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(54) **Title:** A CONTROL SYSTEM FOR CONTROLLING A WATERFLOW FOR AN AUTONOMOUS DRILLING MACHINE

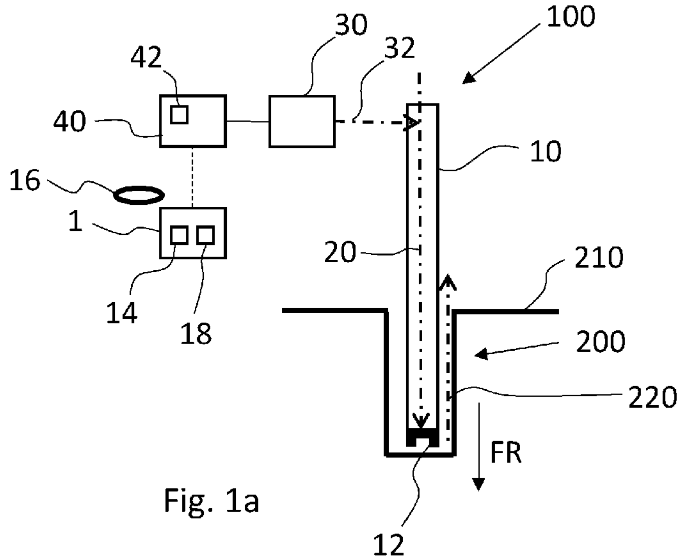

Fig. 1a

(57) **Abstract:** The disclosure relates to a control system (1) for controlling a waterflow (32) for an autonomous drilling machine (100), the autonomous drilling machine (100) comprising: - a water pump (30) and a hydraulic motor (40), wherein the autonomous drilling machine (100) is configured to supply water from the water pump (30) into an air channel (20) during drilling, wherein the control system (1) is configured to: - receive a value indicative of a feed rate (FR) of the drill head (12) during drilling, - in response to determining a change of the feed rate (FR), adjust a level of electric power or electric current provided to a fluid flow valve (42) such that a level of waterflow (32) supplied into the air channel (20) from the water pump (30) is adjusted. Also disclosed are a method, an autonomous drilling machine, a computer program product and a non-transitory computer-readable medium.

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A CONTROL SYSTEM FOR CONTROLLING A WATERFLOW FOR AN AUTONOMOUS DRILLING MACHINE

TECHNICAL FIELD

The present disclosure relates to a control system for controlling a waterflow for an autonomous drilling machine. The present disclosure further relates to an autonomous drilling machine, a method for controlling a waterflow for an autonomous drilling machine, a computer program product and a non-transitory computer-readable medium.

BACKGROUND

Rock drilling, i.e. when drilling a borehole in rock by excavating rock, is a challenging and demanding operation. During rock drilling, e.g., when using a drill string and a drill head for the drilling, cuttings are generated at the bottom of the borehole. These cuttings need to be removed from the borehole during the drilling to enable an efficient drilling operation.

The cuttings may be removed by flushing, such as by supplying pressurized air into the borehole via an air channel. However, if only air is used, unwanted dust may be generated outside the borehole. Therefore, water may be supplied into the air channel to thereby reduce the dust generation. When water is supplied into the air channel with the pressurized air, a water mist is generated, whereby the water mist is used for reducing the dust generation.

Even though it is known to use water in the pressurized air for reducing the dust level, there is still a strive to develop improved technology relating to this, especially for autonomous drilling machines.

SUMMARY

In view of the above, an object of the present disclosure is to provide an improved control system for controlling a waterflow for an autonomous drilling machine, which in at least one aspect alleviates one or more drawbacks of the prior art, or which at least provides a suitable alternative. Other objects of the disclosure are to provide an autonomous drilling machine, a method for controlling a waterflow for an autonomous drilling machine, a computer program product and a non-transitory computer-readable medium, which in at least one aspect alleviate one or more drawbacks of the prior art, or which at least provides suitable alternatives.

According to a first aspect of the disclosure, the object is achieved by a control system according to claim 1. Thus, there is provided control system for controlling a waterflow for an autonomous drilling machine, wherein the autonomous drilling machine comprises:
- a drill string,
- a drill head,
- an air channel for supplying air to the drill head,
- a water pump and a hydraulic motor, wherein the hydraulic motor is configured to drive the water pump, and

wherein the autonomous drilling machine is configured to supply water from the water pump into the air channel during drilling, wherein a fluid flow for powering the hydraulic motor is configured to be controlled based on a level of electric power or electric current provided to a fluid flow valve of the hydraulic motor,
wherein the control system is configured to:
- receive a value indicative of a feed rate of the drill head during drilling,
- in response to determining a change of the feed rate, adjust the level of electric power or electric current provided to the fluid flow valve such that a level of waterflow supplied into the air channel from the water pump is adjusted, wherein the adjustment of the electric power or electric current is based on a predetermined relationship between the level of electric power or electric current and the level of waterflow provided by the water pump.

An autonomous drilling machine as used herein means a drilling machine in which at least one adjustable drilling parameter of a drilling operation is automatically controlled. At least one of the adjustable drilling parameters is herein the waterflow supplied into the air channel from the water pump during drilling. Other examples of adjustable drilling parameters which may be automatically controlled are percussion frequency, percussion force, feed rate of the drill head, rotational speed of the drill head and the drill string, static load exerted on the drill head, and air pressure.

The predetermined relationship is a relationship between the level of electric power and the level of waterflow provided by the water pump, and/or a relationship between the level of electric current and the level of waterflow provided by the water pump.

By the provision of a control system as disclosed herein, improved control of the waterflow during drilling is provided. More specifically, by controlling the waterflow as disclosed herein, dust generation from the cuttings during drilling may be reduced while at the same time assuring that an excessive amount of water is not supplied into the air channel. An excessive amount of water may imply a reduced drilling performance and/or unnecessary waste of water. By the present disclosure, any sensors for measuring the waterflow may not be required. Rather, the waterflow can be controlled based on, such as only based on, the feed rate and the predetermined relationship as disclosed herein. This may imply a reliable and robust control, reduced dust generation, cost-effective control, etc.

Optionally, the control system is further configured to initially set an initial value of electric power or electric current provided to the fluid flow valve such that an initial level of waterflow supplied into the air channel from the water pump is provided. The initial value may be set based on input from a user. The initial value may be set based on a set feed rate at start-up of the drilling operation. Initially setting an initial value may imply improved control of the waterflow, mitigating any unnecessary dust generation or overflow of water at start-up of the drilling operation.

Optionally, the initial value of electric power or electric current is at least partly set based on a type of rock which the autonomous drilling machine is about to drill in. It has been realized that the type of rock may affect the dust generation. Accordingly, by setting the initial value at least partly based on the type of rock, further improved control of the waterflow may be achieved.

Optionally, the initial value of electric power or electric current is at least partly set based on a condition of the autonomous drilling machine which is indicative of a wear state of the drill head. It has been realized that the wear state of the drill head may affect the dust generation. Accordingly, by setting the initial value at least partly based on the condition of the autonomous drilling machine which is indicative of the wear state of the drill head, further improved control of the waterflow may be achieved. For example, the wear state of the drill head may be determined by use of a condition sensor for the drill head which measures the wear state of the drill head. Additionally, or alternatively, the wear state of the drill head may be determined based on a previous use time of the drill head. For example, the previous use time may be a value corresponding to for how long time the drill head has been previously used in operation, such as expressed in minutes and/or hours.

Optionally, the control system is further configured to adjust the level of electric power or electric current provided to the fluid flow valve such that the level of waterflow supplied into the air channel from the water pump is proportionally adjusted with respect to the feed rate of the drill head during drilling. Adjusting the waterflow proportionally with respect to the feed rate has shown to mitigate dust generation while also avoiding an overflow of water into the air channel.

Optionally, the predetermined relationship between the level of electric power or electric current and the level of waterflow provided by the water pump is a non-linear relationship. For example, the predetermined relationship may be expressed by a non-linear curve having an increasing derivative. Alternatively, the predetermined relationship may be expressed by a non-linear curve having a decreasing derivative. The present disclosure is further based on a realization that there may be a non-linear relationship between electric power or electric current provided to a fluid flow valve for a hydraulic motor and the level of waterflow from the water pump which is driven by the hydraulic motor. Accordingly, by way of example, by use of the non-linear predetermined relationship, the waterflow to the air channel can be efficiently controlled, mitigating the risk of dust generation while at the same time avoiding any overflow of water into the air channel.

According to a second aspect of the disclosure, the object is achieved by an autonomous drilling machine according to claim 7. Thus, there is provided an autonomous drilling machine which comprises:

- a drill string,
- a drill head,
- an air channel for supplying air to the drill head,
- a water pump and a hydraulic motor, wherein the hydraulic motor is configured to drive the water pump, and

wherein the autonomous drilling machine is configured to supply water from the water pump into the air channel during drilling, wherein a fluid flow for powering the hydraulic motor is configured to be controlled based on a level of electric power or electric current provided to a fluid flow valve of the hydraulic motor, and wherein the autonomous drilling machine further comprises a control system according to any one of the examples of the first aspect of the disclosure.

Advantages and effects of the second aspect of the disclosure are analogous to the advantages and effects of the first aspect of the disclosure. It shall also be noted that all embodiments of the first aspect of the disclosure are combinable with all embodiments of the second aspect of the disclosure, and vice versa.

According to a third aspect of the disclosure, the object is achieved by a method according to claim 8. Thus, there is provided a method for controlling a waterflow for an autonomous drilling machine, wherein the autonomous drilling machine comprises:
- a drill string,
- a drill head,
- an air channel for supplying air to the drill head,
- a water pump and a hydraulic motor, wherein the hydraulic motor is configured to drive the water pump, and

wherein the autonomous drilling machine is configured to supply water from the water pump into the air channel during drilling, wherein a fluid flow for powering the hydraulic motor is configured to be controlled based on a level of electric power or electric current provided to a fluid flow valve of the hydraulic motor,
wherein the method comprises:
- receiving a value indicative of a feed rate of the drill head during drilling,
- in response to determining a change of the feed rate, adjusting the level of electric power or electric current provided to the fluid flow valve such that a level of waterflow supplied into the air channel from the water pump is adjusted, wherein the adjustment of the electric power or electric current is based on a predetermined relationship between the level of electric power or electric current and the level of waterflow provided by the water pump.

Advantages and effects of the third aspect of the disclosure are analogous to the advantages and effects of the first and second aspects of the disclosure. It shall also be noted that all embodiments of the third aspect of the disclosure are combinable with all embodiments of the first and second aspects of the disclosure, and vice versa.

Optionally, the method further comprises:

- initially setting an initial value of electric power or electric current provided to the fluid flow valve such that an initial level of waterflow supplied into the air channel from the water pump is provided.

Optionally, the initial value of electric power or electric current is at least partly set based on a type of rock which the autonomous drilling machine is about to drill in.

Optionally, the initial value of electric power or electric current is at least partly set based on a condition of the autonomous drilling machine which is indicative of a wear state of the drill head.

Optionally, adjusting the level of electric power or electric current comprises adjusting the level of electric power or electric current provided to the fluid flow valve such that the level of waterflow supplied into the air channel from the water pump is proportionally adjusted with respect to the feed rate of the drill head during drilling.

Optionally, the predetermined relationship between the level of electric power or electric current and the level of waterflow provided by the water pump is a non-linear relationship.

According to a fourth aspect of the disclosure, the object is achieved by a computer program product according to claim 14. Thus, there is provided a computer program product comprising instructions to cause the control system of any one of the examples of the first aspect of the disclosure to execute the steps of the method according to any one of the examples of the third aspect of the disclosure.

According to a fifth aspect of the disclosure, the object is achieved by a non-transitory computer readable storage medium according to claim 15. Thus, there is provided a non-transitory computer-readable medium having stored thereon the computer program product according to the fourth aspect of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a more detailed description of embodiments of the disclosure cited as examples.

In the drawings:

FIG. 1a is a schematic view of an autonomous drilling machine and a control system according to examples of the present disclosure,

FIG. 1b is a schematic view of an autonomous drilling machine and a control system according to examples of the present disclosure,

FIGS. 2a-b depict graphs representing electric power or electric current as a function of waterflow according to examples of the present disclosure,

FIG. 2c depicts a graph representing feed rate as a function of waterflow according to an example of the present disclosure,

FIG. 3 is a flowchart of a method according to an example of the present disclosure, and

FIG. 4 is a side view of an autonomous drilling machine according to an example of the present disclosure.

The drawings are not necessarily drawn to scale. It shall also be noted that some details in the drawings may be exaggerated in order to better describe and illustrate the particular example. Like reference characters refer to like elements throughout the description, unless expressed otherwise.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE DISCLOSURE

FIG. 1a and FIG. 1b depict examples of an autonomous drilling machine 100 and a control system 1 for controlling a waterflow 32 for the autonomous drilling machine 100.

The control system 1, depicted by a box in FIGS. 1a-b, may comprise a control unit 14 which is herein an electronic control unit. The control unit 14 may comprise processing circuitry which is adapted to run a computer program product 16 as disclosed herein. The computer program product 16 may be stored on a non-transitory computer-readable medium 18. The control unit 14 may comprise hardware and/or software for performing the method according to the disclosure. In an embodiment, the control unit 14 and/or the control system 1 may be denoted a computer. The control unit 14 may be constituted by one or more separate sub-control units. The control system 1 may be an at least partly on-board system on the autonomous drilling machine 100. Alternatively, the control system 1 may be an off-board system which is adapted to communicate with the autonomous drilling machine 100, e.g., by wireless and/or wired communication devices (not shown).

The autonomous drilling machine 100 comprises:
- a drill string 10,
- a drill head 12,
- an air channel 20 for supplying air to the drill head 12,
- a water pump 30 and a hydraulic motor 40.

The drill head 12 is located at an end portion of the drill string 10. The drill head 12 may also be denoted a drill bit. The drill string 10 and the drill head 12 are configured to drill a borehole 200 by breaking a mineral substrate 210.

The autonomous drilling machine 100 may for example be configured to perform percussive and/or rotary rock drilling. For example, a hammer (not shown) for providing a percussion force may be air driven or hydraulically driven. The percussion force may for example be provided at a top portion of the drill string 10 or in the vicinity of the drill head 12.

The air channel 20 is configured to receive pressurized air from e.g. an air compressor (not shown) of the autonomous drilling machine 100. The air compressor may in an example also be configured to drive the above mentioned hammer for generating the percussion force during drilling. Alternatively, the hammer may be driven by hydraulic pressure.

The hydraulic motor 40 is configured to drive the water pump 30, i.e., such that the water pump 30 pumps water. The hydraulic motor 40 comprises a fluid flow valve 42 for powering the hydraulic motor 40. The fluid flow valve 42 may also be denoted a hydraulic valve. The hydraulic motor 40 is typically driven by hydraulic oil and configured to convert hydraulic pressure into torque and an angular displacement (rotation). The generated torque and angular displacement are used for driving the water pump 30. The fluid flow valve 42 is configured to control the level of torque and angular displacement of the hydraulic motor 40.

The autonomous drilling machine 100 is configured to supply water from the water pump 30 into the air channel 20 during drilling. In the examples shown in FIGS. 1a-b, the air channel 20 is provided inside the drill string 10. However, in other examples, the air channel may be provided outside the drill string. A fluid flow for powering the hydraulic motor 40 is configured to be controlled based on a level of electric power or electric current provided to the fluid flow valve 42 of the hydraulic motor 40. Accordingly, the fluid flow valve 42 is an electric fluid flow valve 42. A voltage level of the electric fluid flow valve 42 may for example be 12 V (volts) or 24 V.

The control system 1 is configured to:
- receive a value indicative of a feed rate FR of the drill head 12 during drilling. The feed rate FR, or penetration rate, may for example be expressed in m/s (meters/second), and is illustrated by a downwardly directed arrow in FIGS. 1a-b.

The control system 1 is further configured to:
- in response to determining a change of the feed rate FR, adjust the level of electric power or electric current provided to the fluid flow valve 42 such that a level of waterflow 32 supplied into the air channel 20 from the water pump 30 is adjusted. The adjustment of the electric power or electric current is based on a predetermined relationship between the level of electric power or electric current and the level of waterflow 32 provided by the water pump 30.

By the waterflow 32 supplied into the air channel 20, a water mist will be generated in the air channel 20 as a consequence of the pressurized air in the air channel 20. The pressurized air with the water mist will be supplied in the air channel 20 to the drill head 12, whereby cuttings from the drilling operation will be mixed with the water, thereby mitigating dust generation outside the borehole 200. The air, water and the cuttings will be removed from the borehole 200 during drilling, as depicted by an arrow 220 pointing upwardly from the borehole 200. Accordingly, in the examples shown in FIGS. 1a-b, air, water and the cuttings will be removed from the borehole 200 outside the drill string 10. However, in other examples, the air, water and the cuttings may be removed from the borehole 200 in a channel inside the drill string and/or in a channel in the proximity of the drill string.

The feed rate FR may for example be measured by use of a feed rate sensor 50 as depicted in FIG. 1b. As depicted in FIG. 1b, the feed rate sensor is in communicative contact with the control system 1. Additionally, or alternatively, the feed rate FR may be determined based on information indicative of a power level of the autonomous drilling machine 100 during drilling.

The control system 1 may further be configured to initially set an initial value of electric power or electric current provided to the fluid flow valve 42 such that an initial level of waterflow 32 supplied into the air channel 20 from the water pump 30 is provided.

For example, the initial value of electric power or electric current may at least partly be set based on a type of rock which the autonomous drilling machine 100 is about to drill in. The type of rock may be indicative of how much dust may be generated during drilling. As such, by setting the initial value based on the type of rock at start of drilling, dust generation may be further mitigated.

Additionally, or alternatively, the initial value of electric power or electric current may at least partly be set based on a condition of the autonomous drilling machine 100 which is indicative of a wear state of the drill head 12. For example, the wear state may be determined by use of a condition sensor 60 for the drill head 12 which measures the wear state of the drill head. For example, the condition sensor 60 may be configured to measure a length and/or size of wear components of the drill head 12. As depicted in FIG. 1b, the condition sensor 60 is in communicative contact with the control system 1.

FIGS. 2a-b show example graphs of a relationship between electric power or electric current P/I provided to the fluid flow valve 42 and the waterflow Wf (denoted 32 in FIGS. 1a-b) from the water pump 30. FIG. 2c shows an example graph of a relationship between the feed rate FR and the waterflow Wf.

As shown in FIGS. 2a-b, the predetermined relationship between the level of electric power or electric current and the level of waterflow Wf provided by the water pump 30 may be a non-linear relationship. Accordingly, the predetermined relationship between the level of electric current and the level of waterflow Wf provided by the water pump 30 may be a non-linear relationship, and/or the predetermined relationship between the level of electric power and the level of waterflow Wf provided by the water pump 30 may be a non-linear relationship. The electric current I may be expressed in Ampere. The electric power P may be expresses in Watt.

For example, as shown in FIG. 2a, the predetermined relationship may be expressed by a non-linear curve C1 with a decreasing derivative. As another example, as shown in FIG. 2b, the predetermined relationship may be expressed by a non-linear curve C2 with an increasing derivative. The predetermined relationship may be determined by use of empirical tests, simulation and/or by a model which describes properties/characteristics of the fluid flow valve 42, the hydraulic motor 40 and/or the water pump 30. For example, the predetermined relationship may be determined by interpolating between a number of measurement points obtained by empirical tests of the fluid flow valve 42, the hydraulic motor 40 and/or the water pump 30 when in operation. As another example, the predetermined relationship may be determined by interpolating between a number of measurement points obtained by simulating operation of the fluid flow valve 42, the hydraulic motor 40 and/or the water pump 30.

As shown in FIG. 2c, the control system 1 may further be configured to adjust the level of electric power or electric current provided to the fluid flow valve 42 such that the level of waterflow Wf supplied into the air channel 20 from the water pump 30 is proportionally adjusted with respect to the feed rate FR of the drill head 12 during drilling. For example, as shown, the proportional relationship may be expressed by a line L1, such as expressed as $FR = k*Wf$, where k is a constant.

FIG. 3 depicts a flowchart of a method for controlling a waterflow 32 for an autonomous drilling machine 100 according to an example of the present disclosure. The autonomous drilling machine 100 may be configured as mentioned in the above.

The method comprises:
S1: receiving a value indicative of a feed rate FR of the drill head 12 during drilling, and
S2: in response to determining a change of the feed rate FR, adjusting the level of electric power or electric current provided to the fluid flow valve 42 such that a level of waterflow 32 supplied into the air channel 20 from the water pump 30 is adjusted, wherein the adjustment of the electric power or electric current is based on a predetermined relationship between the level of electric power or electric current and the level of waterflow 32 provided by the water pump 30.

The predetermined relationship may be any one of the predetermined relationships as mentioned in the above.

As indicated by a box with dashed lines in FIG. 3, the method may further comprise:
S0: initially setting an initial value of electric power or electric current provided to the fluid flow valve 42 such that an initial level of waterflow 32 supplied into the air channel 20 from the water pump 30 is provided.

The initial value may be set as already mentioned in the above.

Adjusting the level of electric power or electric current may comprise adjusting the level of electric power or electric current provided to the fluid flow valve 42 such that the level of waterflow 32 supplied into the air channel 20 from the water pump 30 is proportionally adjusted with respect to the feed rate FR of the drill head 12 during drilling.

As also mentioned in the above, the predetermined relationship between the level of electric power or electric current and the level of waterflow 32 provided by the water pump 30 may be a non-linear relationship.

FIG. 4 depicts an autonomous drilling machine 100 according to an example of the present disclosure. The autonomous drilling machine 100 may also be denoted an autonomous drilling rig 100.

The autonomous drilling machine 100 comprises:
- a drill string 10,
- a drill head 12,
- an air channel 20 for supplying air to the drill head 12,
- a water pump (not shown) and a hydraulic motor (not shown), wherein the hydraulic motor is configured to drive the water pump, and

wherein the autonomous drilling machine 100 is configured to supply water from the water pump into the air channel 20 during drilling, wherein a fluid flow for powering the hydraulic motor is configured to be controlled based on a level of electric power or electric current provided to a fluid flow valve (not shown) of the hydraulic motor, and wherein the autonomous drilling machine 100 further comprises a control system 1 according to any one of the examples of the first aspect of the disclosure.

As shown, the autonomous drilling machine 100 may be a machine without any driver cabin. However, in other examples, the autonomous drilling machine may comprise a driver cabin.

The autonomous drilling machine 100 is a drilling machine in which at least one adjustable drilling parameter of a drilling operation is automatically controlled, e.g., automatically controlled by the control system 1. At least one of the adjustable drilling parameters is herein the waterflow 32 supplied into the air channel 20 from the water pump 30 during drilling. Other examples of adjustable drilling parameters which may be automatically controlled are percussion frequency, percussion force, feed rate FR of the drill head 12, rotational speed of the drill head 12 and the drill string 10, static load exerted on the drill head 12, and air pressure supplied to the air channel 20.

The autonomous drilling machine 100 may as shown in FIG. 4 comprise crawler members 110, or any other ground engaging means, for moving the autonomous drilling machine 100. The autonomous drilling machine 100 may as further shown comprise one or more hydraulic cylinders 120 for moving/pivoting the drill string 10 relative a main body 130 of the autonomous drilling machine 100. Any one of the crawler members 110, the hydraulic cylinders 120 and the adjustable drilling parameters may be automatically controlled by the control system 1. The drill string 10 may as further shown be connected to the main body 130 via a boom 140 and a feed beam 150 which is attached to the boom 140. The feed beam 150 carries a carriage 160, which is slidably arranged along the feed beam 150 to allow the carriage 160 to run along the feed beam 150. The carriage 160, in turn, carries the drill string 10 which hence may run along the feed beam 150 by sliding the carriage 160. The carriage 160 may further be automatically controlled by the control system 1. For example, the feed rate FR may be determined based on information indicative of a power level used for sliding the carriage 160 during drilling, and/or a by a sensor (not shown) measuring the feed rate of the carriage 160.

It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims.

CLAIMS

1. A control system (1) for controlling a waterflow (32) for an autonomous drilling machine (100), wherein the autonomous drilling machine (100) comprises:

- a drill string (10),
- a drill head (12),
- an air channel (20) for supplying air to the drill head (12),
- a water pump (30) and a hydraulic motor (40), wherein the hydraulic motor (40) is configured to drive the water pump (30), and

wherein the autonomous drilling machine (100) is configured to supply water from the water pump (30) into the air channel (20) during drilling, wherein a fluid flow for powering the hydraulic motor (40) is configured to be controlled based on a level of electric power or electric current provided to a fluid flow valve (42) of the hydraulic motor (40), wherein the control system (1) is configured to:

- receive a value indicative of a feed rate (FR) of the drill head (12) during drilling,
- in response to determining a change of the feed rate (FR), adjust the level of electric power or electric current provided to the fluid flow valve (42) such that a level of waterflow (32) supplied into the air channel (20) from the water pump (30) is adjusted, wherein the adjustment of the electric power or electric current is based on a predetermined relationship between the level of electric power or electric current and the level of waterflow (32) provided by the water pump (30).

2. The control system (1) according to claim 1, wherein the control system (1) is further configured to initially set an initial value of electric power or electric current provided to the fluid flow valve (42) such that an initial level of waterflow (32) supplied into the air channel (20) from the water pump (30) is provided.

3. The control system (1) according to claim 2, wherein the initial value of electric power or electric current is at least partly set based on a type of rock which the autonomous drilling machine (100) is about to drill in.

4. The control system (1) according to any one of claims 2 or 3, wherein the initial value of electric power or electric current is at least partly set based on a condition of the autonomous drilling machine (100) which is indicative of a wear state of the drill head (12).

5. The control system (1) according to any one of the preceding claims, wherein the control system (1) is further configured to adjust the level of electric power or electric current provided to the fluid flow valve (42) such that the level of waterflow (32) supplied into the air channel (20) from the water pump (30) is proportionally adjusted with respect to the feed rate (FR) of the drill head (12) during drilling.

6. The control system (1) according to any one of the preceding claims, wherein the predetermined relationship between the level of electric power or electric current and the level of waterflow (32) provided by the water pump (30) is a non-linear relationship.

7. An autonomous drilling machine (100), comprising:
- a drill string (10),
- a drill head (12),
- an air channel (20) for supplying air to the drill head (12),
- a water pump (30) and a hydraulic motor (40), wherein the hydraulic motor (40) is configured to drive the water pump (30), and

wherein the autonomous drilling machine (100) is configured to supply water from the water pump (30) into the air channel (20) during drilling, wherein a fluid flow for powering the hydraulic motor (40) is configured to be controlled based on a level of electric power or electric current provided to a fluid flow valve (42) of the hydraulic motor (40), and wherein the autonomous drilling machine (100) further comprises a control system (1) according to any one of the preceding claims.

8. A method for controlling a waterflow (32) for an autonomous drilling machine (100), wherein the autonomous drilling machine (100) comprises:
- a drill string (10),
- a drill head (12),
- an air channel (20) for supplying air to the drill head (12),
- a water pump (30) and a hydraulic motor (40), wherein the hydraulic motor (40) is configured to drive the water pump (30), and

wherein the autonomous drilling machine (100) is configured to supply water from the water pump (30) into the air channel (20) during drilling, wherein a fluid flow for powering the hydraulic motor (40) is configured to be controlled based on a level of electric power or electric current provided to a fluid flow valve (42) of the hydraulic motor (40), wherein the method comprises:

- receiving (S1) a value indicative of a feed rate (FR) of the drill head (12) during drilling,
- in response to determining a change of the feed rate (FR), adjusting (S2) the level of electric power or electric current provided to the fluid flow valve (42) such that a level of waterflow (32) supplied into the air channel (20) from the water pump (30) is adjusted, wherein the adjustment of the electric power or electric current is based on a predetermined relationship between the level of electric power or electric current and the level of waterflow (32) provided by the water pump (30).

9. The method according to claim 8, wherein the method further comprises:
- initially setting (S0) an initial value of electric power or electric current provided to the fluid flow valve (42) such that an initial level of waterflow (32) supplied into the air channel (20) from the water pump (30) is provided.

10. The method according to claim 9, wherein the initial value of electric power or electric current is at least partly set based on a type of rock which the autonomous drilling machine (100) is about to drill in.

11. The method according to any one of claims 9 or 10, wherein the initial value of electric power or electric current is at least partly set based on a condition of the autonomous drilling machine (100) which is indicative of a wear state of the drill head (12).

12. The method according to any one of claims 8-11, wherein adjusting the level of electric power or electric current comprises adjusting the level of electric power or electric current provided to the fluid flow valve (42) such that the level of waterflow (32) supplied into the air channel (20) from the water pump (30) is proportionally adjusted with respect to the feed rate (FR) of the drill head (12) during drilling.

13. The method according to any one of claims 8-12, wherein the predetermined relationship between the level of electric power or electric current and the level of waterflow (32) provided by the water pump (30) is a non-linear relationship.

14. A computer program product comprising instructions to cause the control system (1) of any one of claims 1-6 to execute the steps of the method according to any one of claims 8-13.

15. A non-transitory computer-readable medium having stored thereon the computer program product of claim 14.

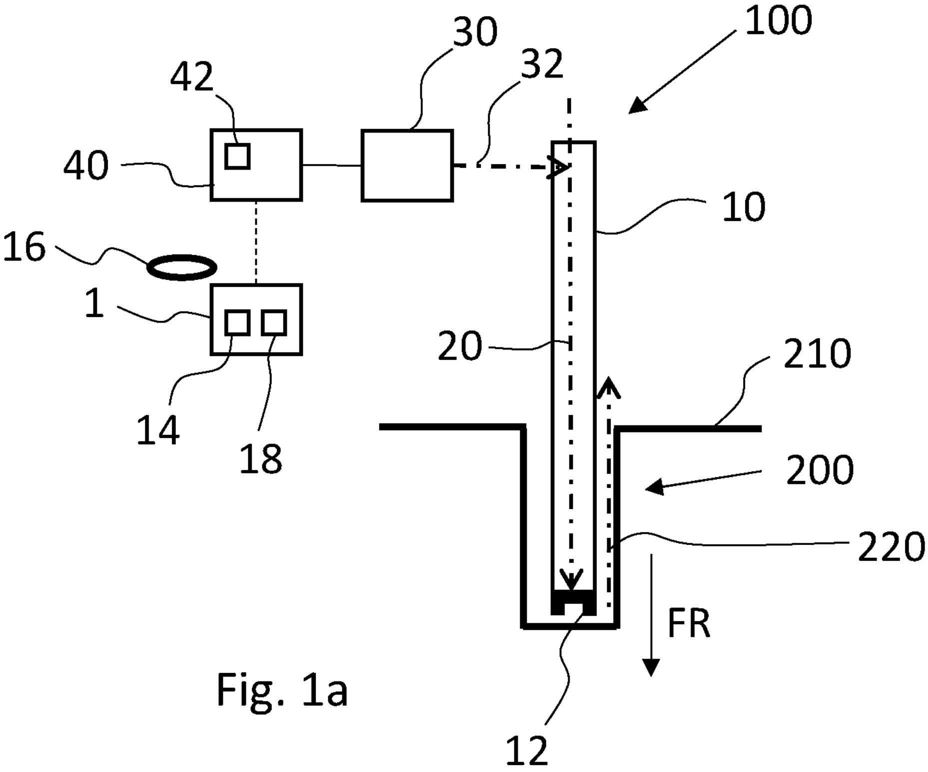
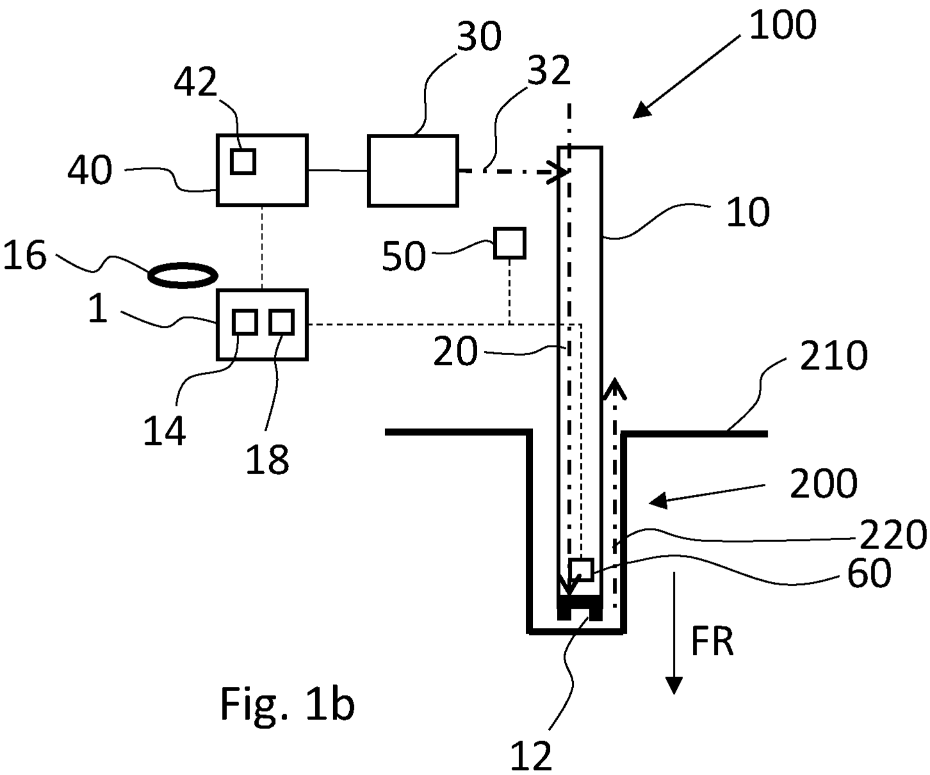

100
30
32
42
40
10
16
1
20
210
14
18
200
220
FR
12

Fig. 1a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16
50
1
20
210
14
18
200
220
60
FR
12

Fig. 1b

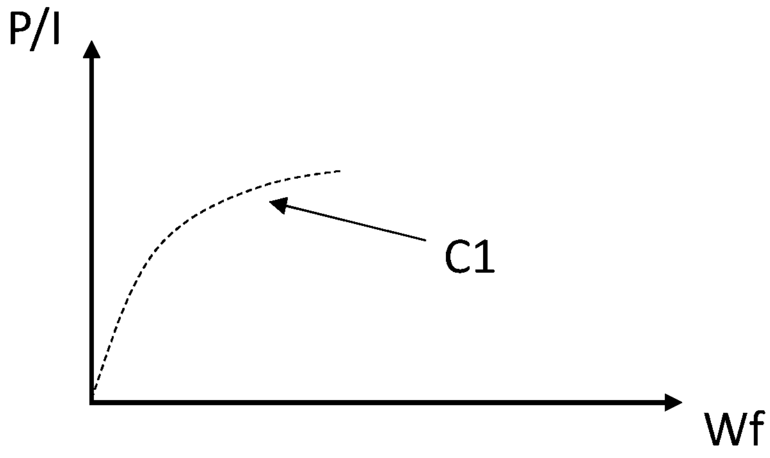

Fig. 2a

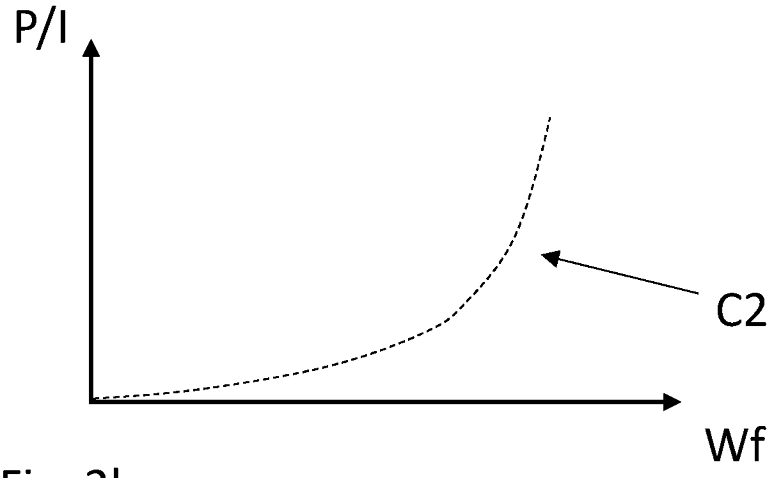

Fig. 2b

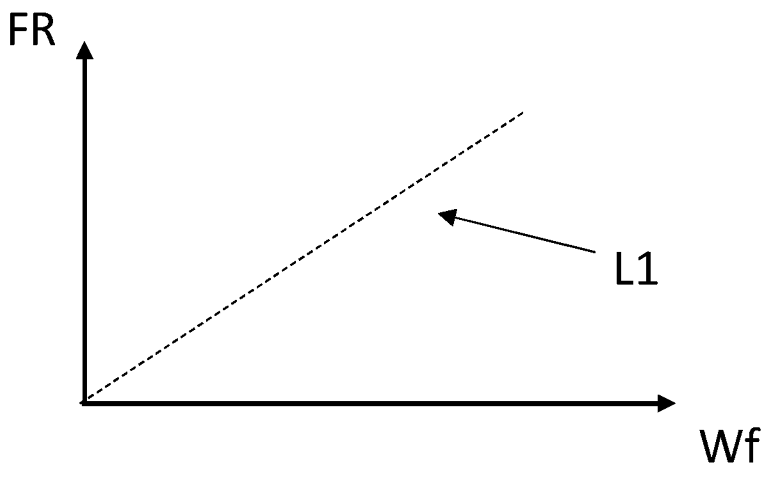

Fig. 2c

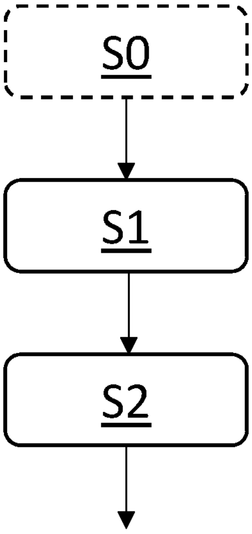

Fig. 3

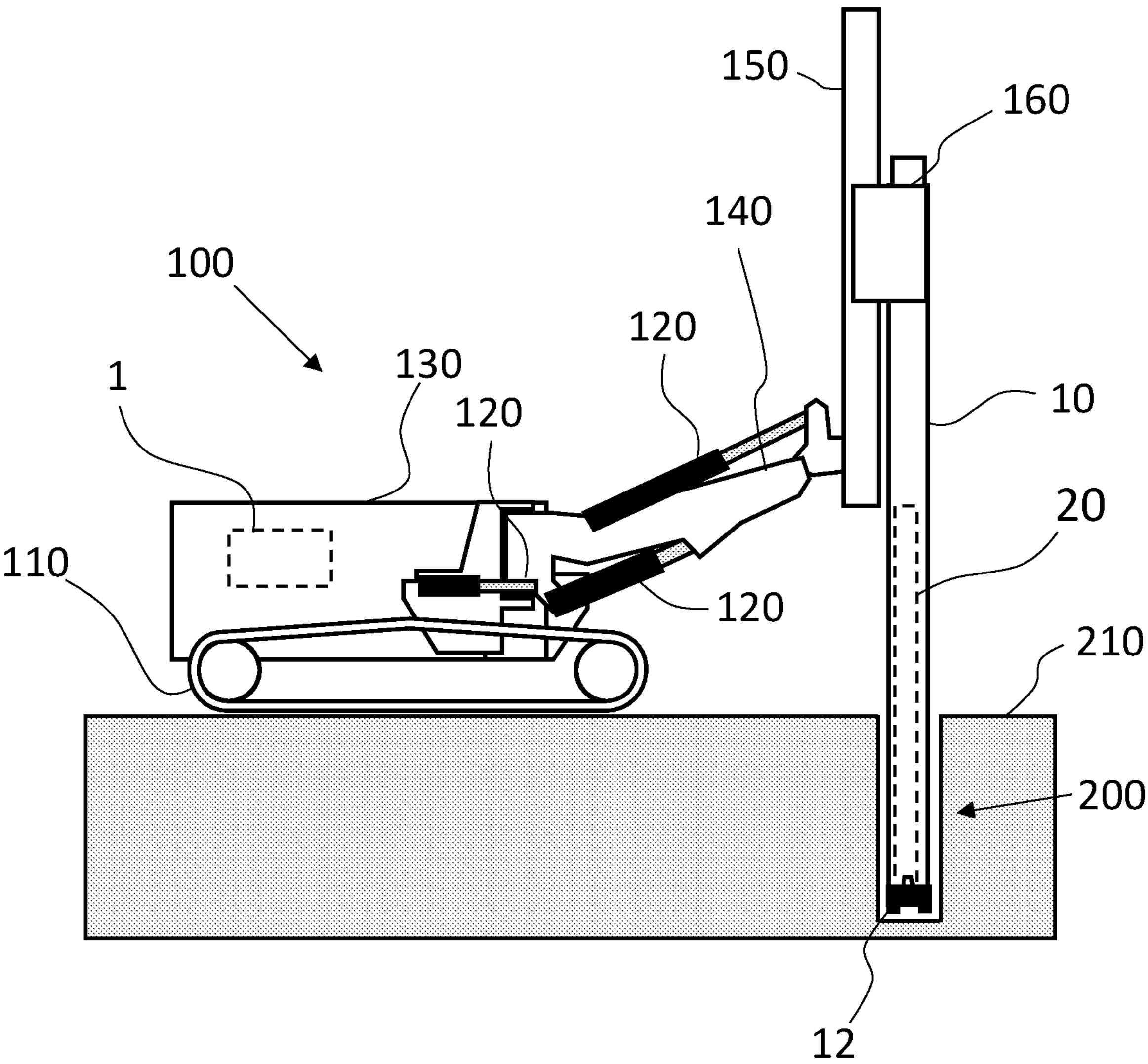

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2023/050714

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B7/02 E21B21/16 E21B44/00 E21F5/02
ADD.

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)
E21B E21F

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP 4 083 371 A1 (SANDVIK MINING & CONSTRUCTION OY [FI]) 2 November 2022 (2022-11-02) abstract figures 1-7 paragraphs [0005], [0010] - [0014], [0015] - [0016], [0019] - [0050], [0054] - [0060] -----	1-10, 12-15 11
X	WO 2018/106287 A1 (EPIROC DRILLING SOLUTIONS LLC [US]) 14 June 2018 (2018-06-14) abstract figure 12 paragraphs [0048] - [0049], [0080] - [0081] -----	1,8
	-/--	

[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 January 2024	24/01/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ing, James

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 2015/361743 A1 (MIIKKULAINEN TATU [FI]) 17 December 2015 (2015-12-17) the whole document -----	1-15

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SE2023/050714

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			US	2015361743	A1	17-12-2015
			WO	2015192151	A2	17-12-2015