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(54) EXCAVATOR AND METHOD FOR EXCAVATING SOIL

(57) Described is an excavator for excavating soil in which a problematic object, such as unexploded ordnance, may be present. The excavator comprises an assembly of mutually pivotable arms which is connected to a chassis, and a pivotably arranged excavator bucket. At least parts of the excavator bucket and the outermost arm are embodied in a substantially non-magnetizable material. The excavator bucket further comprises a measuring device of magnetometers which are positioned at a mutual distance and which are configured to measure the local magnetic field vectors. The magnetometers are connected to a computer via a data and power cable with interposing of a data collection unit for collecting the magnetic field vector data measured by the magnetometers. The measuring device is further configured to determine the vector difference between said local magnetic field vectors, wherein a vector difference differing from zero indicates a disruption of the earth's magnetic field by the object, allowing the presence thereof to be detected.

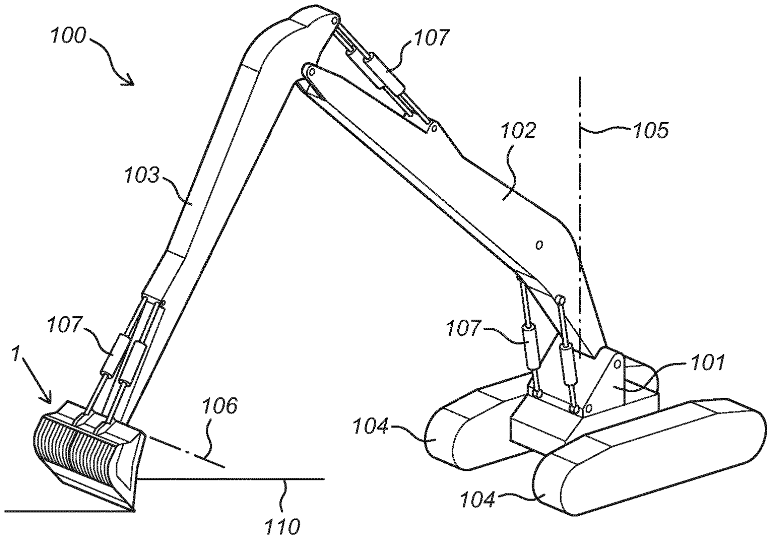


Fig. 1

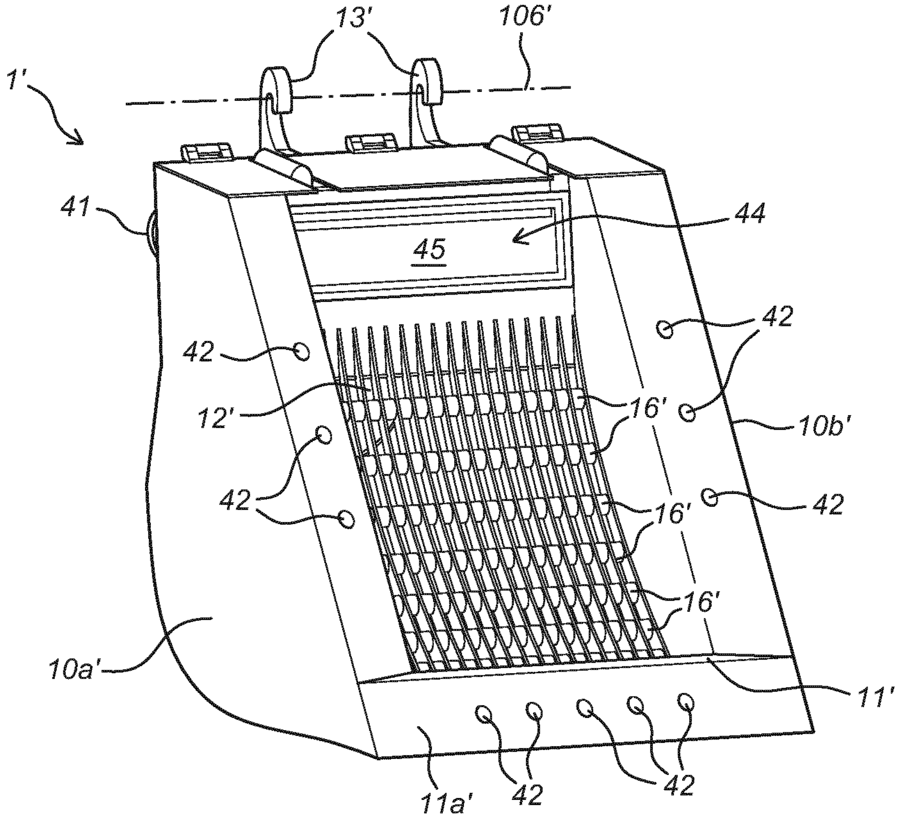


Fig. 5

Description

TECHNICAL FIELD OF THE INVENTION

[0001] The invention relates to an excavator for excavating soil in which a problematic object, such as unexploded ordnance, may be present. The invention further relates to a method for excavating soil which makes use of the excavator, and to a method for removing the problematic object from a ground.

BACKGROUND OF THE INVENTION

[0002] It is known that a great deal of unexploded ordnance (UXO) has remained in the ground since the Second World War, also in relatively densely populated areas. When excavating soil, it must be made sure that the excavation can take place safely. For this purpose the ground is subjected to a thorough preliminary investigation in order to see if and where such unexploded ordnance is present. All unexploded ordnance (UXO) which is found in the soil must then be removed safely and efficiently.

[0003] The preliminary investigation and possible removal must be carried out very meticulously. At this time, this is done manually before excavation is started. This is time-consuming and can moreover be very dangerous. The known systems provide both a passive and an active solution for detecting underground unexploded ordnance. Known passive systems measure variations in the earth's magnetic field and are safest for human personnel because they generally do not result in unexploded ordnance going off and exploding. Such systems are however less accurate because they can be subject to environmental interference. Active metal detectors are more accurate and can in principle measure to a deeper level than the passive systems. In an active system a magnetic transmitter produces a pulsed primary magnetic field in the earth, which generates eddy currents in nearby metal unexploded ordnance. The loss of the eddy current produces a secondary magnetic field which is then measured by a receiver coil. The electric current and the resulting magnetic current generated by the active metal detection equipment can also generate an electric current in the unexploded ordnance. This current can be sufficient to detonate the unexploded ordnance, with catastrophic consequences for the person carrying out the investigation.

[0004] The known methods are based on an investigation or survey which must take place prior to the excavation. This takes time. The detection depth is moreover limited, and in the case of deeper excavations must often take place in layers, wherein a new investigation or survey of the underlying layer must be carried out after each layer. The known method can furthermore also be improved further in respect of accuracy and safety.

[0005] WO 2016/008059 A1 describes an excavator for excavating ore-containing soil in which metal objects may be present. The excavator bucket is provided with a measuring device of magnetometers positioned at a mutual distance. The magnetometers are configured to measure the local magnetic field vector, wherein the magnetometers are connected to a computer via a data and power cable with interposing of a data collection unit for collecting the magnetic field vector data measured by the magnetometers.

[0006] KR 2021 0048913 A and JP 2005 350883 A describe similar excavators.

[0007] The invention has for its object to provide an excavator and corresponding method for excavating soil in which a problematic object, such as unexploded ordnance, may be present, which excavator and method provide an at least partial solution to the above stated drawbacks.

[0008] The problematic object is otherwise not limited to unexploded ordnance but can also comprise other objects, such as metal-polluted soil, or objects which cannot explode but which can break open and in doing so may release chemicals.

SUMMARY OF THE INVENTION

[0009] The invention provides for this purpose an excavator according to claim 1. The invented excavator is intended for excavating soil in which a problematic object, such as unexploded ordnance, may be present, and comprises an assembly of mutually pivotable arms which is connected to a chassis and an excavator bucket which is arranged on an outer end of an outermost arm for pivoting around an excavator bucket pivot axis, wherein the mutually pivoting movements of the arms and the excavator bucket are controlled by actuators, wherein at least parts of the excavator bucket and the outermost arm are embodied in a substantially non-magnetizable material. The excavator bucket is further provided with a measuring device of magnetometers positioned at a mutual distance and configured to measure the local magnetic field vector, wherein the magnetometers are connected to a computer via a data and power cable with interposing of a data collection unit for collecting the magnetic field vector data measured by the magnetometers, and the measuring device is configured to determine the vector difference between said local magnetic field vectors, wherein a vector difference differing from zero indicates a disruption of the earth's magnetic field by the object, allowing the presence thereof to be detected.

[0010] The magnetometers in a series are preferably aligned along a substantially straight line, wherein the magnetometers in a series comprise an elongate ferromagnetic core and the magnetometers are arranged (aligned) such that the ferromagnetic cores of the magnetometers extend at least in a direction parallel to the substantially straight line. The measuring device is configured to determine the vector difference between said local magnetic field vectors. Determining the vector difference between said local magnetic field vectors, wherein they are measured by the magnetometers aligned as described above, makes it possible to detect the presence of a problematic object in accurate manner with the excavator and, in some embodiments, also to determine the position of the object and the magnitude of the magnetic disruption by the object more accurately than was possible heretofore. Having the measuring device form part of the excavator enables the investigation into the presence of the object and the excavation of soil to take place simultaneously. When a problematic object is detected in the ground, excavation of this location can be ceased until the object has been removed. It is also possible to continue the excavation, wherein an excavation path is adjusted such that the object is avoided. In a preferred embodiment of the invented excavator it can also be used to remove the object safely, as will be further elucidated below.

[0011] In an embodiment the magnetometers which are applied in the measuring device comprise scalar and/or vectorial magnetometers, preferably fluxgate magnetometers. Vectorial magnetometers are able to measure one or more vector components of a magnetic field (X, Y, Z). Scalar magnetometers are configured to measure the size of the vector of the magnetic field. A suitable example of a scalar magnetometer comprises a cesium vapor magnetometer.

[0012] According to an embodiment, the invention comprises an excavator wherein the magnetometers comprise axial, biaxial and/or triaxial magnetometers. The invention applies 2 or more (preferably vectorial) magnetometers in order to allow a gradient measurement to be performed. A practical embodiment has the feature that the measuring device comprises a gradiometer (and preferably a plurality of gradiometers) to determine the vector difference between said local magnetic field vectors. A gradiometer is per se known and relates to a measuring device whereby the gradient of a physical quantity such as a magnetic field can be measured.

[0013] Suitable embodiments relate to an excavator wherein the gradiometer comprises an axial, biaxial, triaxial and/or planar gradiometer. In other embodiments the gradiometer comprises two or more scalar magnetometers, and the gradiometer is therefore not limited to the use of vectorial magnetometers.

[0014] According to an embodiment, the excavator is characterized in that the vector difference is determined between every two magnetometers. In another embodiment the vector difference is determined between every two adjacent magnetometers.

[0015] The number of magnetometers can be chosen within wide limits. The magnetometers can in principle also be situated at any position on the excavator bucket, for instance distributed over a surface of the excavator bucket, which surface is formed by a bottom wall, one or more side walls and/or a rear wall of the excavator bucket, or parts thereof.

[0016] In an embodiment the excavator bucket of a suitable excavator can comprise from 2 to 50 magnetometers, although the excavator bucket can also comprise more magnetometers, for instance up to 100-200.

[0017] There are practical advantages to providing an excavator according to an embodiment wherein the magnetometers are aligned along a substantially straight line. The straight line preferably extends parallel to the excavator bucket pivot axis.

[0018] In the excavator according to a preferred embodiment the magnetometers are subdivided into series, and the vector difference is determined between magnetometers of a series. The series of magnetometers differ from each other, particularly in respect of their position in the excavator bucket.

[0019] In an embodiment of the excavator a first series of magnetometers thus comprises a number of magnetometers aligned along a substantially straight line, which first series of magnetometers is situated on or in a bottom wall of the excavator bucket, preferably just behind a digger blade of the bottom wall.

[0020] In another embodiment of the excavator a second series of magnetometers comprises a number of magnetometers aligned along a substantially straight line, which second series of magnetometers is situated on or in a rear wall of the excavator bucket, preferably at the position of an upper side of the rear wall.

[0021] In yet another embodiment of the excavator a third series of magnetometers comprises a number of magnetometers aligned along a substantially straight line, which third series of magnetometers is situated on or in the bottom wall of the excavator bucket, preferably at the position of a transition from the bottom wall to a rear wall of the excavator bucket.

[0022] The first, second and third series of magnetometers can be applied individually or in combination. All series are preferably connected to the computer via the data and power cable with interposing of a data collection unit for collecting the magnetic field vector data measured by the magnetometers. It is however also possible for each series to have its own data and power cable and data collection unit.

[0023] The number of magnetometers in each series can also be chosen within wide limits. An efficient embodiment provides an excavator wherein a series of magnetometers comprises from 2 to 50 magnetometers, more preferably from 4 to 35 magnetometers, and still more preferably from 6 to 15 magnetometers.

[0024] The mutual distance between magnetometers in a series can vary or, in another embodiment, can be chosen to be the same. The mutual distance between the magnetometers can thus for instance be chosen to be from 20 cm to 1 m, more preferably from 30 cm to 80 cm, still more preferably from 40 cm to 60 cm.

[0025] The orientation of the magnetometers can also be chosen freely. In an improved embodiment however, an excavator is provided wherein the magnetometers in a series comprise an elongate ferromagnetic core and the magnetometers are arranged such that the ferromagnetic cores of the magnetometers extend at least in a direction parallel to the substantially straight line.

[0026] The magnetometers can be connected to the excavator bucket in any manner. An excavator according to an embodiment wherein a series of magnetometers is accommodated in an elongate watertight housing is however preferred. The housing can for instance comprise a plastic tube, for instance of PVC. In a suitable embodiment the excavator bucket, particularly the bottom wall, side walls and/or rear wall thereof, is provided with ribs or channels into which the housing can be slid, for instance via an opening arranged in a side wall. The channels or ribs are accessible to the magnetometers, which are if desired accommodated in the housing.

[0027] There are practical advantages to an embodiment of the excavator wherein the housing also comprises a microcontroller unit which is connected to the series of magnetometers and data and power cable, and preferably also an analog-to-digital converter (ADC), optionally integrated with the microcontroller unit.

[0028] In order to be able to fix the magnetometers in the housing and/or rib (channel) in the desired position, use can be made in an embodiment of a carrier element which is slid into the housing and is provided with recesses in which the magnetometers are or can be received in their desired position and direction. A carrier element can for instance be made of a plastic or plastic foam.

[0029] With the excavator provided with an excavator bucket with measuring device according to the invention the presence of a problematic object in a ground can be determined with improved accuracy. It is thus avoided that such an object for instance explodes after contact with the known excavator.

[0030] Once the presence of the programmatic object has been determined, this object should preferably also be removed safely. The removal is facilitated when the position of the object can be determined with great accuracy. For this purpose the excavator is characterized according to a preferred embodiment in that it comprises a global positioning system (GPS). The position of at least the chassis of the excavator relative to a coordinate system (X, Y, Z) connected to the earth can hereby be accurately determined. It is also possible to mount the GPS on one of the mutually pivotable arms, so that the position of at least one of the arms of the excavator relative to the coordinate system (X, Y, Z) connected to the earth can be accurately determined.

[0031] An alternative embodiment provides an excavator which further comprises angular position measuring sensors which are configured to determine the angular positions of the arms and the excavator bucket relative to a reference plane. The combination of the GPS and the angular position sensors allows the position of the excavator bucket relative to the coordinate system (X, Y, Z) connected to the earth to be accurately determined. Because the measuring device measures the position of the problematic object relative to the excavator bucket, the position of the object relative to the coordinate system (X, Y, Z) connected to the earth can also be accurately determined thereby.

[0032] Removal of the object can preferably be performed by an excavator according to the invention, wherein in an embodiment a rear wall of the excavator bucket is permeable to excavated soil and impermeable to the object, and preferably comprises a grate. The object can hereby be taken up, if desired, in the excavator bucket and other material, such as excavated soil, can be removed via the rear wall. For this purpose the excavator is provided in another embodiment with a suction conduit for discharging the excavated soil, which connects to (the rear wall of) the excavator bucket. This embodiment is particularly useful when the excavation takes place under water.

[0033] When removing the object, it must be prevented that the object comes into contact with a part of the excavator bucket, for instance with the blade of the excavator bucket. This could cause the object to explode. An embodiment which at least partially resolves this problem provides an excavator which further comprises nozzles arranged in an edge of a first and/or second side wall and/or bottom wall edge of the excavator bucket, which nozzles are connected to a central high-pressure water conduit. The high-pressure liquid jets coming from the nozzles are injected into the ground and thereby fluidize the ground in the vicinity of the object. The object hereby comes to light relatively free and can be taken up in the excavator bucket with less danger of undesired contact. A further improvement of the excavator comprises an excavator bucket wherein the nozzles are oriented transversely of the side walls and/or parallel to the side walls of the excavator bucket.

[0034] Once the object has been taken up in the excavator bucket, it must be removed from the excavator bucket with great care. For this purpose the excavator has according to an embodiment an excavator bucket which further comprises a preferably removable collecting receptacle for the object received in the excavator bucket. The collecting receptacle can for instance be situated on an upper or rear side of the rear wall of the excavator bucket. The collecting receptacle can also be provided with a closing member along which the object can be received in the collecting receptacle with the closing member in opened state.

[0035] An object taken up in the excavator bucket can be moved to the collecting receptacle by for instance tilting the excavator bucket toward the collecting receptacle, wherein the closing member opens under the influence of gravity or counter to a spring force.

[0036] The excavator according to yet another embodiment can also be used to detect contaminated soil. This can for instance allow the suctioned contaminated soil to be stored separately of the uncontaminated soil. For this purpose the excavator is further provided with measuring equipment for determining the (chemical) composition of the excavated underwater bottom material. The type of measuring equipment can be selected in accordance with the set requirements, but comprises in an embodiment at least a mass spectrometer. The excavator bucket preferably comprises the measuring equipment.

[0037] In order to be able to determine whether an object is located in the excavator bucket of the excavator an embodiment comprises an excavator bucket wherein a series of magnetometers is situated just behind the digger blade (blade) of the excavator bucket.

[0038] According to another aspect of the invention, soil in which a problematic object, such as unexploded ordnance, may be present can be excavated with the invented excavator. For this purpose the invention provides a method comprising the steps of:

- providing an excavator according to an embodiment of the invention;
- moving the excavator bucket through the ground;
- measuring the local magnetic field vector with the measuring device and collecting the magnetic field vector data measured by the magnetometers of the measuring device;
- determining the vector difference between said local magnetic field vectors with the measuring device, and determining the presence of the object by a vector difference differing from zero;
- optionally removing the object.

[0039] It is advantageous to characterize the method in that the position of the object in the ground is determined by a combination of position data generated by a global positioning system (GPS) of the excavator, by angular position measuring sensors of the excavator which are configured to determine the angular positions of the arms and the excavator bucket relative to a reference plane, and by the measured vector differences.

[0040] Once the position of the object has been determined, the object can be removed. For this purpose a method is preferably applied wherein the object is removed with an excavator according to any one of the appended claims 24-34.

BRIEF DESCRIPTION OF THE FIGURES

[0041] The invention will now be elucidated in more detail with reference to the drawings, without otherwise being limited thereto. In the figures:

Figure 1 is a schematic perspective representation of an excavator according to an embodiment of the invention;

Figure 2 is a schematic perspective view of an excavator bucket according to an embodiment of the invention;

Figure 3A is a schematic clarification of the effect of unexploded ordnance on the earth's magnetic field;

Figure 3B is a schematic clarification of the effect of unexploded ordnance on the earth's magnetic field strength;

Figure 4 is a schematic top view of a series of magnetometers according to an embodiment of the invention;

Figure 5 is a schematic perspective front view of an excavator according to another embodiment of the invention;

Figure 6 is a schematic perspective top view of the excavator shown in figure 5;

Figure 7A is a schematic clarification of the effect of a less optimal orientation of the magnetometers on the differential measurement; and

Figure 7B, finally, is a schematic clarification of the effect of a more optimal orientation of the magnetometers on the differential measurement.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0042] Referring to figure 1, an excavator 100 according to an embodiment of the invention is shown. The excavator is intended for excavating soil 110 in which a problematic object may be present. Problematic objects can be of various types, as long as they disrupt the earth's magnetic field. A common example of a problematic object is unexploded ordnance 31 (also referred to as UXO, see figure 3A) which has remained behind as a result of the Second World War or other armed conflicts. It is often not apparent whether such objects are present, where exactly they are located and/or whether they are still harmful, for instance at risk of exploding. The excavator 100 aims to provide a solution to these problems.

[0043] In the shown embodiment excavator 100 comprises an assembly of mutually pivotable arms (102, 103) which is connected to a chassis 101. The number of arms can be chosen freely and can for instance amount to 1, 2, 3 or more. In the shown embodiment the arms comprise a boom 102 which is connected to the chassis and a jib 103 which is connected to an outer end of the boom 102. Chassis 101 can be provided with advancing means, such as the shown set of caterpillar tracks 104. Chassis 101 can be mounted for rotation around a vertical axis 105 relative to the caterpillar tracks 104. The chassis can be provided with a control cab for controlling the excavator on site. The excavator can optionally also be remotely controlled. Arranged on an outer end of jib 103 is an excavator bucket 1 which is pivotable around an excavator bucket pivot axis 106. The mutually pivoting movements of the arms (102, 103) and the excavator bucket 1 are controlled by actuators 107 in form of hydraulic cylinders, for example. These extend at least between the pivoting arms (102, 103), between jib 103 and excavator bucket 1, and between chassis 101 and boom 102. The actuators 107 are controlled by an operator from a cab (not shown) using control means suitable for this purpose.

[0044] For a good operation of excavator 100 at least parts of the excavator bucket 1 and the jib 103 are embodied in a substantially non-magnetizable material. Such materials are per se known and preferably comprise stainless steel alloys, these comprising substantially iron, chrome, nickel and sometimes also carbon. Suitable alloys comprise at least 10% chrome and at most 1.5% carbon. In addition to the above stated elements, suitable steel alloys can also comprise molybdenum, titanium, manganese, nitrogen and silicon. In view of the application, preferred steel alloys are not only non-magnetic or non-magnetizable, but are further also able to withstand seawater and to withstand oil and lubricants, and are weldable and deformable when cold.

[0045] A particularly suitable steel alloy comprises that of the 316 series, if desired with a relatively low carbon content (316L) in order to improve the weldability.

[0046] At least parts of excavator bucket 1 and jib 103 are embodied in a substantially non-magnetizable material, and preferably the whole excavator bucket 1 and jib 103. The actuators 107 of jib 103 and excavator bucket 1 can, if desired, be embodied in a substantially non-magnetizable material. According to the invention, it is not necessary for other arms, such as the boom 102, also to be embodied in a substantially non-magnetizable material. It is however possible to do so.

[0047] Referring to the embodiment shown in figure 2, the excavator bucket 1 comprises two side walls (10a, 10b), a bottom wall 11 and an optionally grate-like, and so water-permeable, rear wall 12. On a front side the bottom wall 11 is provided with a blade 11a. If desired, the excavator bucket 1 is also reinforced in a central surface with a stiffening rib 11c. Excavator bucket 1 is mounted via protrusions 13 on jib 103 for pivoting around the excavator bucket pivot axis 106. In an embodiment without soil suction installation use may also be made of a closed rear wall. A grate-like rear wall can consist of a grate of chains. Such a chain bucket is advantageously used in sticky clay soil and ensures that the excavated soil comes off the excavator bucket more easily when the excavator bucket is emptied by holding it upside down over a storage, such as over a dump truck for example. A grate-like rear wall can thus indeed be applied in an embodiment without suction installation without the objective of flushing the excavated soil through the grate. For excavation in sandy soil use is preferably made (without suction installation) of an excavator bucket with closed rear wall.

[0048] Excavator bucket 1 further comprises a measuring device for measuring a magnetic field vector. The measuring device (14, 15, 16, 17, 18, 19) comprises a number of magnetometers 15 accommodated in a housing 14 (see figure 4). A housing 14 can for instance comprise a plastic tube in which the magnetometers 15 are accommodated. A wall, for instance the bottom wall 11 of excavator bucket 1, is provided with ribs 16 accessible to a housing 14. A housing 14 provided with magnetometers 15 can be slid into each rib 16 via an opening provided in a side wall (10a, 10b), which provides access to each rib 16.

[0049] In the shown embodiment a first rib 16a (and therefore also a first series of magnetometers 15 aligned along a substantially straight line) is situated on a rear side of the blade 11a, while a second rib 16b (optionally provided with a second series of magnetometers 15 aligned along a substantially straight line) is situated at the position of a transition from bottom wall 11 to the rear wall 12 of excavator bucket 1. It is also possible to provide a third series of magnetometers 15 aligned along a substantially straight line, which third series of magnetometers 15 is situated in the rear wall 12 of excavator bucket 1, and preferably at the position of an upper side of rear wall 12. This series is not visible in figure 2.

[0050] The series of magnetometers 15 arranged in ribs 16 are connected on their end surface to a data and power cable 17 via openings in a side wall (10a, 10b) of excavator bucket 1. The arrows (17a, 17b) indicate that the cable 17 can be used as power cable 17a and as data cable 17b for transmitting magnetic field vector data measured by the magnetometers 15 of each series. The data and power cable 17 is connected to a computer 19 with interposing of a data collection unit 18 for collecting the magnetic field vector data measured by magnetometers 15. The data collection unit 18 takes a watertight form when excavation must take place under water. The data collection unit 18 can also form merely a connector box through which the signal cables and power cables are connected.

[0051] As can be seen in figure 4, a housing 14 comprises a number of magnetometers 15 aligned along a substantially straight line 14a. Because each housing 14 is accommodated in a rib 16 of excavator bucket 1 and in the shown embodiment the ribs 16 extend parallel to the excavator bucket pivot axis 106, this also applies to the substantially straight line 14a along which each series of magnetometers 15 is aligned.

[0052] According to the shown embodiment, the housing 14 can also comprise a microcontroller unit 20 which is connected to the series of magnetometers 15 and data and power cable 17 and which preferably also comprises an analog-to-digital converter (ADC), optionally integrated with the microcontroller unit 20.

[0053] The number of magnetometers 15 in a series can be chosen at random and is preferably from 2 to 50 magnetometers 15, more preferably from 4 to 35 magnetometers 15, and still more preferably from 6 to 15 magnetometers 15. In an embodiment wherein use is only made of horizontally oriented magnetometers a number from 5 to 6 magnetometers can be applied over a distance of for instance 2.4 m. In an embodiment wherein three magnetometers are arranged at each position with mutually perpendicular orientations, 15 to 18 magnetometers are necessary for the same width. The same effect can be achieved by placing a triaxial magnetometer at each of the positions. In this latter case a number from 5 to 6 should suffice for the same width.

[0054] The mutual distance 250 between the magnetometers 15 in a series of magnetometers 15 is preferably equal, although this is not essential. The mutual distance 250 between the magnetometers 15 can for instance amount to 20 cm to 1 m, more preferably 30 cm to 80 cm, still more preferably 40 cm to 60 cm.

[0055] Referring to figures 3A and 3B, the measurement principle according to the invention is explained. Figure 3A shows the geomagnetic field lines 30. An unexploded object, such as the bomb 31, is located in the ground 110 beneath the ground surface 111. Air or water 112 can be present above the ground surface 111. Bomb 31 behaves in the manner of a magnetic dipole with a north pole N and a south pole S. The dipole disrupts the local magnetic field of the earth in that the field lines 30 are deflected at the position of bomb 31. This results in changes in the magnetic field strength 32 at the position of the ground surface 111, as shown in figure 3B.

[0056] According to the invention, the magnetometers 15 are provided to measure the local magnetic field vector. The measuring device (14, 15, 16, 17, 18, 19), and preferably the computer 19, is configured to determine the vector difference (33A minus 33B) between said local magnetic field vectors (33A, 33B), see figures 7A and 7B. A vector difference (33A minus 33B) differing from zero indicates a disruption of the earth's magnetic field 30 by the unexploded object 31, allowing the presence thereof to be detected. According to a preferred embodiment, the magnetometers 15 are subdivided into series (one series per housing 14 and rib 16), and the vector difference (33A minus 33B) is determined between magnetometers 15 of a series.

[0057] Magnetometers 15 suitable for the invention are commercially available and can be chosen freely depending on the specific application and requirements. Magnetometers 15 can thus comprise scalar magnetometers, vectorial magnetometers, preferably fluxgate magnetometers, or combinations of the two. The magnetometers 15 can comprise axial, biaxial and/or triaxial magnetometers 15.

[0058] It is important to orient the magnetometers 15 in an optimal manner. This is illustrated in figures 7A and 7B. In the shown embodiment the magnetometers 15 in a series comprise an elongate ferromagnetic core, and the magnetometers are arranged in the housing 14 such that the ferromagnetic cores of the magnetometers 15 extend at least in a direction parallel to the substantially straight line 14a (see also figure 4).

[0059] In the non-optimal orientation according to figure 7A the vector difference (33A minus 33B) in a vertical direction is calculated as 50 nT, while in the more optimal orientation of figure 7B the vector difference (33A minus 33B) in a horizontal direction is calculated as 200 nT, which produces a greater difference. The orientation of figure 7B is therefore more optimal because the differential measurement is more sensitive.

[0060] The measuring device (14, 15, 16, 17, 18, 19) preferably comprises a gradiometer (not shown) for determining the vector difference (33A minus 33B) between said local magnetic field vectors 33A and 33B. The gradiometer can comprise an axial, biaxial, triaxial and/or planar gradiometer.

[0061] The vector difference (33A minus 33B) can be determined between every two magnetometers 15 of a series or, if desired, between every two adjacent magnetometers 15 of a series.

[0062] In order to be able to better determine the exact position of an unexploded object 31 the excavator is further provided with a per se known global positioning system (GPS) (not shown), and more preferably also with angular position measuring sensors (not shown) which are configured to determine the angular positions of the arms (102, 103) and the excavator bucket 1 relative to a reference plane, such as a horizontal plane.

[0063] According to different embodiments, the excavator bucket 1 can be embodied and can also be used for excavations of a water bed. Figure 5 thus shows an embodiment of an excavator bucket 1', the rear wall 12' of which is permeable to excavated soil and impermeable to the object 31, and which preferably comprises a grate. Arranged in rear wall 12' at different heights are ribs 16' which extend parallel to the excavator bucket pivot axis 106'. These make it possible to, among other things, determine whether an object 31 is situated in the excavator bucket 1'.

[0064] The excavator 100 is further provided with a suction conduit 40 for discharging the excavated soil, which is connected to the rear wall 12' of excavator bucket 1'.

[0065] In order to prevent an object 31 from being cut by the blade 11a' of excavator bucket 1' the soil in the vicinity of the object 31 is fluidized. For this purpose the shown embodiment comprises a number of nozzles 42 which are arranged in a front edge of the side walls (10a', 10b') and of the bottom wall of excavator bucket 1' and which are connected to a central high-pressure water conduit 41. In order to improve the effect further nozzles 43 can also be oriented transversely of the side walls (10a', 10b') (see figure 6), in addition to the nozzles 42 oriented parallel to the side walls (10a', 10b') of excavator bucket 1'.

[0066] Excavator bucket 1' can further be provided with a preferably detachable collecting receptacle 44 for an object 31 received in excavator bucket 1'. The collecting receptacle 44 can for instance be situated on an upper or rear side of the rear wall 12' of excavator bucket 1'. Collecting receptacle 44 can be provided with a closing member, for instance the pivotable cover 45, along which the object 31 can be received in collecting receptacle 44.

[0067] Excavator 100 can further comprise measuring equipment (not shown) for determining the (chemical) composition of the excavated underwater bottom material, for instance a mass spectrometer. This measuring equipment can be incorporated in excavator bucket 1' or be suspended from excavator bucket 1'.

Claims

1. Excavator for excavating soil in which a problematic object, such as unexploded ordnance, may be

present, comprising an assembly of mutually pivotable arms which is connected to a chassis and an excavator bucket which is arranged on an outer end of an outermost arm for pivoting around an excavator bucket pivot axis, wherein the mutually pivoting movements of the arms and the excavator bucket are controlled by actuators, wherein at least parts of the excavator bucket and the outermost arm are embodied in a substantially non-magnetizable material, and the excavator bucket further comprises a measuring device of magnetometers positioned at a mutual distance and configured to measure the local magnetic field vector, wherein the magnetometers in a series are aligned along a substantially straight line, wherein the magnetometers in a series comprise an elongate ferromagnetic core and the magnetometers are arranged such that the ferromagnetic cores of the magnetometers extend at least in a direction parallel to the substantially straight line, and wherein the magnetometers are further connected to a computer via a data and power cable with interposing of a data collection unit for collecting the magnetic field vector data measured by the magnetometers, and the measuring device is configured to determine the vector difference between said local magnetic field vectors, wherein a vector difference differing from zero indicates a disruption of the earth's magnetic field by the object, allowing the presence thereof to be detected.

2. Excavator according to claim 1, wherein the magnetometers comprise scalar and/or vectorial magnetometers, preferably fluxgate magnetometers.

3. Excavator according to claim 1 or 2, wherein the magnetometers comprise axial, biaxial and/or triaxial magnetometers.

4. Excavator according to any one of the foregoing claims, wherein the measuring device comprises a gradiometer to determine the vector difference between said local magnetic field vectors.

5. Excavator according to claim 4, wherein the gradiometer comprises an axial, biaxial, triaxial and/or planar gradiometer.

6. Excavator according to claim 5, wherein the substantially straight line extends parallel to the excavator bucket pivot axis.

7. Excavator according to any one of the foregoing claims, wherein the vector difference is determined between every two magnetometers, preferably between every two adjacent magnetometers.

8. Excavator according to any one of the foregoing claims, wherein a first series of magnetometers comprises a number of magnetometers aligned along a substantially straight line, which first series of magnetometers is situated on or in a bottom wall of the excavator bucket, preferably just behind a digger blade of the bottom wall.

9. Excavator according to any one of the foregoing claims, wherein a second series of magnetometers comprises a number of magnetometers aligned along a substantially straight line, which second series of magnetometers is situated on or in a rear wall of the excavator bucket, preferably at the position of an upper side of the rear wall.

10. Excavator according to any one of the foregoing claims, wherein a third series of magnetometers comprises a number of magnetometers aligned along a substantially straight line, which third series of magnetometers is situated on or in the bottom wall of the excavator bucket, preferably at the position of a transition from the bottom wall to a rear wall of the excavator bucket.

11. Excavator according to any one of the foregoing claims, wherein a series of magnetometers is accommodated in an elongate, preferably watertight, housing.

12. Excavator according to claim 11, wherein the housing also comprises a microcontroller unit which is connected to the series of magnetometers and data and power cable, and preferably also an analog-to-digital converter (ADC), optionally integrated with the microcontroller unit.

13. Excavator according to claim 11 or 12, wherein the housing comprises a carrier element which is slid into the housing and has recesses in which the magnetometers are received in their desired position and direction.

14. Excavator according to any one of the foregoing claims, comprising a global positioning system (GPS).

15. Excavator according to any one of the foregoing claims, wherein a rear wall of the excavator bucket is permeable to excavated soil and impermeable to the object, and preferably comprises a grate.

16. Excavator according to claim 15, further comprising a suction conduit for discharging the excavated soil, which connects to the rear wall of the excavator bucket.

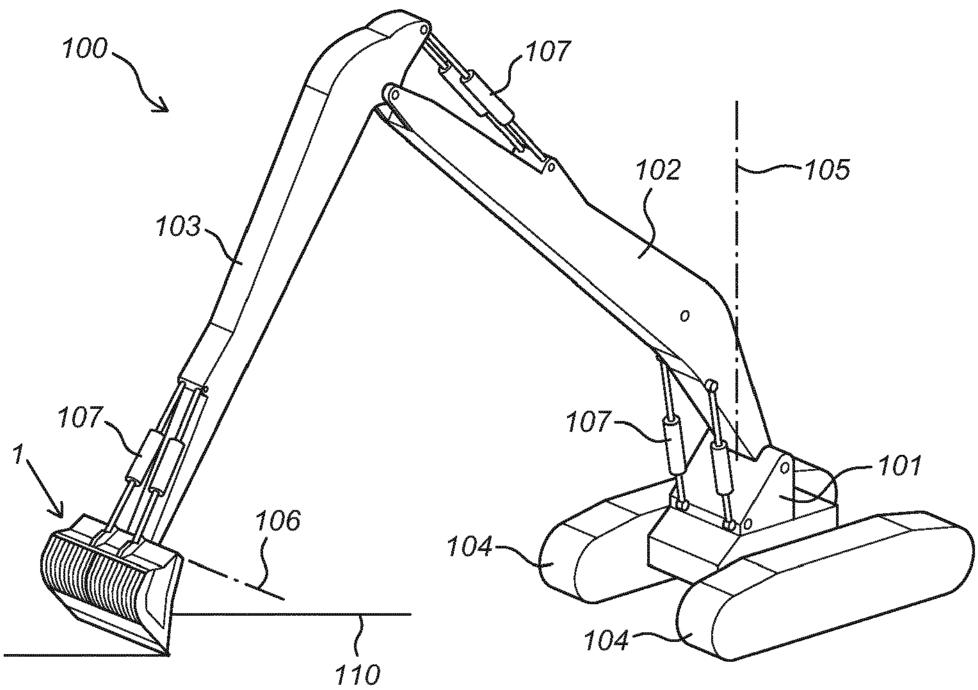
17. Excavator according to any one of the claims 15-16, wherein the excavator bucket further comprises a preferably removable collecting receptacle for the object received in the excavator bucket.

18. Excavator according to any one of the claims 16-17, further comprising measuring equipment for determining the composition of the excavated underwater bottom material.

19. Method for excavating soil in which a problematic object, such as unexploded ordnance, may be present, the method comprising the steps of:

- providing an excavator according to any one of the foregoing claims;
- moving the excavator bucket through the ground;
- measuring the local magnetic field vector with the measuring device and collecting the magnetic field vector data measured by the magnetometers of the measuring device;
- determining the vector difference between said local magnetic field vectors with the measuring device, and determining the presence of the object by a vector difference differing from zero;
- removing the object.

20. Method according to claim 19, wherein the position of the object in the ground is determined by a combination of position data generated by a global positioning system (GPS) of the excavator, by angular position measuring sensors of the excavator which are configured to determine the angular positions of the arms and the excavator bucket relative to a reference plane, and by the measured vector differences.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106
104
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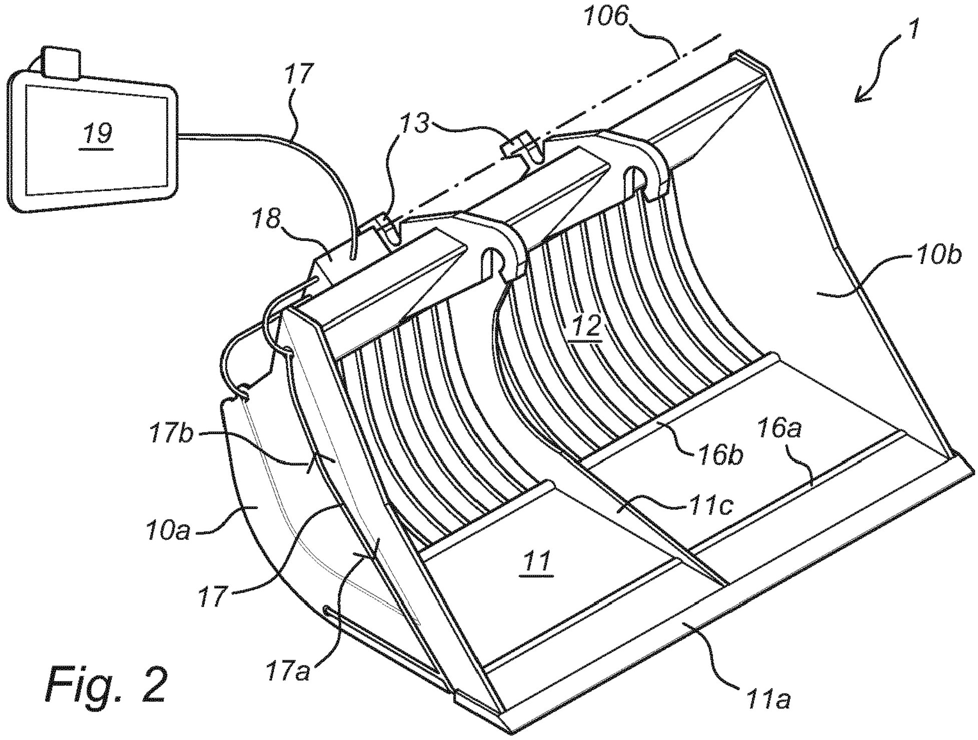
110

Fig. 1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16a
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10a
11
17
17a
11a

Fig. 2

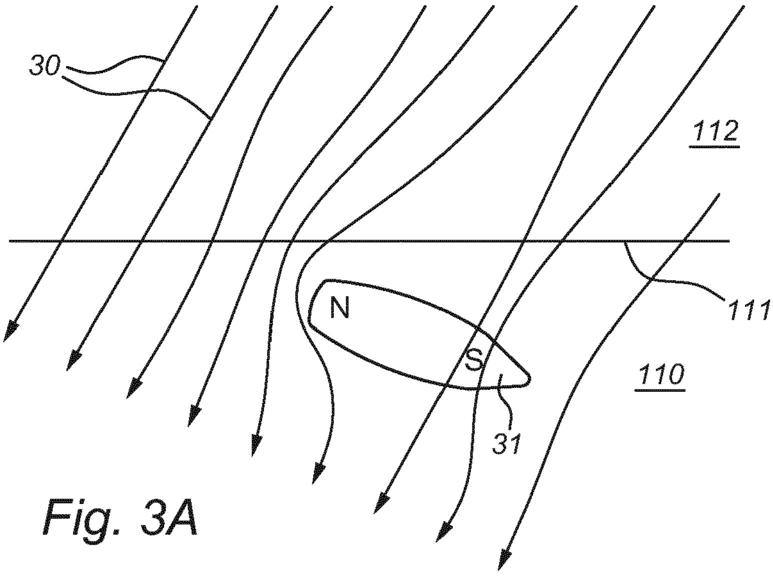


Fig. 3A

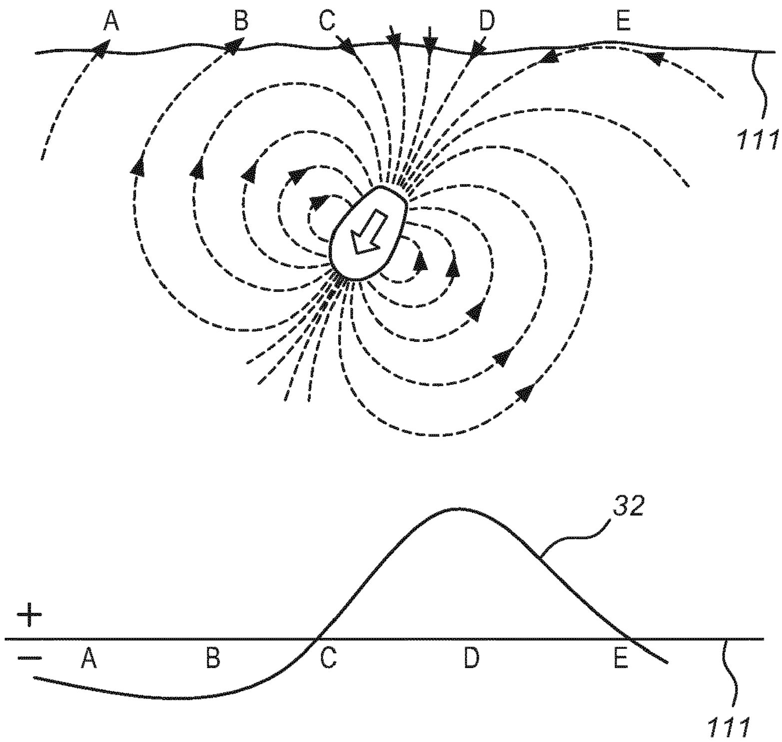
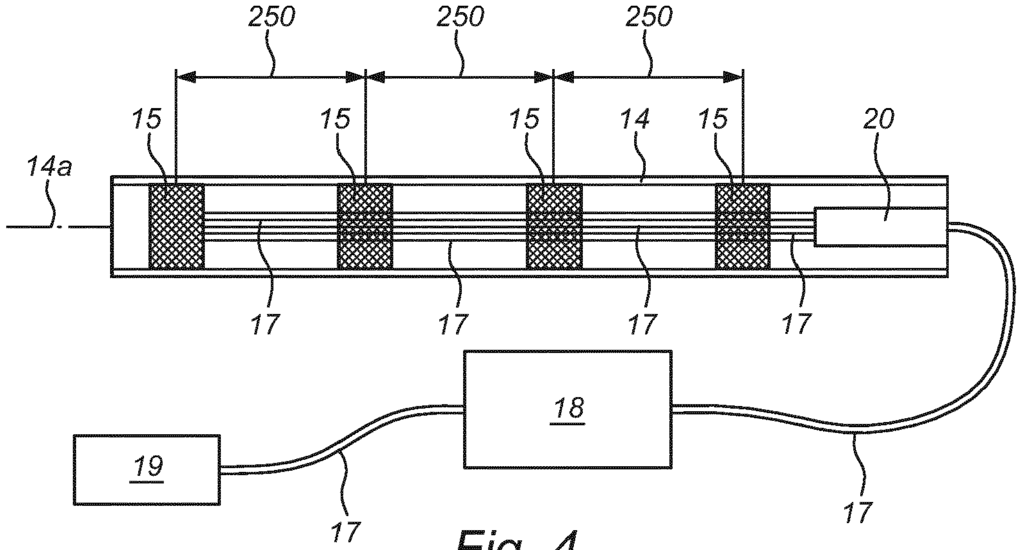


Fig. 3B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14a
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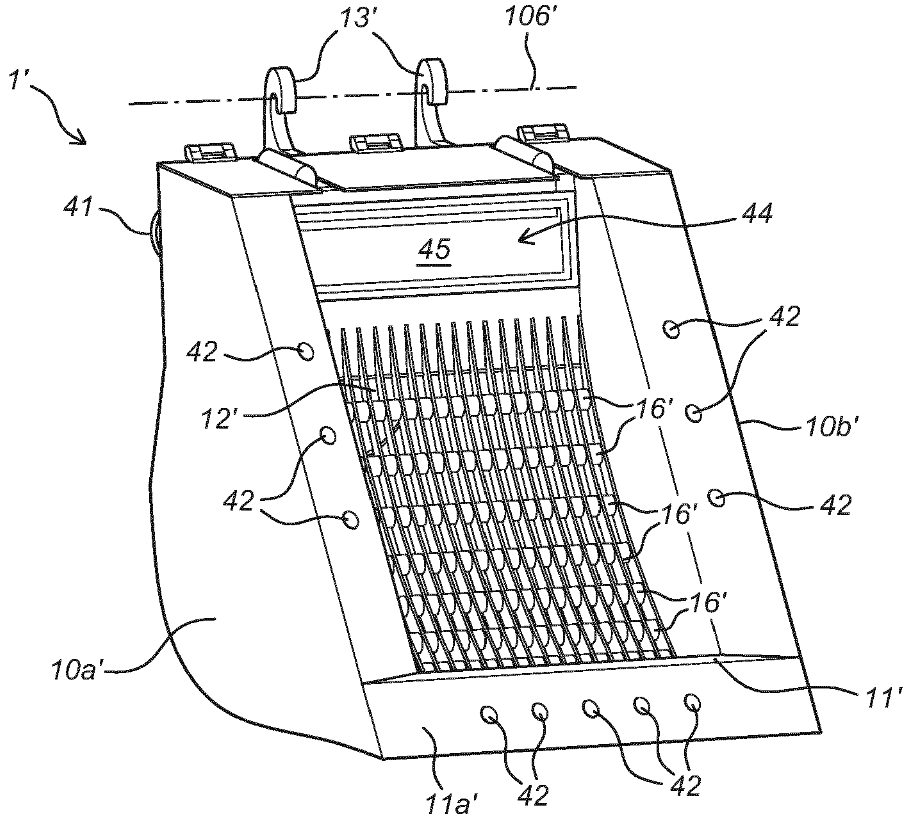
17

Fig. 4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106'
1'
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44
45
42
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12'
16'
10b'
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16'
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16'
10a'
11'
11a'
42
42

Fig. 5

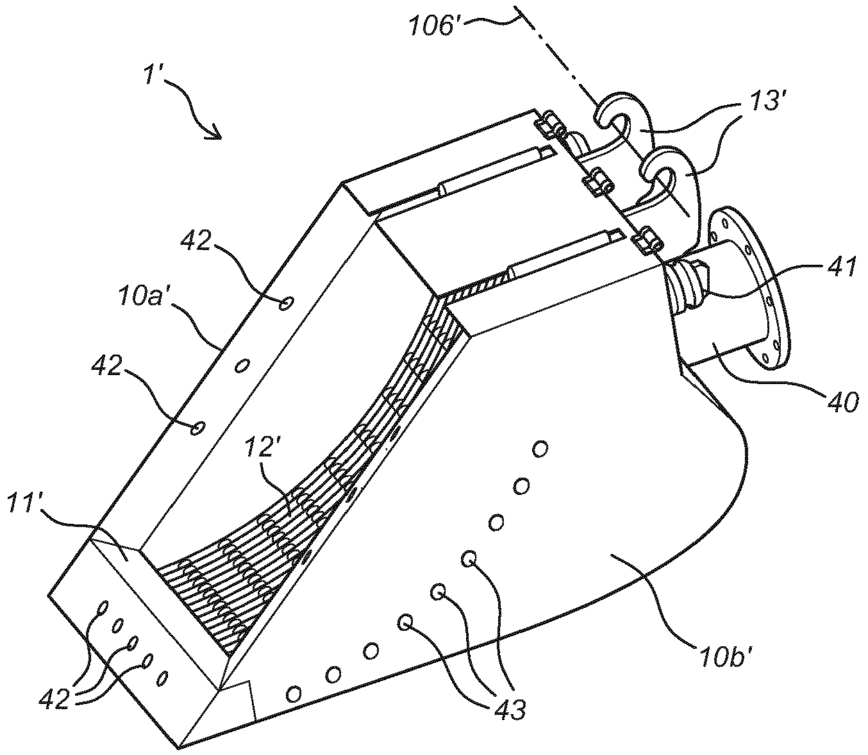

Fig. 6

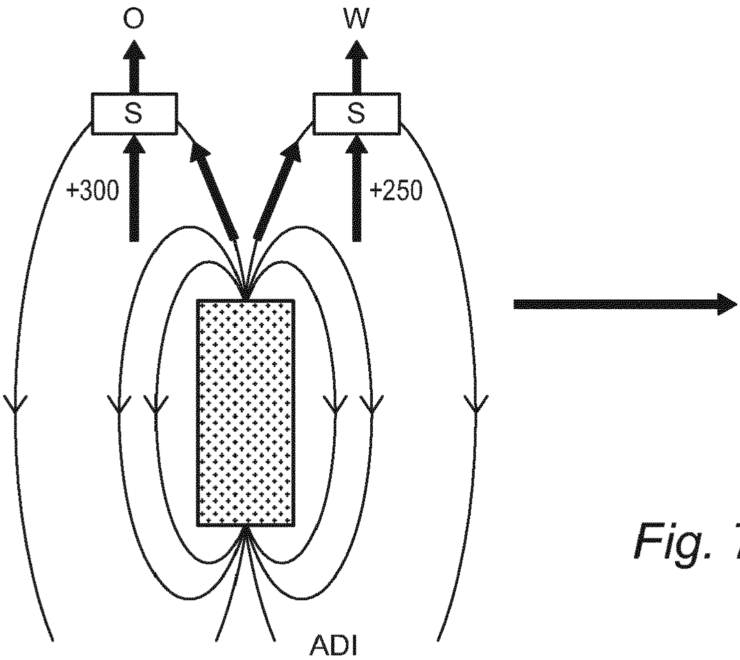

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Fig. 7A

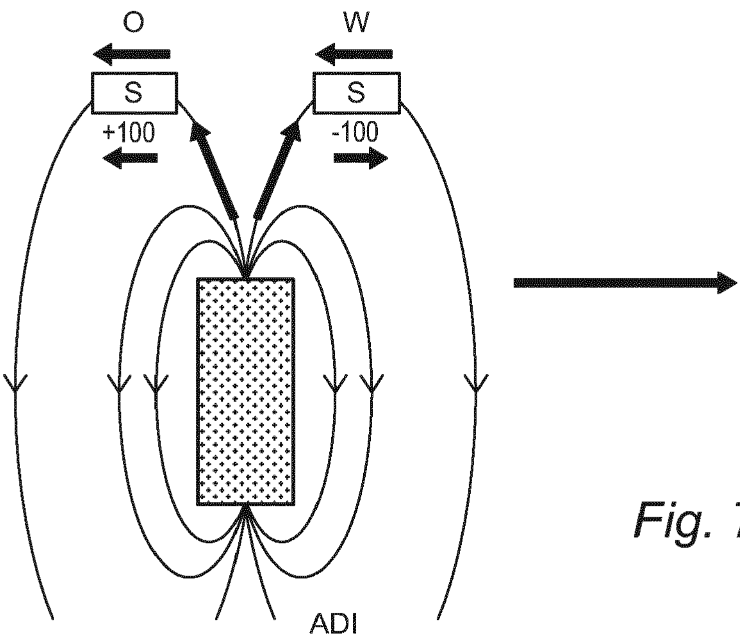

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Fig. 7B

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EUROPEAN SEARCH REPORT

Application Number
EP 22 18 6863

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	8 December 2022	Bultot, Coralie

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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