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(57) ABSTRACT

An arrangement and method for measuring rock breaking dynamics. The arrangement comprises at least one component of a rock breaking system, the component being subjected to stress during rock breaking, at least one element at least part of which is arranged into a state of persistent magnetization, and at least one measuring member for measuring at least one parameter of rock breaking dynamics on the basis of a change in a magnetic property of the component.

(Figure 4)

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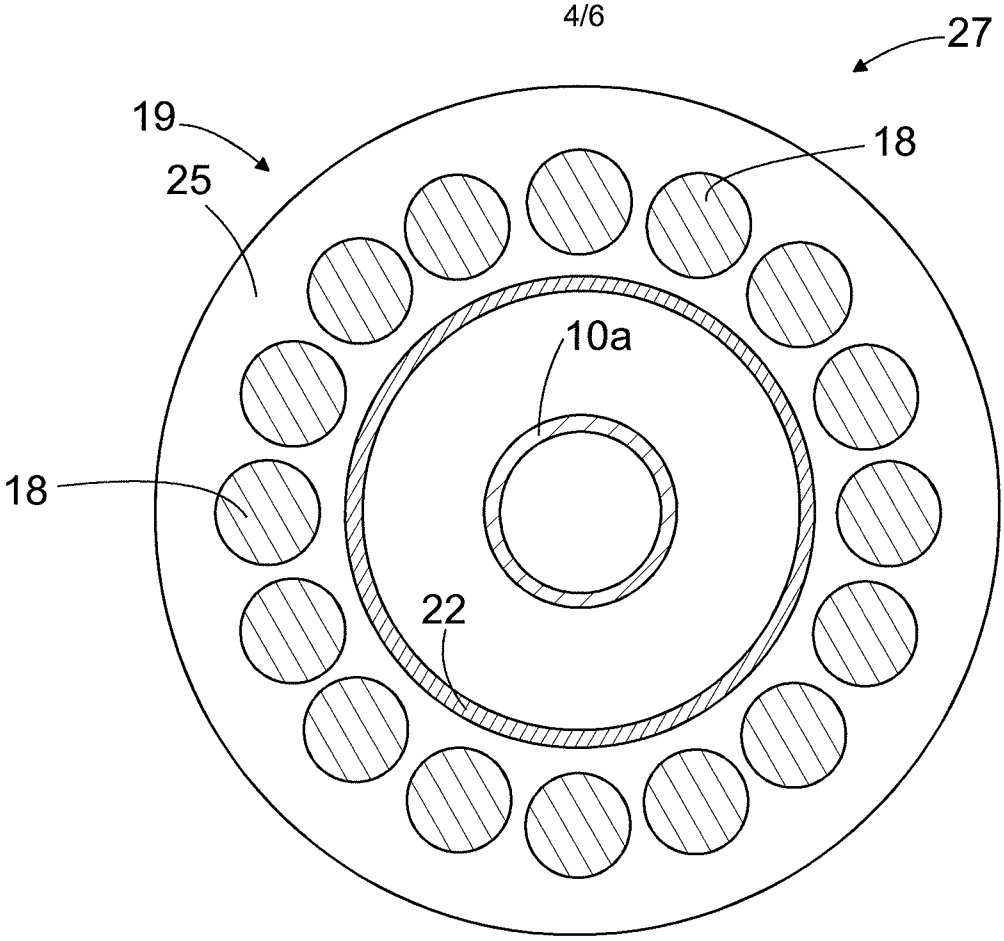

FIG. 8

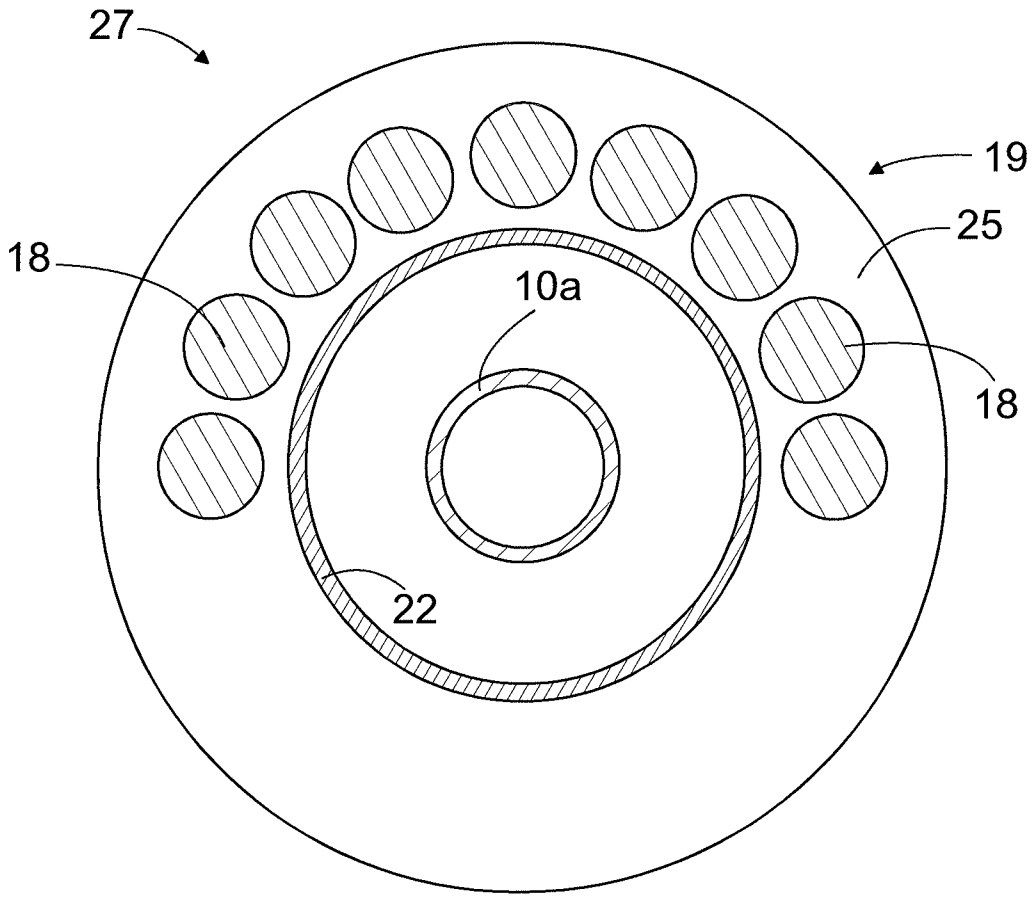

FIG. 9

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Arrangement and method in rock breaking

FIELD OF THE INVENTION

The invention relates to measurement of rock breaking dynamics.

BACKGROUND OF THE INVENTION

Stresses appearing during rock breaking in a rock breaking system may be measured and employed in controlling the rock breaking. FI69680 and US 4,671,366, disclose an example of measuring stress waves appearing during rock breaking and employing the measured stress waves in controlling the operation of a rock breaking device. DE19932838 and US 6,356,077 disclose a signal processing method and device for determining a parameter of a stress wave by measuring magnetoelastic changes caused by stress waves in a component subjected to percussive loads.

BRIEF DESCRIPTION OF THE INVENTION

An object of the present invention is to provide a novel arrangement and method for measuring rock breaking dynamics.

The invention is characterized by the features of the independent claims.

According to an embodiment, an arrangement for measuring rock breaking dynamics comprises at least one component of a rock breaking system, the component being subjected to stress during rock breaking, at least one measuring member for measuring at least one parameter of rock breaking dynamics on the basis of a change in a magnetic property of the component, and at least part of the component of the rock breaking system is arranged into a state of persistent magnetization that is not maintained with an external magnetic source during a measurement period.

According to an embodiment of the arrangement, at least part of the element is arranged into the state of persistent magnetization with a magnetic field external to the rock breaking system.

According to an embodiment of the arrangement, the element is a permanent magnet arranged to provide at least part of the component of the rock breaking system into the state of persistent magnetization.

According to an embodiment of the arrangement, the permanent magnet is arranged to continuously provide at least part of the component of the

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rock breaking system into the state of persistent magnetization.

According to an embodiment of the arrangement, a permanent magnet is arranged to intermittently provide at least part of the component of the rock breaking system into the state of persistent magnetization.

According to an embodiment of the arrangement, the arrangement comprises a number of permanent magnets arranged to at least partly surround the component of the rock breaking system.

According to an embodiment of the arrangement, a single permanent magnet or a group of permanent magnets is arranged to provide at least partly circumferential structure.

According to an embodiment of the arrangement, a single permanent magnet or a group of permanent magnets is openable.

According to an embodiment of the arrangement, a single permanent magnet or a group of permanent magnets is openable for arranging the structure of the single permanent magnet or the group of permanent magnets around the component of the rock breaking system.

According to an embodiment of the arrangement, a single permanent magnet or a group of permanent magnets is arranged to provide a circumferential structure, which is openable for arranging the single permanent magnet or the group of permanent magnets around the component of the rock breaking system.

According to an embodiment of the arrangement, the element at least part of which is arranged into the state of persistent magnetization is the component of the rock breaking system.

According to an embodiment of the arrangement, the arrangement comprises magnetization means for arranging at least part of the component of the rock breaking system into the state of persistent magnetization.

According to an embodiment of the arrangement, the magnetization means is configured to provide an electromagnetic pulse for arranging at least part of the component of the rock breaking system into the state of persistent magnetization.

According to an embodiment of the arrangement, the magnetization means is arranged to at least partly surround the component of the rock breaking system.

According to an embodiment of the arrangement, the magnetization means is arranged to provide at least partly circumferential structure.

According to an embodiment of the arrangement, the magnetization means is openable.

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According to an embodiment of the arrangement, the magnetization means is openable for arranging the structure of the magnetization means at least partially around the component of the rock breaking system.

According to an embodiment of the arrangement, the magnetization means is arranged to provide at least partly circumferential structure, which is openable for arranging the magnetization means at least partially around the component of the rock breaking system.

According to an embodiment of the arrangement, the magnetization means is configured to arrange at least part of the component of the rock breaking system into the state of persistent magnetization at intervals.

According to an embodiment of the arrangement, at least part of the component of the rock breaking system is arranged into the state of persistent magnetization prior to use of the component in the rock breaking system.

According to an embodiment of the arrangement, the rock breaking system comprises at least one void into which at least one permanent magnet or magnetization means is arranged.

According to an embodiment of the arrangement, the component of the rock breaking system is one of a tool, a drill rod, a drill bit, a component of an impact mechanism such as a frame structure of the impact mechanism, an impact device, a drill shank, an attenuating device, an adapter and a coupling sleeve.

According to an embodiment, a method for measuring rock breaking dynamics comprises subjecting a component of a rock breaking system to stress during rock breaking, measuring at least one parameter of rock breaking dynamics on the basis of a change in a magnetic property of the component, arranging at least part of the component of the rock breaking system into a state of persistent magnetization that is not maintained with an external magnetic source during a measurement period, and measuring at least one parameter of rock breaking dynamics on the basis of the change in the magnetic property of the component at least part of which is arranged into the state of persistent magnetization.

According to an embodiment of the method, at least part of the component of the rock breaking system is arranged into the state of persistent magnetization with a magnetic field external to the rock breaking system.

According to an embodiment of the method, at least part of the component of the rock breaking system is arranged into the state of persistent magnetization by at least one permanent magnet, by magnetization means comprising at least one permanent magnet or by magnetization means providing

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an electromagnetic pulse.

According to an embodiment of the method, at least part of the component of the rock breaking system is arranged into the state of persistent magnetization at intervals.

According to an embodiment of a measuring instrument, a measuring instrument comprises at least one magnetization means for arranging at least part of an object into a state of persistent magnetization, and at least one measuring member for measuring at least one parameter describing a change in the magnetic property of the object in response to stress exerted on the object.

According to an embodiment of the measuring instrument, the measuring instrument comprises means configured to provide an electromagnetic pulse for arranging at least part of the object into the state of persistent magnetization.

According to an embodiment of the measuring instrument, the magnetization means is configured to arrange at least part of the object into the state of persistent magnetization at intervals.

According to an embodiment of the measuring instrument, the magnetization means comprises at least one permanent magnet.

According to an embodiment of the measuring instrument, the magnetization means comprises a number of permanent magnets to be arranged to at least partly surround the object.

According to an embodiment of the measuring instrument, a single permanent magnet or a group of permanent magnets is arranged to provide at least partly circumferential structure.

According to an embodiment of the measuring instrument, the single permanent magnet or a group of permanent magnets is openable.

According to an embodiment of a measuring method relating to measuring a change in the magnetic property of an object in response to stress exerted on the object, the method comprises arranging at least part of the object into a state of persistent magnetization and measuring at least one parameter describing a change in the magnetic property of the object in response to stress exerted on the object.

According to an embodiment of the measuring method relating to measuring the change in the magnetic property of the object in response to stress exerted on the object, an electromagnetic pulse is provided for arranging at least part of the object into the state of persistent magnetization.

According to an embodiment of the measuring method relating to

measuring the change in the magnetic property of the object in response to stress exerted on the object, at least part of the object is arranged into the state of persistent magnetization at intervals.

According to an embodiment of the measuring method relating to measuring the change in the magnetic property of the object in response to stress exerted on the object, the object is arranged into the state of persistent magnetization by at least one permanent magnet, by magnetization means comprising at least one permanent magnet or by magnetization means providing an electromagnetic pulse.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in greater detail by means of preferred embodiments, with reference to the accompanying drawings, in which

Figure 1 shows schematically a side view of a rock drilling rig;

Figure 2 shows schematically a stress wave appearing in rock drilling;

Figure 3 shows schematically a partly cross-sectional side view of a rock breaking system;

Figure 4 shows schematically a partly cross-sectional side view of an arrangement for arranging a component of the rock breaking system into a state of persistent magnetization;

Figure 5 shows schematically another partly cross-sectional side view of a second arrangement for arranging a component of the rock breaking system into a state of persistent magnetization;

Figure 6 shows schematically a partly cross-sectional side view of a magnetizing means structure;

Figure 7 shows schematically a partly cross-sectional end view of the magnetizing means structure of Figure 6;

Figure 8 shows schematically a partly cross-sectional end view of a second magnetizing means structure;

Figure 9 shows schematically a partly cross-sectional end view of a third magnetizing means structure;

Figure 10 shows schematically a partly cross-sectional end view of a fourth magnetizing means structure;

Figure 11 shows schematically a partly cross-sectionalized side view of a third arrangement for arranging a component of the rock breaking system into a state of persistent magnetization; and

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Figures 12 and 13 show schematically an example of a measurement result of a stress wave.

DETAILED DESCRIPTION OF THE INVENTION

Rock breaking may be performed by drilling holes in a rock by a rock drilling machine. Alternatively, rock may be broken by a breaking hammer. In this context, the term "rock" is to be understood broadly to cover also a boulder, rock material, crust and other relatively hard material. The rock drilling machine and breaking hammer comprise an impact mechanism, which provides impact pulses to the tool either directly or through an adapter. The impact pulse generates a stress wave which propagates in the tool. When the stress wave reaches the end of the tool facing the rock to be drilled, the tool penetrates into the rock due to the influence of the wave. Some of the energy of the stress wave may reflect back as a reflected wave, which propagates in the opposite direction in the tool, i.e. towards the impact mechanism. Depending on the situation, the reflected wave may comprise only a compression stress wave or a tensile stress wave. However, the reflected wave typically comprises both tension and compression stress components.

Figure 1 shows schematically a significantly simplified side view of a rock drilling rig 1. The rock drilling rig 1 comprises a moving carrier 2 and a boom 3 at the end of which there is a feed beam 4 provided with a rock drilling machine 8 having an impact mechanism 5 and a rotating mechanism 6. The rock drilling rig 1 of Figure 1 further comprises a tool 9, the proximal end of which is coupled to the rock drilling machine 8 and the distal end of which is oriented towards the rock 12 to be drilled. The proximal end 9' of the tool 9 is shown in Figure 1 schematically by a broken line. The tool 9 of the rock drilling rig 1 of Figure 1 comprises drill rods 10a, 10b and 10c and a drill bit 11 at the distal end 9'' of the tool 9. The drill bit 11 may be provided with buttons 11a, although other drill bit structures are also possible. In drilling with sectional drill rods, also known as long hole drilling, a number of drill rods depending on the depth of the hole to be drilled are attached between the drill bit 11 and the rock drilling machine 8. The tool 9 may also be supported with guide supports 13 attached to the feed beam 4.

The drilling machine may also have a structure other than explained above. For example in down-the-hole-drilling the impact mechanism is located in the drilling machine at the bottom of the drilling hole next to the drill bit, the drill bit being connected through the drill rods to the rotating mechanism located above the drilling hole.

The impact mechanism 5 may be provided with an impact piston reciprocating under the influence of pressure medium and striking to the tool either directly or through an intermediate piece, such as a drill shank or another kind of adapter, between the tool 9 and the impact piston. Naturally an impact mechanism of a different structure is also possible. The operation of the impact mechanism 5 may thus also be based on use of electromagnetism or hydraulic pressure without any mechanically reciprocating impact piston and in this context the term impact mechanism refers also to impact devices based on such characteristics. The stress wave generated by the impact mechanism 5 is delivered along the drill rods 10a to 10c towards the drill bit 11 at the distal end of the tool 9. When the stress wave meets the drill bit 11, the drill bit 11 and its buttons 11a strike the rock 12 to be drilled, thereby causing to the rock 12 to be drilled a strong stress due to which cracks are formed in the rock 12. Typically part of the stress wave exerted on or acting on the rock 12 reflects back to the tool 9 and along the tool 9 back towards the impact mechanism 5.

Figure 2 shows schematically a stress wave, wherein the stress wave propagating towards the rock 12 to be drilled is denoted with a reference mark s_i and the stress wave reflected from the rock 12 back to the tool 9 is denoted with a reference mark s_r.

During drilling the rotating mechanism 6 transmits continuous rotating force to the tool 9, thus causing the buttons 11a of the drill bit 11 to change their position after an impact and to strike a new spot on the rock 12 at the next impact. The rock drilling rig 1 of Figure 1 also comprises a feed mechanism 7, which is arranged to the feed beam 4, in relation to which the rock drilling machine 8 is movably arranged. During drilling the feed mechanism 7 is arranged to push the rock drilling machine 8 forward on the feed beam 4 and thus to push the drill bit 11 against the rock 12.

Figure 1 shows the rock drilling rig 1 considerably smaller in relation to the structure of the rock drilling machine 8 than what it is in reality. For the sake of clarity, the rock drilling rig 1 of Figure 1 has only one boom 3, feed beam 4, rock drilling machine 8 and feed mechanism 7, although it is obvious that a rock drilling rig may be provided with a plurality of booms 3 having a feed beam 4, a rock drilling machine 8 and a feed mechanism 7. It is also obvious that the rock drilling machine 8 usually includes flushing means to prevent the drill bit 11 from being blocked. For the sake of clarity, no flushing means are shown in Figure 1. The drilling machine 8 may be hydraulically operated, but it may also be pneumatically or electrically operated.

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Figure 3 shows schematically a partly cross-sectional side view of a rock breaking system 14 which may be used, for example, in the rock drilling rig of Figure 1. The rock breaking system 14 of Figure 3 comprises an impact mechanism 5 and a tool 9 connected to the impact mechanism 5. The tool 9 in the rock breaking system 14 of Figure 3 comprises drill rods 10a, 10b and a drill bit 11 at the distal end of the drill rod 10b. The impact mechanism 5 comprises a frame structure 5' and an impact device 15 arranged to provide impact pulses directed to the tool 9. In the embodiment of Figure 3 the impact device 15 has a form of an impact piston but the actual implementation of the impact device 15 and the impact mechanism 5 may vary in many ways. The impact mechanism 5 of Figure 3 also comprises a drill shank 16 to which the proximal end 9' of the tool 9 is fastened, whereby the impact device 15 is arranged to direct the impact to the drill shank 16 and not directly to the tool 9, the drill shank 16 thus forming an intermediate piece between the impact device 15 and the tool 9. The impact mechanism 5 of Figure 3 further comprises an attenuating device 17, which is shown very schematically in Figure 3 and which is positioned between the drill shank 16 and the impact device 15 and supported to the frame structure 5' of the impact mechanism 5. The function of the attenuating device 17 is to attenuate effects of stresses reflecting back to the tool 9 and the impact mechanism 5 from the rock 12. The attenuating device 17 may also provide positioning of the drill shank 16 at such a point relative to the impact device 15 that the impact provided by the impact device 15 will have an optimal effect on the drill shank 16. The actual implementation of the attenuating device 17 may comprise for example one or more pressure medium operated cylinders.

In the embodiment of Figure 3 the impact mechanism 5 and the tool 9 coupled to the impact mechanism 5 form the rock breaking system 14, which is subjected to stresses during rock breaking. An implementation of the rock breaking system may, however, vary in many ways. In breaking hammers, for example, the rock breaking system comprises typically only an impact device and a tool such that the impact provided by the impact device affects straight to the tool 9. Depending on the implementation the rock breaking system may be hydraulically, pneumatically or electrically operated or the operation of the rock breaking system may be implemented as a combination of hydraulically, pneumatically and/or electrically operated devices. For the sake of clarity, Figures 1 and 3 do not show any pressure medium lines or electrical lines needed for the operation of the rock breaking system, which lines are as such known to the person skilled in the art.

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Figure 4 discloses schematically some possible locations where one or more permanent magnets 18 may be located in the rock breaking system 14 of Figure 3. For the sake of clarity, the frame structure 5' of the impact mechanism 5 is omitted in Figure 4. The permanent magnets 18 are elements which are or can be arranged into a state of persistent magnetization. When the permanent magnets 18 are arranged into the state of persistent magnetization, they have a magnetic field, and when at least part of the component of the rock breaking system 14 is subjected to the effect of the magnetic field of at least one permanent magnet 18, at least part of the component of the rock breaking system 14 is further arranged into a state of persistent magnetization. Further, when stress is acting on the component arranged into the state of persistent magnetization during rock breaking, or in other words, when stress affects the component of the rock breaking system arranged into the state of persistent magnetization, the stress causes a change in a magnetic property of the component.

The component of the rock breaking system 14, at least part of which may be arranged into the state of persistent magnetization, may for example be the impact mechanism 5, the frame structure 5' of the impact mechanism 5, the impact device 15, the drill shank 16, the attenuating device 17, the tool 9 of the rock breaking system 14 such as the drill rods 10a, 10b, 10c and/or the drill bit 11. The component of the rock breaking system 14, at least part of which may be arranged into the state of persistent magnetization, may also be an adapter or a coupling sleeve in the impact mechanism, for example. The components of the rock breaking system 14 which may be arranged into the state of persistent magnetization are thus components which may generate, convey or damp the stresses or the stress waves appearing during rock breaking.

The state of persistent magnetization may be a state of magnetization that remains for a relatively long period of time as in a permanent magnet, a state of magnetization that is maintained by intermittent application of an external magnetic source, a state of magnetization remaining internally in the component material resulting from exposure to an external magnetic field, or a state of persistent magnetization that need not be maintained with an external magnetic source during a measurement period. It is possible that the state of persistent magnetization is provided by a single intermittent application of a magnetic source either by active means, some examples of which are provided later, or by non-active means, such as a permanent magnet.

The change in the magnetic property of the component may be a change in a magnetic field of the component, a change in a magnetic flux of the

magnetic field of the component, a change in a permeability or magnetic inductivity of the component or a change in a state or intensity of magnetization of the component, for example. The change in the magnetic property of the component is thus a consequence of a change in the state of the material of the component being subjected to stress. Because the solution deals with the state of persistent magnetization, changes in the magnetic property of the component subjected to stress can be detected more consistently.

In Figure 4 the permanent magnets 18 are fastened in a supporting structure 19 and have a circular form so that the permanent magnets 18 may be arranged to surround the component at least part of which will be arranged into a state of persistent magnetization with at least one permanent magnet 18. In Figure 4 the permanent magnets 18 are arranged to surround the rod 10a of the tool 9, the drill shank 16, the attenuating device 17 and the impact device 15.

Figure 5 discloses schematically some further possible locations where one or more permanent magnets 18 may be located in the rock breaking system 14 of Figure 3. In Figure 5 the permanent magnets also have the circular shape but the supporting structures 19 disclosed in Figure 4 have been left out. In the embodiment of Figure 5 there are voids 20 formed in the frame structure 5' of the impact mechanism 5, the drill shank 16, the attenuating device 17 and the impact device 15, whereby the permanent magnets 18 may be arranged inside said components by arranging the permanent magnets 18 into the voids 20 in the components. Also the interior of the drill rod 10a, for example, forms a kind of void wherein at least one permanent magnet 18 may be arranged. In the drill shank 16 the permanent magnet 18 may be located in a flushing channel 31 of the drill shank 16, for example, the flushing channel forming a kind of void in the drill shank 16.

Figures 4 and 5 show schematically some possible locations where the permanent magnets 18 may be arranged in the rock breaking system 14. The arrangement may, however, comprise only one permanent magnet 18 to arrange at least part of one rock breaking system component into the state of persistent magnetization. Alternatively, the arrangement may comprise two or more permanent magnets 18 to arrange at least part of one or more rock breaking system components into the state of persistent magnetization. Therefore in the arrangement there may be several rock breaking system components each having a relating permanent magnet 18 or one or more rock breaking system components having several relating permanent magnets 18. Examples of the latter embodiment are also shown schematically in Figures 4 and 5, Figure 4 disclosing

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two successive permanent magnets 18 surrounding the drill shank 16 and Figure 5 disclosing two successive permanent magnets 18 arranged in the void 20 in the frame structure 5' of the impact mechanism 5. If in the arrangement there are several permanent magnets 18 relating to one rock breaking system component, the permanent magnets may also be arranged to be successive in relation to each other in the circumferential direction of the specific rock breaking system component. In this case the permanent magnets may have a form of a rectangle, for example.

Because in the examples of Figures 4 and 5 the permanent magnets are arranged permanently in the vicinity of the rock breaking system components, the permanent magnets are thus arranged to continuously provide at least part of the component of the rock breaking system into the state of persistent magnetization in the examples of Figures 4 and 5.

Figures 4 and 5 disclose schematically also means for measuring at least one parameter of rock breaking dynamics on the basis of the change in the magnetic property of the rock breaking system component, the change in the magnetic property of the component originating from the stress, such as the stress wave, affecting the component of the rock breaking system 14 during the operation of the rock breaking system 14.

In Figure 4 the measuring member for measuring at least one parameter of rock breaking dynamics on the basis of the change in the magnetic property of the component is a measurement coil 21, which in the embodiment of Figure 4 is arranged to surround the drill rod 10a, in the area of the drill rod 10a arranged into the state of persistent magnetization by the permanent magnet 18 next to the drill rod 10a. The measurement coil 21 could, however, alternatively be arranged next to some other rock breaking system component in the area of the component arranged into the state of persistent magnetization by the permanent magnet 18. There could also be more than one measurement coil 21 next to either the same or different rock breaking system components for measuring the change in the magnetic property of the specific one or more components. Due to the change in the magnetic property of the component a voltage or current equivalent to the change in the magnetic property of the component is induced in the measurement coil 21. The induced voltage or current, in turn, indicates the stresses affecting the specific rock breaking system component.

In Figure 5 the measuring member for measuring the change in the magnetic property of the component is a magnetic sensor 22, which in the embodiment of Figure 5 is arranged in the drill shank 16, in the area of the drill

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shank 16 arranged into the state of persistent magnetization by the permanent magnet 18 in the drill shank 16. The magnetic sensor 22 could, however, alternatively be in some other rock breaking system component in the area of the component arranged into the state of persistent magnetization. There could also be more than one magnetic sensor 22 in either the same or different rock breaking system components for measuring at least one parameter of rock breaking dynamics on the basis of the change in the magnetic property of the specific one or more components. The magnetic sensor 22 may, for example, be a coil, a magnetometer, a magnetoresistive element or a Hall-sensor.

The measurement information provided by the measuring member is transferred, either through a wired connection or a wireless connection, schematically indicated by arrow 23, to a data processing unit 24. The data processing unit 24 comprises software- and/or hardware-based means for processing or modifying the measurement information provided by the measuring member to reach a meaningful representation of the measurement information provided by the measuring member such that the measurement information may be analysed and/or used for controlling the operation of the rock breaking system 14 or the whole rock drilling rig 1 or the breaking hammer. The processing or modification methods disclosed in DE19932838 and US 6,356,077, for example, may be applied.

When permanent magnets 18 are used for arranging at least part of the component of the rock breaking system into the state of persistent magnetization, disturbances do not appear in the measurement of the changes in the magnetic property of the rock breaking system component due to the stress acting on the rock breaking system component, which disturbances take place in prior art solutions comprising a magnetizing coil to magnetize the rock breaking system component simultaneously during the measurement of the changes in the magnetic property of the rock breaking system component.

When considering the operation of the arrangement for measuring rock breaking dynamics, instruments relating to the measurement operation, like permanent magnets, are preferably manufactured of electrically non-conductive material. Possible coils, however, are naturally made of electrically conductive material.

Figure 6 shows schematically a partly cross-sectional side view of a magnetizing means structure 27 intended to arrange at least part of the rock breaking system component into the state of persistent magnetization and Figure 7 shows schematically a partly cross-sectional end view of the magnetizing means

structure 27 of Figure 6. The magnetizing means structure 27 comprises a single permanent magnet 18, which in the embodiment of Figures 6 and 7 has a shape of a ring which is arranged to surround the rock breaking system component, i.e. the drill rod 10a, in the example of Figures 6 and 7. The permanent magnet 18 is inserted inside the supporting structure 19 comprising a jacket 25 surrounding the permanent magnet 18 and end plates 26 so that the supporting structure 19 is a closed structure enclosing the permanent magnet 18 inside the supporting structure 19. For the sake of clarity, the lineation indicating the cross-section of the jacket 25 has not been shown in Figure 7. At least one of the end plates 26 may be detachable for inserting the permanent magnet 18 inside the supporting structure 19. The supporting structure 19 forms a guiding member for guiding the magnetic field provided by the permanent magnet 18 to the rock breaking system component for arranging at least part of the rock breaking system component into the state of persistent magnetization by the magnetic field provided by the permanent magnet 18.

In the embodiment of Figures 6 and 7 the ring-shaped permanent magnet 18 is arranged to entirely surround the rock breaking system component, i.e. the drill rod 10a. The permanent magnet 18 surrounding either partly or entirely the rock breaking system component under interest could also have another curvilinear shape. The shape or form of the permanent magnet 18 surrounding at least partly the rock breaking system component under interest may also have other kind of at least partly circumferential shape than the curvilinear or annular form.

In the embodiment of Figures 6 and 7 the measurement sensor 22 is also arranged inside the inner periphery of the permanent magnet 18. The embodiment of Figures 6 and 7 thus provides a combination of the permanent magnet 18, i.e. the element at least part of which is arranged into the state of persistent magnetization, and the measuring member, i.e. the measurement sensor 22. The ends of the measurement sensor 22 (not shown) may be arranged to run through the end plates 26, for example, if the measurement sensor 22 has a form of a coil.

Figure 8 shows schematically a partly cross-sectional end view of a second magnetizing means structure 27. For the sake of clarity the lineation indicating the cross-section of the jacket 25 has not been shown in Figure 8. In Figure 8, compared to Figure 7, the ring-shaped permanent magnet 18 of Figure 6 is replaced by a number of permanent magnets 18 having a shape of a round bar and arranged adjacently to each other in the jacket 25 of the supporting structure

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19 in such a way that that the permanent magnets 18 are arranged to surround the whole periphery of the rock breaking system component, i.e. the drill rod 10a, under interest.

Figure 9 shows schematically a partly cross-sectional end view of a third magnetizing means structure 27. For the sake of clarity the lineation indicating the cross-section of the jacket 25 has not been shown in Figure 9. In Figure 9, compared to Figure 8, the ring-shaped permanent magnets 18 having a shape of a round bar are arranged adjacent to each other in the jacket 25 of the supporting structure 19 in such a way that the permanent magnets 18 are arranged to surround only a part of the periphery of the rock breaking system component, i.e. the drill rod 10a, under interest.

In the embodiments of Figures 6 to 9 there are a number of permanent magnets, i.e. one or more permanent magnets, arranged to at least partly surround the component of the rock breaking system for arranging at least part of the rock breaking system component into the state of persistent magnetization. In the embodiments of Figures 8 and 9 the cross-sectional shape of the bar-like permanent magnets may also differ from the round shape.

Figure 10 shows schematically a partly cross-sectional end view of a fourth magnetizing means structure 27. For the sake of clarity the lineation indicating the cross-section of the jacket 25 has not been shown in Figure 10. The magnetizing means structure 27 of Figure 10 has two portions 27', 27'', each comprising the supporting structure 19, the permanent magnet 18 and the measurement sensor 22 having a shape of semiarch. The two portions 27', 27'' may be combined, for example by using a joint hinge, with each other to form one magnetizing means structure 27 having a round form by placing the portions against each other. The measurement sensors 22 may also be connected together. For the sake of clarity the portions 27', 27'' in Figure 10 are shown to have a small distance between them and no joint hinge is shown in Figure 10. The magnetizing means structure 27 of Figure 10 may be assembled around the rock breaking system component not only from the end of the component but also from the side of the component.

In the embodiment of Figure 10, a group of two permanent magnets is arranged together to form a circumferential structure, which is openable for arranging the group of permanent magnets around the component of the rock breaking system. In the embodiment of Figure 10 the two permanent magnets form, in practice, a single permanent magnet arranged around the rock breaking system component. Also permanent magnets having a shape or a form differing

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from the circumferential structure may be arranged in some way openable. Also a measuring member may be arranged openable in a similar way as explained in the specification relating to Figure 10. When the structure of the magnetization means and/or measuring member is openable, it is openable in a way to enable placement in the vicinity of the rock breaking system or to at least partly surround the rock breaking system. It may also be openable for maintenance and service purposes of the magnet(s), magnetization means, rock breaking system or the rock breaking device, such as a drill rig.

In the embodiments of Figures 6 to 10 the permanent magnet 18 or permanent magnets 18 may be manufactured of electrically conductive material without harmful deteriorating effect to the measurement of rock breaking dynamics if the jacket 25 is made of electrically non-conductive material.

In the examples of Figures 6 to 10 the magnetization means structure 27 provides or forms a measuring instrument for measuring a change in a magnetic property of an object, the measuring instrument comprising at least one magnetization means for arranging at least part of the object into a state of persistent magnetization and at least one measuring member for measuring at least one parameter describing a change in the magnetic property of the object in response to stress exerted on the object, the object being the drill rod 10a in the examples of Figures 6 to 10. The measuring instrument thus comprises both at least one magnetization means for arranging at least part of the object into a state of persistent magnetization and at least one measuring member for measuring at least one parameter describing a change in the magnetic property of the object in response to stress exerted on the object. The magnetization means may be, for example, a permanent magnet 18, as disclosed above, or a magnetizing coil 28 or a combination of one or more permanent magnets 18 and the magnetizing coil 28, as disclosed later. The measuring member may be, for example, a measurement coil 21 or a magnetic sensor 22, as disclosed above. The structure of the measuring instrument may be openable as disclosed above in the example of Figure 10 and the relating description, for example. In the examples of this specification the measuring instrument is used for measuring changes in the magnetic property of the component of the rock breaking system 14, but generally, the measuring instrument disclosed may also be used for measuring changes in the magnetic property of other objects subjected to stress.

In the examples above, in the arrangement for measuring rock breaking dynamics the element, at least part of which is arranged into the state of persistent magnetization, is thus the permanent magnet, the magnetic field of the permanent

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magnet, in turn, arranging at least part of the component of the rock breaking system into the state of persistent magnetization. Alternatively, in the arrangement for measuring rock breaking dynamics the element, at least part of which is arranged into the state of persistent magnetization, may also be the component of the rock breaking system, i.e. for example, referring to Figure 11, the impact mechanism 5, the impact device 15, the drill shank 16, the attenuating device 17, the tool 9 of the rock breaking system 14 such as the drill rods 10a, 10b, 10c and/or the drill bit 11 and also the frame structure 5' of the impact mechanism 15, which is not shown in Figure 11. When at least part of the component of the rock breaking system is arranged into the state of persistent magnetization the component itself is arranged into a state of persistent magnetization, whereby the component itself has a magnetic property, the change of which is measured, for measuring at least one parameter of rock breaking dynamics on the basis of the change in the magnetic property of the component.

Figure 11 discloses magnetizing coils 28 used as magnetizing means, which may be used to arrange at least part of the component of the rock breaking system 14 into the state of persistent magnetization. In the example of Figure 11 one or more magnetizing coils 28 are arranged to surround the drill rod 10a, the drill shank 16, the attenuating device 17 and the impact device 15. One or more magnetizing coils 28 may also be arranged to surround the frame structure of the impact device 5. In Figure 11 the drill rod 10a, the attenuating device 17 and the impact device 5 are surrounded by only one magnetizing coil 28 but they could also be surrounded by two or more magnetizing coils 28. The magnetizing coils 28 could also be inserted in voids provided in the rock breaking system components in a similar way as the permanent magnets in the example of Figure 5. The change in the magnetic property of the component of the rock breaking system 14 may be measured for example as explained in the examples of Figures 4 and 5.

The arrangement in Figure 11 comprises also a power source 29 configured to provide the necessary electric power for the magnetization coils 28 through the connections presented by arrows 30. The power source 29 is configured to provide an electromagnetic pulse in order to arrange at least part of the component of the rock breaking system 14 into the state of persistent magnetization. The length, shape and amplitude of the electromagnetic pulse may be fixed or variable. The component of the rock breaking system 14 may be arranged into the state of persistent magnetization at intervals, for example at regular intervals, on the basis of an operating state of the rock breaking system 14, on the basis of operation of the measuring member or on the basis of a

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change in the magnetic property of the component of the rock breaking system 14. At least part of the component of the rock breaking system 14 may be arranged into the state of persistent magnetization also prior to use of the component in the rock breaking system 14.

When the component of the rock breaking system 14 is arranged into the state of persistent magnetization at intervals, there are certain time periods between which the magnetization operations are provided. The time periods may be related to absolute time, rock breaking time, work shift durations and so on. The interval may also be defined on the basis of rock breaking operations, such as a drilled distance, a number of impacts subjected to the tool 9, an amount of impact energy or energy in general travelled through the tool 9 and so on. An interval may also be used for making magnetization operations occur at least within the interval. That is, if magnetization operations have not taken place during a defined interval, magnetization operations are executed.

When the component of the rock breaking system is arranged into the state of persistent magnetization on the basis of an operating state of the rock breaking system 14, the magnetization operations may be executed, for example, during an idle state of the impact device 15, such as between successive impacts, between impact series, upon beginning to drill a hole, during a change of a new drill rod 10a, upon finishing a hole, during positioning the rock breaking system for drilling a hole, during movement of the rock breaking system or device, such as the rock drilling rig 1, at the rock breaking site.

When the component of the rock breaking system 14 is arranged into the state of persistent magnetization on the basis of the operation of the measuring member, the magnetization operations may be executed during an idle state of the measuring member, or, for example when it is observed that quality of measurement suffers from improper state of magnetization. The magnetization operations may also be executed on the basis of a measured value or measurement result. The measured value or measurement result may be obtained from an additional sensor, possibly external to the rock breaking system or the measurement system.

When the component of the rock breaking system 14 is arranged into the state of persistent magnetization on the basis of a change in the magnetic property of the component of the rock breaking system, the magnetization operations may be executed when it is observed that the state of persistent magnetization has changed to such an extent that no reliable measurement information cannot be obtained.

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When the component of the rock breaking system is arranged into the state of persistent magnetization prior to use of the component in the rock breaking system, at least part of the component may be arranged into the state of persistent magnetization for example after the manufacturing of the component, before assembling the component to the rock breaking system either at the factory or use site of the rock breaking system, or after assembling the component to the rock breaking system but before the actual operation of the rock breaking system. At least part of the component of the rock breaking system may thus be arranged into the state of persistent magnetization with a magnetic field external to the rock breaking system.

The operation of the magnetization may be controlled for example with the data processing unit 24.

In the example of Figure 11 and the related specification above, the component of the rock breaking system is arranged into the state of persistent magnetization by using only the magnetization coil 28 as the magnetization means. It is however possible that a permanent magnet is arranged in combination with the magnetization coil 28. It is also possible that instead of using the magnetization coil 28 only a permanent magnet is used for arranging the specific component of the rock breaking system into the state of persistent magnetization by arranging the permanent magnet in the vicinity of the specific rock breaking system component only for a specific time period as explained above. Thus also only the permanent magnet may be used to intermittently provide at least part of the component of the rock breaking system into the state of persistent magnetization.

When at least part of the component of the rock breaking system is arranged into the state of persistent magnetization, which state of persistent magnetization may be stimulated if necessary, the component of the rock breaking system itself provides the magnetic property which is observed when the parameter of rock breaking dynamics is measured on the basis of the change in the magnetic property of the component. In this case, disturbances do not appear either in the measurement of the changes in the magnetic property of the rock breaking system component due to the stress acting on the rock breaking system component, which disturbances take place in prior art solutions comprising a magnetizing coil to magnetize the rock breaking system component simultaneously during the measurement of the changes in the magnetic property of the rock breaking system component.

According to an embodiment, the magnetization coil 28 may be used as

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a measurement coil too. In this embodiment the magnetization coil 28 may be used both for providing the electromagnetic pulse for arranging a component of the rock breaking system into the state of persistent magnetization and for providing a measurement of a parameter of rock breaking dynamics on the basis of the change in the magnetic property of the component after the component has been arranged into the state of persistent magnetization, i.e. at the time the magnetization coil 28 is not used for arranging the component of the rock breaking system into the state of persistent magnetization.

Figures 12 and 13 show schematically an example of a measurement result of a stress wave, Figure 13 being more detailed presentation of the first part of the measurements of Figure 12. In Figures 12 and 13 the dashed line represents the stress wave measured by a strain gauge attached to a rock breaking system component. The continuous line, in turn, represents the same stress wave measured by a measurement coil when permanent magnets were used for arranging the same rock breaking system component into the state of persistent magnetization. From Figures 12 and 13 it can be seen that the stress wave measurement provided by the presented solution corresponds to the measurement provided by the strain gauge, which can be considered to follow exactly the stress wave appearing in the rock breaking system component, because the strain gauge is directly fixed to the rock breaking system component.

Examples of the measurement arrangement disclosed above relate to the measurement of stresses or stress waves affecting the rock breaking system during rock breaking, but the measurement arrangement may also be utilized in other ways for measurement of rock breaking dynamics or related parameters. The measurement arrangement may also be utilized in the determination of other phenomena or events, such as determination of the impact frequency or characteristics of the broken rock, as well as in the condition monitoring of the rock breaking system or its components.

It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word “comprise” or variations such as “comprises” or “comprising” is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in

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various embodiments of the invention.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An arrangement for measuring rock breaking dynamics, the arrangement comprising

at least one component of a rock breaking system, the component being subjected to stress during rock breaking, and

at least one measuring member for measuring at least one parameter of rock breaking dynamics on the basis of a change in a magnetic property of the component,

wherein

at least part of the component of the rock breaking system is arranged into a state of persistent magnetization that is not maintained with an external magnetic source during a measurement period.

2. The arrangement as claimed in claim 1, wherein at least part of the component is arranged into the state of persistent magnetization with a magnetic field external to the rock breaking system.

3. The arrangement as claimed in claim 1, wherein the arrangement comprises magnetization means for arranging at least part of the component of the rock breaking system into the state of persistent magnetization.

4. The arrangement as claimed in claim 3, wherein the magnetization means is configured to provide an electromagnetic pulse for arranging at least part of the component of the rock breaking system into the state of persistent magnetization.

5. The arrangement as claimed in either claim 3 or 4, wherein the magnetization means is configured to arrange at least part of the component of the rock breaking system into the state of persistent magnetization at intervals.

6. The arrangement as claimed in any one of the preceding claims, wherein at least part of the component of the rock breaking system is arranged into the state of persistent magnetization prior to use of the component in the rock breaking system.

7. The arrangement as claimed in any one of the preceding claims,

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wherein the component of the rock breaking system is one of a tool, a drill rod, a drill bit, a component of an impact mechanism such as a frame structure of the impact mechanism, impact device, a drill shank, an attenuating device, an adapter and a coupling sleeve.

8. A method for measuring rock breaking dynamics, the method comprising

subjecting a component of a rock breaking system to stress during rock breaking, and

measuring at least one parameter of rock breaking dynamics on the basis of a change in a magnetic property of the component,

including

arranging at least part of the component of the rock breaking system into a state of persistent magnetization that is not maintained with an external magnetic source during a measurement period, and

measuring at least one parameter of rock breaking dynamics on the basis of the change in the magnetic property of the component at least part of which is arranged into the state of persistent magnetization.

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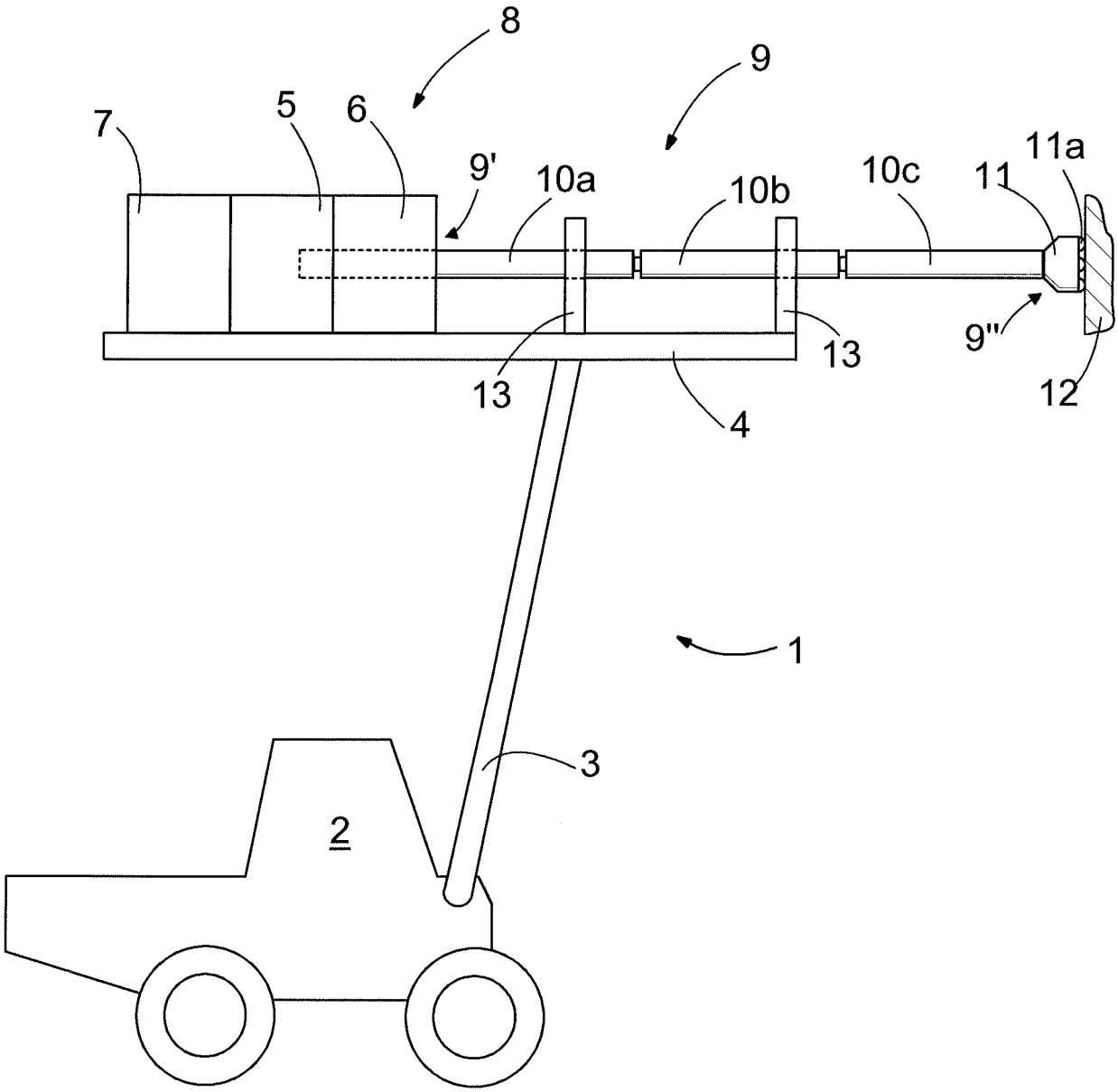

FIG. 1

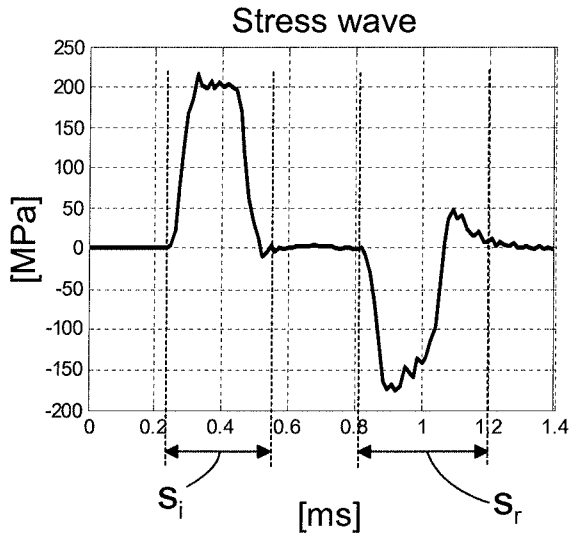

FIG. 2

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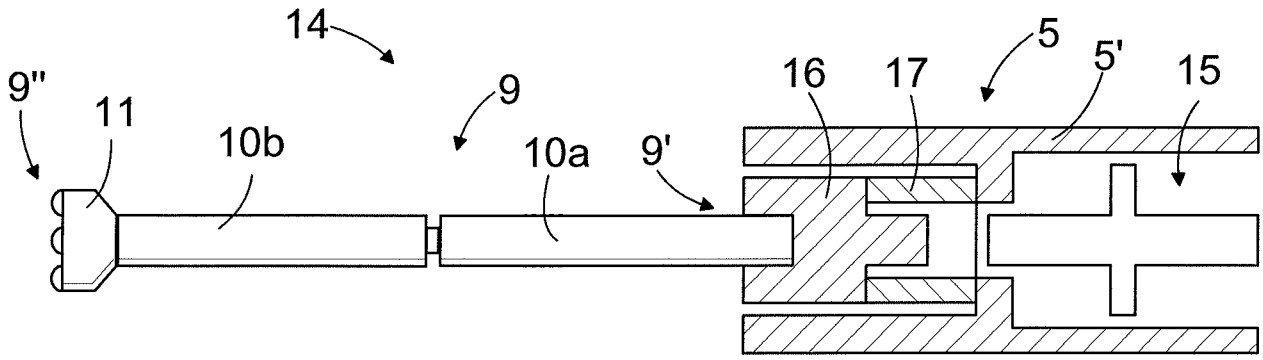

FIG. 3

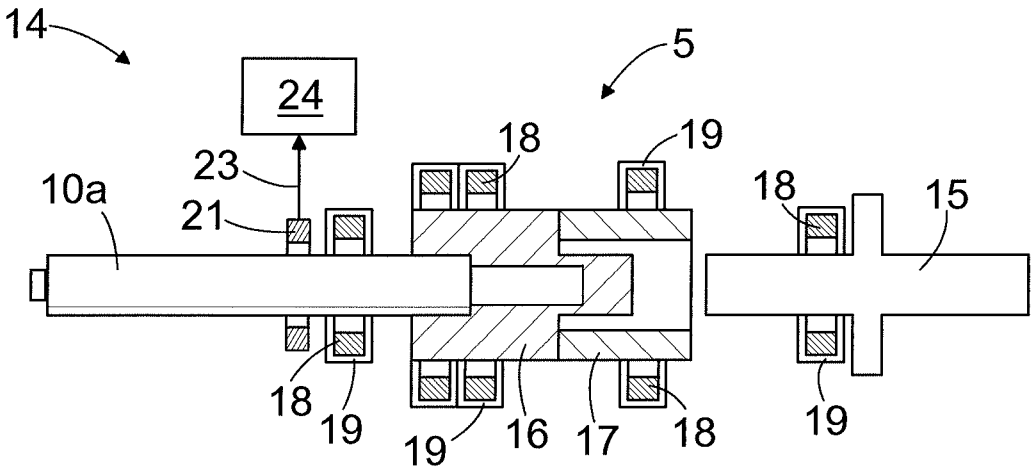

FIG. 4

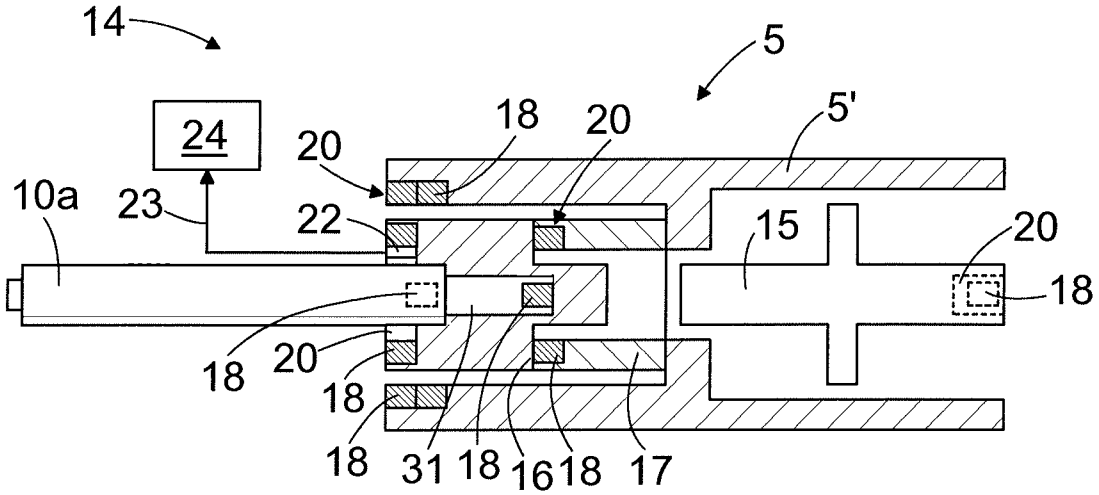

FIG. 5

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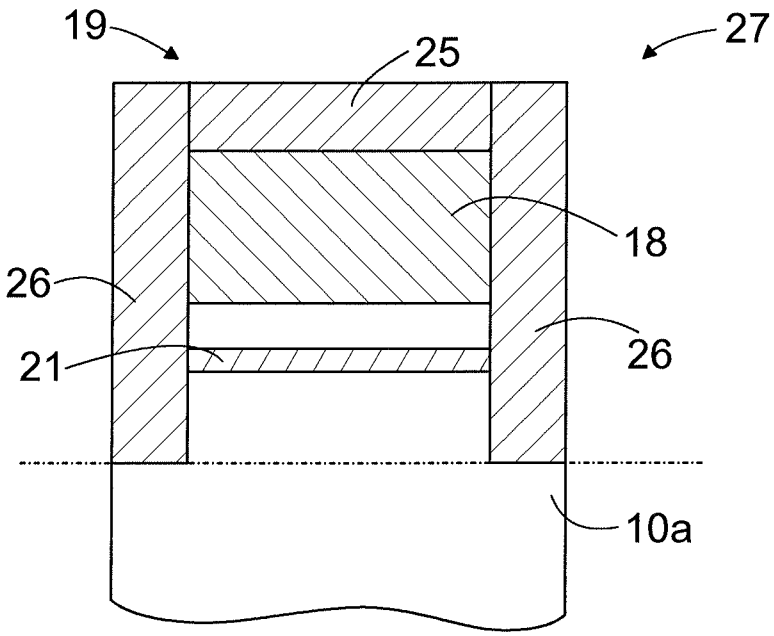

FIG. 6

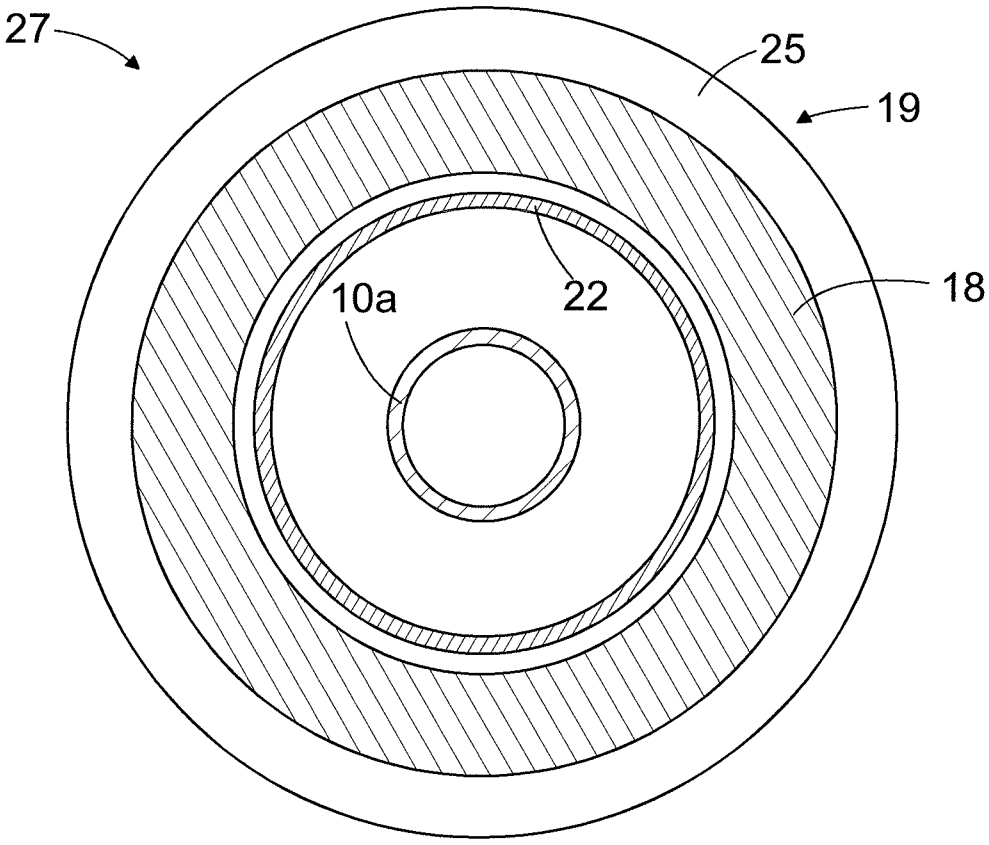

FIG. 7

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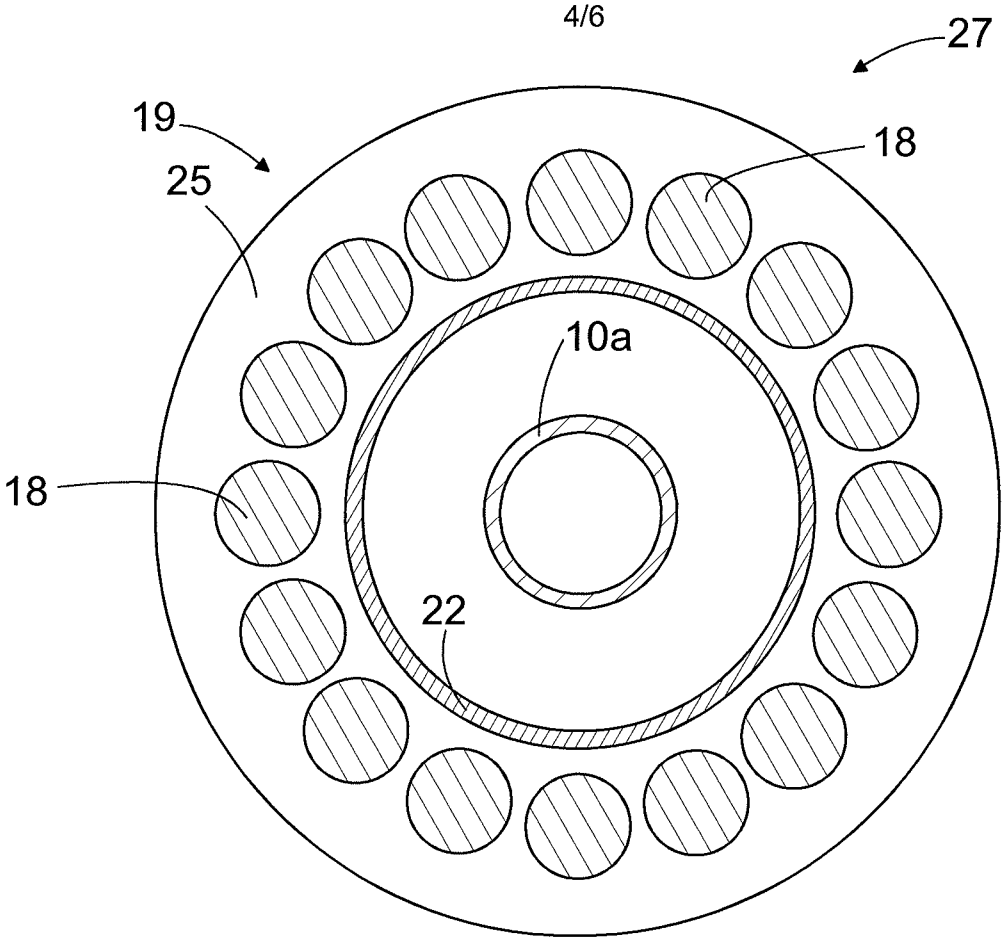

FIG. 8

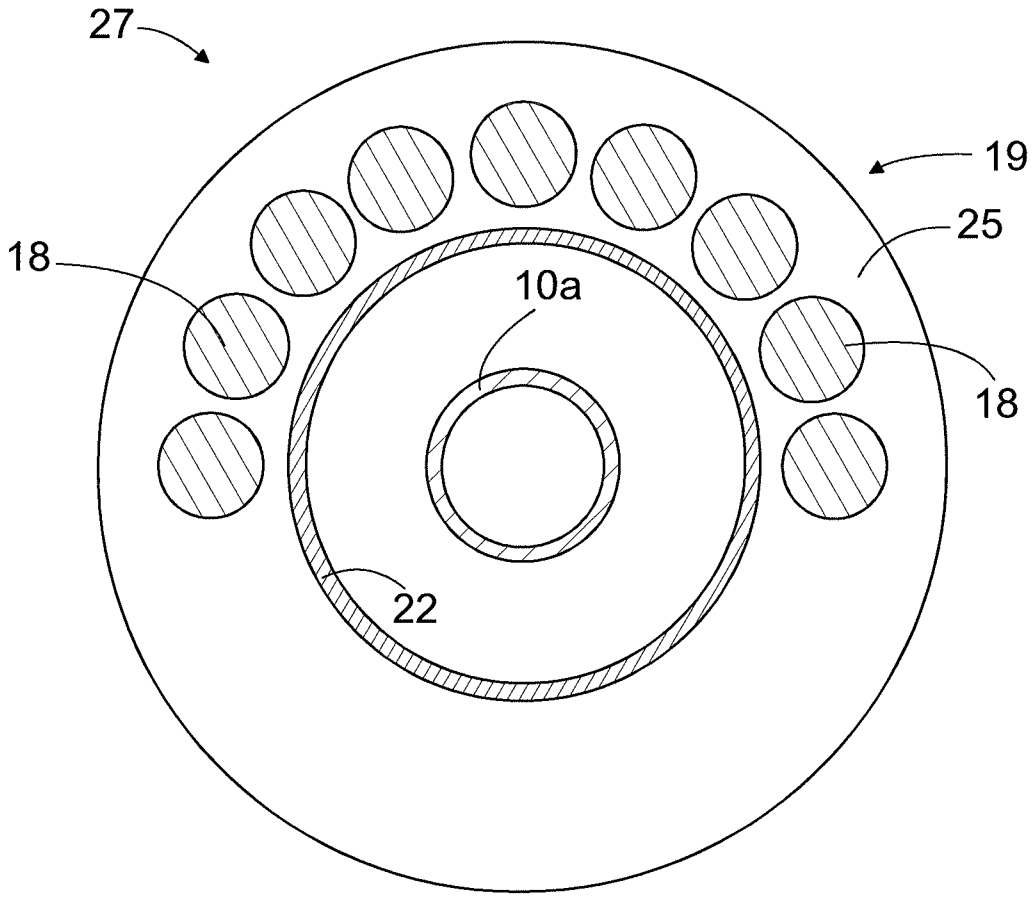

FIG. 9

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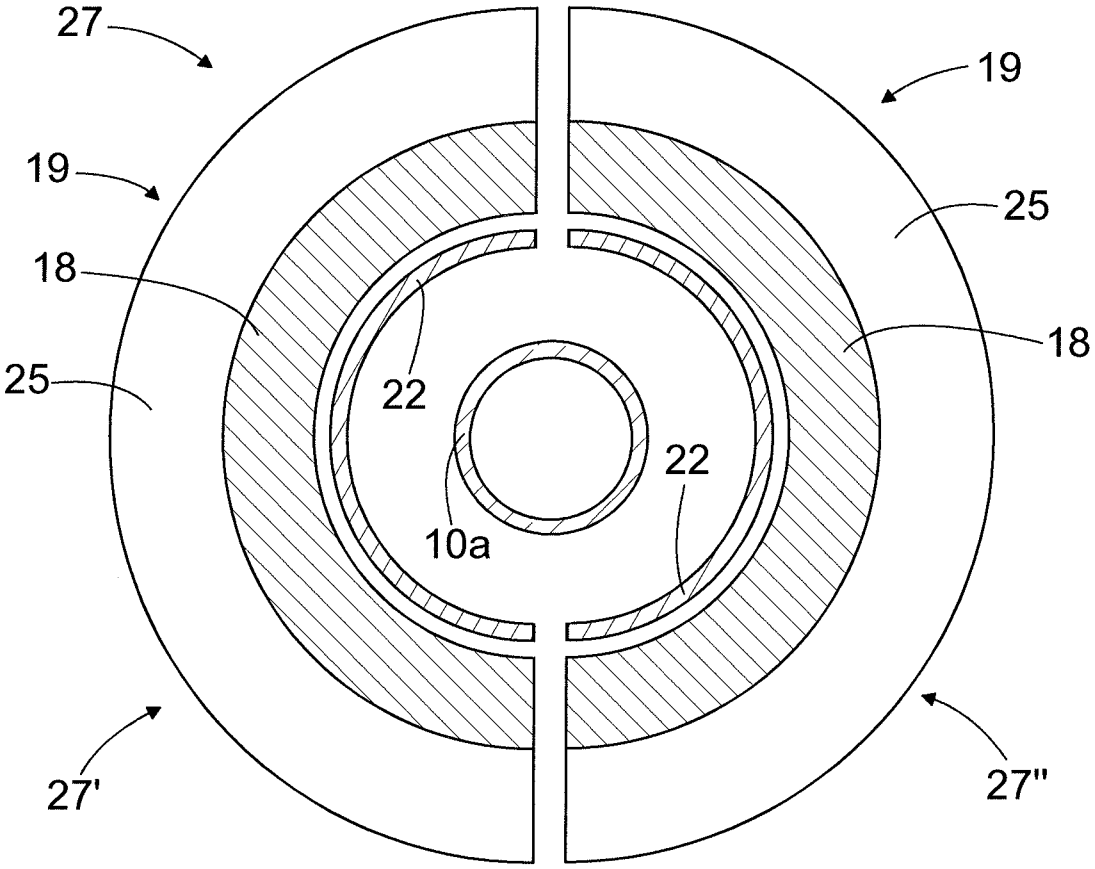

FIG. 10

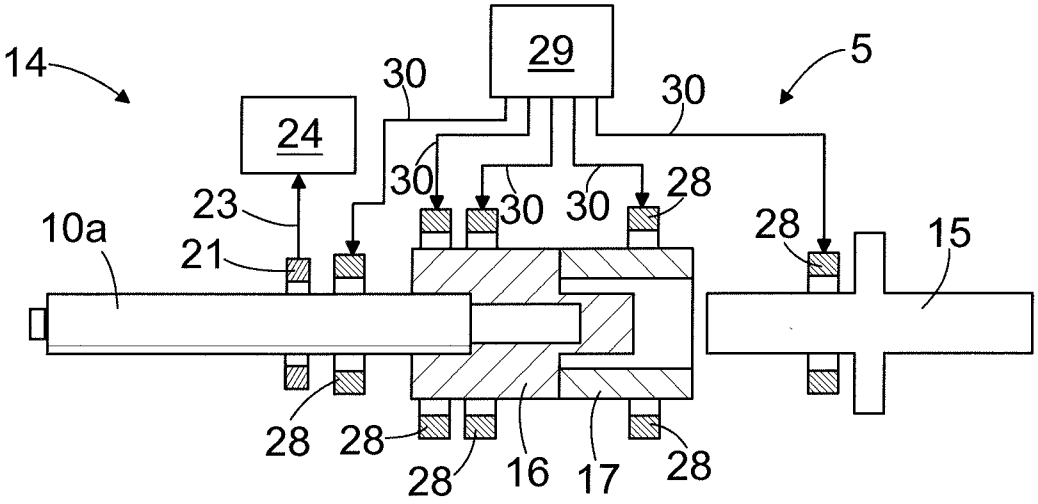

FIG. 11

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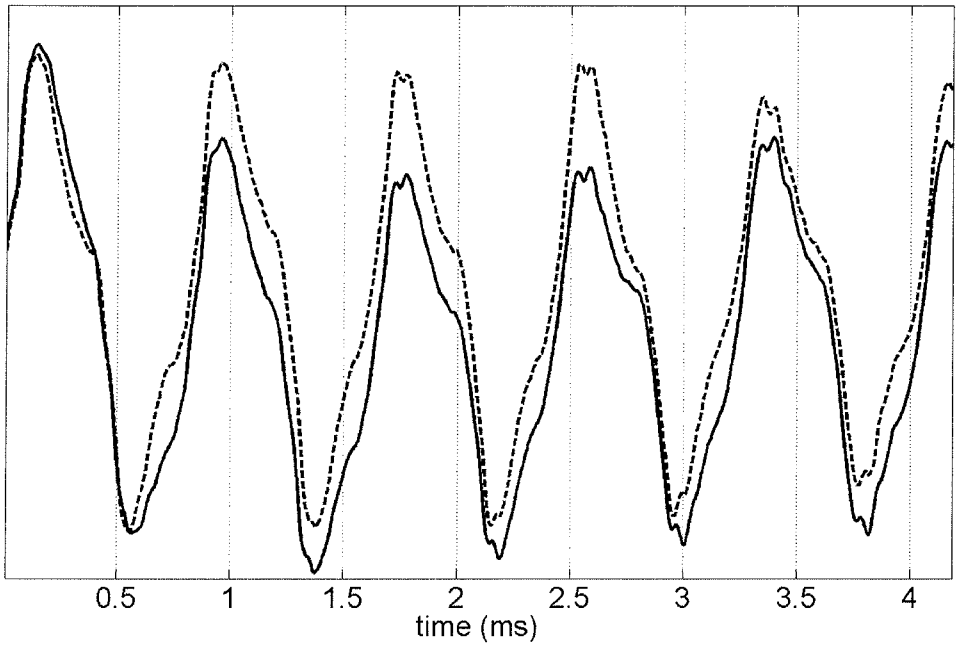

FIG. 12

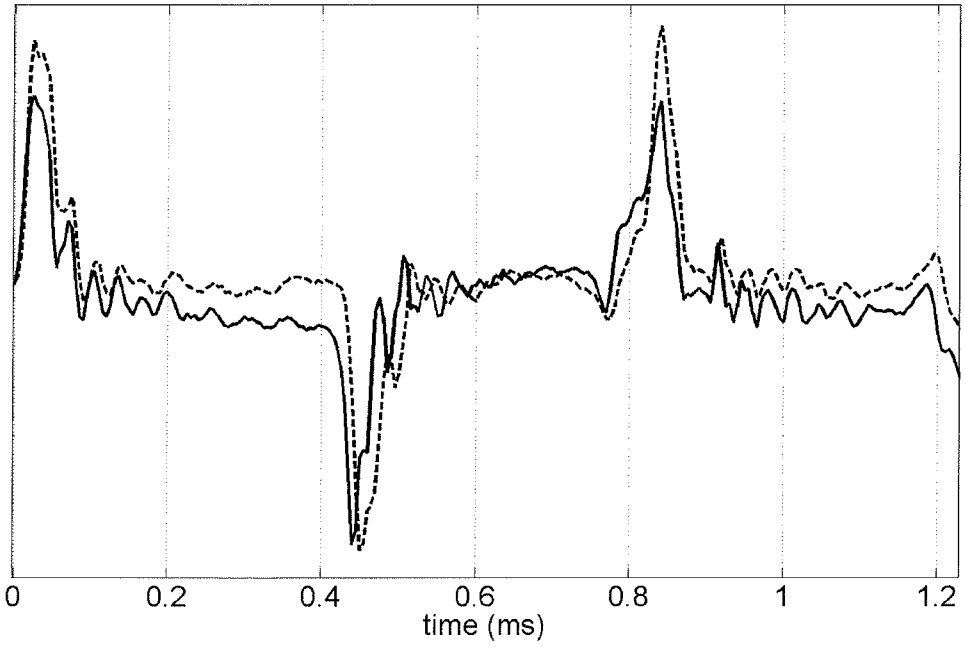

FIG. 13