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(54) **Title:** METHOD AND DEVICE FOR CONTROLLING AT LEAST ONE DRILLING PARAMETER FOR ROCK DRILLING

Fig. 4a

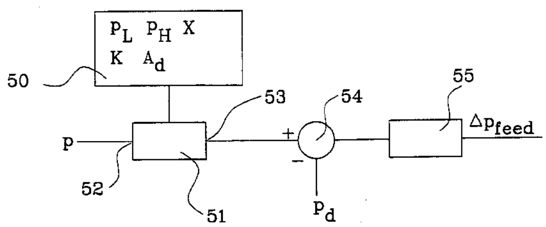
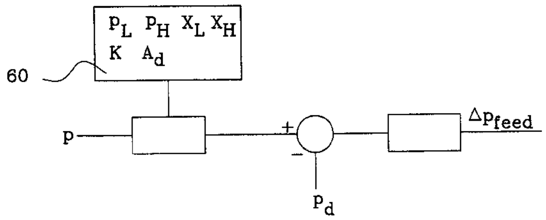


Fig. 4b



(57) Abstract: The present invention relates to a method and a device for controlling at least one drilling parameter when drilling into rock with a drilling machine, where a percussion pressure and/or a feed pressure of the drilling machine, which generate a percussive force and a feed force respectively, are controlled during the drilling operation. A parameter value is determined that represents the mean value of a damping pressure in a damping chamber used both for transmitting a feed force to a drill string that is connected to the drilling machine, and for damping rock reflections from this drill string; a difference between the said mean value of the determined damping pressure and a reference value of the damping pressure is also determined. The percussion pressure and/or the feed pressure of the drilling machine is then controlled on the basis of this difference.

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METHOD AND DEVICE FOR CONTROLLING AT LEAST ONE DRILLING PARAMETER

Field of the invention

The present invention relates to a method and a device for controlling the drilling parameters when drilling in rock.

Background to the invention

Rock drilling is often carried out by percussion drilling, where a percussion piston, which is often operated hydraulically, is used to create a shock wave with the aid of an impact force that is generated by hydraulic pressure (percussion pressure), the shock wave being transmitted to the drill bit and hence to the rock through the drill steel (drill string). On contact with the rock, hard alloy pins of the drill bit contacting the rock, are pushed into the rock, thereby generating a strong enough force to fragment the rock.

It is generally important to ensure the best possible contact between the drill bit and the rock, and therefore the drilling machine is pressed against the rock. The drilling machine can be attached e.g. to a carriage, which moves along a supporting means, such as a feed beam, which is connected to a carrier, such as a vehicle. The drill bit is forced into the rock by moving the carriage, and therefore the drilling machine, along the feed beam towards the rock. The bearing pressure of the drill bit against the rock is influenced by the abovementioned feed pressure through a damping piston arranged in a damping system, which is also used to damp the percussion pulse reflections from the rock.

When drilling, especially with a percussion-type rock drilling machine but also in the case of rotary drilling, it is important to start the drilling correctly. The first part of the borehole must be drilled carefully, because it determines the direction of the borehole. Both a wrong direction and possible bends lead to a great deviation from the intended borehole. This in turn means that the drilling equipment is subject to heavy wear and tear and the blasting conditions deteriorate.

Furthermore, it is important in normal drilling operation, too, that the drilling is carried out with care, so as to ensure that the drilling machine and the rig are protected from damage.

In order to ensure that the initial drilling is carried out correctly so that the borehole ends up at the required spot and has the right direction, one tries both to control the drill steel as well as possible near the drill bit at the beginning of the drilling operation (drill support) and to drill the first part of the hole at a reduced feed force and reduced drilling action, so that the drill steel does not slip on the surface of the rock, which is often uneven and inhomogeneous, e.g. due to earlier blasting operations. In other words, the critical part of the drilling, i.e. its beginning (also called collaring), should be carried out gently and carefully until a hole is obtained that is sufficiently deep and extends in the right direction, after which the full feed force and the full drilling power can be applied. The sufficient depth of the borehole varies with the quality of the rock to a large extent. For example, a soft rock with numerous fissures calls for a deeper borehole to enable us to ensure that it has the right direction before switching over to the full feed force.

There are various methods for changing over from a reduced feed and percussion pressure to normal drilling values.

An example of a known method for controlling the drilling process in the initial operation is described in European Patent EP 0,564,504. According to this patent, the percussive force and the feed force of the drilling machine are adjusted in such a way that the rotary power of the drilling action does not exceed a predetermined limit. To achieve this, the drilling is controlled in at least three different stages: the first of which constitutes the initial drilling, the second represents a transition to the third stage, and the third one constitutes normal operation. In this method, the appropriate values of the percussive force and the feed force have to be set for each stage of drilling.

However, the method described in EP 0,564,504 has several drawbacks, one of which is that the control program for a process with three or more stages is unnecessarily complicated, partly because it calls for the determination of how long the first, reduced stage should be, the determination of the percussive force level and the level of the feed force for this stage, and the determination of what the transitional stage should be like.

Furthermore, problems can arise not only in the initial drilling stage but also in the normal drilling operation, due to discontinuities in the medium. For example, if the rock contains a large number of fissures or its hardness varies greatly so that the drill steel loses contact with the rock ahead of it from time to time, harmful reflections can arise if the percussion pressure is too high in such cases.

It would therefore be desirable to have a method and device that simplify the initial phase of drilling into rocks and reduce the risk of wear and tear in drilling in general.

Object of the invention and its most important features

One of the objects of the present invention is to provide a method for controlling at least one drilling parameter in order to solve the above problems.

Another object of the present invention is to provide a device for controlling at least one drilling parameter in order to solve the above problems.

These and other objects are achieved according to the present invention with the aid of a method for controlling at least one of the drilling parameters as defined in Claim 1, and a device according to Claims 8 and 15. Advantageous embodiments are described in the sub-claims.

According to the present invention, the above objects are achieved by controlling at least one drilling parameter when drilling into rock with a drilling machine, where the percussion pressure that generates the percussive force of the drilling machine, and/or the feed pressure that generates its feed force are controlled during drilling. The method includes the steps of determining a parameter value that represents a mean value of the damping pressure in a damping chamber. The damping chamber is used both for transmitting the feed force to the drill string that is connected to the drilling machine and for damping the rock reflections from this drill string. The method also involves a determination of a difference between the said mean value of the damping pressure that has been established on the one hand, and a reference value for the damping pressure on the other hand. It also involves control of the percussion pressure and/or the feed pressure of the drilling machine on the basis of the said difference. The said mean value of the damping pressure can be determined on the basis of a number of percussion cycles.

This arrangement has the advantage that, when the percussion pressure or the feed pressure is controlled on the basis of a signal representing the difference between the mean damping pressure value averaged over time on the one hand and the reference value of the damping pressure on the other hand, it can be ensured in each situation that a correct feed pressure is obtained in relation to the percussion pressure, or vice versa.

The said mean value can be a time-average value determined over a number of percussion cycles.

The method and device according to the invention can also have one or more of the characteristics described below.

The feed rate of the drilling machine can also be used to control the percussion pressure and/or the feed pressure. In this case, the reference value of the damping pressure can be arranged to vary with the feed rate. If for example the feed rate is high, the reference value of the damping pressure can be reduced in order to reduce the feed pressure and so also the feed rate. It will be realized that this may also involve a reduction of the percussion pressure when the damping pressure is reduced. Conversely, if the feed rate is low, the reference value of the damping pressure can be raised in order to increase the feed pressure and so also the feed rate. This can also have the effect of increasing the percussion pressure.

The method may also include the following steps:

- determining the feed rate of the drilling machine by sensoring, monitoring, measurment or calculation, either continuously and/or at certain intervals, and
- comparing the determined feed rate with a first cavity speed, which represents a speed at which the drilling is known to have encountered a cavity, and controlling the percussion pressure of the drilling

machine on the basis of this comparison. It is advantageous to arrange the system in such a way that the percussion pressure is reduced when the drilling speed exceeds the cavity speed, the aim being to reduce the risk of harmful reflections in the case of percussions without rock contact. The feed pressure can advantageously also be reduced in order to reduce the feed rate.

The damping pressure can be arranged to be determined continuously and/or at certain intervals e.g. by sensoring, monitoring, measurements or calculations.

Furthermore, the percussion pressure can be delimited according to the invention in the following cases: if the damping pressure does not exceed the idling pressure of the damping system with certainty, if the drill shank is not in the percussion position, or if the damping pressure is too low for the percussion pressure prevailing at the time. This, in turn, means that the harmful reflections can be prevented both during initial drilling and during normal drilling. The percussion pressure can be delimited e.g. to its initial value, but it can be increased again to its normal drilling value later.

The method can also include the step of measuring the damping pressure continuously and/or at certain intervals, and comparing resulting damping pressure with what is required at the percussion pressure of the drilling machine at the time, and control the feed pressure of the drilling machine on the basis of this comparison in order to obtain the required damping pressure. The comparison can be carried out e.g. with the aid of a mathematical relation between the damping pressure and the percussion pressure or by look-up in a table that gives a relationship between the damping pressure and the percussion pressure. The mathematical relation or the table is advantageously entered into a computer memory.

This has the advantage that it can be ensured that the relationship between the damping pressure and the percussion pressure is kept within the required range throughout the entire drilling operation.

The method can be used for control purposes when the percussion pressure and the feed pressure of the drilling machine change from a first level to a second level.

For example, the method can be used in the initial drilling stage, where the percussion pressure and/or the feed pressure of the drilling machine are changed from a first, reduced level to a second level, which essentially represents normal drilling. The advantage of this is that the method can be used in the case of initial drilling to ensure that the initial borehole gets the required direction and position.

The method can also include a step of raising/lowering the percussion pressure from a first level to a second level during a predetermined period and/or a predetermined hole depth, wherein the increase/ decrease is being carried out in steps and/or continuously and/or in stages and/or with continuously increasing derivatives and/or linearly. In the case of initial drilling, this means that a simple process for initial drilling is obtained, whereby we can ensure that the damping pressure matches the percussion pressure or vice versa throughout the entire operation. Furthermore, the number of parameters involved in the initial drilling process can be minimized, e.g. to initial and final values for the percussion pressure and a value for the duration of the initial phase, or alternatively for the depth of the borehole.

The percussion pressure can be raised or lowered linearly or according to continuously increasing or decreasing derivatives.

The method can be used for initial drilling and/or normal drilling. This has the advantage that it can be employed both during initial drilling (collaring), where it is important to obtain a borehole that extends in the right direction, and during normal drilling, where drilling into rocks with e.g. numerous cavities can damage the drilling equipment if e.g. full percussive force is applied to a drill string at the opposite end of which the drill steel loses contact with the rock, due to a cavity, for example. When the damping pressure is reduced, e.g. because of a cavity, the percussion pressure can be e.g. delimited, after which it is raised again to the normal drilling level. This increase can be effected much more quickly in normal drilling than in initial drilling, because the borehole is by then long enough to have the right direction.

The percussion pressure can be delimited when the damping pressure does not exceed the idling pressure of the damping system with certainty.

The present invention also relates to a device of this type, with the aid of which the advantages described above are obtained, owing to the characteristics of the device.

Further advantages are derived from the various aspects of the invention and will emerge from the following detailed description.

Brief description of the drawings

Fig. 1 shows a time diagram taken during initial drilling by a known method.

Fig. 2a shows an example of a drilling rig in the case of which the present invention can be applied.

Fig. 2b shows in greater detail the drilling machine illustrated in Fig. 2a.

Figs. 3a-3c show an example of the control principles according to the present invention.

Figs. 4a and 4b show an example of the control system according to the present invention.

Detailed description of the preferred embodiments

Fig. 1 shows a known way of controlling electrically controlled and computer-controlled hydraulic systems during rock drilling. This method comprises numerous parameters that have to be set. The initial values and the duration of the initial drilling stage (collaring) must be determined, as must also the nature of the transition stage, illustrated in Fig. 1, between time T1 and time T2. In other words, it must be decided what the transition stage will be like in order to ensure that it is sufficiently smooth. At the same time, the reduced-power drilling should not be maintained for too long, because that would mean a loss of time. Consequently, this method is complicated.

Fig. 2a shows a rock drilling rig 20 for which the present invention can be used. The rock drilling rig 20 comprises a boom 21, one end of which being connected to a carrier, represented by a vehicle 23, while its other end carries a feeder 24 that supports a drilling machine 22. The drilling machine 22 can be displaced along the feeder 24 and is coupled to a drill string component 25. The drill string component 25 constitutes the first component, which is used during the drilling of a special borehole and which is fitted with a drill bit at its end opposite the drilling machine. Otherwise it is generally threaded for example to connect it to the drilling string component that was used before.

Fig. 2b shows the drilling machine 22 in more detail. This drilling machine comprises an adapter 31, one end of which being provided with connecting means 30, for example a screw thread, to establish a connection with a drilling string component (not shown). The drilling machine also comprises a piston 32, which impacts against the adapter 31 to transfer percussion pulses first to the drill string and onto the rock. The drill string is advanced (fed) towards the rock through a sleeve 33 with the aid of a damping piston 34, which is arranged in a damping system that is also used to damp percussion pulse reflections from the rock. During operation, a determined force produced by hydraulic pressure in a first damping chamber 37 is transmitted to the adapter 31 via the damping piston 34 and the sleeve 33, this force being used to ensure that the drill bit is pressed against the rock at all times. When a percussion gives rise to reflections from the rock, these reflections are damped by the damping piston 34 being forced into a second damping chamber 38. As a result of this, the fluid in this second damping chamber 38 is pressed into the first damping chamber 37 through a small slit between the damping piston 34 and the chamber wall 35, as the damping piston 34 is being pressed into the second damping chamber 38. In another embodiment, the damping piston 34 and the casing 33 may consist of a single component.

The present invention involves a simple control principle based on the control of the "rod force". The term "rod force" is used here to denote the force acting on the drill steel, apart from the pulses generated by the percussions of the piston (the percussion force). This rod force can be calculated by measuring the damping pressure $\boldsymbol{p_d}$ of the drilling machine in or a number of damping chambers arranged along the drill string, such as for example the first damping chamber 37 shown in Fig.2b, and by multiplying this pressure by the area of the operating surface A_d of the damping piston, against which the damping pressure operates in the damping chamber, i.e. $F_{rod} = p_d A_d$ or, in the case where a number of damping chambers are used, $F_{rod} = \sum_{1}^{i} p_i A_i$.

At initial drilling, a suitable value of the percussion pressure is established for both initial drilling and normal (full) drilling. These pressure levels can be determined for example in advance or they can be adjusted later. The pressure levels can vary with the type of rock, but the minium level is often limited by the required idling levels of the machine.

The initial value of the percussion pressure is chosen in such a way that the initial drilling is sufficiently gentle to ensure that the borehole has the right direction and position; while at the same time, as mentioned before, the pressure should not be too low, since this can cause problems with the drilling machine. For example, it is advantageous to choose an initial value that is only slightly greater than the charging or loading pressure of the accumulator, in order to prevent problems with its membrane. Of course, the initial value should not be too low either, otherwise no borehole is obtained at all. In the case of a typical drilling machine, the initial value of the percussion pressure can be for example about 130 bar. The final value is the value that the percussion pressure should have in the case of normal (full) drilling, i.e. the value that gives the fastest possible drilling without endangering the machine, for example a pressure of 200 bar. This value should in principle be as high as possible. However, it may be necessary in some situations to operate the machine at less than full power, in which case appropriate values can be set. To control the drilling machine for a period corresponding to the time elapsing before T2 is reached in Fig. 1, the length of this period is established, together with the way the percussion pressure is to be raised from the lower value to the higher one during this period.

The control is then effected by determining the damping pressure in a damping chamber, such as the first damping chamber 37, e.g. by measurements or sensoring with the aid of a pressure sensor fitted in or connected to the damping chamber. This pressure sensor can generate a signal that represents a time-average value of the pressure in the damping chamber, where the mean value can be a mean value based on a number of percussion cycles. Alternatively, the damping pressure can be determined sufficiently often, for example continuously, so as to be able to establish the variation of the damping pressure with the percussions delivered by the percussion tool, i.e. so that the pressure-increasing pulses arising on reflection from the rock can be detected, after which the mean value of the damping pressure can be determined during a single percussion cycle. For example, the pressure sensor can be so constructed as to comprise a device for effecting the calculation of the said mean value and so give a representation of the mean value for each percussion cycle. Alternatively, the pressure sensor can be arranged to produce signals continuously or at certain intervals, these signals being then used by an external device to determine the mean value of the damping pressure for a percussion cycle. The intervals can be arrange to depend on the percussion frequency of the drilling machine; a drilling machine operating at a percussion frequency of the order of hundreds of Hertz or in the kilo-Hertz region calls for significantly more closely-set intervals than a drilling machine operating at a percussion frequency of the order of 30-50 Hz. Instead of determining the mean value of one percussion cycle, the mean value for a number of percussion cycles can be determined. The mean value of the determined damping pressure is then compared with the actual percussion pressure, using a predetermined relation between the damping pressure and the percussion pressure. This can be done e.g. by table look-up, in which table the required damping pressure for various values of the percussion pressure can be stored. Alternatively, the calculation can be based on established mathematical relationships. Instead of measuring the damping pressure in a damping chamber, it is also possible to determine the pressure e.g. in the feed pipe leading to the damping chamber. This has the advantage that the measurement can be carried out on the rig itself, so less cabling is needed.

If the determined damping pressure is below the required damping pressure, i.e. if $p_{d,exp} < p_{d,req}$, the feed pressure is raised until the condition is fulfilled. When raising the feed pressure (in the case of initial drilling), the increase in the percussion pressure may be either stopped for a time or it may be allowed to proceed. It is also possible to reduce the percussion pressure occasionally in order not to risk any damage to the drilling machine if the measured damping pressure is too low. The percussion pressure and the damping pressure are preferably measured continuously or at such short intervals, so that the control of the feed pressure can be considered fast in comparison with the increase in the percussion pressure. This makes a satisfactory control of the feed pressure possible without interrupting the increase in the percussion pressure. In this way, the mean value of the damping pressure can be determined for a number of percussion cycles and still allow a satisfactory control of the feed pressure. Conversely, the feed pressure can be reduced when the reverse relationship applies, i.e. when $p_{d,exp} > p_{d,req}$.

Several different methods can be used to increase the damping pressure from the initial value to the normal value. For example, the percussion pressure increment can be raised according to a continuously increasing function. Figs. 3a-3c show some examples of the appearance of the percussion pressure increment during initial drilling, i.e. in the period elapsing from 0 to T2 in Fig. 1. In Fig. 3a, the increase follows a continuously increasing function, with successively increasing derivatives, such as an exponential function, for example.

Fig. 3b shows a linear increase, and Fig. 3c shows an increase effected in the form of staircase-like steps.

The present invention therefore provides a system that only comprises two control stages. The parameters for the first stage - initial drilling - comprise the initial value of the percussion pressure and the length of the initial stage. The number of parameters that have to be set is therefore minimized. During initial drilling, the percussion pressure is raised in a predetermined way, and the feed pressure is then controlled on the basis of the damping pressure.

The duration of the initial stage can be determined e.g. by setting either the required depth of the initial borehole or the time over which the initial drilling should proceed.

In an embodiment of the present invention, the time-average value of the percussive force can be calculated from the equation $F_{drill} = mvf(1+R)$, where m is the mass of the piston, v is the percussion velocity, f is the percussion frequency and R is the piston rebound coefficient, i.e. the speed of rebound divided by the percussion velocity. The actual feed force operating in the drilling machine is the sum of the time-average value of the percussive force F_{drill} and the force on the rod F_{rod}. This actual feed force F_{feed} is different from the theoretical one, owing to frictional losses and similar effects. This difference varies from one machine to the next, depending e.g. on whether or not these machines are subject to different frictional losses. In another embodiment, the percussive force is generated directly by the fluid pressure without involving a percussion piston. This variant is denoted pulse percussion tool.

The variation of the time-average value of the percussion force with the percussion pressure $\boldsymbol{p}$ is given by:

$$F_{drill} = fkn(p),$$

and for a percussion piston we have that

$$F_{drill} = mvf(1+R) = mv_0 f_0(1+R) * \frac{p}{p_0} = Kp \qquad (1)$$

where $\boldsymbol{p}$ is the percussion pressure. $\boldsymbol{K}$ is a constant that is specific to the drilling machine, since $\boldsymbol{m}$, $\boldsymbol{v_0}$, $\boldsymbol{f_0}$, $\boldsymbol{R}$ **and** $\boldsymbol{p_0}$ are parameters that are themselves specific to the drilling machine and which can therefore, e.g., when being mounted on a specific drilling rig, be fed into a memory of the control system of the drilling rig. $\boldsymbol{R}$ depends on the shank adapter, and when this is replaced by one of another type, it may be necessary to change the stored $\boldsymbol{R}$ value accordingly. $\boldsymbol{K}$ also changes when the percussion position of the percussion piston is altered, so the stored value of $\boldsymbol{K}$ is changed also in such a case.

Since $\boldsymbol{F_{feed} = F_{rod} + F_{drill}}$ and $\boldsymbol{F_{rod} = p_d A_d}$, that is to say:

$$F_{feed} = p_d A_d + Kp = X * Kp \qquad (2)$$

the relationship between the feed force and the time-average value of the percussive force can be defined in a general form as follows:

$$X = \frac{p_d A_d}{fkn(p)} + 1$$

which gives the following relationship for a percussion apparatus according to Eq. (1):

$$X = \frac{p_d A_d}{Kp} + 1 \qquad (3)$$

The control can be effected according to the principle shown in Fig. 4a by choosing suitable values for the percussion pressure in the case of initial drilling and normal drilling, together with a value for the relation $\boldsymbol{X}$.

The control principle shown in Fig. 4a is based on linear control, as in Fig. 3b, but of course any other control principle can also be used. With linear control from $\boldsymbol{X_L}$ to $\boldsymbol{X_H}$, the actual value of $\boldsymbol{X}$ can be obtained e.g. in the following way:

$$X = X_L + \frac{X_L - X_H}{p_L - p_H} * (p - p_L) \qquad (4)$$

Furthermore, the required damping pressure $\boldsymbol{p_{d,ref}}$ can be calculated as follows:

$$p_{d,ref} = \frac{(X-1)}{A_d} Kp \qquad (5)$$

where $\boldsymbol{X}$ is either kept constant or is determined from Eq. (4). For example, a suitable value of $\boldsymbol{X}$, which can be specific to the drilling machine, may be known in advance and be stored already when the drilling machine is manufactured; alternatively, $\boldsymbol{X}$ can be determined after a period of drilling.

In the embodiment illustrated in Fig. 4a, the value of $\boldsymbol{X}$ is kept constant and it is stored in the memory 50 together with a number of parameters for the drilling machine. In this figure, these parameters are $\boldsymbol{X}$, $\boldsymbol{p_L}$, $\boldsymbol{p_H}$,

$\boldsymbol{K}$ and $\boldsymbol{A_d}$, where $\boldsymbol{p_L}$ is the initial level of the percussion pressure and $\boldsymbol{p_H}$ is the percussion pressure in the case of normal drilling. These stored parameters are used in drilling for calculating $\boldsymbol{p_{d,ref}}$ with the aid of calculation means 51, using Eq. (5). As shown in this figure, the calculation means 51 has means 52 for receiving the actual percussion pressure $\boldsymbol{p}$. The calculated value of $\boldsymbol{p_{d,ref}}$ that this parameter should have is then transmitted by the calculation means 51 as output data via output means 53 and is then compared with the actual damping pressure in a comparator 54. The output end of the latter is coupled to a means 55 that uses the difference between $\boldsymbol{p_{d,ref}}$ and $\boldsymbol{p_d}$. The value of $\boldsymbol{p_d}$ is determined e.g. by a pressure sensor as mentioned above. The said difference is used in order to calculate a change in the feed pressure $\boldsymbol{\Delta p_{feed}}$ for the feed pressure $\boldsymbol{p_{feed}}$ and to transmit this difference $\boldsymbol{\Delta p_{feed}}$ to a suitable device (not shown), which makes a correction in the feed pressure, using the calculated difference. The feed pressure is increased if $\boldsymbol{p_{d,ref}}$ is greater than $\boldsymbol{p_d}$, and it is reduced if $\boldsymbol{p_{d,ref}}$ is smaller than $\boldsymbol{p_d}$. This process can be carried out continuously or at certain intervals, such as 1 time, 10 times or 100 times a second.

In an alternative embodiment shown in Fig. 4b, it is not a fixed value of $\boldsymbol{X}$ that is used but instead two different $\boldsymbol{X}$ values are stored in the memory 60, namely $\boldsymbol{X_L}$ and $\boldsymbol{X_H}$, the first of which being used for initial drilling, and the second for normal drilling. In this case, $\boldsymbol{X}$ can be determined for the actual percussion pressure by using a predetermined relation, such as for example a linear one according to Eq. (4).

Instead of determining a feed pressure change as shown in Figs. 4a and 4b, it is also possible to determine a change in the percussion pressure, in which case the percussion pressure is altered, so that the actual damping pressure assumes the required value of damping pressure.

Furthermore, the feed rate of the drilling machine, i.e. the speed at which the drilling proceeds, can also be used for the said control of the percussion pressure and/or feed pressure. In this case, a value of $p_{d,ref}$ is determined that varies with the actual feed rate as well.

The present invention has been described above in connection with initial drilling. However, the invention can also be applied in the case of normal drilling. With normal drilling, discontinuities of the medium can present a problem. If for example the rock contains a large number of fissures or if its hardness varies greatly so that the drill steel loses contact with the rock ahead of it from time to time, harmful reflections can arise if the feed pressure and the percussion pressure are too high in this case. If the drilling steel loses contact with the rock facing it, this is immediately reflected in a drop in the damping pressure and an increase in feed rate. Instead of raising the feed pressure to maintain the value of the quotient X, it is possible to reduce the percussion pressure instead. For example, the feed rate can be compared with a cavity speed representing a speed at which the drilling is known to have reached a cavity, and the percussion pressure of the drilling machine can then be reduced if the cavity speed is reached or exceeded. The cavity speed is determined (set) at a value of the feed rate that represents a speed that is higher than the value at which drilling into the rock is possible. In other words, if the feed rate rises to the cavity speed that has been set, it can be taken as an indication that the drilling has reached a cavity.

For example, the percussion pressure can be reduced to the initial or start value in such a case, because this has been chosen e.g. with respect to the accumulator pressure. However, one need not necessarily go down to this initial or start value but can instead reduce the percussion pressure to a level at which it is delimited with respect to the idling pressure of the damping system.

Furthermore, the present invention has been described here in connection with a percussion drilling machine that comprises a percussion piston, where the energy of the percussion or impact pulses in principle consists of the kinetic energy of the percussion piston, which is transmitted to the drill steel. However, the invention can also be used with other types of pulse-generating systems, such as those in which the shock-wave energy is instead generated by pressure pulses that are transmitted to the drill string from an energy store through a percussion organ that only performs a very small movement. In the case of such impulse-generating devices, too, a damping pressure can be determined in a damping chamber, which can be suitable chamber, provided that it performs the required damping function.

Claims

1. Method of controlling at least one drilling parameter when drilling into rock with a drilling machine, where a percussion pressure and/or a feed pressure of the drilling machine, which generate a percussive force and a feed force respectively, are controlled during drilling, **characterized in that**:

- a parameter value is determined that represents a mean value of the damping pressure in a damping chamber that transmits a feed force to a drill string connected to the drilling machine,
- a difference between the said determined mean value of the damping pressure and a reference value of the damping pressure is determined, and
- the percussion pressure and/or the feed pressure of the drilling machine is controlled on the basis of the said difference.

2. Method according to Claim 1, where the said damping chamber that transmits the feed force to a drill string connected to the drilling machine also ensures damping of rock reflections from the said drill string.

3. Method according to Claim 1 or 2, further including the step of determining a change in percussion pressure and/or a change in feed pressure on the basis of the said difference, and controlling the percussion pressure and/or the feed pressure according to the said change in the percussion pressure and/or feed pressure.

4. Method according to Claim 1, further including the steps of:

- reducing the said percussion pressure and/or increasing the said feed pressure when the said mean value of the damping pressure that has been determined falls below the said reference value of the damping pressure, and/or
- increasing the said percussion pressure and/or

reducing the said feed pressure when the said mean value of the damping pressure that has been determined exceeds the said reference value of the damping pressure.

5. Method according to any one of Claims 1-4, where the feed rate of the drilling machine is also used for the said control of the percussion pressure and/or feed pressure.

6. Method according to any one of Claims 1-5, characterized in that the said feed pressure is controlled in such a way that the required damping pressure is obtained.

7. Method according to any one of Claims 1-6, wherein the said method is used for control purposes when the percussion pressure of the drilling machine is controlled from a first level to a second level.

8. Device for controlling at least one drilling parameter when drilling into rock with a drilling machine, where a percussion pressure and/or a feed pressure of the drilling machine, which generate a percussive force and a feed force respectively, are arranged to be controlled during drilling, **characterized in that** the device includes means for:

- determing a parameter value that represents a mean value of a damping pressure in a damping chamber that is arranged to transmit a feed force to a drill string connected to the drilling machine,
- determining a difference between the said mean value of the damping pressure and a reference value of the damping pressure, and
- controlling the percussion pressure and/or the feed pressure of the drilling machine on the basis of the said difference.

9. Device according to Claim 8, characterized in that

the said damping chamber that is arranged to transmit a feed force to a drill string connected to the drilling machine also is arranged to damp rock reflections from the said drill string.

10. Device according to Claim 8 or 9, characterized in that it also includes means for, on the basis of the said determined difference, determine a change in the percussion pressure and/or in the feed pressure, and control the percussion pressure and/or the feed pressure according to the said change in the percussion pressure and/or in the feed pressure.

11. Device according to Claim 1 which further includesmeans for:

- reducing the said percussion pressure and/or increasing the said feed pressure when the said mean value of the damping pressure that has been determined falls below the said reference value of the damping pressure, and/or
- increasing the said percussion pressure and/or reducing the said feed pressure when the said mean value of the damping pressure that has been determined exceeds the said reference value of the damping pressure.

12. Device according to any one of Claims 8-11, characterized in that it further includes means for using the feed rate of the drilling machine in the said control of the percussion pressure and/or feed pressure.

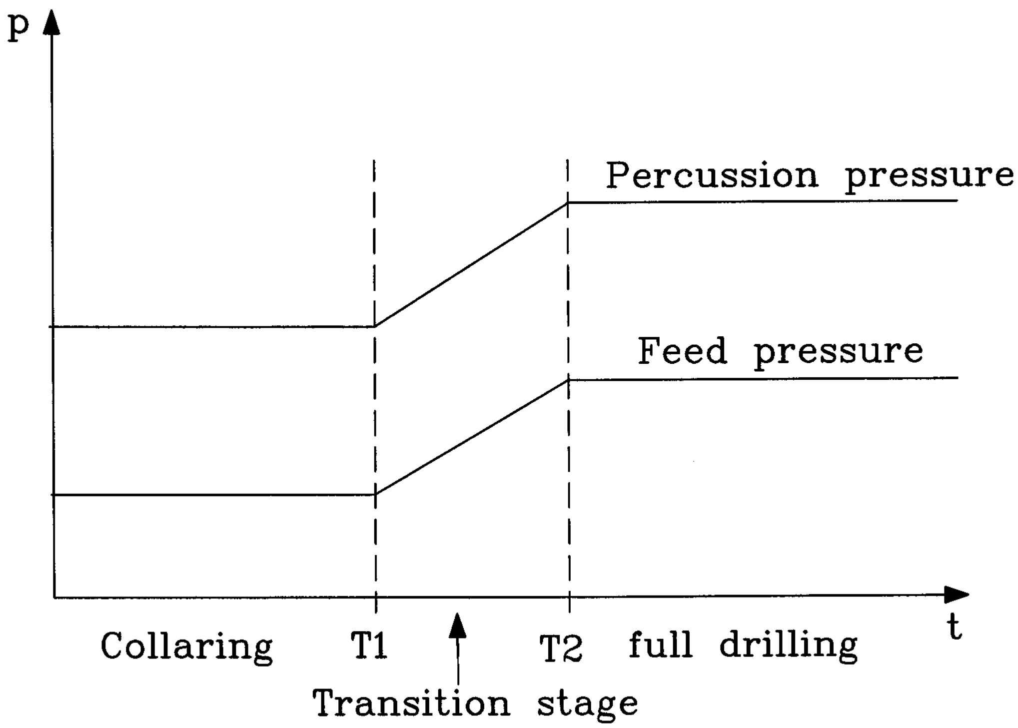
13. Device according to any one of Claims 8-12, characterized in that it further includes means for controlling the said feed pressure in such a way that the required damping pressure is obtained.

14. Device according to any one of Claims 8-13, characterized in that it further includes means for

controlling the percussion pressure and/or the feed pressure of the drilling machine when the percussion pressure of the drilling machine is controlled from a first level to a second level.

15. Rock drilling rig, characterized in that it includes a device according to any one of Claims 8-14.

Fig. 1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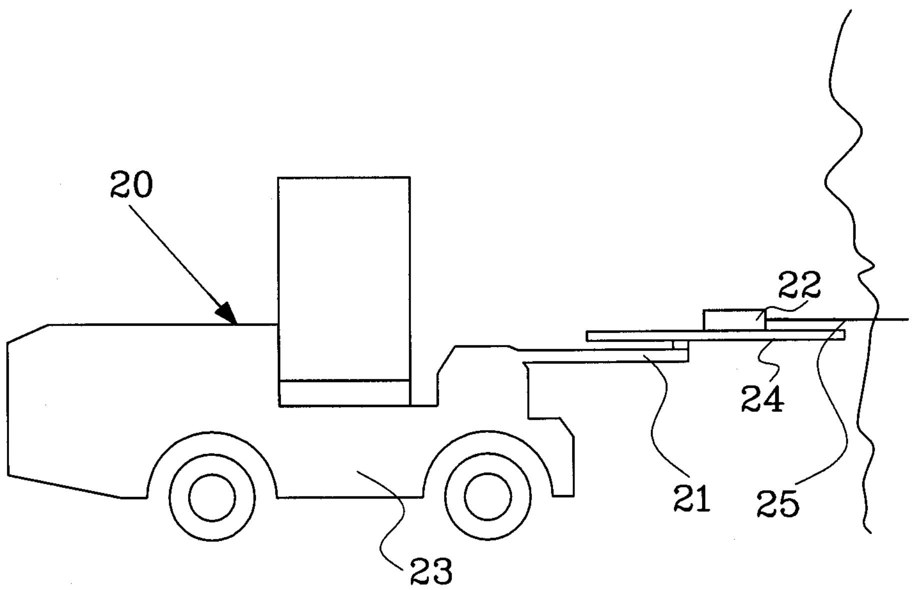
Percussion pressure
Feed pressure
t
Collaring
T1
T2
full drilling
Transition stage

Fig. 2a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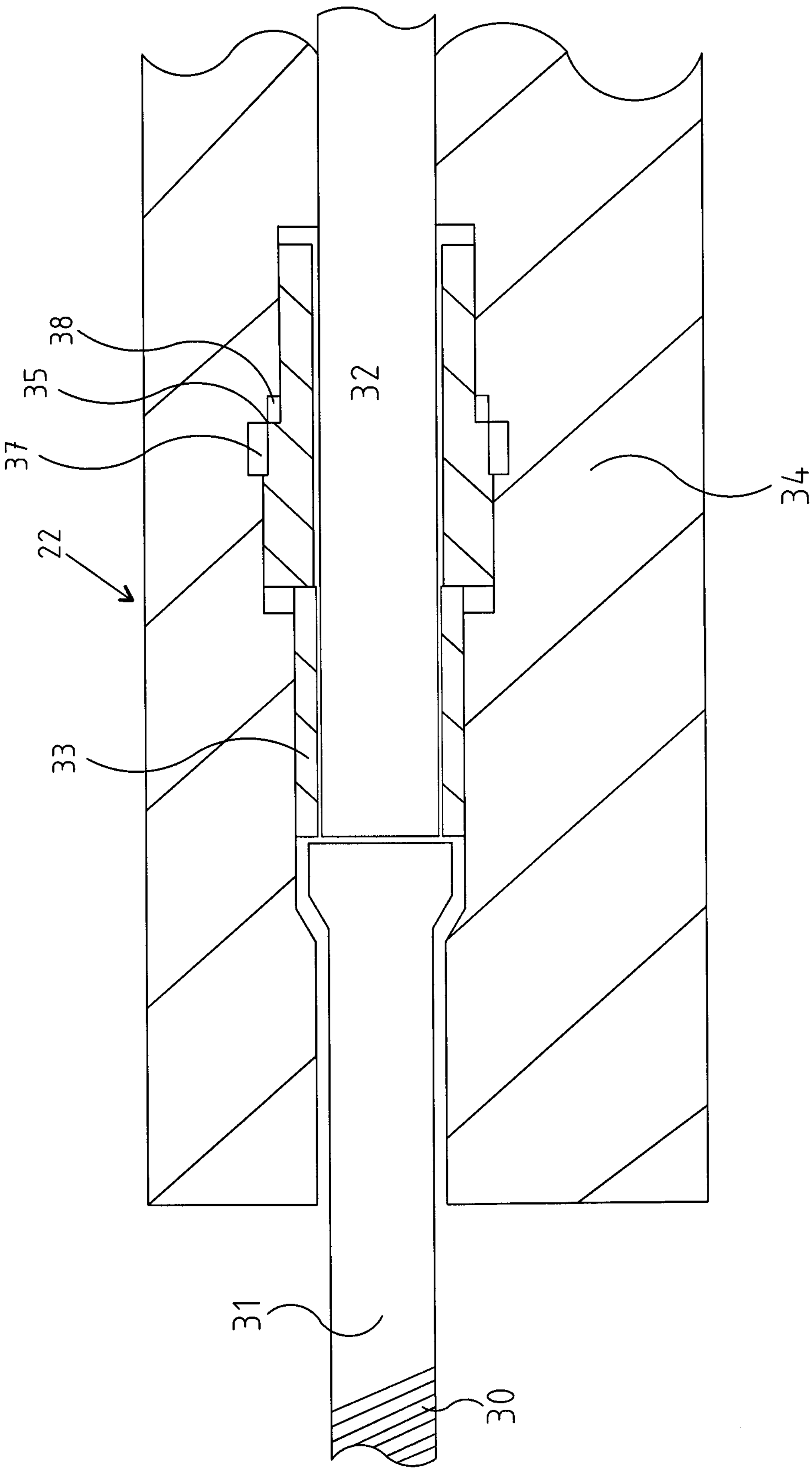


Fig. 2b

Fig. 3a

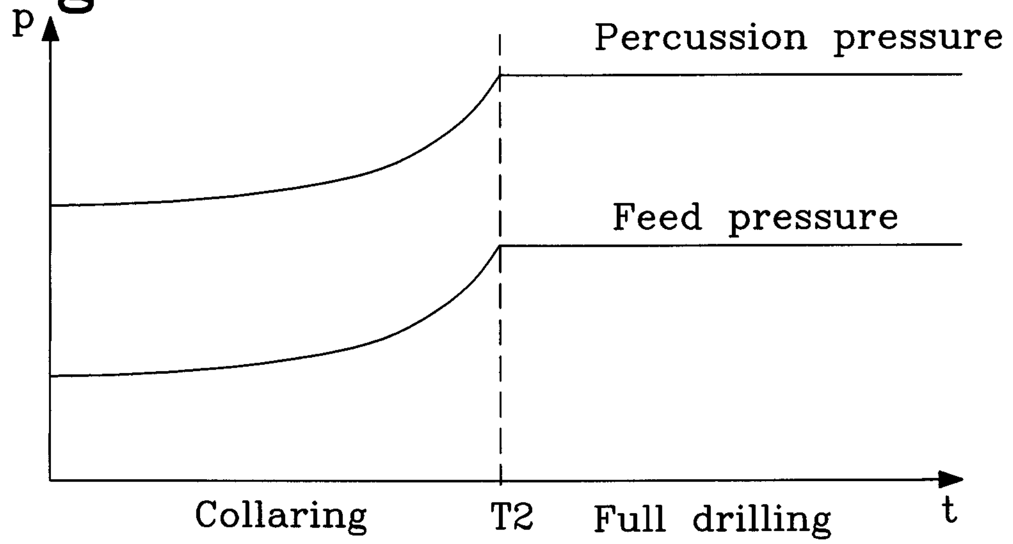


Fig. 3b

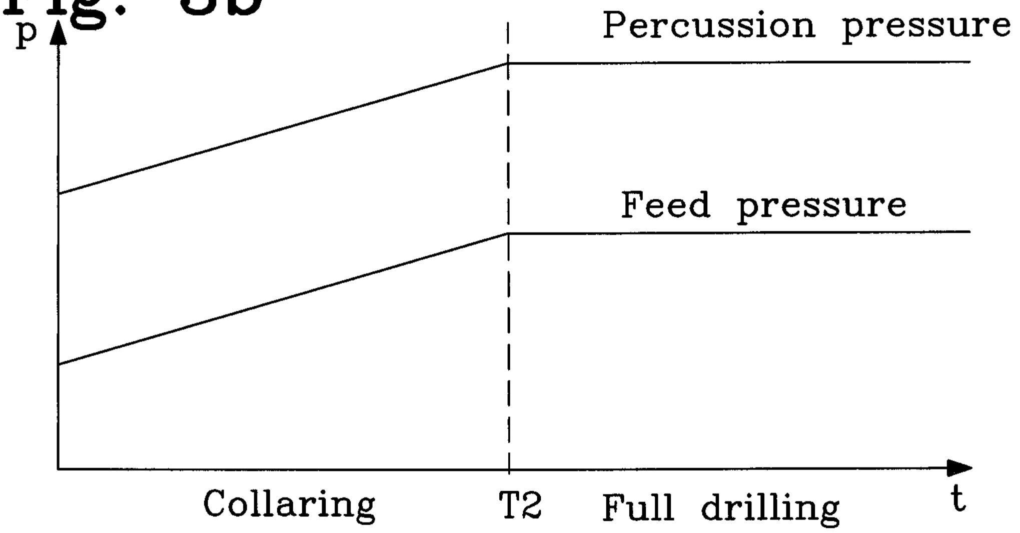


Fig. 3c

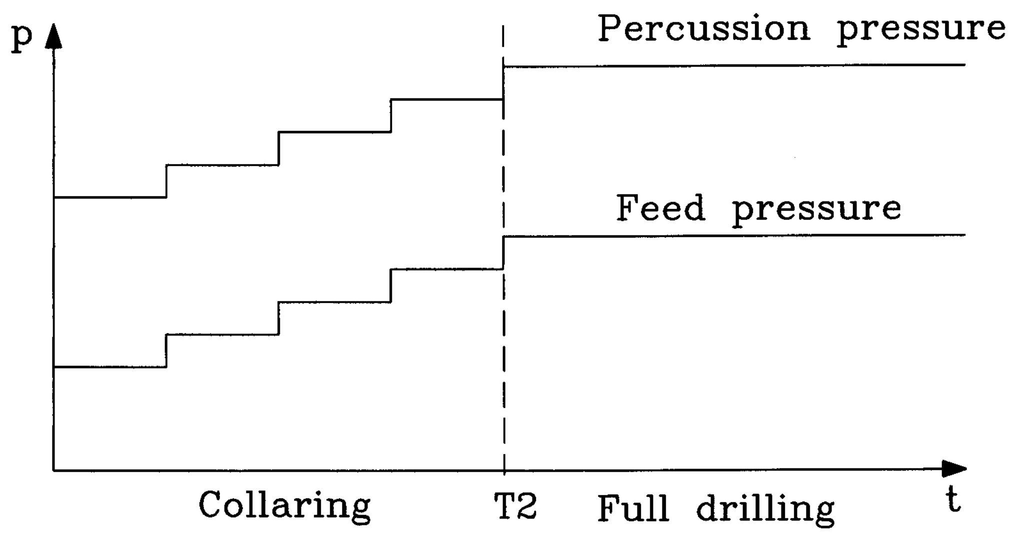
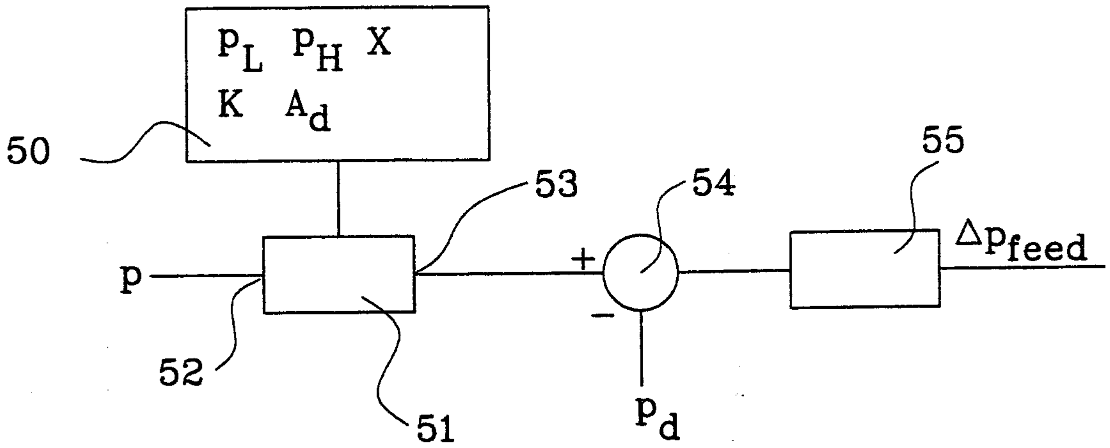


Fig. 4a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K A_d
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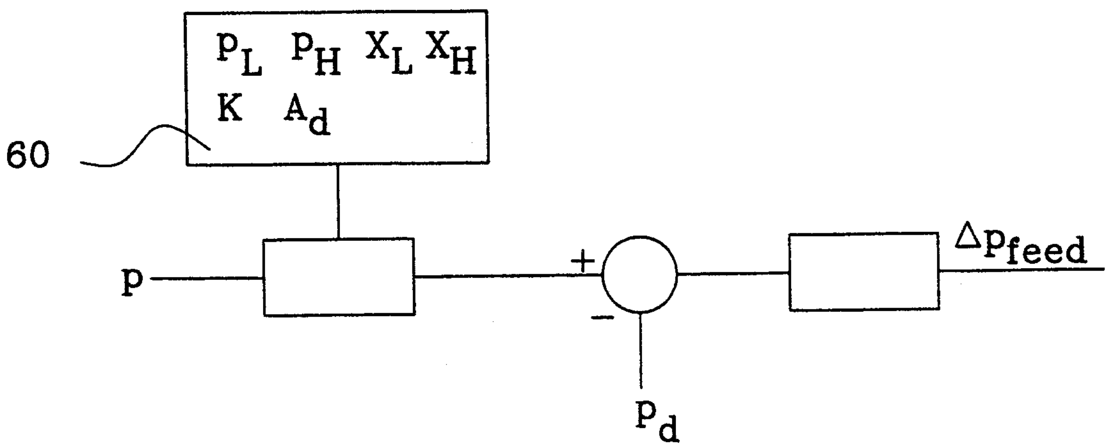
51
52
53
54
55
p
+
−
p_d
Δp_feed

Fig. 4b


p_L p_H X_L X_H
K A_d
60
p
+
−
p_d
Δp_feed

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2008/000255

A. CLASSIFICATION OF SUBJECT MATTER

IPC: 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: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0648915 A1 (ATLAS COPCO ROCKTECH AB), 19 April 1995 (19.04.1995) --	1-15
A	WO 03044319 A1 (ATLAS COPCO ROCK DRILLS AB), 30 May 2003 (30.05.2003) --	1-15
A	WO 2005121506 A1 (ATLAS COPCO ROCK DRILL AB), 22 December 2005 (22.12.2005) --	1-15

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

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 June 2008	26 -06- 2008

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Christer Bäcknert / JA A Telephone No. +46 8 782 25 00

International patent classification (IPC)

E21B 44/06 (2006.01)
E21B 44/00 (2006.01)

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Cited literature, if any, will be enclosed in paper form.

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