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(54) **METHOD AND SYSTEM FOR DIAGNOSING AN ACCUMULATOR IN A HYDRAULIC CIRCUIT**

PROCEDE ET SYSTEME DE DIAGNOSTIC D'UN ACCUMULATEUR DANS UN CIRCUIT HYDRAULIQUE

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Description

Technical Field

[0001] The present disclosure relates to percussive rock drilling, and, more specifically, to a method and system for diagnosing an accumulator in a hydraulic circuit. The disclosure also relates to a drill rig, as well as a system that implements the method according to the disclosure.

Background

[0002] Rock drilling rigs may be used in a number of areas of application. For example, rock drilling rigs may be utilised in tunnelling, surface mining, underground mining, rock reinforcement, raise boring, and be used e.g. for drilling blast holes, grout holes, holes for installing rock bolts, water wells and other wells, piling and foundations drilling etc. There is hence a vast use for rock drilling rigs.

[0003] The actual breaking of the rock may be carried out according to various different technologies, and is oftentimes carried out by a drill tool contacting the rock, where the drill tool is connected to a drilling machine, in general by means of a drill string. The drilling can be performed according to different drilling technologies, e.g. as rotational drilling where the drill tool is pushed towards the rock at high pressure to crush the rock by means of rotation force and applied pressure.

[0004] The drilling may also be of a percussive type, where a percussion piston repeatedly strikes the drill tool, directly, or via a drill string, to transfer percussive pulses, stress waves to the drill tool and further into the rock. Percussive drilling may be combined with rotation in order to obtain a drilling where buttons, inserts, of the drill tool strikes fresh rock at each stroke, thereby increasing the efficiency of the drilling.

[0005] The reciprocating action of the percussion device may be powered by pressurised hydraulic fluid, where the percussion piston is caused to accelerate and strike the drill tool by the pressurised hydraulic fluid, and where the hydraulic fluid may also cause the percussion piston to perform a return stroke to a position where, again, the piston will be accelerated to impact the drill string in a subsequent stroke. The reciprocating motion of the percussion piston is oftentimes accomplished by opening and closing hydraulic flows, which in turn give rise to pressure and/or flow variations in the hydraulic circuit.

[0006] The percussion piston may be powered by one hydraulic circuit, and damping piston, comprised in the percussion device, may be powered by a further separate hydraulic circuit; the damping piston being present for reducing reflections. The variations caused by the reciprocating motion of the percussion piston (as well as those of the damping piston) may be harmful, and for this reason the hydraulic fluid supply and return paths

typically comprise one or more accumulators for reducing such pressure/fluid variations. In case the accumulator does not operate properly, this may go unnoticed for a long period of time while causing excessive wear.

[0007] Background art methods and systems applicable in the area of monitoring operational state of a drilling machine are disclosed in US 2004/244493 and US2007/007039. Further background art is disclosed in US 4,967,553 and US 2014/0060932.

[0008] While disclosing solutions applicable also for accumulator diagnostics and being at least in part performed through signal processing in a processor, the diagnosing is based on absolute pressure measurements, e.g., sensed peak pressure averaged over a plurality of strokes. Percussive pressure and percussive frequency of the drilling machine impacts the diagnosing and the ability to perform a correct diagnosing, especially for low pressure accumulators.

[0009] Consequently, there is a need for further improvements of accumulator state diagnosing.

Summary

[0010] An object of the disclosure to provide a method and system that is capable of diagnosing the function of at least one accumulator in hydraulic circuit. This and other objects are achieved by the method and system defined in the appended claims.

[0011] According to a first aspect of the present disclosure, it is provided a computerimplemented method for diagnosing the function of at least one accumulator in a hydraulic circuit in percussive rock drilling. The hydraulic circuit provides pressurised hydraulic fluid to power a percussion device comprising a reciprocating percussion piston for generating stress waves in a drill tool. The reciprocating motion of the percussion piston and/or a damping piston gives rise to pressure and flow variations in the hydraulic circuit, and the at least one accumulator is configured to reduce pressure and/or flow variations in the hydraulic circuit.

[0012] The method comprises a step of obtaining a plurality of pressure measurements over one or more time period, wherein the plurality of pressure measurements are obtained at a frequency being at least twice a frequency of the reciprocating motion of the percussion device and/or damping piston. The method further comprises a step of determining, during drilling, a representation of pressure and/or flow variations in the hydraulic circuit caused by the reciprocating motion of the percussion piston and/or damping piston over the one or more time periods. The method also comprises the step of diagnosing the function of the at least one accumulator based on the determined representation of the pressure and/or flow variations in the hydraulic circuit and a reference representation of pressure and/or flow variations in the hydraulic circuit. The diagnosing comprises comparing the determined representation of pressure and/or flow variations in the hydraulic circuit with the reference

representation of pressure and/or flow variations in the hydraulic circuit. The method further comprises the step of generating a signal indicating a fault when the determined representation of pressure and/or flow variations in the hydraulic circuit deviates from the reference representation of pressure and/or flow variations by a predetermined difference, indicating improper function of the at least one accumulator.

[0013] The drilling may be carried out through the use of a rock drilling rig, wherein the rock drilling rig may comprise a carrier, and wherein, during drilling, a percussion device carried by the carrier may be connected, by a drill string comprising one or more drill rods, to the drill tool being used to break rock. Drilling is carried out through the use of a hydraulic percussion device, such as a hydraulic top hammer or any other kind of hydraulic percussion device. Embodiments of the disclosure relate to any such hydraulic percussion device, and hence to percussion devices that repeatedly strikes a drill bit, directly, or via a drill string, to transfer percussive pulses, stress waves, into the drill bit and further into the rock for breaking/crushing thereof.

[0014] As was mentioned above, accumulators may be used in percussive rock drilling. Accumulators may be of various designs and e.g. include a diaphragm that separates the hydraulic fluid from an accumulator charging media (e.g. nitrogen gas). In order to ensure proper operation of the percussion device, and avoid excessive wear caused by variations of pressure and flow in the hydraulic circuit, the accumulators apply a pressure on the hydraulic fluid in order to dampen pressure peaks. The accumulator also contains a hydraulic fluid volume so that a temporary insufficient supply of hydraulic fluid provided by the hydraulic pump can be compensated for by hydraulic fluid in the accumulator.

[0015] The reciprocating motion of the percussion piston is accomplished by alternately supplying pressurised hydraulic fluid for acting on opposite surfaces of the percussion piston to urge the piston in the desired direction (towards the drill string to perform a stroke and be returned to a position for a subsequent stroke). The reciprocating motion of the piston causes pressure and flow variations in the hydraulic circuit, for example by the selective supply of hydraulic fluid oftentimes being carried out by opening and closing hydraulic fluid conduits, which may be opened and closed in dependence of the position of the percussion piston. The above applies analogously to damping pistons, in case a damping piston is present. A damping piston may give rise to pressure and flow variations in a hydraulic circuit powering the damping piston, oftentimes separate from the hydraulic circuit powering the percussion piston.

[0016] However, in order to obtain an efficient drilling process while avoiding excessive stress and wear in the system, the one or more accumulators in the system must, as discussed above, be operating properly. An accumulator that is subject to a fault, however, may be difficult to detect, and drilling while an accumulator is not

operating properly may continue for periods of time and give rise to wear and possible damage that could have been avoided if the faulty accumulator had been detected at an earlier point in time.

[0017] According to the disclosure, the one or more accumulators can be diagnosed, e.g. by a control system in a drill rig. According to the disclosure, a representation of the pressure and/or flow variations is determined. This may be performed in different ways. For example, a plurality of consecutive measurements of the pressure in the hydraulic circuit may be used to determine the representation of the pressure variations. Alternatively, e.g. a flow meter may be utilised to determine flow variations. Flow variations may also be determined using consecutive flow measurements, where the flow will be determined e.g. using pressure measurements from two pressure sensors in the hydraulic circuit with a known throttling of the flow between the pressure sensors. Such flow determination is well known in the art. The function of the at least one accumulator is then diagnosed based on the determined representation of the pressure and/or flow variations in the hydraulic circuit, and a reference representation of the pressure and/or flow variations in the hydraulic circuit. The reference representation may be e.g. determined empirically beforehand, such as during construction or manufacturing of the drill rig. The reference representation may also be calculated from a model of the hydraulic circuit. The reference representation may also be determined using table look-up, where a table may comprise reference representations e.g. for various percussion and/or feed pressures that may be utilised in the drilling. In addition, e.g. a control system of the drill rig may be arranged to determine the reference representation, e.g., reference maxima and minima, through measuring during drilling when the accumulator is confirmed to be operating properly, and e.g. setting the machine to drill at one or more different percussion pressures. This may also be performed with regard to flow variations.

[0018] The representation of pressure or flow variations may comprise one or more values, e.g., maximum and/or minimum values, and similarly the reference representation may comprise one or more values.

[0019] According to embodiments of the disclosure a signal indicating a fault may be generated when the diagnosing indicates improper function of the at least one accumulator, so that e.g. an operator of the drill rig, and/or a control system of the drill rig, and/or a remote control location can be alerted about the fault and take proper action.

[0020] According to embodiments of the disclosure, when diagnosing the function of the at least one accumulator, the determined representation of pressure and/or flow variations in the hydraulic circuit is compared with the reference representation of pressure and/or flow variations in the hydraulic circuit, and a signal indicating a fault may be generated when the determined representation of pressure and/or flow variations in the hydraulic

circuit deviates from the reference representation of pressure and/or flow variations by a predetermined difference. For example, it may be determined if a value of the determined representation of pressure and/or flow variations in the hydraulic circuit exceeds a value of the reference representation of pressure and/or flow variations by a predetermined extent.

[0021] According to embodiments of the disclosure, a signal indicating a fault is generated when a minimum value of the determined representation of pressure and/or flow variations in the hydraulic circuit exceeds a maximum allowed value of the reference representation of the pressure and/or flow variations, e.g. by a predetermined extent.

[0022] According to embodiments of the disclosure, the representation of pressure and/or flow variations in the hydraulic circuit is a representation of a difference between a maximum and a minimum pressure or flow in the hydraulic circuit. In this way, increases in the variations in pressure or flow can be detected and used to determine whether the accumulator is operating properly.

[0023] According to embodiments of the disclosure, the representation of the maximum and/or minimum pressure or flow in the hydraulic circuit is determined using a difference between an upper and lower envelope of the pressure or flow variations in the hydraulic circuit. It is also contemplated that e.g. only an upper envelope is utilised.

[0024] According to embodiments of the disclosure, an amplitude of one or more harmonics of the pressure or flow variations is utilised as representation of the maximum and/or minimum pressure or flow in the hydraulic circuit. The harmonics may be determined using any suitable signal processing of the pressure or flow variations, where a suitable processing algorithm may be used in the signal processing, such as a Fourier transform, fast Fourier transform (FFT), Power Spectral Density (PSD) or any other suitable algorithm. The accumulator may then be diagnosed based on deviations from expected harmonics, e.g. in terms of amplitude.

[0025] According to embodiments of the disclosure, the representation of pressure and/or flow variations in the hydraulic circuit may be a waveform, i.e., curve shape, of the pressure or flow variation in the hydraulic circuit, where the waveform may be subjected to analysis e.g. in terms of derivatives and/or amplitudes to determine if the waveform deviates from a reference waveform.

[0026] As was mentioned, representation of pressure and/or flow variations may be determined based on a plurality of measurements of the pressure or flow to be compared with the reference representation of pressure and/or flow variations in the diagnose.

[0027] The plurality of measurements of the pressure may be obtained using at least one pressure sensor, where the variations may be determined using a plurality of consecutive pressure measurements of the at least one pressure sensor. The pressure sensor may be ar-

ranged e.g. on a carrier of the drilling rig. The pressure sensor hence need not be located in the vicinity of the percussion device although this may also be the case. The pressure sensor may be configured to deliver pressure signals at a frequency being at least twice, or e.g. any frequency in the interval 2-1000 (or more) times the percussion frequency of the percussion device, so as to allow a sufficient resolution of the variations of the pressure in the hydraulic circuit.

[0028] The pressure sensor may be arranged downstream the hydraulic pump providing the pressurised hydraulic fluid flow. The pressure sensor may e.g. also be arranged downstream the percussion device. The pressure sensor may also be arranged in a damping circuit of the percussion device.

[0029] The one or more hydraulic circuits may comprise one or more accumulators from an accumulator arranged downstream a hydraulic pump providing the hydraulic pressure and upstream the percussion device, an accumulator arranged downstream the percussion device and an accumulator arranged in a damping circuit of the percussion device.

[0030] A single pressure sensor may be utilised to diagnose more than one accumulator. Alternatively, e.g. a pressure sensor in the high pressure path (downstream a hydraulic pump providing the hydraulic pressure and upstream the percussion device) may be utilised to diagnose an accumulator in this path, and where a pressure sensor in the low pressure path (downstream the percussion device) may be utilised to diagnose an accumulator in the low pressure path. This applies both to a hydraulic path powering the percussion piston as well as a hydraulic path powering a damping piston. With regard to the damping circuit, an accumulator may be utilised e.g. only in the supply (high pressure) path.

[0031] According to embodiments of the disclosure, two pressure sensors with a known distance between the sensors are utilised in a same path of the hydraulic circuit, e.g. from hydraulic pump to percussion device. The signals from two pressure sensors in combination with a known distance between the sensors may then be utilised to determine the pressure at any position in the hydraulic circuit. This is known as the two-microphone method. In this way pressure maxima and minima in the circuit may be accurately determined even when the maxima or minima occurs at a position in the hydraulic circuit being different from the actual position of a pressure sensor.

[0032] The diagnosing of the at least one accumulator may be arranged to be performed continuously and/or at predetermined intervals during drilling. This ensures that the occurrence of a fault will be detected as soon as, or soon after the fault occurs, so that suitable actions can be taken prior to excessive wear is caused by the percussion device being operated for longer periods of time while an occurred fault remains unnoticed.

[0033] It will be appreciated that the embodiments described in relation to the method aspect of the present

disclosure are all applicable also for the system aspect of the present disclosure. That is, the system may be configured to perform the method as defined in any of the above described embodiments. Further, the method may be a computer implemented method which e.g. may be implemented in one or more control units of a drill rig.

[0034] Further characteristics of the present disclosure and advantages thereof are indicated in the detailed description of exemplary embodiments set out below and the attached drawings.

Brief description of the drawings

[0035]

Fig. 1 illustrates an exemplary drill rig in which embodiments of the disclosure may be utilised;

Fig. 2 illustrates exemplary hydraulic circuitry of the drilling rig according to fig. 1;

Fig. 3 illustrates an exemplary method according to embodiments of the disclosure.

Fig. 4 illustrates pressure variations in a hydraulic circuit during drilling with a properly functioning accumulator;

Fig. 5 illustrates exemplary changes in pressure variations in time when an accumulator is subject to a fault.

Detailed description

[0036] Embodiments of the present disclosure will be exemplified in the following in view of a particular kind of drill rig, where drilling is carried out through the use of a percussion device in the form of a top hammer. The drill rig may also be of any other kind where drilling is carried out through the use of a hydraulic percussion device for transmitting stress waves into a drill tool for breaking rock.

[0037] Fig. 1 illustrates a rock drilling rig 100 according to an exemplary embodiment of the present disclosure for which an inventive method of diagnosing an accumulator will be described. The drill rig 100 is in the process of drilling a hole, where the drilling currently has reached a depth x.

[0038] The rock drilling rig 100 according to the present example constitutes a surface drill rig, although it is to be understood that the drill rig may also be of a type being primarily intended e.g. for underground drilling, or a drill rig for any other use. The rock drilling rig 100 comprises a carrier 101, which carries a boom 102 in a conventional manner. Furthermore, a feed beam 103 is attached to the boom 102. The feed beam 103 carries a carriage 104, which is slidably arranged along the feed beam 103 to allow the carriage 104 to run along the feed beam 103.

The carriage 104, in turn, carries a percussion device 105, e.g. also comprising a rotation unit (not shown, but the rotation is indicated by 119), which hence may run along the feed beam 103 by sliding the carriage 104.

[0039] The percussion device 105 is, in use, connected to a drill tool, such as a drill bit 106, according to the present example, by means of a drill string 107. For practical reasons (except possibly for very short holes) the drill string 107 in general does not consist of a drill string in one piece, but consists, in general, of a number of drill rods. When drilling has progressed a distance corresponding to a drill rod length, a new drill rod is threaded together with the one or more drill rods that already has been threaded together to form the drill string, whereby drilling can progress for another drill rod length before a new drill rod is threaded together with existing drill rods. Drill rods of the disclosed kind may be extended essentially to any desired length as drilling progress.

[0040] In use, an impact piston 115 of the percussion device 105 repeatedly strikes the drill rod in order to transfer shock wave energy to the drill string 107 and thereby the drill bit 106 and further into the rock for breaking thereof. In addition to providing rotation of the drill string, and thereby drill bit 106 during drilling, the percussion device 105, and/or carriage 104, by being subjected to a force acting in the drilling direction, also provides a feed force acting on the drill string 107 to thereby press the drill bit 106 against the rock face being drilled.

[0041] According to the illustrated example, the percussion device 105, in particular the percussion piston 115, is powered by pressurised hydraulic fluid being supplied to the percussion device by a hydraulic pump 116 arranged on the carrier 101 and suitable hosing 118. The carrier 101 also comprises a hydraulic fluid tank 119 from which hydraulic fluid is taken and returned to using the hydraulic circuit powering the percussion device. There may be further hydraulic pumps being used to provide pressurised hydraulic fluid in one or more additional hydraulic circuits, such as e.g. a damping circuit (see below).

[0042] According to the illustrated example, compressed air is led to the drill bit 106 through a channel (not shown) inside the drill string 107, where the compressed air is supplied to the drill string 107 from a tank 109 through a suitable coupling 110 in a manner known per se, and a hose 113 or other suitable means. The compressed air is generated by a compressor (not shown), which may charge the tank 109 from which the compressed air is supplied to the drill string. The compressed air may be discharged through holes in the drill bit 106 to be used to clean the drill hole from drilling remnants. The compressed air may alternatively e.g. be a mixture of compressed air and water, or of any other suitable kind.

[0043] The hydraulic pump 116 and compressor are driven by a power source 111, e.g. in the form of a combustion engine such as a diesel engine or any other

suitable power source, such as e.g. an electric motor, or combination of power sources. Fig. 1 also schematically illustrates an accumulator 112 in the hydraulic circuit powering the percussion device 105. The hydraulic circuit powering the percussion device may comprise further and/or other accumulators, and, similarly, other hydraulic circuits may also comprise one or more accumulators that may be diagnosed according to the disclosure. Fig. 1 also illustrates a pressure sensor 108 being used to measure the pressure in the supply path providing pressurised hydraulic fluid to the percussion piston 115 from the hydraulic pump 116.

[0044] The rock drilling rig 100 further comprises a rig control system comprising at least one control unit 120. The control unit 120 is configured to control functions of the drill rig 100, such as controlling the drilling process. In case the drill rig 100 is manually operated, the control unit 120 may receive control signals from the operator, e.g. being present in an operator cabin 114 through operator controllable means such as joysticks and other means requesting various actions to be taken, and where the control signals, such as operator inflicted joystick deflections and/or manoeuvring of other means, may be translated by the control system to suitable control commands. The control unit 120 may, for example, be configured to request motions to be carried out by various actuators such as cylinders/motors/pumps etc., e.g. for manoeuvring boom 102, feeder 103 and controlling the percussion device 105, and various other functions. The described control, as well as other functions, may alternatively be partly or fully autonomously controlled by the control unit 120.

[0045] Drill rigs of the disclosed kind may comprise more than one control unit, e.g. a plurality of control units, where each control unit, respectively, may be arranged to be responsible for monitoring and carrying out various functions of the drill rig 100. For reasons of simplicity, however, it will be assumed in the following that the various functions are controlled by the control unit 120.

[0046] Control systems of the disclosed kind may further comprise a data bus (not shown), which may be a CAN bus, or any other suitable kind of data bus, and which may be used to allow communication between various units of the machine 100, and which may utilise e.g. CANopen and/or a similar protocol or any other suitable protocol in the communication. For example, the control unit 120 may communicate with, and/or form part of, one or more displays in the operator cabin 114 for display of various data, e.g. with regard to the drilling process, and, according to embodiments of the present disclosure, e.g., provide visible and/or audible alerts to alert an operator when an accumulator is diagnosed to be subject to a fault.

[0047] The control unit 120 may also communicate, e.g. via the CAN bus or other interface, with the one or more pressure sensors for receiving pressure signals using which the one or more accumulators may be diagnosed. The pressure sensors may also be communicat-

ing with an interface, e.g. I/O interface or similar comprising means for processing the pressure signals, where the I/O may e.g. generate the representation of pressure or flow variations, and e.g., provide these signals to the control unit 120.

[0048] According to embodiments of the disclosure, the diagnosing is performed by a control unit of the drill rig, such as control unit 120 of fig. 1, but the diagnosing may also be configured to be carried out by drill rig external computer means, such as in a remote control centre. The diagnosing may e.g. also be carried out in an I/O interface. The drill rig may then comprise means for transmitting pressure signals to the remote computer means. Alerts may also be generated in a remote control centre, e.g. in case the drill rig is remote controlled. Furthermore, when it is diagnosed that an accumulator is malfunctioning this may cause the drill rig control system to stop drilling, or at least reduce percussion power to reduce the risk that damages caused by the malfunctioning accumulator arises.

[0049] Fig. 2 illustrates exemplary hydraulic circuits of the drill rig of fig. 1. The figure illustrates the percussion device 105 and percussion piston 115 which generates percussive pulses, stress waves, by repeatedly being accelerated and striking the drill string 107 to be transferred by the drill string 107 to the drill bit 106 and further into the rock. The reciprocating motion is caused by alternately pressurising and depressurising surfaces 201, 202, respectively, of the percussion piston 115 to generate the reciprocating motion.

[0050] The pressurised hydraulic fluid is supplied by the hydraulic pump 116, and the pressurised hydraulic fluid is alternatively supplied through a high pressure supply path (from hydraulic pump 116 to percussion device) to pressure chambers 203, 204 through the use of a valve 205, where the state of the valve 205 may be controlled in any suitable manner, e.g. by the pressure of a chamber 206 of the percussion device 105, where the pressure of the chamber 206 depends on the current position of the percussion piston 115. When one of the pressure chambers 203, 204 is pressurised, the other is depressurised and the hydraulic fluid is returned to tank 119 through a low pressure return path from the percussion device 105. This pressurisation and depressurisation, and opening and closing of pressure chambers, will give rise to pressure and flow variations in the hydraulic fluid of the hydraulic circuit.

[0051] In order to reduce negative impact from such pressure variations, the high-pressure supply path, and, according to the present example, the low pressure return path as well, are provided with one or more accumulators. The accumulators may be mounted directly on, or in the vicinity of, the percussion device. This is schematically illustrated in fig. 1 by accumulator 112. The accumulators 112, 208 are used to dampen peak pressure surges that arise in the system, and may also maintain the pressure of the hydraulic fluid in the system in case the flow from the hydraulic pump 116 would be

insufficient for proper operation at some instance. With regard to the accumulator 208 on the return (low-pressure) path, the accumulator 208 may stabilise pressure and flow and avoid cavitation in the hydraulic fluid which may otherwise occur, and which may be harmful. An accumulator oftentimes includes a diaphragm 209, 210 that separates the hydraulic fluid from pressurised accumulator charging media (e.g., nitrogen gas). The pressurised charging media acts on the hydraulic fluid through the diaphragm to counteract pressure variations in the hydraulic circuit.

[0052] Furthermore, in addition to the hydraulic circuit powering the percussion piston 115, fig. 2 also illustrates a hydraulic circuit powering a damping piston 220 of the percussion device 105. The damping piston 220 is configured to absorb harmful reflections of energy that are returned through the drill string 107 following rock impact of a shock wave transmitted from the percussion device 105. A damping chamber 222 is pressurised by a hydraulic pump 221, which may be the hydraulic pump 116 or a separate hydraulic pump. The reflections in the drill string increases the pressure in the damping chamber 222, and causes hydraulic fluid to be evacuated to tank through a return channel 223. Similar to the hydraulic circuit powering the percussion piston 105, the hydraulic circuit powering the damping piston 220 comprises an accumulator 224 to reduce pressure variations and ensure adequate supply of hydraulic fluid to the damping chamber 222 to ensure proper dampening.

[0053] According to embodiments of the disclosure, each of the accumulators 112, 208, 224 can be separately diagnosed to ensure proper operation and detect possible malfunctions. According to the disclosure, this is performed using pressure and/or flow variations of the hydraulic fluid. According to the present example, the accumulators 112, 208, 224 are diagnosed through the use of pressure variations. The pressure variations are determined through the use of one or more pressure sensors 231-233, where, according to the present example, a pressure sensor in each path (supply or return) comprising an accumulator is used. According to embodiments of the disclosure, a single pressure sensor, such as pressure sensor 231, may be utilised e.g. to diagnose the accumulators 112, 208. The pressure sensors may be arranged in the vicinity of the hydraulic pump 116, 221, and hence e.g. on the carrier 101 and deliver pressure signals at a rate sufficient to perform the diagnosis. For example, the pressure sensors may be configured to deliver pressure signals at least two times the maximum drilling frequency (which e.g. may be in the order of 60-80 Hz) of the percussion device, but are preferably of a design that delivers pressure signals at a yet higher rate, e.g. any rate in the interval 2-1000 times the maximum drilling frequency or maximum frequency that occur in the variations in the hydraulic flow. The pressure sensors 231-233 deliver the pressure signals to the control unit 120 or other processing unit for processing according to embodiments of the disclosure.

[0054] An exemplary method 300 according to embodiments of the disclosure will be discussed in the following with reference to fig. 3. The method 300 optionally starts in step 301, where it is determined whether the diagnosing of one or more accumulators 112, 208, 224 of the hydraulic circuit is to be estimated. When this is the case the method may continue to step 302, otherwise the method remains in step 301. The diagnosing of the one or more accumulators 112, 208, 224, and hence transition from step 301 to step 302, may be arranged to take place e.g. continuously as drilling is ongoing, or e.g. at suitable intervals, such as when a certain period of time has lapsed. According to embodiments of the disclosure, the diagnosing is performed as soon as drilling has started, or within a predetermined period of time from when drilling of a hole has started, and may then be continuously carried out during the drilling of the hole. According to embodiments of the disclosure, there may also be further requirements regarding the transition from step 301 to step 302. For example, there may also be requirements e.g. regarding drilling pressure, i.e. that the drilling has reached a state where normal drilling pressure, such as the pressure of the hydraulic fluid powering the percussion device, has been reached. According to embodiments of the disclosure, however, there are no such additional requirements and the diagnosing may be performed when the drilling has commenced.

[0055] In step 302 a plurality of pressure measurements from pressure sensor 231 are retrieved, i.e., obtained. The plurality of pressure measurements are obtained over one or more time periods and at a frequency being at least twice a frequency of the reciprocating motion of the percussion piston and/or damping piston. Preferably, the obtaining is performed with one or more high bandwidth pressure sensors distanced from the percussion piston and/or damping piston, so that the sensors are protected from vibrations and mechanical exposure caused by the reciprocating motion. The method further comprises determining, in step 303, a representation of pressure and/or flow variations in the hydraulic circuit caused by the reciprocating motion of the percussion piston and/or damping piston over the one or more time periods, e.g., determining an envelope representation of pressure and/or flow variations in the hydraulic circuit. According to the present example, this representation is consequently determined using the plurality of consecutive pressure measurements from the pressure sensor 231, where, as discussed above the pressure measurements are provided at a rate being at least twice, preferably higher, the percussion frequency, and where the signals from the pressure sensor may, for example, be supplied to the control unit 120, e.g. using the data bus or by a direct connection, for processing in the control unit 120.

[0056] The representation of the pressure variation may be of any suitable kind, e.g., an envelope representation. Fig. 4 illustrates one example of an exemplary pressure variation as a function of time and determined

using signals from the pressure sensor 231. The amplitude of the pressure in the hydraulic circuit varies between a minimum pressure slightly above 200 bar up to a maximum of approximately 250 bars, where the variation between two maxima corresponds to a full stroke cycle of the percussion piston 105. The graph of fig. 4 represents a situation where the accumulator 112 is operating properly. The representation of pressure variations in the hydraulic circuit being determined in step 302 may, as discussed, be of various different kinds, and for example constitute a representation of the difference between the maximum and minimum pressure in the hydraulic circuit. This may be determined in any suitable manner. For example, as is disclosed in fig. 4, the difference may be determined as a difference between an upper 401 and a lower 402 envelope of the pressure variations in the hydraulic circuit. The upper 401 and lower 402 envelopes may be determined in a straightforward manner according to well-known signal processing, and may be determined continuously or during a predetermined period of time, to determine a representative representation of the differences between minimum and maximum values in the hydraulic circuit. For example, maximum and minimum values of the difference between the envelopes may be determined, e.g. during a period of time, where one, or both, of these values may be utilised as representation of the pressure variations in the hydraulic circuit.

[0057] The method then continues to step 304, where the determined representation of pressure variations in the hydraulic circuit is evaluated in relation to a reference representation of pressure variations in the hydraulic circuit. For example, the determined representation of pressure variations in the hydraulic circuit can be compared with the reference representation of the pressure variations in the hydraulic circuit. For as long as is determined in step 304 that the representation of pressure variations in the hydraulic circuit does not deviate from the reference representation of pressure variations by more than a predetermined extent and hence is less than a limit deviation, the method returns to step 301 for a further determination of a representation of pressure variations in a subsequent diagnosing of the accumulator 112. The diagnosing may be arranged to be performed continuously or at suitable intervals.

[0058] If, on the other hand, it is determined in step 304 that the determined representation of pressure variations in the hydraulic circuit deviates from the reference representation of pressure variations by more than the predetermined extent the method continues to step 305, where a signal indicating a fault is generated.

[0059] Fig. 5 illustrates an exemplary development of the pressure variations, and corresponding envelopes 501, 502 in the hydraulic circuit when a fault occurs. From time t_0 up to time t_{damage} the accumulator 112 is working properly. At time t_{damage} a fault occurs. For example, a leakage in the diaphragm 209 may occur, with the result that the accumulator gas may enter the hydraulic fluid.

The accumulator 112 may otherwise suffer a pressure reduction. The accumulator 112 may also be subject to other faults that prevents proper accumulator operation. As a result of the faulty accumulator operation, pressure variations are no longer suppressed to the desired extent, but the pressure variations start to increase as gas pressure of the accumulator decrease. At time t_1 the situation no longer deteriorates further, e.g. because the accumulator no longer is capable of providing the desired dampening function.

[0060] In the evaluation performed in step 304, it may be determined whether the determined representation of pressure variations in the hydraulic circuit exceeds a value of the reference representation of the pressure variations by a predetermined extent. According to the present example, it can be determined whether the difference between the upper and lower envelope exceeds a predetermined difference by a predetermined extent, i.e., exceeding an acceptable variation range. According to embodiments of the disclosure, it can further be determined if a minimum value of the determined representation of pressure variations in the hydraulic circuit, such as the minimum difference between upper and lower envelope in fig. 5, e.g. during a period of time, exceeds a maximum allowed value according to the reference representation of the pressure variations. In the present example this may be a determination of whether a minimum value of the difference between the upper and lower envelope exceeds a maximum allowed value of the difference between the upper and lower envelope, and when this is the case a signal indicating a fault can be generated. According to the example of fig. 5, this occurs at time t_1 .

[0061] This signal that is generated in step 305 may e.g. be used to alert an operator of the drill rig, e.g. by an audible and/or visible signal so that the operator may take proper action, e.g. stopping ongoing drilling to attend to the malfunctioning accumulator. In case the drill rig, for example, is operating autonomously, a signal may be generated to the part of the control system controlling the drilling so that the drilling thereby can be automatically stopped. A signal may also be transmitted e.g. to a remote control centre to alert surveillance and/or other personnel of the fault so that proper actions e.g. in terms of repair can be taken. With regard to the accumulators 208 and 224, these may be diagnosed in precisely the same manner, and in parallel to the diagnosing of the accumulator 112. Alternatively, the accumulators may be diagnosed in sequence. According to embodiments of the disclosure, pressure sensor 231 or pressure sensor 232 is used to diagnose both accumulators 112, 208.

[0062] In general, the reference representation being used in step 304 may be determined empirically, e.g. for a particular configuration in regard of drill rig and percussion device, where values may be determined for each such combination being manufactured. The reference value may also be determined for various percussion pressures, so that diagnosed may be performed also

when different percussion pressures are used in the drilling. It is also contemplated that the reference values are calculated e.g. from a model representation of the hydraulic system. The reference values may also be established by the system itself, e.g. by measuring pressure variations in a situation when the accumulator is working properly, and where such measurements may be stored as reference values for subsequent use in the diagnosis.

[0063] According to the embodiment that has been exemplified above, variations in pressure are used for diagnosing a state of the accumulator. According to embodiments of the disclosure, two pressure sensors at different locations in the hydraulic circuit are used to determine the pressure variations. For example, two pressure sensors may be utilised e.g. in the high pressure supply. This is indicated by an additional pressure sensor 230 in dashed lines in fig. 2. The signals from two pressure sensors, in combination with a known distance between the sensors, may then be utilised to determine maxima and minima in the hydraulic circuit, to ensure that a representative value is used in the diagnosing, and to avoid that measurements are performed for a pressure minima in a standing wave in the hydraulic circuit. The pressure of any position in the hydraulic circuit may be determined, and is denoted the two-microphone method in the art. In general, however, a single pressure sensor is sufficient to perform the desired diagnosing.

[0064] According to embodiments of the disclosure, flow variations are used in the diagnosing instead of pressure variations. The flow may vary in a similar manner as the pressure, and the flow variations may be utilised instead of pressure variations. The flow may be determined using a flow meter, but may also be determined e.g. using two pressure sensors with a known throttling of the flow between them in a manner known per se.

[0065] The variations of pressure or flow may also be determined in any other suitable manner. For example, the pressure or flow variations may be subjected to signal processing to determine the amplitude of one or more harmonics, where a change in the amplitude of the one or more harmonics may be utilised in diagnosing the accumulator state.

[0066] As is realised, a single type of drill rig may utilise different hammers, and drill tools of different diameters and/or drill bit insert configuration, and also different variants of drill rods. A reference representation of pressure or flow may be valid for one or more such combinations, but various reference representation may need to be determined to account for various combinations. Alternatively the control system may determine the reference variation itself for the current combination. The generated reference representations, when determined beforehand, may be stored in the control system of the drill rig for use e.g. during the service life of all drill rigs for which the reference representations are applicable, so that an accumulator may be diagnosed for the particular

combination being utilised. Different reference representations may hence be generated for different types of drill rigs, and/or different combinations of drill rig, percussion hammer, drill bit etc.

[0067] The present disclosure may be utilised for essentially any kind of drill rig where hydraulic percussive drilling is utilised. The disclosure is also applicable for underground drill rigs as well drill rigs operating above ground.

Claims

1. A method for diagnosing the function of at least one accumulator (112, 208, 224) in a hydraulic circuit in percussive rock drilling, the hydraulic circuit providing pressurised hydraulic fluid to power a percussion device (105) comprising a reciprocating percussion piston (115) for generating stress waves in a drill tool (106) and/or a damping piston (220), wherein the reciprocating motion of the percussion piston (115) and/or a damping piston (220) gives rise to pressure and flow variations in the hydraulic circuit; and the at least one accumulator (112, 208, 224) is configured to reduce pressure and/or flow variations in the hydraulic circuit; the method further comprising, during drilling:

obtaining a plurality of pressure measurements during a first period of time, wherein the plurality of pressure measurements are obtained at a frequency being at least twice a frequency of the reciprocating motion of the percussion piston (115) and/or damping piston (220);
determining a representation of pressure and/or flow variations in the hydraulic circuit caused by the reciprocating motion of the percussion piston (115) and/or damping piston (220) during the first period of time;
diagnosing the function of the at least one accumulator (112, 208, 224) based on the determined representation of the pressure and/or flow variations in the hydraulic circuit and a reference representation of pressure and/or flow variations in the hydraulic circuit, wherein the diagnosing comprises comparing the determined representation of pressure and/or flow variations in the hydraulic circuit with the reference representation of pressure and/or flow variations in the hydraulic circuit; and
generating a signal indicating a fault when the determined representation of pressure and/or flow variations in the hydraulic circuit deviates from the reference representation of pressure and/or flow variations by a predetermined difference, indicating improper function of the at least one accumulator (112, 208, 224).

2. Method according to claims 1, further comprising:
generating a signal indicating a fault when a value of
the determined representation of pressure and/or
flow variations in the hydraulic circuit exceeds a
value of the reference representation of pressure
and/or flow variations by a predetermined extent. 5
3. Method according to claim 1 or 2, further comprising:
generating a signal indicating a fault when a mini-
mum value of the determined representation of pres-
sure and/or flow variations in the hydraulic circuit
exceeds a maximum value of the reference repre-
sentation of the pressure and/or flow variations by a
predetermined extent. 10
4. Method according to any one of the claims 1-3,
wherein the representation of pressure and/or flow
variations in the hydraulic circuit is a representation
of a difference between a maximum and a minimum
pressure or flow in the hydraulic circuit. 15
5. Method according to claim 4, wherein the represen-
tation of the maximum and/or minimum pressure or
flow in the hydraulic circuit is determined using one or
more from: 20
 - a difference between an upper and lower envel-
ope of the pressure or flow variations in the
hydraulic circuit; and
 - an amplitude of one or more harmonics of the
pressure and/or flow variations, the harmonics
being determined using signal processing of the
pressure and/or flow variations, such as a signal
processing of the pressure and/or flow varia-
tions based on a Fourier transform. 30
6. Method according to any one of the claims 1-5,
wherein the representation of pressure and/or flow
variations in the hydraulic circuit is a waveform, i.e.
curve shape, of the pressure variation in the hydrau-
lic circuit. 35
7. Method according to any of the preceding claims,
further comprising:
obtaining the plurality of measurements of the pres-
sure using at least one pressure sensor, the varia-
tions being determined using a plurality of consecu-
tive pressure measurements of the at least one
pressure sensor. 40
8. Method according to any one of claims 1-7, further
including:
determining the representation of the pressure and/
or flow variations using a pressure sensor ar-
ranged downstream a hydraulic pump (116, 221)
providing the pressurised hydraulic fluid flow, and/or
a pressure sensor arranged downstream the percus-
sion device (105), and/or a pressure sensor ar-
ranged in a damping circuit of the percussion device
(105). 45
9. Method according to any one of the claims 1-8,
wherein the reference representation of the varia-
tions of the hydraulic fluid is set and/or determined in
dependence on the percussion pressure and/or feed
pressure. 50
10. Method according to any one of the claims 1-9,
further comprising:
diagnosing the at least one accumulator (112, 208,
224) continuously and/or at predetermined intervals
during drilling, and, if the diagnose indicates a fault,
generating a signal indicating the fault to alert a
drilling operator and/or a control system controlling
the drilling. 55
11. Computer program comprising instructions which,
when the program is executed by a computer, cause
the computer to carry out the method according to
any one of the preceding claims.
12. Computer-readable medium comprising instructions
which, when executed by a computer, cause the
computer to carry out the method according to any
one of the claims 1-10.
13. A system for diagnosing the function of at least one
accumulator (112, 208, 224) in a hydraulic circuit in
percussive rock drilling, the hydraulic circuit provid-
ing pressurised hydraulic fluid to power a percussion
device (105) comprising a reciprocating percussion
piston (115) for generating stress waves in a drill tool
(106), wherein the reciprocating motion of the per-
cussion piston (115) and/or a damping piston (220)
gives rise to pressure and flow variations in the
hydraulic circuit; and the at least one accumulator
(112, 208, 224) is configured to reduce pressure
and/or flow variations in the hydraulic circuit;
the system further comprising:

obtaining means configured to obtain a plurality
of pressure measurements during a first period
of time, wherein the plurality of pressure mea-
surements are obtained at a frequency being at
least twice a frequency of the reciprocating mo-
tion of the percussion piston (115) and/or damp-
ing piston (220);
determination means configured to, during drill-
ing, determine a representation of pressure
and/or flow variations in the hydraulic circuit
caused by the reciprocating motion of the per-
cussion piston (115) and/or damping piston
(220) during the first period of time;
calculation means configured to diagnose the
function of the at least one accumulator (112,
208, 224) based on the determined representa-

tion of the pressure and/or flow variations in the hydraulic circuit and a reference representation of pressure and/or flow variations in the hydraulic circuit, wherein the diagnose comprises comparing the determined representation of pressure and/or flow variations in the hydraulic circuit with the reference representation of pressure and/or flow variations in the hydraulic circuit; and fault indication means configured to generate a signal indicating a fault when the determined representation of pressure and/or flow variations in the hydraulic circuit deviates from the reference representation of pressure and/or flow variations by a predetermined difference, indicating improper function of the at least one accumulator (112, 208, 224).

14. System according to claim 13, wherein the at least one accumulator (112, 208, 224) in the hydraulic circuit is one or more from:

an accumulator (112) arranged downstream a hydraulic pump (116, 221) providing the hydraulic pressure and upstream the percussion device (105);
an accumulator (208) arranged downstream the percussion device (105); and
an accumulator (224) arranged in a damping circuit of the percussion device (105).

15. Rock drilling rig (100) comprising a system according to claim 14 or 15.

Patentansprüche

1. Verfahren zur Diagnose der Funktion mindestens eines Akkumulators (112, 208, 224) in einem Hydraulikkreis beim Schlagbohren von Gestein, wobei der Hydraulikkreis unter Druck stehendes Hydraulikfluid bereitstellt, um eine Schlagvorrichtung (105) anzutreiben, die einen hin- und hergehenden Schlagkolben (115) zum Erzeugen von Spannungswellen in einem Bohrwerkzeug (106) und/oder einen Dämpfungskolben (220) umfasst, wobei die Hin- und Herbewegung des Schlagkolbens (115) und/oder eines Dämpfungskolbens (220) zu Druck- und Durchflussschwankungen im Hydraulikkreis führt; und der mindestens eine Akkumulator (112, 208, 224) konfiguriert ist, um Druck- und/oder Durchflussschwankungen im Hydraulikkreis zu reduzieren; das Verfahren weiter umfassend, während des Bohrens:

Erhalten einer Vielzahl von Druckmessungen während einer ersten Zeitperiode, wobei die Vielzahl von Druckmessungen mit einer Frequenz erhalten wird, die zumindest das doppel-

te einer Frequenz der Hin- und Herbewegung des Schlagkolbens (115) und/oder des Dämpfungskolbens (220) ist;

Bestimmen einer Darstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis, die durch die Hin- und Herbewegung des Schlagkolbens (115) und/oder des Dämpfungskolbens (220) während des ersten Zeitraums verursacht werden;

Diagnostizieren der Funktion des mindestens einen Akkumulators (112, 208, 224) auf der Grundlage der bestimmten Darstellung der Druck- und/oder Durchflussschwankungen im Hydraulikkreis und einer Referenzdarstellung der Druck- und/oder Durchflussschwankungen im Hydraulikkreis, wobei das Diagnostizieren das Vergleichen der bestimmten Darstellung von Druck und/oder Durchflussschwankungen im Hydraulikkreis mit der Referenzdarstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis umfasst; und

Erzeugen eines Signals, das einen Fehler anzeigt, wenn die bestimmte Darstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis von der Referenzdarstellung von Druck- und/oder Durchflussschwankungen um einen vorbestimmten Unterschied abweicht, was auf eine Fehlfunktion des mindestens einen Akkumulator (112, 208, 224) hinweist.

2. Verfahren nach Ansprüchen 1, weiter umfassend:
Erzeugen eines Signals, das einen Fehler anzeigt, wenn ein Wert der bestimmten Darstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis einen Wert der Referenzdarstellung von Druck- und/oder Durchflussschwankungen um einen vorbestimmten Betrag überschreitet.
3. Verfahren nach Anspruch 1 oder 2, weiter umfassend:
Erzeugen eines Signals, das einen Fehler anzeigt, wenn ein Mindestwert der bestimmten Darstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis einen Maximalwert der Referenzdarstellung der Druck- und/oder Durchflussschwankungen um einen vorbestimmten Betrag überschreitet.
4. Verfahren nach einem der Ansprüche 1-3, wobei die Darstellung von Druck und/oder Durchflussschwankungen im Hydraulikkreis eine Darstellung einer Differenz zwischen einem maximalen und einem minimalen Druck oder Durchfluss im Hydraulikkreis ist.
5. Verfahren nach Anspruch 4, wobei die Darstellung des maximalen und/oder minimalen Drucks oder Durchflusses im Hydraulikkreis unter Verwendung eines oder mehrerer der folgenden Elemente bestimmt wird:

- einem Unterschied zwischen einer oberen und einer unteren Hüllkurve der Druck- oder Durchflussschwankungen im Hydraulikkreis; und einer Amplitude von einer oder mehreren Harmonischen der Druck- und/oder Durchflussschwankungen, wobei die Harmonischen durch Signalverarbeitung der Druck- und/oder Durchflussschwankungen bestimmt werden, wie z. B. eine Signalverarbeitung der Druck- und/oder Durchflussschwankungen auf der Grundlage einer Fourier-Transformation. 5 10
6. Verfahren nach einem der Ansprüche 1-5, wobei die Darstellung von Druckund/oder Durchflussschwankungen im Hydraulikkreis eine Wellenform, d. h. eine Kurvenform, der Druckschwankung im Hydraulikkreis ist. 15
7. Verfahren nach einem der vorstehenden Ansprüche, weiter umfassend: 20
Erhalten der Vielzahl von Druckmessungen unter Verwendung mindestens eines Drucksensors, wobei die Variationen unter Verwendung einer Vielzahl von aufeinanderfolgenden Druckmessungen des mindestens einen Drucksensors bestimmt werden. 25
8. Verfahren nach einem der Ansprüche 1-7, weiter einschließend: 30
Bestimmen der Darstellung der Druck- und/oder Durchflussschwankungen unter Verwendung eines Drucksensors, der stromabwärts einer Hydraulikpumpe (116, 221) angeordnet ist, die den Druckfluss des Hydraulikfluids bereitstellt, und/oder eines Drucksensors, der stromabwärts der Schlagvorrichtung (105) angeordnet ist, und/oder eines Drucksensors, der in einem Dämpfungskreis der Schlagvorrichtung (105) angeordnet ist. 35
9. Verfahren nach einem der Ansprüche 1-8, wobei die Referenzdarstellung der Variationen des Hydraulikfluids in Abhängigkeit vom Schlagdruck und/oder Zufuhrdruck eingestellt und/oder bestimmt wird. 40
10. Verfahren nach einem der Ansprüche 1-9, weiter umfassend: 45
Diagnostizieren mindestens eines Akkumulators (112, 208, 224) kontinuierlich und/oder in vorbestimmten Intervallen während des Bohrens und, wenn die Diagnose einen Fehler anzeigt, Erzeugen eines Signals, das den Fehler anzeigt, um einen Bohrarbeiter und/oder ein Steuersystem, das das Bohren steuert, zu alarmieren. 50
11. Computerprogramm, das Anweisungen umfasst, die, wenn das Programm von einem Computer ausgeführt wird, den Computer veranlassen, das Verfahren nach einem der vorstehenden Ansprüche durchzuführen. 55
12. Computerlesbares Medium, das Befehle umfasst, die, wenn sie von einem Computer ausgeführt werden, den Computer veranlassen, das Verfahren nach einem der Ansprüche 1-10 durchzuführen.
13. System zum Diagnostizieren der Funktion mindestens eines Akkumulators (112, 208, 224) in einem Hydraulikkreis beim Schlagbohren in Gestein, wobei der Hydraulikkreis unter Druck stehendes Hydraulikfluid bereitstellt, um eine Schlagvorrichtung (105) anzutreiben, die einen hin- und hergehenden Schlagkolben (115) zum Erzeugen von Spannungswellen in einem Bohrwerkzeug (106) umfasst, wobei die Hin- und Herbewegung des Schlagkolbens (115) und/oder eines Dämpfungskolbens (220) zu Druck- und Durchflussschwankungen im Hydraulikkreis führt; und der mindestens eine Akkumulator (112, 208, 224) konfiguriert ist, um Druckund/oder Durchflussschwankungen im Hydraulikkreis zu reduzieren; 60
das System weiter umfassend:
Erhalten von Mitteln, die konfiguriert sind, um während eines ersten Zeitraums eine Vielzahl von Druckmessungen zu erhalten, wobei die Vielzahl von Druckmessungen mit einer Frequenz erhalten wird, die zumindest das doppelte einer Frequenz der Hin- und Herbewegung des Schlagkolbens (115) und/oder des Dämpfungskolbens (220) ist; 65
Bestimmungsmittel, die konfiguriert sind, um während des Bohrens eine Darstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis zu bestimmen, die durch die Hin- und Herbewegung des Schlagkolbens (115) und/oder des Dämpfungskolbens (220) während des ersten Zeitraums verursacht werden; 70
Berechnungsmittel, die konfiguriert sind, um die Funktion des mindestens einen Akkumulators (112, 208, 224) auf der Grundlage der bestimmten Darstellung der Druck- und/oder Durchflussschwankungen im Hydraulikkreis und einer Referenzdarstellung der Druck- und/oder Durchflussschwankungen im Hydraulikkreis zu diagnostizieren, wobei die Diagnose das Vergleichen der bestimmten Darstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis mit der Referenzdarstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis umfasst; und 75
Fehleranzeigemittel, die konfiguriert sind, um ein Signal zu erzeugen, das einen Fehler anzeigt, wenn die bestimmte Darstellung von Druck- und/oder Durchflussschwankungen im Hydraulikkreis von der Referenzdarstellung von Druck- und/oder Durchflussschwankungen um einen vorbestimmten Unterschied abweicht, 80

was auf eine Fehlfunktion des mindestens einen Akkumulators (112, 208, 224) hinweist.

14. System nach Anspruch 13, wobei der mindestens eine Akkumulator (112, 208, 224) in dem Hydraulikkreis einer oder mehrere ist aus:

einem Akkumulator (112), der stromabwärts einer Hydraulikpumpe (116, 221), die den Hydraulikdruck bereitstellt, und stromaufwärts der Schlagvorrichtung (105) angeordnet ist; 10
einem Akkumulator (208), der stromabwärts der Schlagvorrichtung (105) angeordnet ist; und
einem Akkumulator (224), der in einem Dämpfungskreis der Schlagvorrichtung (105) angeordnet ist. 15

15. Gesteinsbohranlage (100), die ein System nach Anspruch 14 oder 15 umfasst.

Revendications

1. Procédé destiné à diagnostiquer le fonctionnement d'au moins un accumulateur (112, 208, 224) dans un circuit hydraulique dans un forage de roche par percussion, le circuit hydraulique fournissant un fluide hydraulique sous pression pour alimenter un dispositif de percussion (105) comprenant un piston à percussion alternatif (115) pour une génération d'ondes de contrainte dans un outil de forage (106) et/ou un piston d'amortissement (220), dans lequel le mouvement alternatif du piston de percussion (115) et/ou d'un piston d'amortissement (220) donne lieu à des variations de pression et de débit dans le circuit hydraulique ; et l'au moins un accumulateur (112, 208, 224) est configuré pour réduire les variations de pression et/ou de débit dans le circuit hydraulique ; 25
le procédé comprenant en outre, pendant le forage :

obtenir une pluralité de mesures de pression pendant une première période de temps, dans lequel la pluralité de mesures de pression sont obtenues à une fréquence représentant au moins deux fois une fréquence du mouvement alternatif du piston de percussion (115) et/ou piston d'amortissement (220) ; 30
déterminer une représentation des variations de pression et/ou de débit dans le circuit hydraulique causées par le mouvement alternatif du piston de percussion (115) et/ou piston d'amortissement (220) pendant la première période de temps ; 35
diagnostiquer la fonction de l'au moins un accumulateur (112, 208, 224) sur la base de la représentation déterminée des variations de pression et/ou de débit dans le circuit hydraulique et 40

d'une représentation de référence des variations de pression et/ou de débit dans le circuit hydraulique, dans lequel le diagnostic comprend une comparaison de la représentation déterminée des variations de pression et/ou de débit dans le circuit hydraulique à la représentation de référence des variations de pression et/ou de débit dans le circuit hydraulique ; et générer un signal indiquant un défaut lorsque la représentation déterminée des variations de pression et/ou de débit dans le circuit hydraulique dévie de la représentation de référence des variations de pression et/ou de débit d'une différence prédéterminée, indiquant un fonctionnement incorrect de l'au moins un accumulateur (112, 208, 224).

2. Procédé selon les revendications 1, comprenant en outre : 45
générer un signal indiquant un défaut lorsqu'une valeur de la représentation déterminée des variations de pression et/ou de débit dans le circuit hydraulique dépasse une valeur de la représentation de référence des variations de pression et/ou de débit d'une certaine mesure prédéterminée.
3. Procédé selon la revendication 1 ou la revendication 2, comprenant en outre :
générer un signal indiquant un défaut lorsqu'une valeur minimale de la représentation déterminée des variations de pression et/ou de débit dans le circuit hydraulique dépasse une valeur maximale de la représentation de référence des variations de pression et/ou de débit d'une certaine mesure prédéterminée.
4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel la représentation des variations de pression et/ou de débit dans le circuit hydraulique est une représentation d'une différence entre une pression ou un débit maximal(e) et minimal(e) dans le circuit hydraulique.
5. Procédé selon la revendication 4, dans lequel la représentation de la pression ou du débit maximal(e) et/ou minimal(e) dans le circuit hydraulique est déterminée en utilisant un ou plusieurs éléments parmi :

une différence entre une enveloppe supérieure et inférieure des variations de pression ou de débit dans le circuit hydraulique ; et
une amplitude d'un ou plusieurs harmoniques des variations de pression et/ou de débit, les harmoniques étant déterminés en utilisant un traitement de signal des variations de pression et/ou de débit, tel qu'un traitement de signal des variations de pression et/ou de débit sur la base d'une transformée de Fourier.

6. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel la représentation des variations de pression et/ou de débit dans le circuit hydraulique est une forme d'onde, c'est-à-dire une forme de courbe, de la variation de pression dans le circuit hydraulique. 5
7. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre : obtenir la pluralité de mesures de la pression en utilisant au moins un capteur de pression, les variations étant déterminées en utilisant une pluralité de mesures de pression consécutives de l'au moins un capteur de pression. 10
8. Procédé selon l'une quelconque des revendications 1 à 7, incluant en outre : déterminer la représentation des variations de pression et/ou de débit en utilisant un capteur de pression agencé en aval d'une pompe hydraulique (116, 221) fournissant le débit de fluide hydraulique sous pression, et/ou un capteur de pression agencé en aval du dispositif de percussion (105), et/ou un capteur de pression agencé dans un circuit d'amortissement du dispositif de percussion (105). 15 20 25
9. Procédé selon l'une quelconque des revendications 1 à 8, dans lequel la représentation de référence des variations du fluide hydraulique est définie et/ou déterminée en fonction de la pression de percussion et/ou la pression d'alimentation. 30
10. Procédé selon l'une quelconque des revendications 1 à 9, comprenant en outre : diagnostiquer l'au moins un accumulateur (112, 208, 224) de manière continue et/ou à certains intervalles prédéterminés pendant un forage et, si le diagnostic indique un défaut, générer un signal indiquant le défaut pour alerter un opérateur de forage et/ou un système de commande commandant le forage. 35 40
11. Programme d'ordinateur comprenant des instructions qui, lorsque le programme est exécuté par un ordinateur, amène l'ordinateur à effectuer le procédé selon l'une quelconque des revendications précédentes. 45
12. Support lisible par un ordinateur comprenant des instructions qui, lorsqu'elles sont exécutées par un ordinateur, amènent l'ordinateur à effectuer le procédé selon l'une quelconque des revendications 1 à 10. 50
13. Système destiné à diagnostiquer le fonctionnement d'au moins un accumulateur (112, 208, 224) dans un circuit hydraulique dans un forage de roche par percussion, le circuit hydraulique fournissant un fluide hydraulique sous pression pour alimenter un

dispositif de percussion (105) comprenant un piston de percussion en alternance (115) pour une génération d'ondes de contrainte dans un outil de forage (106), dans lequel le mouvement alternatif du piston de percussion (115) et/ou d'un piston d'amortissement (220) donne lieu à des variations de pression et de débit dans le circuit hydraulique ; et l'au moins un accumulateur (112, 208, 224) est configuré pour réduire les variations de pression et/ou de débit dans le circuit hydraulique ; le système comprenant en outre :

un moyen d'obtention configuré pour obtenir une pluralité de mesures de pression pendant une première période de temps, dans lequel la pluralité de mesures de pression sont obtenues à une fréquence représentant au moins deux fois une fréquence du mouvement alternatif du piston de percussion (115) et/ou piston d'amortissement (220) ;

un moyen de détermination configuré pour, pendant le forage, déterminer une représentation des variations de pression et/ou de débit dans le circuit hydraulique causées par le mouvement alternatif du piston de percussion (115) et/ou piston d'amortissement (220) pendant la première période de temps ;

un moyen de calcul configuré pour diagnostiquer le fonctionnement de l'au moins un accumulateur (112, 208, 224) sur la base de la représentation déterminée des variations de pression et/ou de débit dans le circuit hydraulique et d'une représentation de référence des variations de pression et/ou de débit dans le circuit hydraulique, dans lequel le diagnostic comprend une comparaison de la représentation déterminée des variations de pression et/ou de débit dans le circuit hydraulique à la représentation de référence des variations de pression et/ou de débit dans le circuit hydraulique ; et un moyen d'indication de défaut configuré pour générer un signal indiquant un défaut lorsque la représentation déterminée des variations de pression et/ou de débit dans le circuit hydraulique dévie de la représentation de référence des variations de pression et/ou de débit d'une différence prédéterminée, indiquant un fonctionnement incorrect de l'au moins un accumulateur (112, 208, 224).

14. Système selon la revendication 13, dans lequel l'au moins un accumulateur (112, 208, 224) dans le circuit hydraulique est un ou plusieurs accumulateurs parmi :

un accumulateur (112) agencé en aval d'une pompe hydraulique (116, 221) fournissant la pression hydraulique et en amont du dispositif

de percussion (105) ;
un accumulateur (208) agencé en aval du dispositif de percussion (105) ; et
un accumulateur (224) agencé dans un circuit d'amortissement du dispositif de percussion (105). 5

15. Appareil de forage de roche (100) comprenant un système selon la revendication 14 ou la revendication 15. 10

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Fig. 1

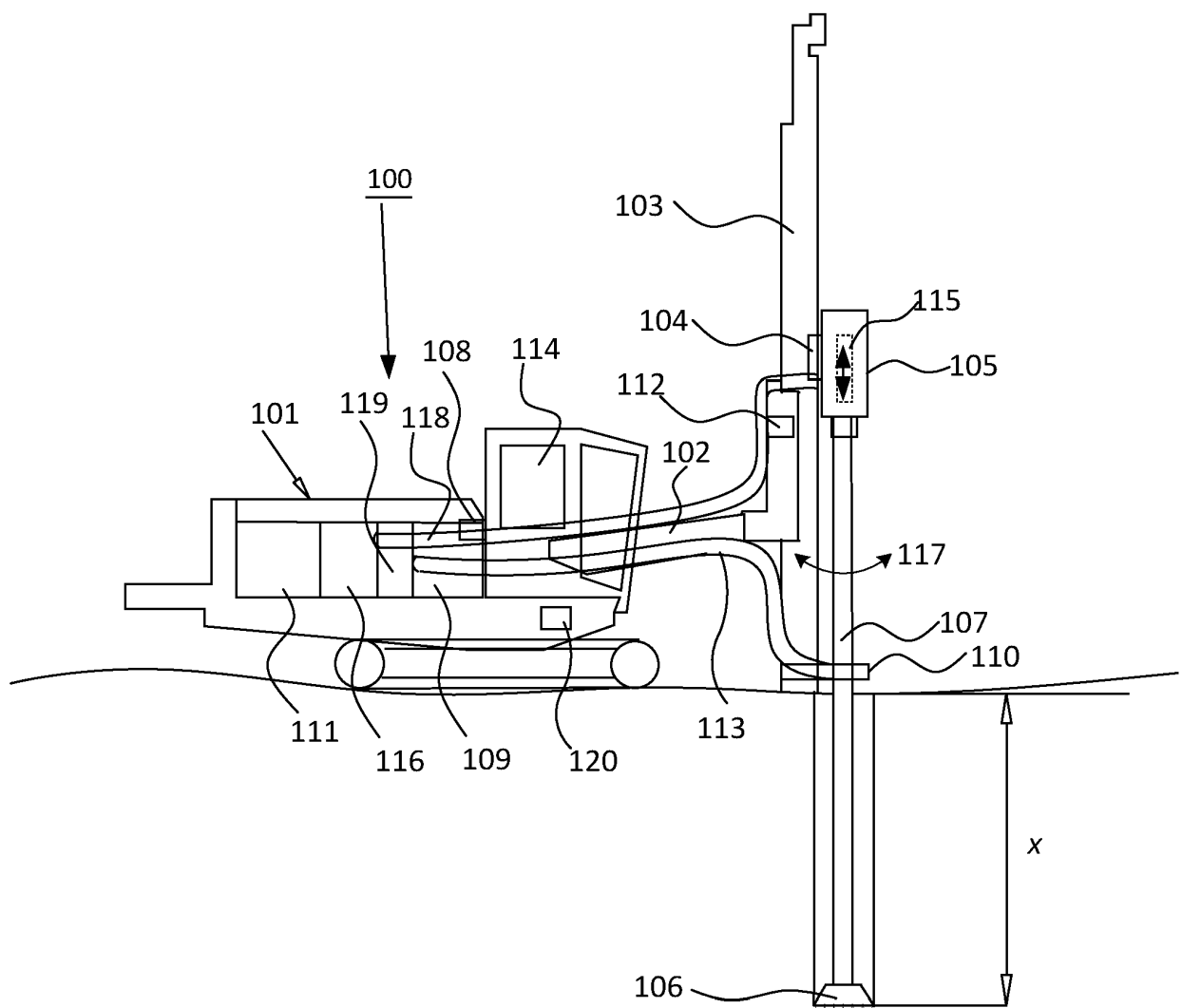


Fig. 2

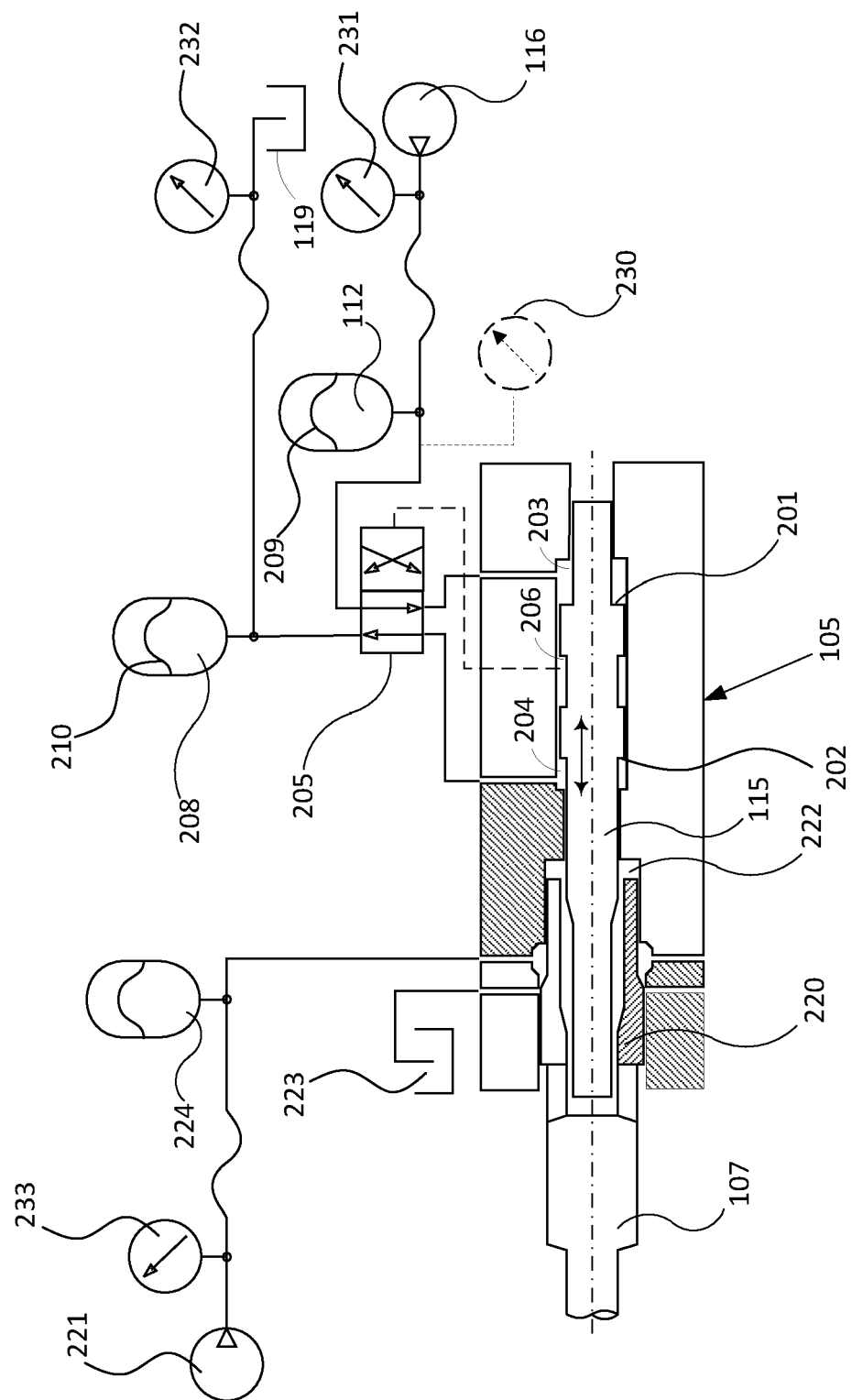


Fig. 3

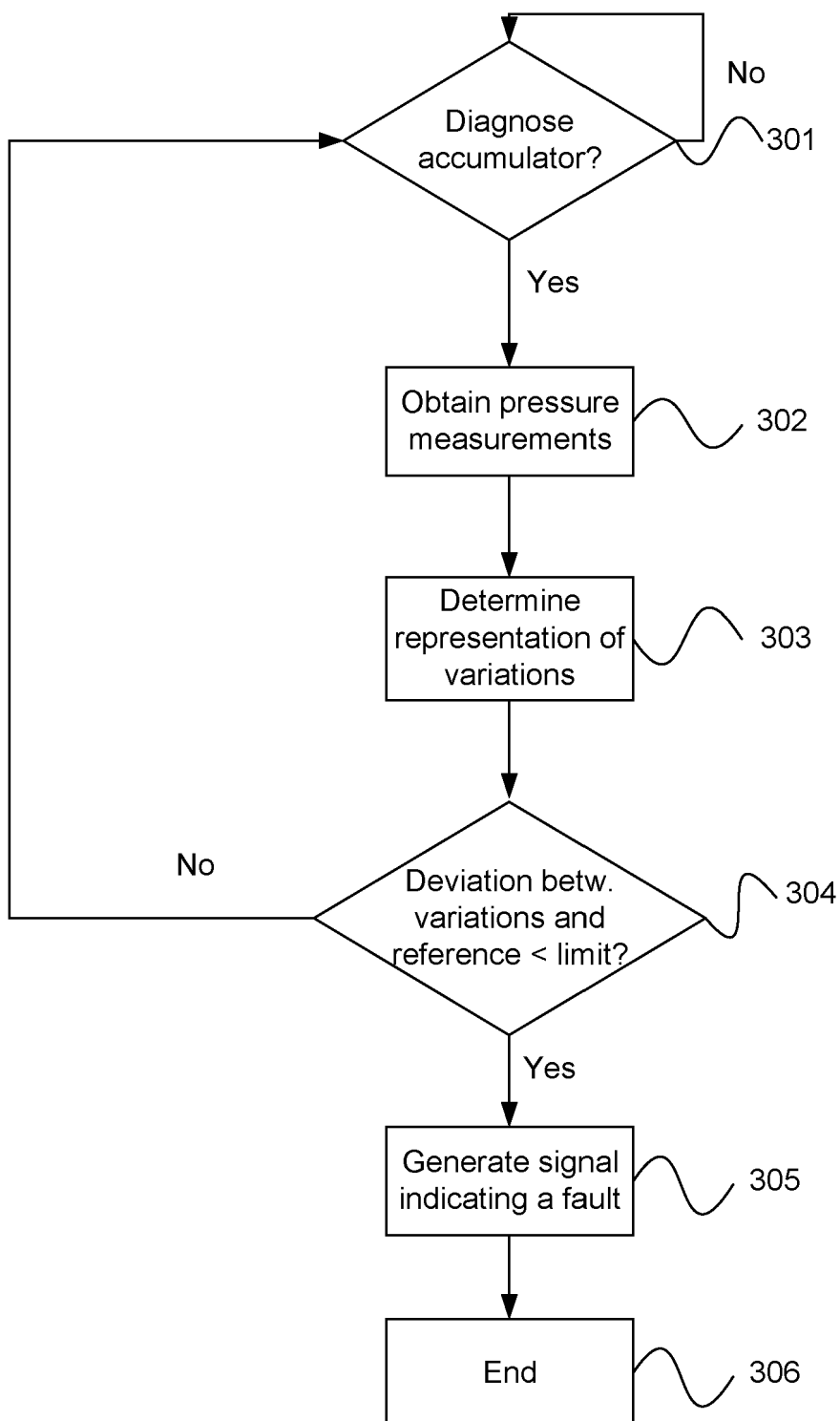
300

Fig. 4

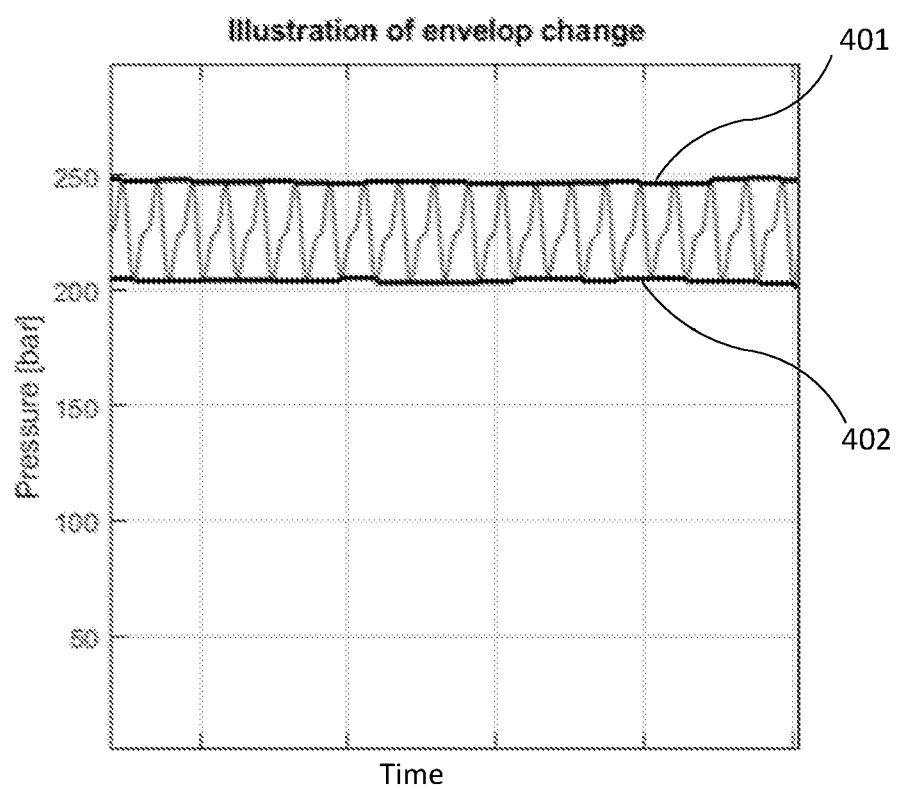
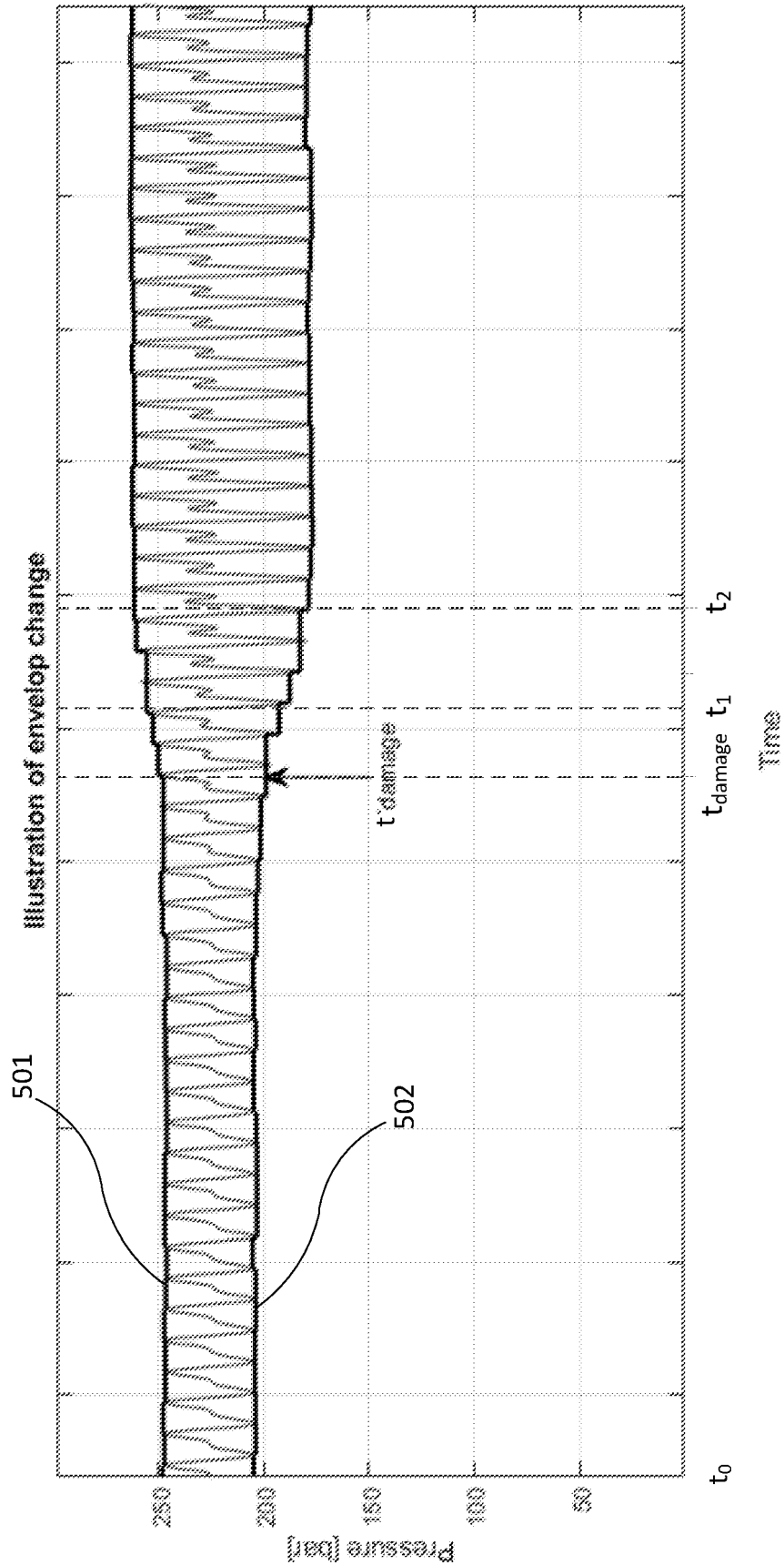


Fig. 5



REFERENCES CITED IN THE DESCRIPTION

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