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(54) **SWITCHABLE MAGNET**

SCHALTBARER MAGNET

AIMANT COMMUTABLE

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WO-A1-2012/160262
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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to a magnet according to the preamble of the appended independent claim.

BACKGROUND OF THE INVENTION

[0002] Magnets are used in many fields of technology to perform various operations, such as to control motion, to switch electrical circuits and to move objects. A magnet is typically provided with a certain functionality to change its magnetic state. A magnet may comprise, for example, a coil which produces a magnetic field that is dependent on the amount and the direction of the electric current supplied to the coil. The coil may be used alone, or it can be combined with a permanent magnet, whereby the coil is used to increase or decrease the magnetic field produced by the permanent magnet. Alternatively, a magnet may comprise a movable part, the position of which determines the magnetic state of the magnet. The movable part, which comprises a permanent magnet, is moved relative to a body of the magnet, for example, with a magnetic force produced by a coil that is arranged to encircle the movable part.

[0003] An example of a magnet that comprises a movable part for changing the magnetic state of the magnet is disclosed in the document WO 2012/160262. The magnet of the document WO 2012/160262 is a so-called bistable magnet, wherein the movable part, which comprises a permanent magnet, is arranged to be movable relative to a body of the magnet between two positions. In the first position, the movable part is in contact with the body, whereby the magnetic flux generated by the permanent magnet may be directed through the body to an object to be attached. In the second position, the movable part is separated from the body so that the flow of the magnetic flux in the body is significantly reduced and thus the holding force of the magnet is almost negligible. The body of the magnet comprises a coil that is arranged around the movable part. The movable part is moved between the two positions by supplying a sufficient amount of electric current through the coil in a suitable direction.

[0004] A problem associated with the magnet of the document WO 2012/160262 relates to the second position of the movable part, i.e. to the position, wherein the movable part is not in contact with the body. In order to make sure that the movable part stays in its second position, either electric current must constantly be supplied to the coil, or the magnet must be provided with springs or other suitable means to push the movable part towards the second position. In the first case, a disadvantage is the power consumption of the coil, whereas in the second case, a disadvantage is the complicated structure, which may easily be damaged, thus resulting in a malfunction of the magnet.

OBJECTIVES OF THE INVENTION

[0005] It is the main objective of the present invention to reduce or even eliminate prior art problems presented above.

[0006] It is an objective of the present invention to provide a magnet having stable magnetic states at which the magnet does not consume electrical energy. It is also an objective of the invention to provide a magnet, whose magnetic state can be changed easily using very little electrical energy. It is also an objective of the invention to provide a magnet that is modular and easily expandable.

[0007] It is a further objective of the invention to provide a magnet having a structure that enables to achieve a large holding force with a small size. It is still a further objective of the invention to provide a magnet that has a simple structure, low manufacturing costs, a long life expectancy and a great reliability.

[0008] In order to realise the above-mentioned objectives, the magnet according to the invention is characterised by what is presented in the characterising part of the appended independent claim. Advantageous embodiments of the invention are described in the dependent claims.

DESCRIPTION OF THE INVENTION

[0009] A typical magnet according to the invention comprises a body and a first slide arranged to be movable relative to the body between a first and a second position, the first slide comprising a first permanent magnet, and a first and a second pole piece attached to opposite magnetic pole surfaces of the first permanent magnet. In a typical magnet according to the invention the body comprises a first and a second plate made of magnetic material, the first and the second plate being arranged in parallel and at a first distance from each other, and the second plate comprising a first through hole, in which the first slide is movably arranged so that the first pole piece is directed towards the first plate, wherein at the first position of the first slide, the first pole piece is located outside the first through hole and at least part of the second pole piece is located inside the first through hole, and at the second position of the first slide, the first permanent magnet and at least part of the first and the second pole piece are located inside the first through hole.

[0010] The state of the magnet can be changed by moving the first slide from one position to the other. At the first position of the first slide, the magnet is intended to attach to an object, whereas at the second position of the first slide, the magnet is not intended to attach to an object. The first and the second positions are stable positions, wherein the first slide remains until it is acted upon by a force that moves the first slide to the other position.

[0011] At the first position of the first slide, the first pole piece is located outside the first through hole and at least part of the second pole piece is located inside the first through hole. Preferably, the first permanent magnet is also located outside the first through hole. At the first position of the first slide, the first pole piece is preferably in contact with the first plate, and the second pole piece is preferably in contact with the second plate, so that the magnetic flux is efficiently conducted between the first pole piece and the first plate, and between the second pole piece and the second plate. At the first position of the first slide, magnetic flux is mainly directed between the second pole piece and the second plate in a direction essentially perpendicular to a wall of the first through hole, and between the first pole piece and the first plate in a direction essentially perpendicular to the plane of the first plate.

[0012] When the first slide is at the first position, magnetic flux generated by the first permanent magnet may flow through the first and the second plate to an object to be attached. The object that is arranged in contact with both the first and the second plate closes the magnetic circuit, whereby magnetic flux is conducted from one pole piece to the other through the first and the second plate and the object. Preferably, the object is arranged in contact with one side of the first plate and one side of the second plate.

[0013] At the second position of the first slide, the first permanent magnet and at least part of the first pole piece and at least part of the second pole piece are located inside the first through hole. At the second position of the first slide, magnetic flux generated by the first permanent magnet is essentially short-circuited by the second plate. This means that the magnetic flux flows from one pole piece to the other mainly through a portion of the second plate that surrounds the first through hole.

[0014] The second position of the first slide is a position of equilibrium to which the magnetic force of the first permanent magnet actively guides the first slide when the first permanent magnet is inside the first through hole. If the first slide is moved from the second position in either direction, the first permanent magnet produces a counterforce that works against the moving force and tries to pull the first slide back to the second position. At the second position of the first slide, magnetic flux is mainly directed from one pole piece to the second plate and from the second plate to the other pole piece in a direction, which is essentially perpendicular to the wall of the first through hole. The direction of the magnetic flux to/from the first pole piece is thus turned by about 90 degrees between the first and the second position of the first slide.

[0015] In the magnet according to the invention the first slide is movably arranged in the first through hole. This means that at least part of the first slide is always inside the first through hole. The first slide is movable in the longitudinal direction of the first through hole, i.e. in a direction, which is perpendicular to the plane of the first and the second plate. The first slide is arranged to be movable relative to the first and the second plate. The first slide is arranged to be linearly movable between the first and the second position. The first slide can be designed to be moved between the first and the second position manually, for example with a shaft attached to the first slide, or with the help of suitable driving means.

[0016] The first and the second plate can have various shapes and dimensions. The first and the second plate can be, for example, rectangular. The first and the second plate can be milled from a plate or a bar. Preferably, the shape and the dimensions of the first and the second plate are essentially identical. The shape of the first and the second plate can be optimised in such a manner that the leakage flux between the plates is small or the attachment surface is large. The thickness of the first and the second plate can be, for example, less than 3 mm, 3-10 mm, 10-100 mm or 100-500 mm. Sides of the first and the second plate that are meant to be in contact with an object can be straight or curved. Preferably, sides of the first and the second plate that are meant to be in contact with an object are shaped to correspond to the shape of the object. The first and the second plate are made of magnetic material that is suitable for conducting magnetic flux. Magnetic material of the first and the second plate is ferromagnetic material, such as iron, nickel, cobalt or their alloys. The first and the second plate can be made from cast iron.

[0017] The magnet according to the invention is suitable for moving objects and can thus be used as a lifting magnet. The magnet can be used as follows to move an object from one location to another. First, the magnet is arranged in contact with an object in such a manner that sides of the first and the second plates are in contact with the object. Next, the first slide is moved to the first position as a result of which the magnet is attached to the object. And then, the object is moved with the magnet to a desired location and the magnet is detached from the object by moving the first slide to the second position.

[0018] According to an embodiment of the invention the body comprises a plurality of first connecting members attached between the first and the second plate. The first connecting members are preferably made of non-magnetic material. The purpose of the first connecting members is to arrange the first and the second plate magnetically separated and at the first distance from each other. The number of the first connecting members can vary depending on the application. Preferably, a first connecting member is attached to each corner of the first and the second plate, whereby if the first and the second plate are rectangular, the body comprises four first connecting members. Preferably, the first connecting members are rods or bars, whose first ends are attached to the first plate, and whose second ends are attached to the second plate. The first connecting members can be made of non-magnetic material, which can be paramagnetic material, such as resin, brass or aluminium, or diamagnetic material, such as acid-proof steel or stainless steel.

[0019] According to an embodiment of the invention the magnet comprises a first coil arranged between the first and the second plate, the first coil being configured to generate a magnetic force for moving the first slide towards the first or the second position depending on the direction of electric current that is supplied to the first coil. Preferably, the first coil is arranged between the first and the second plate to at least partly encircle the first slide, when the first slide is at the first position. Although the first coil is primarily used for moving the first slide between the first and the second position, it may also be used to adjust the holding force of the magnet. When the first slide is at the first position, the holding force of the magnet can be increased or decreased by supplying electric current to the coil in a suitable direction.

[0020] According to an embodiment of the invention the magnet comprises a second slide arranged to be movable relative to the body between a third and a fourth position, the second slide comprising a second permanent magnet, and a third and a fourth pole piece attached to opposite magnetic pole surfaces of the second permanent magnet, and the body comprises a third plate made of magnetic material, the second and the third plate being arranged in parallel and at a second distance from each other, and the third plate comprising a second through hole in line with the first through hole, in which second through hole the second slide is movably arranged so that the third pole piece is directed towards the second plate, wherein at the third position of the second slide, at least part of the third pole piece is located inside the first through hole and at least part of the fourth pole piece is located inside the second through hole, and at the fourth position of the second slide, the second permanent magnet and at least part of the third and the fourth pole piece are located inside the second through hole.

[0021] The state of the magnet can be changed by moving the second slide from one position to the other. At the third position of the second slide, the magnet is intended to attach to an object, whereas at the fourth position of the second slide, the magnet is not intended to attach to an object. The third and the fourth positions are stable positions, wherein the second slide remains until it is acted upon by a force that moves the second slide to the other position.

[0022] At the third position of the second slide, at least part of the third pole piece is located inside the first through hole and at least part of the fourth pole piece is located inside the second through hole. Preferably, the second permanent magnet is located outside the first and the second through hole, meaning that the second distance is larger than the thickness of the second permanent magnet. At the third position of the second slide, the third pole piece is preferably in contact with the second plate, and the fourth pole piece is preferably in contact with the third plate, so that the magnetic flux is efficiently conducted between the third pole piece and the second plate, and between the fourth pole piece and the third plate. At the third position of the second slide, magnetic flux is mainly directed between the third pole piece and the second plate in a direction essentially perpendicular to a wall of the first through hole, and between the fourth pole piece and the third plate in a direction essentially perpendicular to a wall of the second through hole.

[0023] When the second slide is at the third position, magnetic flux generated by the second permanent magnet may flow through the second and the third plate to an object to be attached. The object that is arranged in contact with both the second and the third plate closes the magnetic circuit, whereby magnetic flux is conducted from one pole piece to the other through the second and the third plate and the object. Preferably, the object is arranged in contact with one side of the second plate and one side of the third plate.

[0024] At the fourth position of the second slide, the second permanent magnet and at least part of the third pole piece and at least part of the second pole piece are located inside the second through hole. At the fourth position of the second slide, magnetic flux generated by the second permanent magnet is essentially short-circuited by the third plate. This means that the magnetic flux flows from one pole piece to the other mainly through a portion of the third plate that surrounds the second through hole. The fourth position of the second slide is a position of equilibrium to which the magnetic force of the second permanent magnet actively guides the second slide when the second permanent magnet is inside the second through hole. If the second slide is moved from the fourth position in either direction, the second permanent magnet produces a counterforce that works against the moving force and tries to pull the second slide to the fourth position. At the fourth position of the second slide, magnetic flux is mainly directed from one pole piece to the third plate and from the third plate to the other pole piece in a direction which is essentially perpendicular to the wall of the second through hole.

[0025] The first and the second slide are arranged consecutively in the magnet in such a manner that the second pole piece of the first slide and the third pole piece of the second slide are facing each other. The second pole piece of the first slide can be attached to the third pole piece of the second slide. The first and the second slide are preferably arranged in such a manner that the same poles of the first and the second permanent magnet are facing each other.

[0026] Depending on the application, the first and the second slide can be arranged to be movable separately or together. Preferably, the first and the second slide are immobile with respect to each other and arranged at a third distance from each other. The third distance is smaller than the thickness of the second plate. Preferably, the first and the second slide are arranged to be movable in such a manner that when the first slide is at the first position the second slide is at the third position, and when the first slide is at the second position the second slide is at the fourth position.

[0027] The second slide is movably arranged in the

second through hole. This means that at least part of the second slide is always inside the second through hole. The thickness of the second slide is larger than the distance between the second and the third plate, i.e. the second distance. The second slide is movable in the longitudinal direction of the second through hole, i.e. in a direction, which is perpendicular to the plane of the third plate. The longitudinal direction of the second through hole corresponds to the longitudinal direction of the first through hole. The second slide is arranged to be linearly movable between the third and the fourth position. The second slide can be designed to be moved between the third and the fourth position manually, for example with a shaft attached to the second slide, or with the help of suitable driving means.

[0028] The third plate can have various shapes and dimensions. The third plate can be, for example, rectangular. The third plate can be milled from a plate or a bar. Preferably, the shape and the dimensions of the first, the second and the third plate are essentially identical. The shape of the plates can be optimised in such a manner that the leakage flux between the plates is small or the attachment surface is large. The thickness of the third plate can be, for example, less than 3 mm, 3-10 mm, 10-100 mm or 100-500 mm. A side of the third plate that is meant to be in contact with an object can be straight or curved. Preferably, a side of the third plate that is meant to be in contact with an object is shaped to correspond to the shape of the object. The third plate is made of magnetic material that is suitable for conducting magnetic flux. Magnetic material of the third plate is ferromagnetic material, such as iron, nickel, cobalt or their alloys. The third plate can be made from cast iron.

[0029] The first and the second slide have a sandwich structure, wherein the permanent magnet is arranged between the two pole pieces. The pole pieces are attached to different poles of the permanent magnet, and are made of magnetic material so that the magnetic flux generated by the permanent magnet may be conducted through them. Magnetic material of the pole piece is ferromagnetic material, preferably iron. The permanent magnet can be, for example, a neodymium magnet, an alnico magnet or a samarium-cobalt magnet.

[0030] The pole pieces of the slide can be, for example, disc-shaped and have the same diameter. The permanent magnet can be, for example, disc-shaped and have the same diameter as or smaller diameter than the pole pieces. The thickness of the first permanent magnet is smaller than the thickness of the second plate. The thickness of the second permanent magnet is smaller than the thickness of the third plate.

[0031] The permanent magnet of the slide may consist of one or more magnet pieces arranged in one or more layers. The permanent magnet can, for example, be formed of sector pieces arranged in one layer in such a manner that the same poles of the sector pieces are disposed on the same side of the permanent magnet. The number of sector pieces can be, for example, 2, 3, 4-6 or 7-10. The permanent magnet can alternatively be formed of magnet pieces arranged one on the other. The magnet pieces can be arranged one on the other in such a manner that ferromagnetic discs are arranged between the magnet pieces and the different poles of the magnet pieces are arranged to face each other.

[0032] Preferably, the slide is cylindrical and is arranged to be movable in the through hole that is also cylindrical. The slide and the through hole can, however, have other forms, such as rectangular. Preferably, the diameter of the cylindrical slide is only slightly smaller than the diameter of the cylindrical through hole, whereby the wall of the through hole can efficiently support the slide while it is moved between the two positions. The diameter of the through hole can be, for example, less than 10 mm, 10-50 mm, 50-200 mm or 200-500 mm. The diameter of the slide can be, for example, less than 2 mm, less than 1 mm, less than 0.5 mm, less than 0.1 mm or 0.005-0.5 mm smaller than the diameter of the through hole. The thickness of the first slide is preferably larger than the depth of the first through hole, i.e. the thickness of the second plate, whereby the first slide settles quickly into the second position. The thickness of the second slide is preferably larger than the depth of the second through hole, i.e. the thickness of the third plate, whereby the first slide settles quickly into the fourth position. The thickness of the first and the second slide can be, for example, less than 3 mm, 3-10 mm, 10-100 mm or 100-500 mm.

[0033] The magnet may comprise more than two slides. The structure of the magnet can, for example, be multiplied so that the magnet comprises more than two plates having a through hole in which a slide is movably arranged. It is also possible to arrange a plate with a plurality of through holes in each of which a slide is movably arranged.

[0034] According to an embodiment of the invention the body comprises a plurality of second connecting members attached between the second and the third plate. The second connecting members are preferably made of non-magnetic material. The purpose of the second connecting members is to arrange the second and the third plate magnetically separated and at the second distance from each other. The number of the second connecting members can vary depending on the application. Preferably, a second connecting member is attached to each corner of the second and the third plate, whereby if the second and the third plate are rectangular, the body comprises four second connecting members. Preferably, the second connecting members are rods or bars, whose first ends are attached to the second plate, and whose second ends are attached to the third plate. The second connecting members can be made of non-magnetic material, which can be paramagnetic material, such as resin, brass or aluminium, or diamagnetic material, such as acid-proof steel or stainless steel.

[0035] According to an embodiment of the invention the magnet comprises a second coil arranged between

the second and the third plate, the second coil being configured to generate a magnetic force for moving the second slide towards the third or the fourth position depending on the direction of electric current that is supplied to the second coil. Preferably, the second coil is arranged between the second and the third plate to at least partly encircle the second slide.

[0036] According to an embodiment of the invention the magnet comprises means for supplying electric current to the first and/or the second coil. The means for supplying electric current may comprise, for example, a battery that is connected to the first and/or the second coil via a control unit. The control unit is configured to control the amount and the direction of electric current supplied to the first and/or the second coil. The control unit may comprise one or more operating switches for using the magnet, and/or a wireless receiver for receiving control commands from a remote controller. The control unit may also comprise one or more indicator lights for indicating the status of the magnet, and/or a wireless transmitter for transmitting the status information to the remote controller.

[0037] The state of the magnet, i.e. the position of the first and/or the second slide, can be changed with an electric current pulse that has a certain duration, magnitude and polarity. The duration and the magnitude of the electric current pulse that is needed to change the state of the magnet are highly dependent on the structure and the size of the magnet, and the magnetic properties of the object to be attached. The polarity of the electric current pulse depends on the direction to which the first and/or the second slide need to be moved. Typically, the duration of an electric current pulse is 30-300 ms.

[0038] According to an embodiment of the invention the magnet comprises a shaft to which the first and the second slide are attached. The shaft is arranged to extend and to be movable in the longitudinal direction of the first and the second through hole. A first end of the shaft extends into or through the first slide, and a second end of the shaft extends through the second slide. The first and the second slide are attached to the shaft in such a manner that when the first slide is at the first position the second slide is at the third position, and when the first slide is at the second position the second slide is at the fourth position. The distance between the first and the second slide is smaller than the thickness of the second plate.

[0039] According to an embodiment of the invention the magnet comprises an actuator attached to the shaft for moving the first and the second slide. The actuator is attached to the second end of the shaft, and is arranged to move the shaft in both directions so that the first and the second slide can be moved from one position to the other. The actuator is preferably a linear actuator that creates motion in a straight line. Examples of a linear actuator are a solenoid and a hydraulic cylinder.

[0040] According to an embodiment of the invention the first plate comprises a recess in line with the first through hole for receiving at least part of the first pole piece. The recess enables to arrange the first and the second plate closer to each other. The depth of the recess is smaller than the thickness of the first pole piece. Instead of a recess, the first plate may comprise a through hole for receiving at least part of the first pole piece.

[0041] According to an embodiment of the invention the first slide comprises a guiding rod extending from the first pole piece to a bore in the first plate. The guiding rod, which extends in the longitudinal direction of the first through hole, may be arranged to extend partly or completely through the first slide. The guiding rod is preferably dimensioned in such a manner that at least part of the guiding rod stays in the bore all the time. The purpose of the guiding rod is to reduce the movement of the first slide in other directions than the longitudinal direction of the first through hole. The guiding rod is made of non-magnetic material, which can be paramagnetic material, such as resin, brass or aluminium, or diamagnetic material, such as acid-proof steel or stainless steel. If the shaft is arranged to extend through the first slide, the first end of the shaft may act as a guiding rod.

[0042] According to an embodiment of the invention the magnet comprises a magnetic flux sensor configured to measure magnetic flux density in the body and means for determining the position of the first and/or the second slide based on the measured magnetic flux density. By a magnetic flux sensor it is meant a transducer that varies its output voltage and/or current in response to magnetic flux density. The magnetic flux sensor can be attached to the first plate, whereby the position of the first slide can be determined, to the second plate, whereby the position of the first and/or the second plate can be determined, or to the third plate, whereby the position of the second plate can be determined. Since the path of the magnetic flux in the first, the second or the third plate is dependent on the position of the first and/or the second slide, the position of the first and/or the second slide can be determined from the output voltage and/or current of the magnetic flux sensor. The means for determining the position of the slide may comprise, for example, a comparator circuit for providing, as a response to the voltage and/or current of the magnetic flux sensor, an output signal identifying at which position the first and/or the second slide is. The magnetic flux sensor may also be configured to indicate the position of the slide directly as a binary output. The magnetic flux sensor may also be used to detect whether an object is attached to the magnet or not.

[0043] The magnetic flux sensor can be arranged inside the first, the second or the third plate, or attached on their surface. If the magnetic flux sensor is arranged to the second or the third plate, it is preferably arranged inside the portion of the plate that surrounds the through hole.

[0044] The magnet may comprise a plurality of magnetic flux sensors configured to measure magnetic flux densities in different spatial locations and/or directions. The number of magnetic flux sensors can be, for exam-

ple, 2, 3, or more than 3. Preferably, the magnetic flux sensors are configured to measure magnetic flux densities in orthogonal directions.

[0045] According to an embodiment of the invention the magnetic flux sensor is one of the following: a Hall sensor, an AMR magnetometer, a MEMS sensor or a reed relay.

[0046] An advantage of the magnet according to the invention is that the magnet does not consume electrical energy when the slide is at either of its two positions. Also the magnet does not have any complex structure for keeping the slide at either of its two positions. In fact, the slide stays in place at both of its two positions with the help of the magnetic field produced by the permanent magnet. Another advantage of the magnet is that its magnetic state can be changed easily. Still another advantage of the magnet is its simple structure that makes the magnet very robust and reliable. Still another advantage of the magnet is that it enables to achieve a large holding force with a small size. Still another advantage of the invention is that the magnet is easily expandable by adding more plates and slides.

[0047] Still another advantage of the magnet is that the demagnetization of the permanent magnet is almost prevented because the magnetic circuit is closed at the second position of the first slide and at the fourth position of the second slide. Still another advantage of the magnet is that its holding force is minimal when the magnet is in an OFF state, i.e. when the first slide is at the second position and the second slide is at the fourth position.

BRIEF DESCRIPTION OF THE DRAWINGS

[0048] The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the description of specific embodiments when read in connection with the accompanying drawings.

Fig. 1 illustrates a magnet according to a first embodiment of the invention,

fig. 2 illustrates the magnetic field generated by the magnet of fig. 1, when the first slide is at the first position,

fig. 3 illustrates the magnetic field generated by the magnet of fig. 1, when the first slide is at the second position, and

fig. 4 illustrates a magnet according to a second embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0049] The same reference signs are used of the same or like components in different embodiments.

[0050] Fig. 1 illustrates a magnet according to a first embodiment of the invention. The magnet 100 comprises a first slide 101 (shown with dashed lines) that is arranged to be movable relative to a body 102 of the magnet 100 between a first and a second position. The magnetic state of the magnet 100 is changed by moving the first slide 101 from one position to the other. At the first position, the magnet 100 can attach to an object, whereas at the second position, the magnet 100 cannot.

[0051] The body 102 of the magnet 100 comprises a first and a second plate 103, 104 that are arranged in parallel and at a first distance from each other with four first rods 105. The first rods 105 are attached to the corners of the first and the second plate 103, 104 in such a manner that the first ends of the first rods 105 are attached to the first plate 103, and the second ends of the first rods 105 are attached to the second plate 104. The first rods 105 are arranged perpendicularly to the plane of the first and the second plate 103, 104. The first and the second plate 103, 104 are made of magnetic material, whereas the first rods 105 are made of non-magnetic material.

[0052] The first slide 101 that is cylindrical comprises a first permanent magnet 106, and a first and a second pole piece 107, 108, which are attached to opposite magnetic pole surfaces of the first permanent magnet 106. The first and the second pole piece 107, 108 and the first permanent magnet 106 are disc-shaped and have the same diameter.

[0053] The first slide 101 is movably arranged in a first through hole 109 of the second plate 104 in such a manner that the first pole piece 107 is directed towards the first plate 103. At the first position of the first slide 101, the first pole piece 107 and the first permanent magnet 106 are located outside the first through hole 109 and part of the second pole piece 108 is located inside the first through hole 109. At the second position of the first slide 101, the first permanent magnet 106, part of the first pole piece 107 and part of the second pole piece 108 are located inside the first through hole 109.

[0054] The magnet 100 comprises a first coil 110 that is arranged between the first and the second plate 103, 104 and around the first slide 101. The first coil 110 is configured to generate a magnetic force for moving the first slide 101 towards the first or the second position depending on the direction of electric current that is supplied to the first coil 110. The magnet 100 comprises a battery 111 that is connected via a control unit 112 to the first coil 110. The control unit 112 controls the amount and the direction of electric current supplied from the battery 111 to the first coil 110. The state of the magnet, i.e. the position of the first slide 101, is changed with an electric current pulse that has a certain duration, magnitude and polarity. The position of the first slide 101 is determined with a magnetic flux sensor 113 that is arranged inside the second plate 104, close to the first through hole 109.

[0055] Fig. 2 illustrates the magnetic field generated by the magnet of fig. 1, when the first slide is at the first

position. The magnetic field is represented by magnetic field lines. At the first position of the first slide 101, the first pole piece 107 is in contact with the first plate 103 and the second pole piece 108 is in contact with the second plate 104, so that magnetic flux generated by the first permanent magnet 106 may be conducted between the first pole piece 107 and the first plate 103, and between the second pole piece 108 and the second plate 104. Magnetic flux flows through an object 200 that is arranged in contact with sides of the first and the second plate 103, 104. The object 200 closes the magnetic circuit, whereby magnetic flux is conducted from the first pole piece 107 to the second pole piece 108 through the first plate 103, the object 200 and the second plate 104. The magnet 100 is thus attached to the object 200.

[0056] Fig. 3 illustrates the magnetic field generated by the magnet of fig. 1, when the first slide is at the second position. The magnetic field is represented by magnetic field lines. At the second position of the first slide 101, the first and the second pole piece 107, 108 are in contact with the second plate 104, whereby magnetic flux is short-circuited by the second plate 104. This means that the magnetic flux flows from the first pole piece 107 to the second pole piece 108 mainly through a portion of the second plate 104 that surrounds the first through hole 109. Therefore, the magnet 100 cannot attach to the object 200.

[0057] Fig. 4 illustrates a magnet according to a second embodiment of the invention. The magnet of fig. 4 differs from the magnet of fig. 1, inter alia, in that it comprises a second slide 114, a third plate 115 and different means for moving the slides 101,114.

[0058] The second slide 114 is arranged to be movable relative to the body 102 of the magnet 100 between a third and a fourth position. At the third position, the magnet 100 can attach to an object, whereas at the fourth position, the magnet cannot.

[0059] The second and the third plate 104, 115 are arranged in parallel and at a second distance from each other with four second rods 116. The second rods 116 are attached to the corners of the second and the third plate 104, 115 in such a manner that the first ends of the second rods 116 are attached to the second plate 104, and the second ends of the second rods 116 are attached to the third plate 115. The second rods 116 are arranged perpendicularly to the plane of the second and the third plate 104, 115. The third plate 115 is made of magnetic material, whereas the second rods 116 are made of non-magnetic material.

[0060] The second slide 114 that is cylindrical comprises a second permanent magnet 117 (shown with dashed lines) and a third and a fourth pole piece 118, 119, which are attached to opposite magnetic pole surfaces of the second permanent magnet 117. The third and the fourth pole piece 118, 119 and the second permanent magnet 117 are disc-shaped and have the same diameter.

[0061] The second slide 114 is movably arranged in a second through hole 120 of the third plate 115 in such a manner that the third pole piece 118 is directed towards the second plate 104. The second through hole 120 is in line with the first through hole 109. The first and the second slide 101, 114 are arranged consecutively in the magnet 100 in such a manner that the second pole piece 108 of the first slide 101 and the third pole piece 118 of the second slide 114 are facing each other. The first and the second slide 101, 114 are arranged in such a manner that the same poles of the first and the second permanent magnet 106, 117 are facing each other.

[0062] At the third position of the second slide 114, part of the third pole piece 118 is located inside the first through hole 109 and part of the fourth pole piece 119 is located inside the second through hole 120. At the third position, magnetic flux generated by the second permanent magnet 117 may flow through the second and the third plate 104, 115 to an object to be attached. The object that will be arranged in contact with both the second and the third plate 104, 115 closes the magnetic circuit, whereby magnetic flux is conducted from one pole piece to the other through the second and the third plate 104, 115 and the object.

[0063] At the fourth position of the second slide 114, the second permanent magnet 117 and part of the third and the fourth pole piece 118, 119 are located inside the second through hole 120. At the fourth position, magnetic flux generated by the second permanent magnet 117 is short-circuited by the third plate 115. This means that the magnetic flux flows from one pole piece to the other mainly through a portion of the third plate 115 that surrounds the second through hole 120.

[0064] The first and the second slide 101, 114 are attached to a shaft 121, which is arranged to extend and to be movable in the longitudinal direction of the first and the second through hole 109, 120. The first end of the shaft 121 extends into the first slide 101, and the second end of the shaft 121 extends through the second slide 114. The first and the second slide 101, 114 are attached to the shaft 121 in such a manner that when the first slide 101 is at the first position the second slide 114 is at the third position, and when the first slide 101 is at the second position the second slide 114 is at the fourth position.

[0065] The magnet 100 comprises a linear actuator 122, which is attached to the second end of the shaft 121. The linear actuator 122 can move the shaft 121 in two directions so that the first and the second slide 101, 114 are moved from one position to the other. The first plate 103 comprises a recess 123 that is in line with the first through hole 109. The recess 123 is arranged to receive part of the first pole piece 107, when the first slide 101 is at the first position.

Claims

1. A magnet (100), comprising:

- a body (102), and

- a first slide (101) arranged to be movable relative to the body (102) between a first and a second position, the first slide (101) comprising a first permanent magnet (106), and a first and a second pole piece (107, 108) attached to opposite magnetic pole surfaces of the first permanent magnet (106);

characterised in that:

- the body (102) comprises a first and a second plate (103, 104) made of magnetic material, the first and the second plate (103, 104) being arranged in parallel and at a first distance from each other, and the second plate (104) comprising a first through hole (109) in which the first slide (101) is movably arranged so that the first pole piece (107) is directed towards the first plate (103),

wherein at the first position of the first slide (101), the first pole piece (107) is located outside the first through hole (109) and at least part of the second pole piece (108) is located inside the first through hole (109), and at the second position of the first slide (101), the first permanent magnet (106) and at least part of the first and the second pole piece (107, 108) are located inside the first through hole (109).

2. The magnet according to claim 1, **characterised in that** the body (102) comprises a plurality of first connecting members (105) attached between the first and the second plate (103, 104).

3. The magnet according to claim 1 or 2, **characterised in that** the magnet (100) comprises a first coil (110) arranged between the first and the second plate (103, 104), the first coil (110) being configured to generate a magnetic force for moving the first slide (101) towards the first or the second position depending on the direction of electric current that is supplied to the first coil (110).

4. The magnet according to any of the preceding claims, **characterised in that**:

- the magnet (100) comprises a second slide (114) arranged to be movable relative to the body (102) between a third and a fourth position, the second slide (114) comprising a second permanent magnet (117), and a third and a fourth pole piece (118, 119) attached to opposite magnetic pole surfaces of the second permanent magnet (117), and
- the body (102) comprises a third plate (115) made of magnetic material, the second and the third plate (104, 115) being arranged in parallel and at a second distance from each other, and the third plate (115) comprising a second through hole (120) in line with the first through hole (109), in which second through hole (120) the second slide (114) is movably arranged so that the third pole piece (118) is directed towards the second plate (104),

wherein at the third position of the second slide (114), at least part of the third pole piece (118) is located inside the first through hole (109) and at least part of the fourth pole piece (119) is located inside the second through hole (120), and at the fourth position of the second slide (114), the second permanent magnet (117) and at least part of the third and the fourth pole piece (118, 119) are located inside the second through hole (120).

5. The magnet according to claim 4, **characterised in that** the body (102) comprises a plurality of second connecting members (116) attached between the second and the third plate (104, 115).

6. The magnet according to claim 4 or 5, **characterised in that** the magnet (100) comprises a second coil arranged between the second and the third plate (104, 115), the second coil being configured to generate a magnetic force for moving the second slide (114) towards the third or the fourth position depending on the direction of electric current that is supplied to the second coil.

7. The magnet according to any of the claims 4 to 6, **characterised in that** the magnet (100) comprises a shaft (121) to which the first and the second slide (101, 114) are attached.

8. The magnet according to claim 7, **characterised in that** the magnet (100) comprises an actuator (122) attached to the shaft (121) for moving the first and the second slide (101, 114).

9. The magnet according to any of the preceding claims, **characterised in that** the first plate (103) comprises a recess (123) in line with the first through hole (109) for receiving at least part of the first pole piece (107).

10. The magnet according to any of the preceding claims, **characterised in that** the first slide (101) comprises a guiding rod extending from the first pole piece (107) to a bore in the first plate (103).

11. The magnet according to any of the preceding claims, **characterised in that** the magnet (100) comprises:

- a magnetic flux sensor (113) configured to measure magnetic flux density in the body (102),

and
- means for determining the position of the first and/or the second slide (101, 114) based on the measured magnetic flux density.

12. The magnet according to claim 11, **characterised in that** the magnetic flux sensor (113) is one of the following: a Hall sensor, an AMR magnetometer, a MEMS sensor or a reed relay.

Patentansprüche

1. Magnet (100), umfassend:

- einen Körper (102) und
- ein erstes Gleitstück (101), das so angeordnet ist, dass es relativ zum Körper (102) zwischen einer ersten und einer zweiten Position beweglich ist, wobei das erste Gleitstück (101) einen ersten Permanentmagneten (106) und ein erstes und ein zweites Polstück (107, 108) umfasst, die an gegenüberliegenden magnetischen Polflächen des ersten Permanentmagneten (106) angebracht sind;

dadurch gekennzeichnet, dass

- der Körper (102) eine erste und eine zweite Platte (103, 104) aus magnetischem Material umfasst, wobei die erste und die zweite Platte (103, 104) parallel und in einem ersten Abstand voneinander angeordnet sind, und die zweite Platte (104) ein erstes Durchgangsloch (109) umfasst, in dem das erste Gleitstück (101) beweglich angeordnet ist, so dass das erste Polstück (107) auf die erste Platte (103) gerichtet ist,

wobei an der ersten Position des ersten Gleitstücks (101) das erste Polstück (107) außerhalb des ersten Durchgangslochs (109) angeordnet ist und mindestens ein Teil des zweiten Polstücks (108) innerhalb des ersten Durchgangslochs (109) angeordnet ist, und an der zweiten Position des ersten Gleitstücks (101) der erste Permanentmagnet (106) und mindestens ein Teil des ersten und des zweiten Polstücks (107, 108) innerhalb des ersten Durchgangslochs (109) angeordnet sind.

2. Magnet nach Anspruch 1, **dadurch gekennzeichnet, dass** der Körper (102) eine Vielzahl von ersten Verbindungselementen (105) umfasst, die zwischen der ersten und der zweiten Platte (103, 104) angebracht sind.

3. Magnet nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Magnet (100) eine erste Spule (110) umfasst, die zwischen der ersten und der zweiten Platte (103, 104) angeordnet ist, wobei die erste Spule (110) so konfiguriert ist, dass sie eine Magnetkraft erzeugt, um das ersten Gleitstück (101) abhängig von der Richtung des elektrischen Stroms, der der ersten Spule (110) zugeführt wird, in Richtung der ersten oder zweiten Position zu bewegen.

4. Magnet nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass**:

- der Magnet (100) ein zweites Gleitstück (114) umfasst, das so angeordnet ist, dass es relativ zu dem Körper (102) zwischen einer dritten und einer vierten Position beweglich ist, wobei das zweite Gleitstück (114) einen zweiten Permanentmagneten (117), und ein drittes und ein viertes Polstück (118, 119), die an gegensätzlichen magnetischen Polflächen des zweiten Permanentmagneten (117) angebracht sind, umfasst, und
- der Körper (102) eine dritte Platte (115) aus magnetischem Material umfasst, wobei die zweite und die dritte Platte (104, 115) parallel und in einer zweiten Entfernung voneinander angeordnet sind und wobei die dritte Platte (115) ein zweites Durchgangsloch (120) in einer Linie mit dem ersten Durchgangsloch (109) umfasst, wobei in dem zweiten Durchgangsloch (120) das zweite Gleitstück (114) beweglich angeordnet ist, so dass das dritte Polstück (118) auf die zweite Platte (104) gerichtet ist,

wobei sich an der dritten Position des zweiten Gleitstücks (114) mindestens ein Teil des dritten Polstücks (118) innerhalb des ersten Durchgangslochs (109) befindet und mindestens ein Teil des vierten Polstücks (119) innerhalb des zweiten Durchgangslochs (120) befindet, und an der vierten Position des zweiten Gleitstücks (114) der zweite Permanentmagnet (117) und mindestens ein Teil des dritten und des vierten Polstücks (118, 119) sich innerhalb des zweiten Durchgangs befinden.

5. Magnet nach Anspruch 4, **dadurch gekennzeichnet, dass** der Körper (102) eine Vielzahl von zweiten Verbindungselementen (116) umfasst, die zwischen der zweiten und der dritten Platte (104, 115) angebracht sind.

6. Magnet nach Anspruch 4 oder 5, **dadurch gekennzeichnet, dass** der Magnet (100) eine zweite Spule umfasst, die zwischen der zweiten und der dritten Platte (104, 115) angeordnet ist, wobei die zweite Spule so konfiguriert ist, dass sie eine Magnetkraft erzeugt, um das zweiten Gleitstück (114), abhängig von der Richtung des elektrischen Stroms, der der zweiten Spule zugeführt wird, in Richtung der dritten

oder vierten Position zu bewegen.

7. Magnet nach einem der Ansprüche 4 bis 6, **dadurch gekennzeichnet, dass** der Magnet (100) eine Welle (121) umfasst, an der das erste und das zweite Gleiststück (101, 114) angebracht sind.

8. Magnet nach Anspruch 7, **dadurch gekennzeichnet, dass** der Magnet (100) einen Aktuator (122) umfasst, der an der Welle (121) angebracht ist, um das erste und das zweite Gleitstück (101, 114) zu bewegen.

9. Magnet nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** die erste Platte (103) eine Vertiefung (123) in einer Linie mit dem ersten Durchgangsloch (109) umfasst, um wenigstens einen Teil des ersten Polstücks (107) aufzunehmen.

10. Magnet nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** das erste Gleitstück (101) eine Führungsstange umfasst, die sich von dem ersten Polstück (107) zu einer Bohrung in der ersten Platte (103) erstreckt.

11. Magnet nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** der Magnet (100) umfasst:

- einen Magnetflusssensor (113), der konfiguriert ist, die magnetische Flussdichte in dem Körper (102) zu messen und
- Mittel zur Bestimmung der Position des ersten und/oder zweiten Gleitstücks (101, 114) basierend auf der gemessenen magnetischen Flussdichte.

12. Magnet nach Anspruch 11, **dadurch gekennzeichnet, dass** der Magnetflusssensor (113) ein Hallsensor, ein AMR-Magnetometer, ein MEMS-Sensor oder ein Reed-Relais ist.

Revendications

1. Aimant (100), comprenant :

- un corps (102), et
- une première lame (101) agencée pour être mobile par rapport au corps (102) entre une première et une deuxième position, la première lame (101) comprenant un premier aimant permanent (106), et une première et une deuxième pièce polaire (107, 108) fixées à des surfaces polaires magnétiques opposées du premier aimant permanent (106) ;

caractérisé en ce que :

- le corps (102) comprend une première et une deuxième plaque (103, 104) réalisées en matériau magnétique, la première et la deuxième plaque (103, 104) étant agencées en parallèle et à une première distance l'une de l'autre, et la deuxième plaque (104) comprenant un premier trou traversant (109) dans lequel la première lame (101) est agencée mobile de sorte que la première pièce polaire (107) soit dirigée vers la première plaque (103),

dans lequel à la première position de la première lame (101), la première pièce polaire (107) est située à l'extérieur du premier trou traversant (109) et au moins une partie de la deuxième pièce polaire (108) est située à l'intérieur du premier trou traversant (109), et à la deuxième position de la première lame (101), le premier aimant permanent (106) et au moins une partie de la première et de la deuxième pièce polaire (107, 108) sont situés à l'intérieur du premier trou traversant (109).

2. Aimant selon la revendication 1, **caractérisé en ce que** le corps (102) comprend une pluralité de premiers organes de raccordement (105) fixés entre la première et la deuxième plaque (103, 104).

3. Aimant selon la revendication 1 ou 2, **caractérisé en ce que** l'aimant (100) comprend une première bobine (110) agencée entre la première et la deuxième plaque (103, 104), la première bobine (110) étant configurée pour générer une force magnétique pour déplacer la première lame (101) vers la première ou la deuxième position selon la direction du courant électrique qui est fourni à la première bobine (110).

4. Aimant selon l'une quelconque des revendications précédentes, **caractérisé en ce que** :

- l'aimant (100) comprend une seconde lame (114) agencée pour être mobile par rapport au corps (102) entre une troisième et une quatrième position, la seconde lame (114) comprenant un second aimant permanent (117), et une troisième et une quatrième pièce polaire (118, 119) fixées à des surfaces polaires magnétiques opposées du second aimant permanent (117), et
- le corps (102) comprend une troisième plaque (115) réalisée en matériau magnétique, la deuxième et la troisième plaque (104, 115) étant agencées en parallèle et à une seconde distance l'une de l'autre, et la troisième plaque (115) comprenant un second trou traversant (120) aligné avec le premier trou traversant (109), second trou traversant (120) dans lequel la seconde lame (114) est agencée mobile de sorte que

la troisième pièce polaire (118) soit dirigée vers la deuxième plaque (104),

dans lequel à la troisième position de la seconde lame (114), au moins une partie de la troisième pièce polaire (118) est située à l'intérieur du premier trou traversant (109) et au moins une partie de la quatrième pièce polaire (119) est située à l'intérieur du second trou traversant (120), et à la quatrième position de la seconde lame (114), le second aimant permanent (117) et au moins une partie de la troisième et de la quatrième pièce polaire (118, 119) sont situés à l'intérieur du second trou traversant (120).

5. Aimant selon la revendication 4, **caractérisé en ce que** le corps (102) comprend une pluralité de seconds organes de raccordement (116) fixés entre la deuxième et la troisième plaque (104, 115).

6. Aimant selon la revendication 4 ou 5, **caractérisé en ce que** l'aimant (100) comprend une seconde bobine agencée entre la deuxième et la troisième plaque (104, 115), la seconde bobine étant configurée pour générer une force magnétique pour déplacer la seconde lame (114) vers la troisième ou la quatrième position selon la direction du courant électrique qui est fourni à la seconde bobine.

7. Aimant selon l'une quelconque des revendications 4 à 6, **caractérisé en ce que** l'aimant (100) comprend un arbre (121) auquel sont fixées la première et la seconde lame (101, 114).

8. Aimant selon la revendication 7, **caractérisé en ce que** l'aimant (100) comprend un actionneur (122) fixé à l'arbre (121) pour déplacer la première et la seconde lame (101, 114).

9. Aimant selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la première plaque (103) comprend un évidement (123) aligné avec le premier trou traversant (109) pour recevoir au moins une partie de la première pièce polaire (107).

10. Aimant selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la première lame (101) comprend une tige de guidage s'étendant depuis la première pièce polaire (107) jusqu'à un alésage dans la première plaque (103).

11. Aimant selon l'une quelconque des revendications précédentes, **caractérisé en ce que** l'aimant (100) comprend :

- un capteur de flux magnétique (113) configuré pour mesurer une densité de flux magnétique dans le corps (102), et
- un moyen de détermination de la position de la première et/ou de la seconde lame (101, 114) d'après la densité de flux magnétique mesurée.

12. Aimant selon la revendication 11, **caractérisé en ce que** le capteur de flux magnétique (113) est l'un des suivants : un capteur à effet de Hall, un magnétomètre AMR, un capteur MEMS ou un relais à contact sous vide.

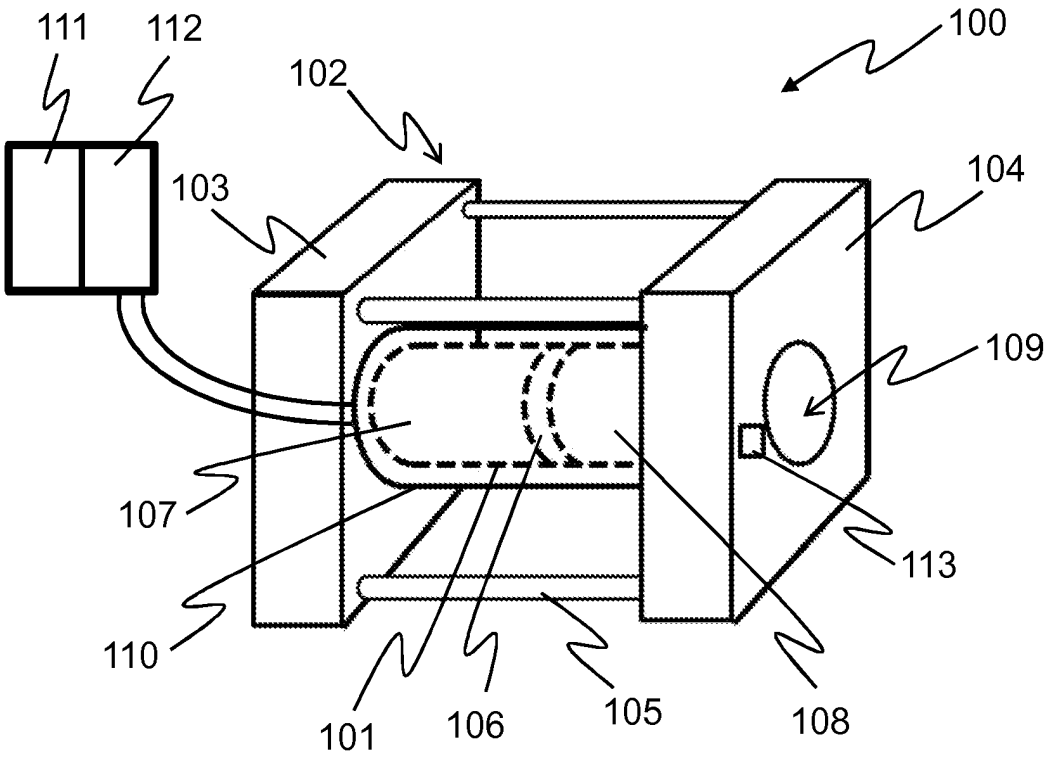
111
112
102
100
103
104
109
107
113
110
101
106
105
108

Fig. 1

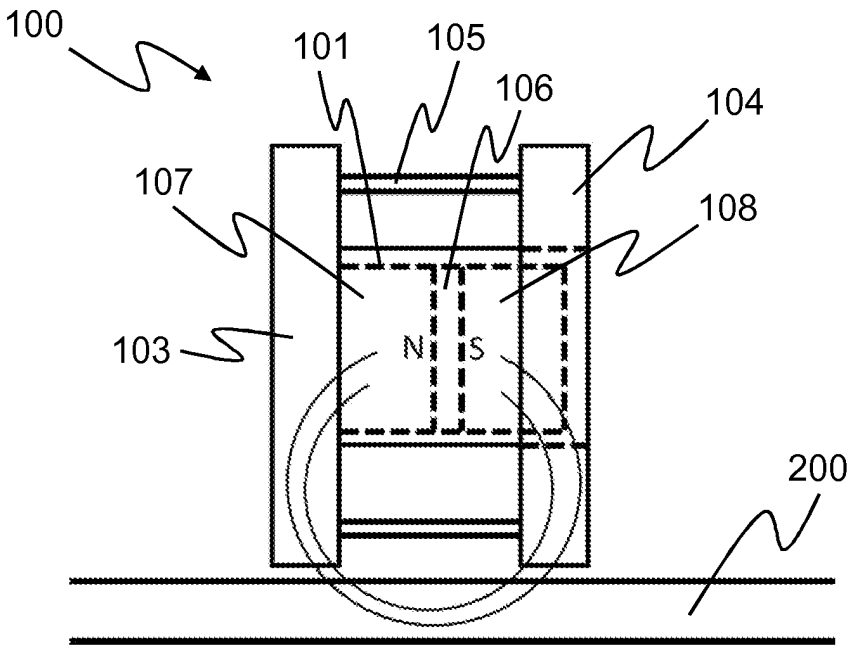
100
101
105
106
104
107
108
103
N
S
200

Fig. 2

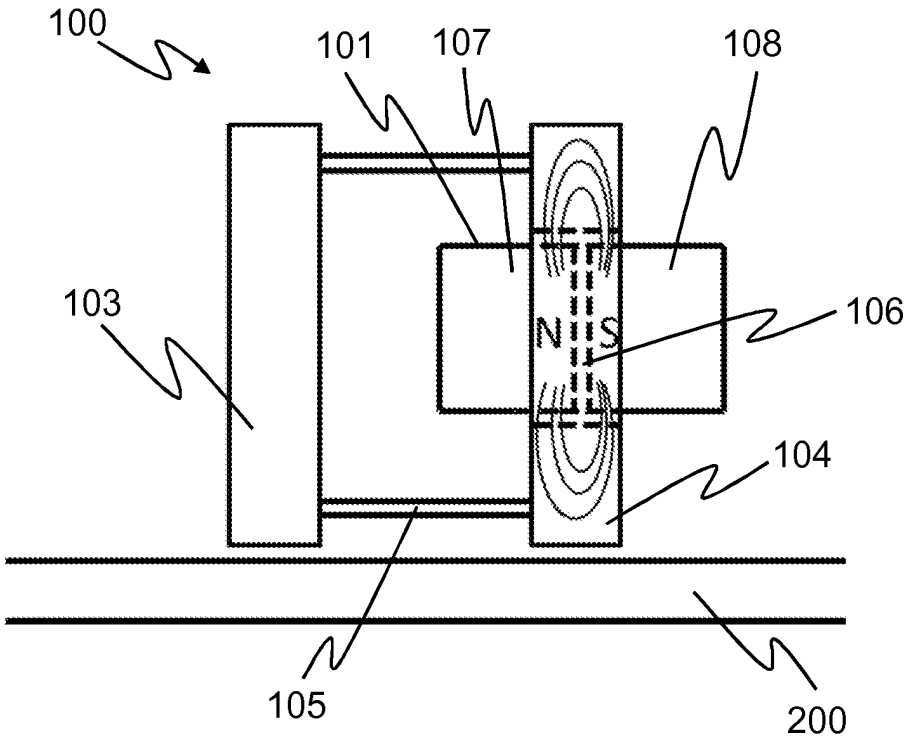
100
101
107
108
103
N
S
106
104
105
200

Fig. 3

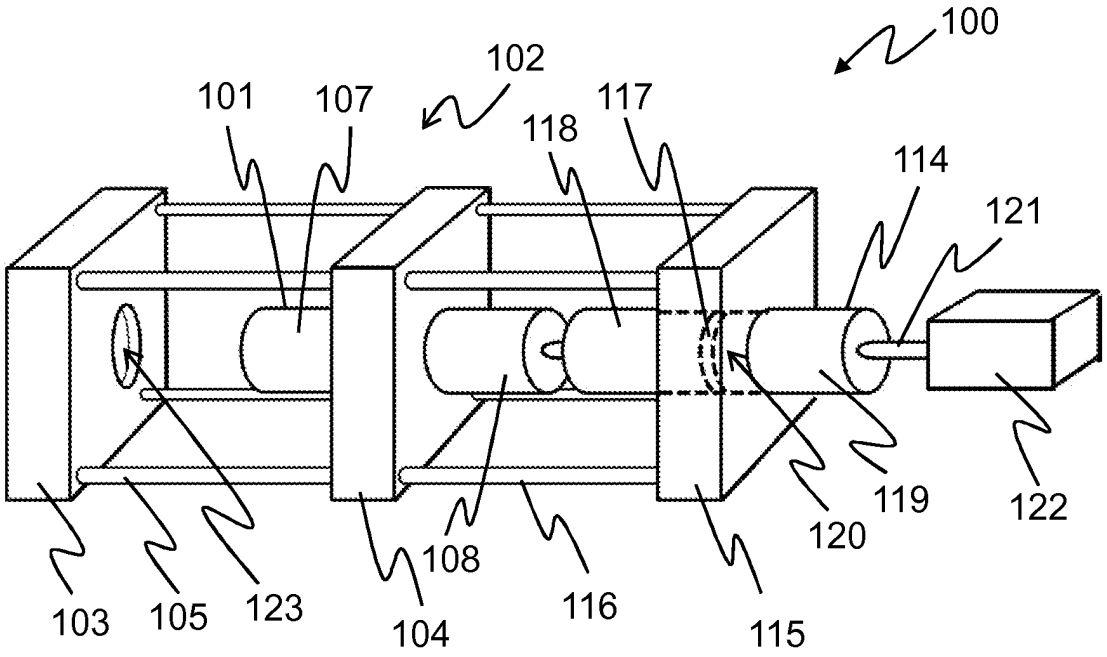
100
102
101
107
118
117
114
121
103
105
123
108
104
116
115
120
119
122

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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