown as white circles. A control unit of a rock drilling rig may

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determine position data on the realized drill holes during the drilling and may update the drilling pattern 27 simultaneously. The system may also determine positions of neighbouring drill holes and may generate a complete drilling pattern for a drilling area. The drilling pattern may be updated always when new data is received from drilling and positioning processes.

[0073] Figure 8 shows a display device 31, wherein is indicated for an operator shortest distances 32 between drill holes 20 of a first drill hole row 24a and a detected realized face 19 of a bench. The face may be detected by means of bench scanning, for example, and a control unit may visualize the face 19 on the display device 31. The operator may place a drilling pattern 27 so that it best matches to the face 19. The system may alert or indicate if any drill hole is at a shorter distance that a predetermined minimum distance. In Figure 2 it is also show the closest distance 32 between the realized face 19a and the closest drill hole 20.

[0074] Figure 9a shows a curved drilling pattern 27, which is in an incorrect position relative to a realized face 19 of a bench. The realized face 19 may be determined as disclosed in this patent application, and it may be displayed in a display device for an operator together with the drilling pattern 27. The operator may desire to change the position of the hole drilling pattern 27 and may move it by using input means of an on-board control unit. The system may also replace the drilling pattern automatically if needed. Figure 9b shows the situation after the operator or system has positioned the drilling pattern 27 correctly by implementing detected bench face data.

**[0075]** Figure 10 shows a work site wherein several rock drilling rigs 1a-1 c are drilling a same bench. Data relating to drilling patterns and realized drill holes may be shared with on-board control units of the rock drilling rigs 1a - 1 c and may also be shared with one or more external control units 11.

[0076] Figure 11 shows a bench drilling situation wherein initial directions of some drill holes are being amended. As can be noted, the made amendment is gradually changed back to the desired initial inclination. In Figure 11 the initial direction is shown by using dotted lines. There may be cracks or other faults 33 in the bench causing a need to deviate from the initial direction of the holes. A change in the direction in a first row 24a causes changes in following two other drill hole rows. A last row 24c may have the desired initial inclination. The inclinations are gradually amended towards the desired angle value, whereby the next bench round is not affected by the changes made in the previous bench round.

[0077] Figure 12 shows a bench 18 and a bottom plane 34 of the bench. The bottom plane 34 may be provided with a shaft 35. The bottom plane 34 may be slanting or it may comprise a slanting portion 36. Desired shape of the bottom plane 34 may be taken into consideration when creating and modifying a drilling pattern for bench drilling. The same principles discloses earlier in this patent application apply also when the shape of the bottom

plane is designed.

[0078] Rock breaking by blasting, e.g. in underground or open-pit mines, always induces some vibration to surrounding rock. This vibration may incur damages to nearby structures, e.g. buildings, and the permitted level of vibration is often strictly regulated. Blast-induced ground vibrations may be measured and reported in [mm/s]. The smaller the spacing between the blast holes is, the less charging material is required for blasting, and the lower level of vibration is incurred. Vibration measurement results, e.g. from previously blasted holes, may be taken into consideration when creating and modifying a drilling pattern, e.g. for bench drilling, other open-pit mine drilling, or underground drilling applications. Also, regulations and desired vibration levels may be input to the drilling pattern creating and modification.

[0079] The disclosed apparatus comprises at least a processing device for determining current position and direction of a tool and assisting or executing the disclosed creation and modifying procedures. Blasting technical data may be input to the processing device as individual data elements or may be retrieved from one or more memory devices. The processing device may comprise a computer program product, which is executed. The computer program may be recorded on non-transitory computer-readable media including program instructions for implementing various operations executed by a computer. The operator may input data and make selections via one or more input devices. The input device may be a touch screen, a keypad, a mouse or any other suitable control device. By means of the input device, the operator of the rock drilling rig may inform the processing device of the needed amendments of the drilling pattern, for example. The operator may also instruct the processing device of fixed elements and provide the processing device with any other needed data. The processing device may execute needed calculations and may display drilling pattern data on a display device. The processing device may also provide the operator with predetermined drilling aid and may show assisting symbols and data on the display device. Further, the apparatus may comprise an output device for storing produced data on a memory device or transmitting the data to another control unit or mining vehicle. Let it be mentioned that the processing device and a control unit of the rock drilling rig may be separate devices or they can be integrated.

[0080] A computer program for implementing the features disclosed in this patent application may be recorded in non-transitory computer-readable media including program instructions to implement various operations embodied by a computer. The media may also include, alone or in combination with the program instructions, data files, data structures, and the like. Examples of computer-readable media or computer-readable storage devices include magnetic media such as hard disks, and optical media such as CR-ROM disks and DVDs, flash memory means, and hardware devices that are configured to store software. The computer-readable media may be a

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plurality of computer-readable storage devices in a distributed network, so that the program instructions are stored in a plurality of computer-readable storage devices and executed in a distributed fashion. The program instructions may be executed by one or more processors or processing devices.

**[0081]** The drawings and the related description are only intended to illustrate the idea of the invention. In its details, the invention may vary within the scope of the claims.

#### **Claims**

 An apparatus comprising at least one data processing device for creating and modifying a drilling pattern for drilling a vertical bench round of a bench by means of a rock drilling rig,

wherein the apparatus is configured to:

create an initial drilling pattern for the bench round;

receive data on area of the initial drilling pattern; receive blasting technical data of the bench round:

define at least one drill hole row for the initial drilling pattern and several vertical drill holes in the row:

receive data on the drill holes; and

determine at least spacing between the drill holes in the row in accordance with the received blasting technical data;

**characterized in that** the apparatus is further configured to:

receive updated control data relating to at least one parameter of the initial drilling pattern;

modify at least one drill hole of the initial drilling pattern in accordance with the received control data, whereby at least one drill hole is deviated from the initial drilling pattern;

even out the executed deviation by causing changes to at least one other drill hole of the initial drilling pattern; and update the initial drilling pattern.

- The apparatus as claimed in claim 1, characterized in that the apparatus allows position of the at least one modified drill hole to deviate from the position defined by means of the received blasting technical data.
- The apparatus as claimed in claim 1 or 2, characterized in that

the received updated control data comprises data on shape of a face of the bench, whereby the control data limits the area of the drilling pattern; and the apparatus is configured to modify the initial drilling pattern by repositioning at least one drill hole in accordance with the received data on the face.

The apparatus as claimed in claims 1 - 3, characterized in that

the apparatus is configured to receive actual position and direction data on a drilling tool of the rock drilling rig; and

the received position and direction data of the drilling tool is serving as the updated control data.

- 5. The apparatus as claimed in claim 4, characterized in that the apparatus is configured to receive data on the drilling tool positioned in accordance with a shape of a face of the bench.
- The apparatus as claimed in claim 4 or 5, characterized in that

the apparatus is configured to modify the drilling pattern in accordance with data on at least one realized drill hole.

75 7. The apparatus as claimed in claim 3, characterized in that

the apparatus is configured to receive at least one data element comprising measuring data of a shape of a face of the bench, wherein the measuring data is produced by means of a measuring device external to the rock drilling rig.

- 8. The apparatus as claimed in any one of the preceding claims 1 7, **characterized in that**the apparatus is configured to receive data on at least
- one fixed element limiting allowable modifications for the drilling pattern.
- 9. The apparatus as claimed in claim 8, characterized in that

the received at least one fixed elements prevents position change of at least one drill hole in at least one direction.

45 **10.** The apparatus as claimed in claim 8 or 9, **characterized in that** 

the apparatus is configured to create at least a first drill row and a last drill hole row for the initial drilling pattern, wherein the last drill hole is located at a longer distance from a face of the bench as compared to the first drill hole row; and

the received at least one fixed element is configured to determine a shape of the last drill hole row.

11. The apparatus as claimed in any one of the preceding claims 1 - 10, characterized in that
 the apparatus is configured to create at least three drill hole rows for the initial drilling pattern; and

the apparatus is configured to even out the executed change of at least one drill hole in one drill hole row by modifying at least one property of at least one drill hole in at least one other drill hole row.

12. The apparatus as claimed in any one of the preceding claims 1 - 11, characterized in that the initial drilling pattern defines directions of the drill holes;

the apparatus is configured to modify direction of at least one drill hole on the basis of received updated control data; and

the apparatus is configured to even out the executed change in direction by changing directions of several other drill holes of the initial drilling pattern.

13. The apparatus as claimed in any one of the preceding claims 1 - 12, characterized in that the apparatus is arranged in the rock drilling rig comprising a carrier, at least one drilling boom, at least one rock drilling unit, a drilling tool connected to the drilling unit, and at least one control unit; and the data processing unit of the apparatus is integrated in the control unit of the rock drilling rig.

**14.** A method of drilling a vertical bench round of a bench, the method comprising:

using in the drilling a rock drilling rig comprising at least one rock drilling unit and a drilling tool connected to the drilling unit; employing an initial drilling pattern in the drilling

of the bench round;

drilling several vertical drill holes for the bench round; and

determining the actual position and direction of the drilling tool;

#### characterized by

indicating by means of the drilling tool a modification of at least one drill hole of the initial drilling pattern;

providing the control unit with the indication data; executing the modification of the initial drilling pattern by means of the control unit; and changing at least one property of at least one other drill hole in order to even out the performed modification indicated by the drilling tool.

15. A computer program product,

#### characterized in that

the computer program product comprises program code means configured to execute the steps and procedures disclosed in the independent claims when being run on a computer or a data processing device.

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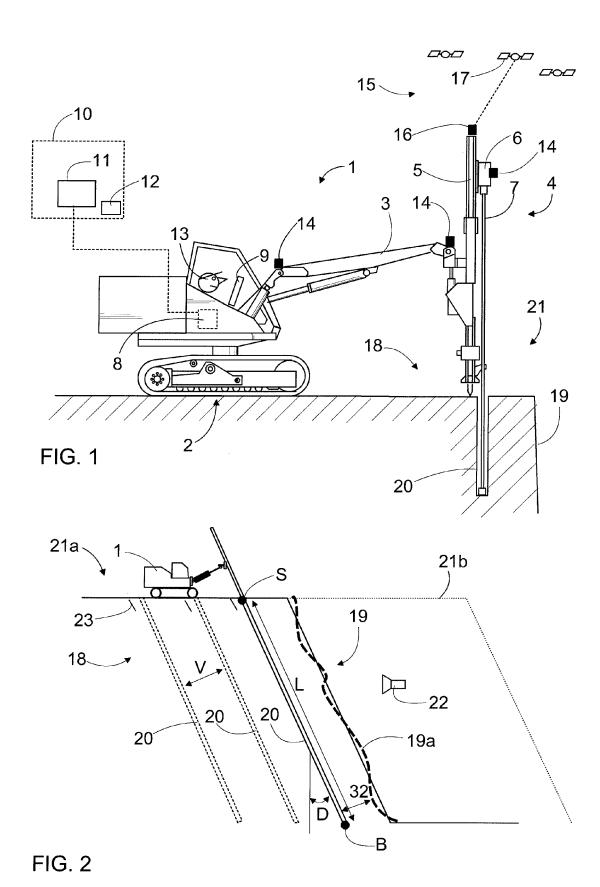
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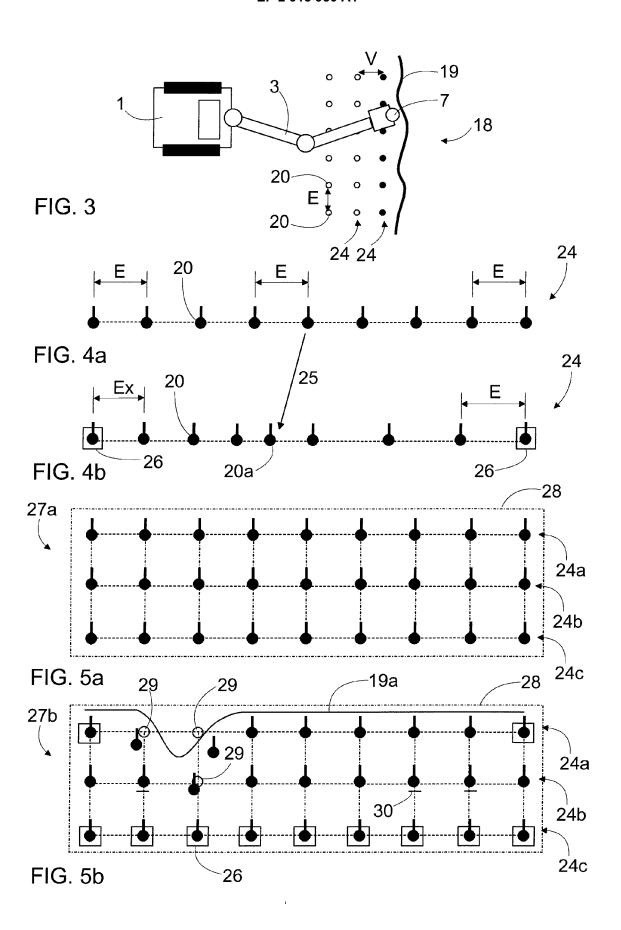
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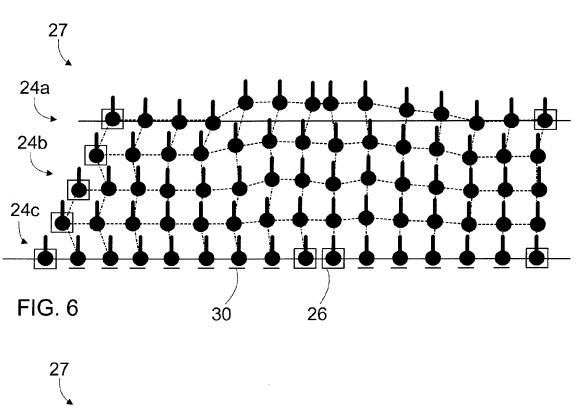
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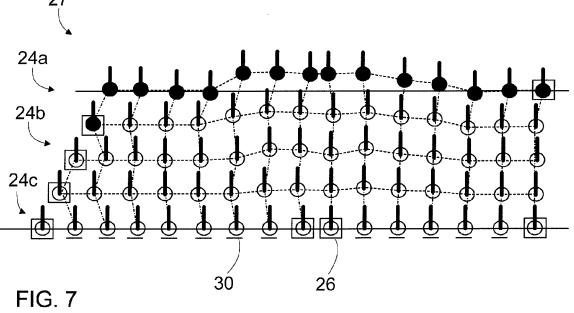
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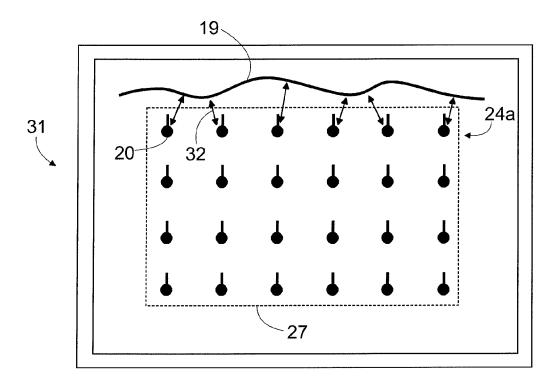
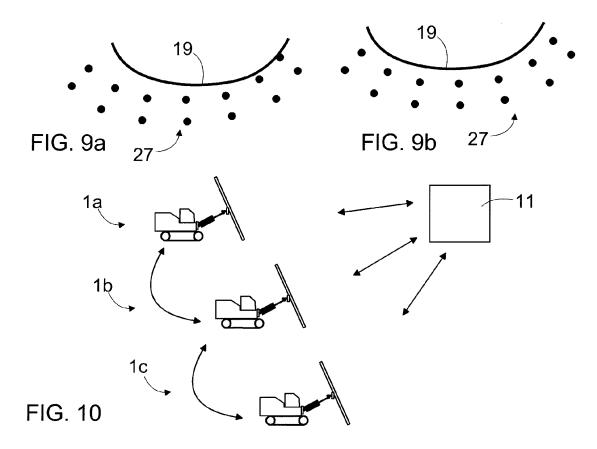
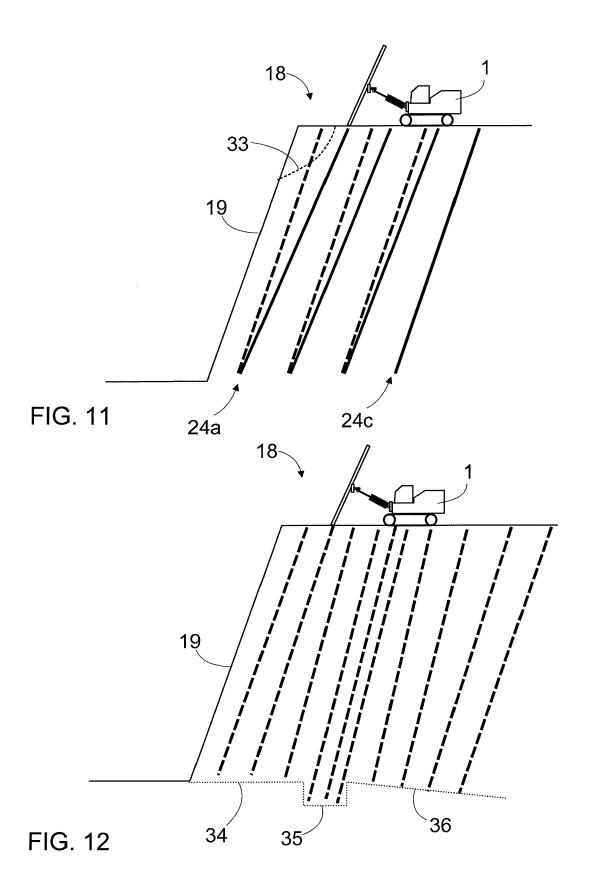


FIG. 8







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