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(54) ROTARY OPERATING ELEMENT

(57) A rotary operating element for controlling a function of a machine is provided. The rotary operating element (10) comprises a shaft (12), wherein the shaft (12) is rotatable to provide a rotary control function and wherein the shaft is actuatable in an axial direction of the shaft to provide an axial control function. The shaft (12) has a default position in the axial direction. The rotary operating element (10) further comprises a restoring assembly (15) configured to apply a restoring force in the axial direction to the shaft (12) to return the shaft into the default position. The restoring assembly (15) is a magnetic restoring assembly that comprises a first component (20) coupled to a housing (11) of the rotary operating element (10) and a second component (30) provided on the shaft (12). The first component (20) and/or the second component (30) comprises a magnet (40). The first component (20) and the second component (30) are configured to interact magnetically to generate the restoring force when the shaft (12) is moved in axial direction out of the default position.

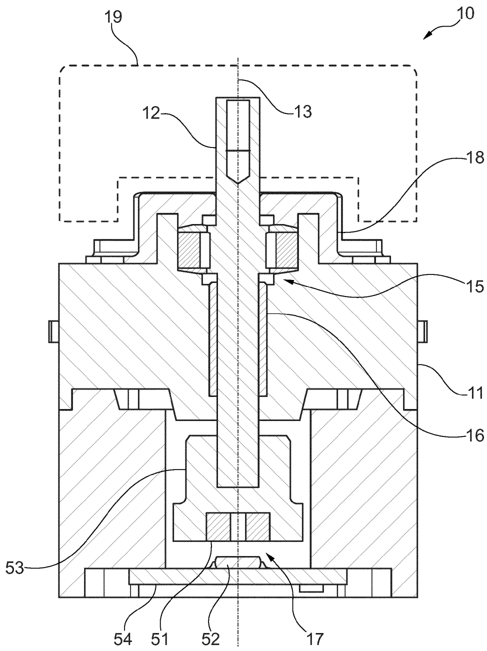

Fig. 1

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Description

BACKGROUND

[0001] Rotary operating elements that are operable also in axial direction, such as a rotary pull/push button, are known in the art and are used in a wide variety of machinery, such as mobile machines. Examples are agricultural or construction vehicles that may comprise a respective rotary operating element.

[0002] Repeated use of such rotary operating element may result in increased wear and may reduce the lifetime. In such harsh operating environment, debris may further enter the control element, which can lead to a malfunction of the mechanical components used therein. To avoid such problems, operating elements that employ optical means for detecting an actuation are known. However, such optical detection may likewise be degraded in such environment, for example by dust particles entering the operating element. Further, the problems related to the mechanical actuation mechanism remain.

[0003] It is thus desirable to provide a compact but robust operating element that can be used in a respective harsh environment. It is in particular desirable to enable a secure operation that does not result in increased wear and in a reduced lifetime of the operating element.

SUMMARY

[0004] Accordingly, there is a need to mitigate at least some of the drawbacks mentioned above and to provide an improved rotary operating element. It is particularly desirable to reduce wear experienced by such rotary operating element while at the same time providing an intuitive operation thereof.

[0005] This need is met by the features of the independent claims. The dependent claims describe embodiments of the invention.

[0006] According to an embodiment of the invention, a rotary operating element for controlling a function of a machine, such as of a mobile machine, in particular of a vehicle, is provided. The rotary operating element comprises a shaft, wherein the shaft is rotatable to provide a rotary control function and wherein the shaft is actuable in the axial direction of the shaft to provide an axial control function. The shaft has a default position in the axial direction. The rotary operating element further comprises a restoring assembly configured to apply a restoring force in the axial direction to the shaft to return the shaft to the default position. The restoring assembly is a magnetic restoring assembly that comprises a first component coupled to (in particular mounted to) a housing of the rotary operating element and a second component provided on the shaft. The first component and/or the second component comprises a magnet. The first component and the second component are configured to interact magnetically to generate the restoring force when the shaft is moved in axial direction out of the default position.

[0007] By providing the rotary operating element (abbreviated herein as "operating element") with a magnetic restoring assembly, the wear associated with a respective mechanical restoring assembly may be avoided. Furthermore, since the shaft needs to be rotated for implementing the rotary control function, wear generally occurs on the mechanical components of the axial control function during such rotation. By employing such magnetic restoring assembly, such wear can be avoided and the shaft may be rotated without causing friction on the mechanical components as in a conventional restoring assembly. Such benefits may in particular be experienced when the shaft is rotated while being pushed or pulled in the axial direction.

[0008] The rotary operating element may in particular be a rotary button, such as a rotary push and/or pull button. The default position may correspond to an equilibrium position of the forces applied to the shaft by the magnetic restoring assembly. The first and second components may in particular interact to maintain the shaft in the default position. It is not precluded that further restoring forces act on the shaft; however, it is preferred that only a magnetic restoring force provided by the magnetic restoring assembly acts on the shaft in axial direction.

[0009] The shaft may be movable from the default position in two axial directions including a pushing axial direction and a pulling axial direction. The magnetic restoring assembly may be configured to generate the restoring force for movement of the shaft in both axial directions. A magnetic restoring force may thus be applied both, when the shaft is moved in the pushing direction and is moved in the pulling direction. The operating element may provide a respective pulling control function and pushing control function, such as switching a particular device or tool on and off, moving a tool up or down, or moving a tool left or right, and the like. In other embodiments, the shaft may be movable only in one axial direction.

[0010] In an embodiment, the magnetic restoring assembly is configured to provide a contactless interaction between the first component and the second component to apply the restoring force to the shaft. Wear may thus be reduced, and debris entering the rotary operating element may only have a limited effect on the functionality of the magnetic restoring assembly. For example, in the default position, a circumferential gap may be present between the first component and the second components, so that they are not in physical contact. The restoring assembly does accordingly not impede the rotation of the shaft and shaft rotation may not result in increased wear.

[0011] The first component may have an annular shape that includes a through-hole. The shaft may extend through the through-hole, wherein in the default position, a first contour of a radially inwardly facing surface of the annular first component faces a second contour of a radially outwardly facing surface of the second component provided on the shaft. Such contours that face each other may facilitate the generation of magnetic force between the first and second components. The contours may for example be rotationally symmetric about the rotation axis. This may avoid forces in radial direction, and may thus support contactless operation of the restoring assembly. The first component may be arranged concentrically with the shaft that includes the second component.

[0012] The first contour and the second contour may be shaped to define the default position. The default position may thus not be mechanically fixed, such as by a latching mechanism or the like, but may be defined by the magnetic interaction.

[0013] The magnetic restoring assembly may be configured to generate a predefined force profile for the restoring force acting on the shaft at different axial positions of the shaft. A desired force characteristic for the actuation of the rotary operating element may thus be obtained.

[0014] For example, the first contour and the second contour may be shaped to generate a predefined force profile for the restoring force acting on the shaft at different axial positions of the shaft.

[0015] The magnetic restoring assembly may be configured to generate a force profile for the restoring force that has a maximum at an axial position of the shaft that is located between the default position and an axial position of the shaft at an end stop, e.g. in push and/or pull direction.

[0016] For example, the first contour and the second contour may be shaped to generate a force profile for the restoring force that has a maximum at an axial position of the shaft that is located between the default position and an axial end stop of the shaft. When the user actuates the operating element in axial direction, the user will thus experience an increased force that has to be overcome before reaching, e.g., a position of the shaft at which the respective control function is triggered. A pressure point may thus be generated in the force profile that provides haptic feedback to the user. In particular, by overcoming such pressure point when pushing or pulling the operating element, the user will know precisely whether or not he has actuated the function he/she intends to control.

[0017] The force profile may be shaped such that if the shaft is moved past the position at which the restoring force has a maximum, the restoring force drops again. The user thus obtains a clear indication that the maximum, i.e. the pressure point, has been passed.

[0018] In a particular implementation, the shaft may be actuable from the default position into a pushing axial direction to provide a push control function and into a pulling axial direction to provide a pull control function. The first contour and the second contour may be shaped such that the force profile of the restoring force has a respective maximum for both the push axial direction and the pull axial direction. Haptic feedback may thus be provided for either direction of actuation. It is also conceivable to provide plural (e.g. local) maxima in the force profile for one or for both axial directions of actuation. The user may thus experience plural pressure points when either pulling or pushing the shaft.

[0019] The restoring force at the first maximum may be similar to or may be different from the restoring force at the second maximum. The restoring force at the second maximum is preferably smaller than at the first maximum, so that the force required by the user to overcome the pressure point in a pulling direction is smaller than the force required for overcoming the pressure point in the pushing direction. This may improve the haptic experience for the user as pushing is generally performed more effortless than pulling.

[0020] It is also conceivable that the first contour and the second contour are shaped such that the force profile comprises an axial position of the shaft at which the restoring force changes sign to provide a locked position of the shaft that is different from the default position. The force profile may in particular change sign twice, wherein at the second intersection of the force profile with the zero force, a second stable position may be generated at which the shaft will be locked when actuated to that position. This may allow latching the shaft at a particular position to continuously activate the respective control function, until the user brings back the shaft into the default position. Such locked position may also be provided at an end stop of the shaft in axial direction, which simplifies the force profile required for implementing a locked position.

[0021] In an embodiment, the first component comprises one, two, or more protrusions extending in radial direction towards the shaft and/or the second component comprises one, two, or more protrusions extending in a radial direction away from the shaft. At least in the default position of the shaft, at least one of the protrusions of the respective component forms part of a magnetic path towards the respective other component. Such protrusion may close a magnetic path or may form part of a magnetic circuit from the magnet through the respective other component. Such configuration may allow the generation of relatively high restoring forces and may further provide an improved definition of the default position. If two or more protrusions are provided on the same component, they may be spaced apart in axial direction. A protrusion may be continuous in circumferential direction, i.e. it may be a ring-shaped protrusion, or it may be provided as one or more sections in circumferential direction. A ring-shaped or rotationally symmetric protrusion may provide symmetrical forces that facilitate centering the shaft in radial direction in the restoring assembly.

[0022] The first contour may for example be defined by the one, two or more protrusions of the first component. The second contour may be defined by the one, two, or more protrusions of the second component. Preferably, in the default position of the shaft, at least one or two of the protrusions on the first component are arranged radially opposite to at least one or two of the protrusions on the second component, respectively, they may in particular face each other. By such arrangement of the protrusions, a defined alignment and a high holding force may be achieved in the default position.

[0023] At least two of the protrusions on the first component and/or at least two of the protrusions on the second component may have a different extension in axial direction configured to generate an asymmetric force profile of the restoring force. By such configuration, the haptic feedback experienced by the user may be adjusted in an efficient manner. Such configuration may in particular allow the generation of different maxima of the force profile for different axial directions of movement of the shaft. If the second component is for example provided with a protrusion closer to a knob/handle of the shaft and a protrusion further away from the knob/handle of the shaft, the axial extension of the latter protrusion may be made larger to reduce the maximum pulling force in the force profile. Preferably, at least two protrusions on the second component are provided with different axial extensions, which may simplify the mechanical configuration.

[0024] At least one protrusion on the first component may have a different axial extension than a protrusion on the second component that it faces in the default position. The change in restoring force with axial movement of the shaft may be made less steep (for the contribution of these facing protrusions) which allows tuning of the force profile and also reduction of the maximum restoring force for the respective axial direction.

[0025] In an embodiment, the number of protrusions of the second component may be different from the number of protrusions of the first component to achieve a predefined force profile of the restoring force. Such additional protrusions may allow modulating the force profile in the desired way. Interaction of an additional protrusion on the shaft with a protrusion of the first component may for example generate additional force after the shaft has been moved for a predefined distance in axial direction. More protrusions may for example be provided by the second component than by the first component.

[0026] In a particular implementation, the first component may comprise one, two, or more return rings that are arranged concentrically with the rotational axis. The shaft including the second component may be arranged radially inwardly of the one, two, or more return rings, wherein the one, two, or more return rings may form part of a magnetic path towards the second component. Such rings may provide a simple mechanical implementation that closes a magnetic circuit via the second component. Each return ring may form a respective protrusion at its radially inner edge, i.e. the above-mentioned ring-shaped protrusion. The inner radial surface of each return ring may face a respective ring-shaped protrusion of the second component when the shaft in the default position.

[0027] The first component may for example comprise a ring magnet, which may be concentric with the shaft. Such ring magnet may be arranged between two of the return rings (and concentrically therewith). Each return ring for example protrudes radially inwardly from the ring magnet and may thus form a respective ring-shaped protrusion.

[0028] The first component may for example comprise one, two, or more magnets, e.g. ring magnets. The first component may comprise one, two, three, or more return rings. The one, two, or more magnets may be arranged between respective two, three, or more return rings. Between two return rings, one, two, or more magnets may for example be arranged (in axial direction). If three or more return rings are provided, one, two, or more magnets may for example be stacked between at least one pair or between each pair of return rings.

[0029] The second component may similarly comprise one, two, or more magnets.

[0030] The magnet may be a permanent magnet or may be an electromagnet. A magnet may be provided in one of the first and second components, or in each of these components. One component may be provided with a permanent magnet, and the other with an electromagnet, or both with the same type of magnet. The first component may for example comprise a respective winding of an electromagnet, which may be concentric with the shaft. In other implementations, a winding may be provided on the second component, e.g. around or within the shaft. Any combinations are conceivable.

[0031] The first and/or second component may also be provided with plural magnets of the same type or of a different type.

[0032] In an embodiment, at least one of the first component and the second component comprises an electromagnet, and the operating element further comprises a controller configured to control the restoring force applied by the magnetic restoring assembly in dependence on an axial position of the shaft. Control may for example be provided by controlling a current through the electromagnet. The force profile may thus be determined by the controller, alone or optionally in combination with the shape of the above-mentioned contours. The force profile may thus also be adjusted dynamically, e.g. in dependence on an operating mode of the control element. The controller may be configured to control the restoring force in accordance with any of the force profiles disclosed herein (e.g., a force profile having one or more pressure points and/or one or more locked positions).

[0033] The second component may be mounted to the shaft or may be formed integrally with the shaft. The second component and/or the return rings may comprise or consist of soft iron. The rotary operating element may not have a mechanical return element for the axial direction, i.e. the restoring force in axial direction may solely be supplied by the magnetic return element.

[0034] The operating element may further comprise a bushing that supports the shaft. The bushing may be configured to allow an axial movement and a rotational movement of the shaft. The bushing may for example provide a glide bearing.

[0035] In an embodiment, the rotary operating element further comprises a magnetic sensor configured to detect a rotation of the shaft and/or to detect an axial movement of the shaft. Preferably, the detection occurs contactless. By providing a contactless restoring force and providing a contactless detection, wear of the operating element can further be reduced and the operating element is made particularly resistant to debris and harsh environments. The electrical and mechanical configuration may further be simplified by detecting both the axial actuation and the rotary actuation by the same magnetic sensor.

[0036] The operating element may further comprise a permanent magnet element mounted to the shaft, in particular to an axial end of the shaft that is opposite to the end that is to be actuated by the user. The magnetic sensor may be mounted spaced apart from the end of the shaft, in particular from the permanent magnet element. Rotation of the shaft may for example lead to a rotating magnetic field which may be detected by the magnetic sensor. Axial movement of the shaft may result in a different field strength (due to the different distance) that is detected by the magnetic sensor. The same magnetic sensor may thus detect both the rotation and the axial actuation of the shaft by detecting changes to the magnetic field generated by the permanent magnet element.

[0037] The sensor may for example be a Hall-sensor. The Hall-sensor may be provided on an integrated circuit that is mounted on a circuit board of the rotary operating element. The magnetic sensor, in particular the integrated circuit, may provide two or more Hall-sensors, thus providing redundancy and fail-safe operation.

[0038] The rotary operating element may further include an axial stop for stopping a movement of the shaft in axial direction, either in one or both directions if provided. Such axial stop may be provided by a housing part and/or by a bushing supporting the shaft and/or by the first component. The axial stop may for example include a protrusion on the shaft that makes contact with the respective housing part or first component. An axial stop is preferably provided in push direction and is arranged such that the above-mentioned magnet element is spaced apart from the magnetic sensor when the axial stop in push direction is engaged. A contactless operation of the magnetic sensor may thus be ensured.

[0039] According to a further embodiment of the invention, a machine, in particular a mobile machine, such as an agricultural, construction, or industrial vehicle is provided. The machine comprises a rotary operating element having any of the configurations disclosed herein for controlling a function of the machine. By such machine, advantages similar to the ones outlined further above may be achieved.

[0040] According to a further embodiment of the invention, a method of operating a rotary operating element for a controlling a function of a machine is provided. The operating element may have any of the configurations described herein. The method comprises moving the shaft of the operating element in axial direction out of the default position and generating the restoring force by magnetic interaction between the first component and the second component of the magnetic restoring assembly. By such method, a contactless operation in axial direction may be achieved. Further, advantages similar to the ones outline above with respect to the rotary operating element may be achieved by such method.

[0041] It is to be understood that the features mentioned above and those yet to be explained below can be used not only in the respective combinations indicated, but also in other combinations or in isolation, without leaving the scope of the present invention. In particular, the features of the different aspects and embodiments of the invention can be combined with each other unless noted to the contrary.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] The forgoing and other features and advantages of the invention will become further apparent from the following detailed description read in conjunction with the accompanying drawings. In the drawings, like reference numerals refer to like elements.

Fig. 1 is a schematic drawing showing a sectional side view of a rotary operating element according to an embodiment.

Fig. 2 is a schematic drawing showing an enlarged section of the rotary operating element of figure 1.

Fig. 3 is a schematic drawing showing an exemplary implementation of the magnetic restoring assembly of figure 2.

Fig. 4 is a diagram showing a restoring force profile of the magnetic restoring assembly of figure 3.

Fig. 5 is a schematic drawing showing an exemplary implementation of the magnetic restoring assembly of figure 2.

Fig. 6 is a diagram showing a restoring force profile of the magnetic restoring assembly of figure 5.

Fig. 7 is a schematic drawing showing an exemplary implementation of the magnetic restoring assembly of figure 2.

Fig. 8 is a diagram showing a restoring force profile of the magnetic restoring assembly of figure 7.

Fig. 9 is a schematic drawing showing an exemplary implementation of the magnetic restoring assembly of figure 2.

Fig. 10 is a diagram showing a restoring force profile of the magnetic restoring assembly of figure 9.

Fig. 11 is a schematic drawing showing an exemplary implementation of the magnetic restoring assembly of figure 2.

Fig. 12 is a flow diagram illustrating a method of operating a rotary operating element according to an embodiment.

DETAILED DESCRIPTION

[0043] In the following, embodiments of the invention will be described in detail with reference to the accompanying drawings. It is to be understood that the following description of the embodiments is given only for the purpose of illustration and is not to be taken in a limiting sense. It should be noted that the drawings are to be regarded as being schematic representations only, and elements in the drawings are not necessarily to scale with each other. Rather, the representation of the various elements is chosen such that their function and general purpose become apparent to a person skilled in the art. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprising," "having," "including," and "containing" are to be construed as openended terms (i.e., meaning "including, but not limited to,") unless otherwise noted.

[0044] Fig. 1 schematically illustrates a rotary operating element 10 implemented as a rotary push and pull button. In other implementations, it may only be a rotary push button or a rotary pull button. It comprises a knob or button 19 to be actuated by a user that has a recess for receiving the rotary shaft 12. The user can push or pull knob 19 to actuate shaft 12 in axial direction to activate a respective axial control function and can rotate the knob 19 to rotate shaft 12 about rotational axis 13 in order to operate a rotary control function. A bushing 16 supports shaft 12 rotationally in housing 11 such that it is actuable in axial direction, i.e. in a direction parallel to the rotational axis 13. Bushing 16 provides a sliding bearing; however, other types of rotational support may be provided.

[0045] Restoring assembly 15 returns the shaft to a default position, in particular an equilibrium position, when the operating element 10 is not actuated (in axial direction). Assembly 15 is a magnetic restoring assembly that employs magnetic interaction to provide a force in axial direction that returns the shaft to the default position, which is illustrated in Fig. 1. The magnetic restoring assembly 15 will be described in more detail further below.

[0046] A sensor assembly 17 detects both axial operation and rotational operation of the operating element 10. Sensor assembly 17 includes a magnet element 51 mounted by the magnet holder 53 to the shaft 12 and magnetic sensor 52. Magnet element 51 may be magnetized in a direction perpendicular to rotational axis 13 (e.g., north pole on the left side and a south pole on the right side in Fig. 1), or may include any other configuration, such as a ring magnet having plural opposing poles distributed circumferentially, so that two north poles and two south poles for example face the magnetic sensor 52. Rotation of shaft 12 thus results in a rotating magnetic field that is sensed by magnetic sensor 52 to detect rotary actuation. Movement of shaft 12 in axial direction results in a different field strength being experienced by magnetic sensor 52, so that the axial position of shaft 12 and thus a push or pull operation of operating element 10 can be detected. A reliable and contactless detection of the actuation of rotary operating element 10 is thus achieved. Magnetic sensor 52 is provided on circuit board 54 that is mounted to housing 11. A Hall-sensor may for example be used. It should be clear that the geometric configuration of the arrangement of magnetic element 51 and magnetic sensor 52 can be changed and can be adapted in accordance with the spatial requirements.

[0047] Magnet element 51 is mounted to an end of shaft 12 that is opposite to the end to which the knob 19 is mounted. Magnet element 51 is arranged rotationally symmetrically about the rotation axis 13. Magnet element 51 faces and is spaced apart from the magnetic sensor 52.

[0048] Fig. 2 is an enlarged section of the drawing of Fig. 1 that illustrates the restoring assembly 15 in more detail. Restoring assembly 15 comprises a first component 20 that is mounted to the housing 11 and a second component 30 that is provided on the shaft 12. Second component 30 is in the present example integral with shaft 12, but it may also be or comprise a separate component that is mounted to shaft 12 or integrated therein. A magnet 40 is provided in the first component 20 but may additionally or alternatively be provided in second component 30. Both component 20 and component 30 are rotationally symmetric about the rotational axis 13 of shaft 12. Component 20 has a radially inwardly facing contour 21 that faces the radially outwardly facing contour 31 of the second component 30. Contour 21 of component 20 comprises the protrusions 25 and 26 protruding radially inwardly, they are ring-shaped protrusions in the present example. The contour 31 of the second component 30 comprises protrusions 35 and 36 that extend radially outwardly and similarly form ring-shaped protrusions. Protrusion 35 is shaped and arranged to face protrusion 25, and protrusion 36 is shaped and arranged to face protrusion 26.

[0049] The protrusions 25, 26 and 35, 36, and in particular the parts providing these protrusions, may be made of soft iron material. Magnet 40 may be a ring magnet that is magnetized to have opposite magnetic poles at its respective opposite annular end faces.

[0050] It may for example present a north pole on the annular end face 40-1 and a south pole on the annular end face 40-2, or vice versa. Protrusions 25, 26 may be provided by annular return rings 27, 28 between which the magnet 40 is arranged. Via return rings 27, 28 and their protrusions 25, 26, and via the second component 30 and its protrusions 35, 36, a magnetic circuit is thus formed. The magnetic field lines will concentrate in the return rings 27, 28 and a magnetic path is formed via the second component 30 that closes the magnetic field lines. The magnetic field lines may in particular concentrate in the soft iron material of the return rings 27, 28 and of the second component 30.

[0051] Opening this magnetic circuit by either pulling or pushing the shaft 12 thus requires the application of a force, and the restoring assembly 15 generates a respective restoring force that acts to bring the shaft 12 back into the equilibrium position illustrated in Fig. 2. The restoring assembly 15 can be adapted to generate a desired force profile for the restoring force, which can be the same or can be different for the pulling direction and the pushing direction of shaft 12. The force profile can be adapted by adjusting properties of magnet 40, adapting the position where magnet 40 is placed, adapting the shape of the contours 21, 31, adapting the material of the protrusions, and the like. To increase the restoring force or further modulate the restoring force, further magnetic restoring assemblies 15 may be provided on shaft 12.

[0052] A gap is present between the first component 20 and the second component 30, in particular between the respective protrusions that face each other. The restoring force is thus applied contactlessly to the shaft 12. Further, rotation of shaft 12 is not impeded by the restoring assembly 15. Restoring assembly 15 thus provides no resistance to the rotation and significantly reduces wear of the operating element 10, even when used in harsh conditions.

[0053] Operating element 41 further comprises an axial stop 41 in push direction that is contacted by a protrusion on shaft 12 to stop any further axial travel of the shaft. Axial stop 41 is formed by bushing 16 in the present example. Further, an axial stop 42 in pull direction is provided by housing 11. A protrusion on shaft 12 contacts axial stop 42 to prevent any further movement of shaft in pull direction. The protrusions on the shaft are in the present example provided by the protrusions of the second component 30, thus implementing two functionalities in component 30 and improving the compactness of element 10. In other embodiments, axial stops 41, 42 may be provided at another position and may be contacted by another part of the shaft.

[0054] Fig. 3 schematically illustrates the restoring assembly 15 of Fig. 2 wherein other components of operating element 10 are not shown to simplify the presentation. Fig. 3 illustrates a situation in which the shaft 12 has been pulled (in positive Z-direction) so that a restoring force acts towards the default position (in negative Z-direction). Protrusions 25, 26 and 35, 36 are of a similar size (with respect to their extension in axial direction) and are arranged so that they face each other in the default position. For such symmetric configuration, the force profile for the restoring force F illustrated in Fig. 4 is obtained. It can be seen that the restoring force F reaches a maximum value at position 71, which corresponds to the position shown in Fig. 3 (the force value is negative in Fig. 4 as it acts in negative Z-direction). When shaft 12 is pushed, the restoring force F reaches a maximum at position 72. Due to the symmetric configuration, the force at maxima 71, 72 has a similar magnitude. As the restoring force becomes smaller again once the maximum value has been passed, the user will experience a point of resistance (pressure point) when actuating the operating element 10 either in push or in pull direction. The maxima 71, 72 thus constitute pressure points that provide haptic feedback to the user. This allows the user to safely recognize when the respective function controlled by the control element is activated.

[0055] Fig. 5 illustrates a further exemplary implementation of the restoring assembly 15 of Fig. 2. To reduce the maximum value of the restoring force that has to be overcome by the user when actuating the operating element 10 in the pull direction, the protrusion 36 of the second component 30 has been enlarged in axial direction. In the resulting force profile of Fig. 6, it can be seen that the maximum restoring force 71 in pulling direction is smaller (5 N) than the maximum restoring force 72 in pushing direction (about 6.5 N) that has to be overcome by the user. This may improve the haptic feedback for the user, since the subjective perception is generally such that a higher force needs to be applied for pulling than for pushing even though both forces are the same. The (absolute) force values at the maxima 71, 72 can thus be made different so that the subjective perception of a similar pulling force and pushing force is obtained.

[0056] Fig. 7 illustrates a further possible implementation of the restoring assembly 15 of Fig. 2. For changing the restoring force profile, a further protrusion 39 is provided on the second component 30. The resulting restoring force profile is shown in Fig. 8. Although the sizes of the protrusions 25, 26 and 35, 36 are similar (in particular their axial extension), the maximum pulling force 71 that has to be overcome is further reduced. The maximum restoring force 72 that has to be overcome when actuating shaft 12 in the pushing direction is of a similar value. Further, by means of the further protrusion 39, a zero crossing 73 of the restoring force profile is obtained in the pull-direction. The restoring force is thus reversed, so that the shaft will not by itself return to the default position. A locked position is thereby generated in which the shaft remains until the user pushes the shaft back towards the default position (in particular to a position in which the restoring force acts again towards the default position). Additionally or alternatively, a respective locked position may be provided in the push-direction, e.g. by providing one or more respective protrusions. One or more of such further protrusions 39 may additionally or alternatively be provided on the first component 20, in particular if a magnet is provided on the second component 30.

[0057] A plurality of possibilities thus exists for adapting the contour 31 for changing the restoring force profile.

Additionally or alternatively, the contour 21 may be adapted (e.g. in a similar manner) to adjust the restoring force profile.

[0058] In the example of Fig. 2, a further possibility of adapting the contours 21, 31 is shown. In this example, the axial extension of protrusions 35 is larger than the axial extension of protrusion 25, and the axial extension of protrusion 36 is smaller than the axial extension of protrusion 26. A variety of ways thus exist for adjusting the force profile.

[0059] Fig. 9 illustrates a further example, wherein not only the contours 21, 31 are adapted to adjust the restoring force profile, but a second magnet 40 is provided in the second component 30. The poles of both magnets 40 may be aligned such that the magnetic strength is increased. This is illustrated in Fig. 10, where it can be seen that the maximum restoring force 72 in the pushing direction is increased to almost 10 N. Due to the asymmetric contours 21, 31, the maximum restoring force 71 in pull direction is maintained below 7.5 N. Two pressure points that provide an improved haptic feedback may thus be provided similar to the example of Figs. 5 and 6, but with an overall higher restoring force.

[0060] In the above examples, the magnet 40 is implemented as a permanent magnet, but may also be implemented as an electromagnet. Fig. 11 shows an example in which magnet 40 is implemented as an electromagnet 45. An electromagnet may be provided in the first component 20 and/or in the second component 30. In the first component 20, either magnet sections having windings around them may be distributed circumferentially about the rotation axis 13 (as shown in figure 11), or windings of component 20 may extend circumferentially about the shaft 12 (shaft 12 may then essentially be arranged inside a coil formed by such windings of the first component 20). For the second component 30, such electromagnet 45 may for example comprise windings 44 that are wound about the shaft 12, e.g. in a respective recess provided in the shaft or on the surface of the shaft. Such electromagnet 45 provided in the first component 20 and/or in the second component 30 may in a similar manner generate a magnetic field that applies a restoring force to the shaft 12. As mentioned above, the restoring assembly 12 may comprise an electromagnet in only one of the components 20, 30, or may combine an electromagnet in one component with a permanent magnet in the other component. A combination of an electromagnet and a permanent magnet in the same component is likewise possible.

[0061] Operating element 10 may comprise a controller 46 for controlling the electromagnet 45. A power source 47 may for example be controlled to apply a respective current to the windings in order to control the magnetic field. Changes to the current, e.g. due to changes in flux due to movement of the shaft, may be detected by current sensors 49 and may provide feedback for controller 46. Additionally or alternatively, a position sensor 48 may employed that detects the axial position of shaft 12 for providing feedback to controller 46. Controller 46 may thus control the restoring force profile in dependence on the axial position of the shaft 12. The skilled person will recognize that this allows the implementation of a variety of restoring force profiles, such as any of the force profiles disclosed herein. Besides controlling the restoring force, the controller 46 may additionally or alternatively provide impedance control, which may control a mechanical impedance of the shaft in axial direction in dependence on the axial position of the shaft (using, e.g., stiffness and damping as control variables). An impedance profile may be employed and may define a mechanical target impedance, and the magnetic restoring force generated by the electromagnet 45 may be controlled in accordance with such target impedance. For example, feedback control may be employed (e.g., position-based active impedance control) based on a position detected by position sensor 48.

[0062] The position sensor 48 may be an additional sensor, or position measurements by Hall-sensor 52 may be used.

[0063] The above-described restoring force profiles have two pressure points, one for actuation in pulling direction and one for actuation in pushing direction. The force profiles may be modified to have any desired number of pressure points such as plural or no pressure points in a certain direction of actuation. The restoring force profile may also be adapted so that a locking position is generated, for example by reducing the restoring force so that at a certain point, it changes sign, so that the shaft is driven towards the end stop. Additional protrusions may for example be provided on the second component 20 to generate the respective magnetic force. Additional lock positions may be generated by providing additional protrusions.

[0064] The skilled person will readily appreciate that the above-described ways of modifying the restoring force profile can be combined with each other to generate any desired restoring force profile that is suitable for the particular application of rotary operating element 10.

[0065] Fig. 12 is a flow diagram showing a method of operating a rotary operating element having any of the configurations described herein. In step S 1, the rotary operating element including the magnetic restoring assembly is provided. In step S2, the shaft 12 is moved in axial direction out of the default position. In step S3, the magnetic restoring assembly 15 generates a restoring force that acts on the shaft towards the default position. In step S4, the axial movement of the shaft is detected contactlessly by the magnetic sensor 52. Besides the shaft being supported by the bushing 16, a completely contactless operation of the operating element 10 may thus be achieved. Some steps of the method are optional (such as step S4) and the steps may be performed in a different order or simultaneously, such as steps S2, S3, and S4.

[0066] While specific embodiments are disclosed herein, various changes and modifications can be made without departing from the scope of the invention. The present embodiments are to be considered in all respects as illustrative and non-restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

List of reference signs

[0067]

10	rotary operating element
11	housing
12	shaft
13	rotation axis
15	restoring assembly
16	bushing
17	sensor assembly
18	housing cover
19	knob/button
20	first component of restoring assembly
21	contour of first component
25, 26	protrusion
27, 28	return ring
30	second component of restoring assembly
31	contour of second component
31	contour of second component
35, 36	protrusion
37, 38	return ring
39	protrusion
40	magnet
40-1	magnet annular end face
40-2	magnet annular end face
41	axial stop push direction
42	axial stop pull direction
44	windings
45	electromagnet
46	controller
47	power source
48	position sensor
49	current sensor
51	magnet element
52	magnetic sensor
53	magnet holder
54	circuit board
71	maximum restoring force in pull direction
72	maximum restoring force in push direction
73	zero crossing of restoring force
S1-S4	method steps

Claims

1. A rotary operating element for controlling a function of a machine, wherein the rotary operating element (10) comprises:

- a shaft (12), wherein the shaft (12) is rotatable to provide a rotary control function and wherein the shaft is actuatable in an axial direction of the shaft to provide an axial control function, wherein the shaft (12) has a default position in the axial direction; and
- a restoring assembly (15) configured to apply a restoring force in the axial direction to the shaft (12) to return the shaft into the default position,

wherein the restoring assembly (15) is a magnetic restoring assembly that comprises a first component (20) coupled to a housing (11) of the rotary operating element (10) and a second component (30) provided on the shaft (12), wherein the first component (20) and/or the second component (30) comprises a magnet (40), and wherein the first component (20) and the second component (30) are configured to interact magnetically to generate said restoring force when the shaft (12) is moved in axial direction out of the default position.

2. The rotary operating element according to claim 1, wherein the shaft (12) is movable from the default position in two axial directions including a pushing axial direction and a pulling axial direction, wherein the magnetic restoring assembly (15) is configured to generate the restoring force for movement of the shaft (12) in both axial directions.

3. The rotary operating element according to claim 1 or 2, wherein the magnetic restoring assembly (15) is configured to provide a contactless interaction between the first component (20) and the second component (30) to apply the restoring force to the shaft (12).

4. The rotary operating element according to any of the preceding claims, wherein the first component (20) has an annular shape including a though hole, wherein the shaft (12) extends through the through hole, wherein in the default position, a first contour (21) of a radially inwardly facing surface of the annular first component (20) faces a second contour (31) of a radially outwardly facing surface of the second component (30) provided on the shaft (12).

5. The rotary operating element according to claim 4, wherein the first contour (21) and the second contour (31) are shaped to generate a force profile for the restoring force that has a maximum (72, 71) at an axial position of the shaft (12) that is located between the default position and an axial position of the shaft at an end stop (41, 42).

6. The rotary operating element according to claim 5, wherein the shaft (12) is actuatable from the default position into a pushing axial direction to provide a push control function and into a pulling axial direction to provide a pull control function, wherein the first contour (21) and the second contour (31) are shaped such that the force profile of the restoring force has a first respective maximum (72) when the shaft (12) is moved in the pushing axial direction and has a second respective maximum (71) when the shaft (12) is moved in the pulling axial direction.

7. The rotary operating element according to claim 6, wherein the restoring force at the first maximum (72) is similar to or is different from the restoring force at the second maximum (71).

8. The rotary operating element according to any of the preceding claims, wherein the first component (20) comprises one, two, or more protrusions (25, 26) extending in radial direction towards the shaft (12) and/or the second component (30) comprises one, two, or more protrusions (35, 36, 39) extending in radial direction away from the shaft (12), wherein at least in the default position of the shaft (12) at least one of the protrusions (25, 26; 35, 36) of the respective component (20; 30) forms part of a magnetic path towards the respective other component (30; 20).

9. The rotary operating element according to claim 8 when dependent on any of claims 4-7, wherein the first contour (21) is defined by the one, two, or more protrusions (25, 26) of the first component (20) and/or wherein the second contour (31) is defined by the one, two, or more protrusions (35, 36, 39) of the second component (30).

10. The rotary operating element according to claim 8 or 9, wherein at least two of the protrusions (25, 26) on the first component (20) and/or at least two of the protrusions (35, 36) on the second component (30) have a different extension in axial direction configured to generate an asymmetric force profile of the restoring force.

11. The rotary operating element according to any of the preceding claims, wherein the first component (20) comprises one, two, or more return rings (27, 28) that are arranged concentrically with a rotational axis (13) of the shaft (12), wherein the shaft (12) including the second component (30) is arranged radially inwardly of the one, two, or more return rings (27, 28), wherein the one, two, or more return rings (27, 28) form part of a magnetic path towards the second component (30).

12. The rotary operating element according to any of the preceding claims, wherein the first component (20) comprises a ring magnet (40), wherein the ring magnet is concentric with the shaft (12).

13. The rotary operating element according to any of the preceding claims, further comprising a magnetic sensor (52) configured to detect a rotation of the shaft and/or to detect an axial movement of the shaft, wherein the detection occurs contactlessly.

14. The rotary operating element according to claim 13, wherein the sensor (52) is a Hall sensor.

15. A method of operating a rotary operating element (10) for a controlling a function of a machine, wherein the rotary operating element (10) comprises a shaft (12), wherein the shaft (12) is rotatable to provide a rotary control function and wherein the shaft (12) is actuatable in an axial direction of the shaft to provide an axial control function, wherein the shaft (12) has a default position in the axial direction; and a restoring assembly (15) configured to apply a restoring force in the axial direction to the shaft (12) to return the shaft (12) into the default position, wherein the restoring assembly (15) is a magnetic restoring assembly that comprises a first component (20) coupled to a housing (11) of the rotary operating element and a second component (30) provided on the shaft, wherein the first component (20) and/or the second component (30) comprises a magnet (40), and wherein method comprises:

- moving the shaft (12) in axial direction out of the default position; and
- generating said restoring force by magnetic interaction between the first component (20) and the second component (30).

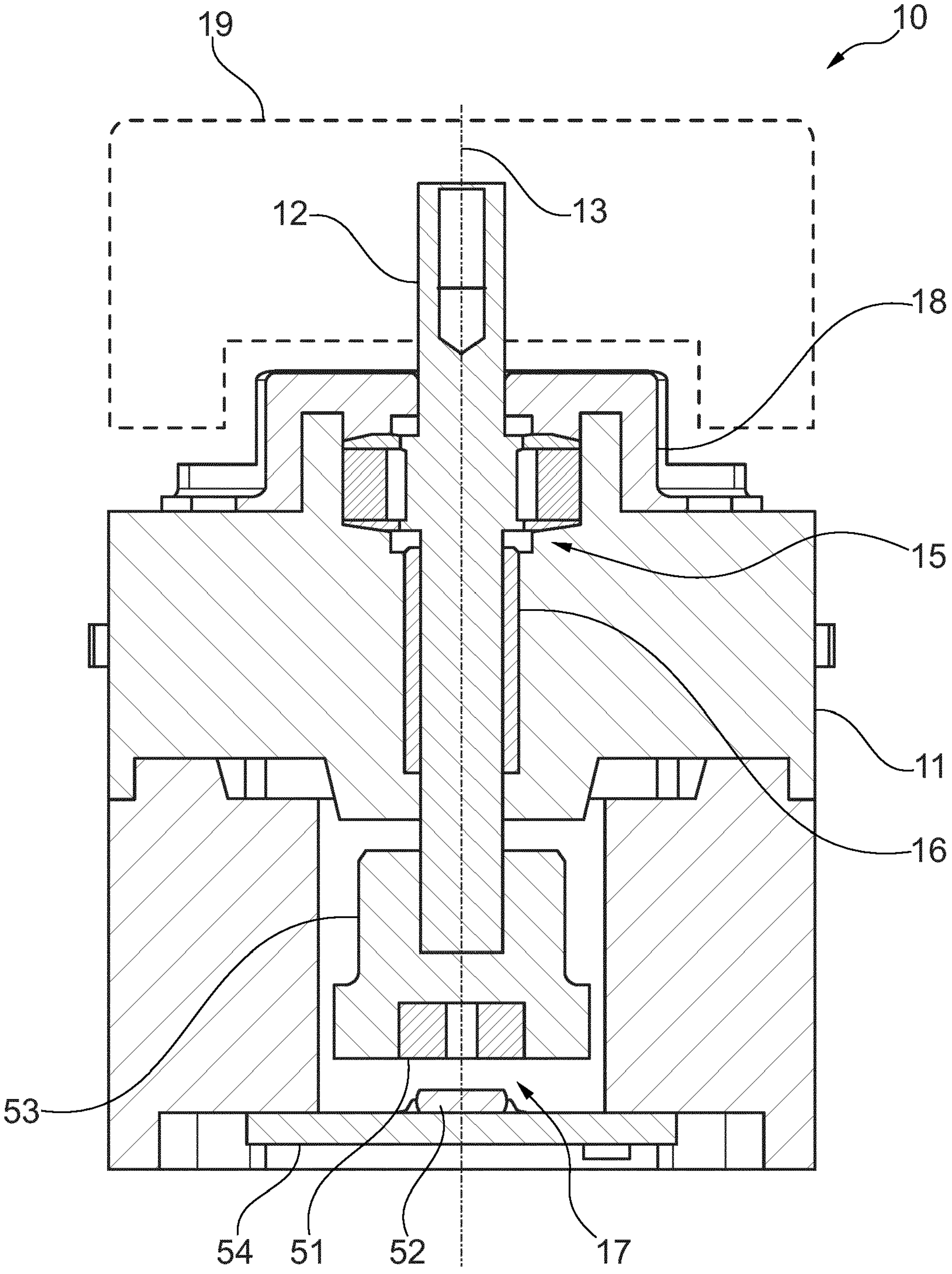

Fig. 1

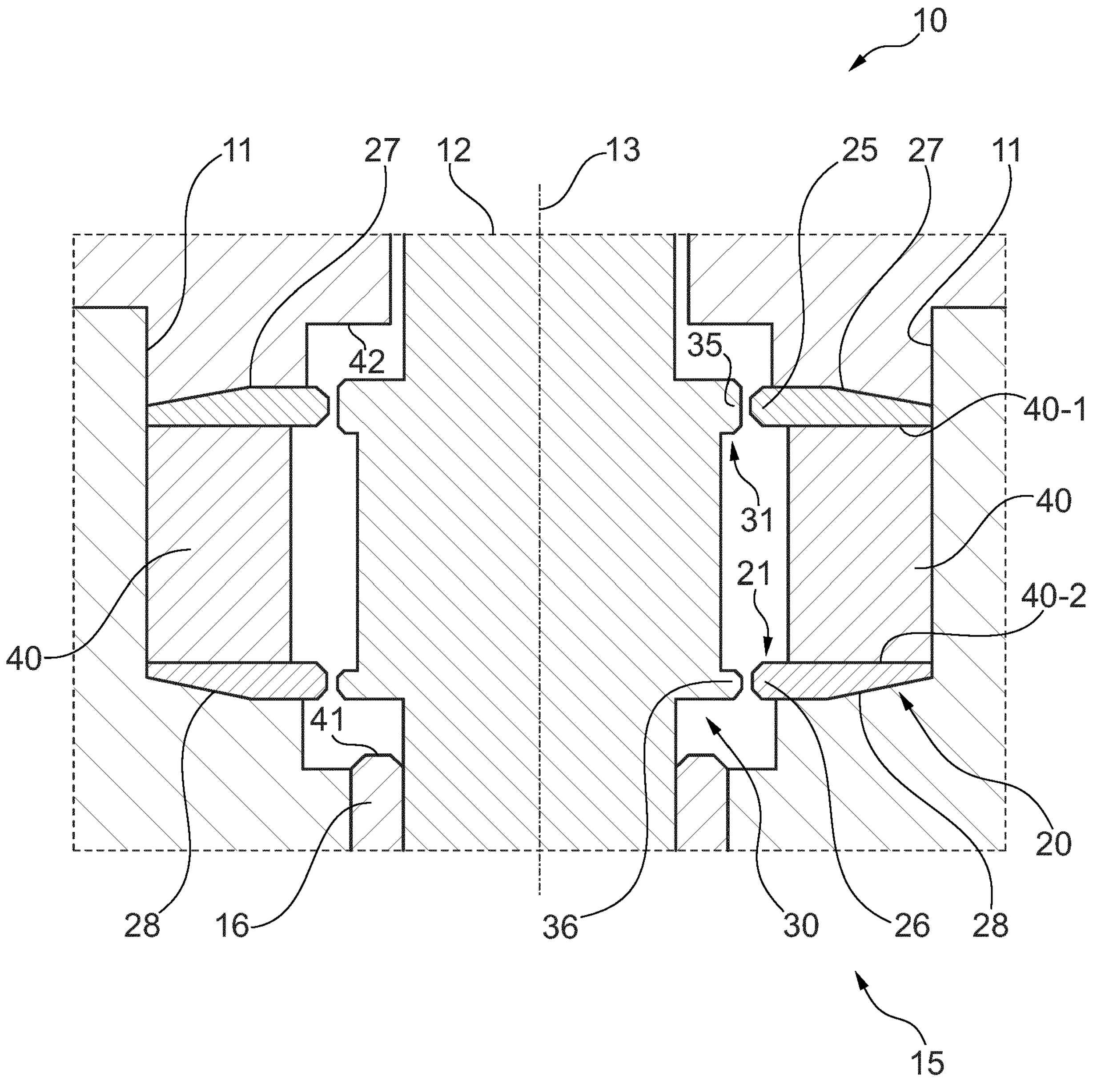
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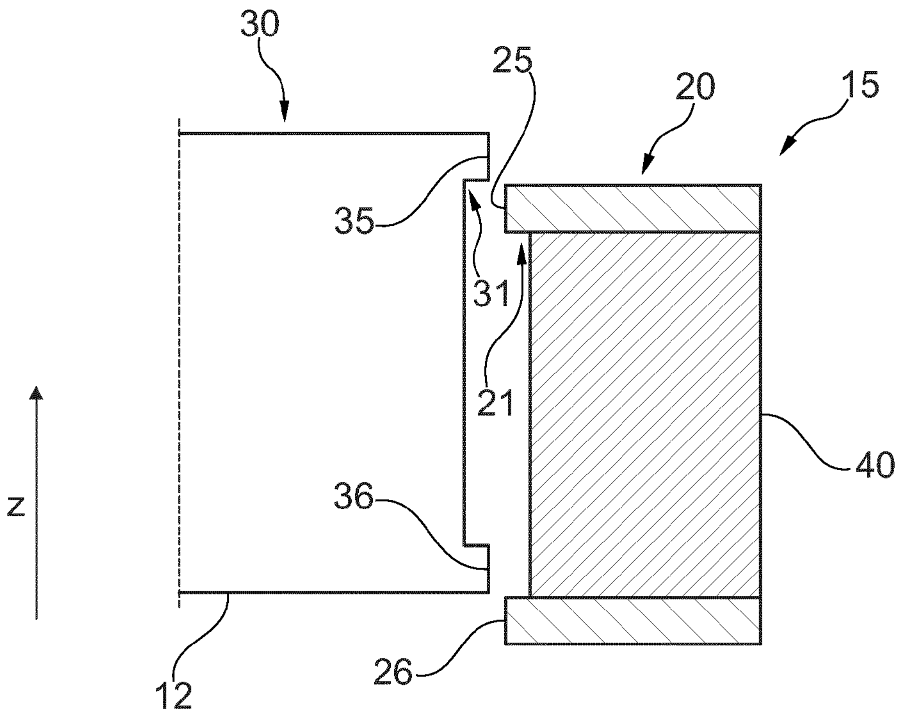
Fig. 2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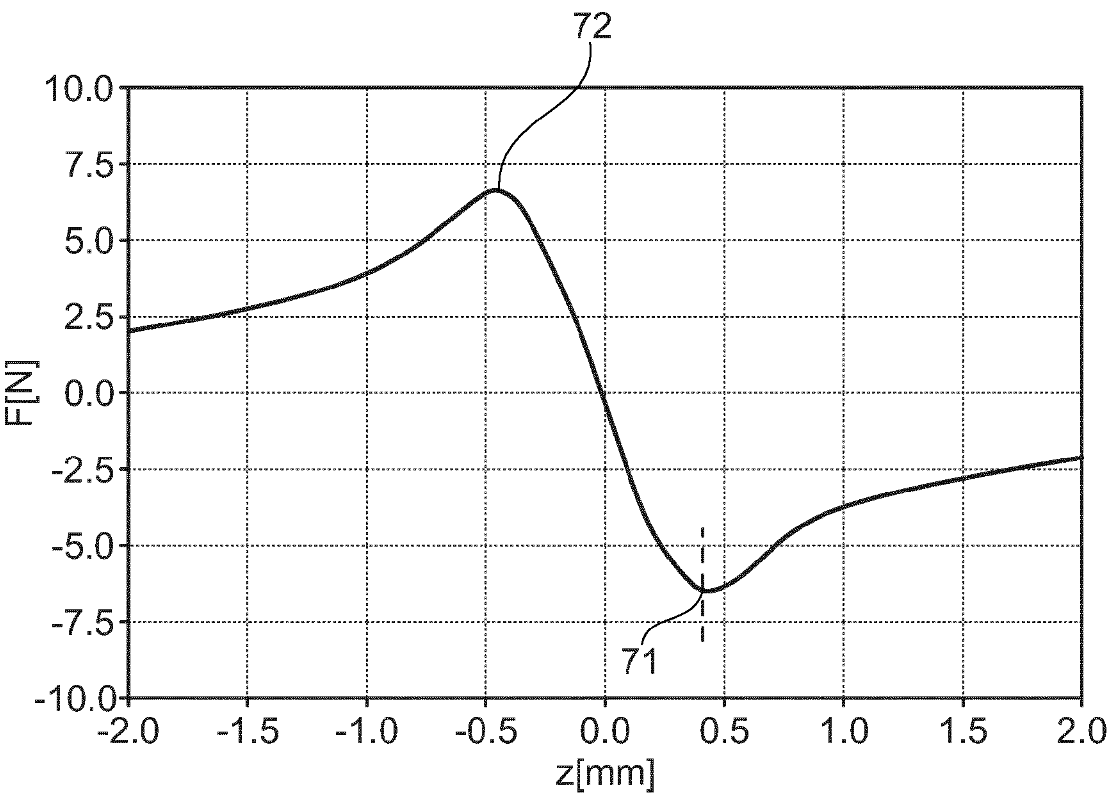
12
26

Fig. 3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71

Fig. 4

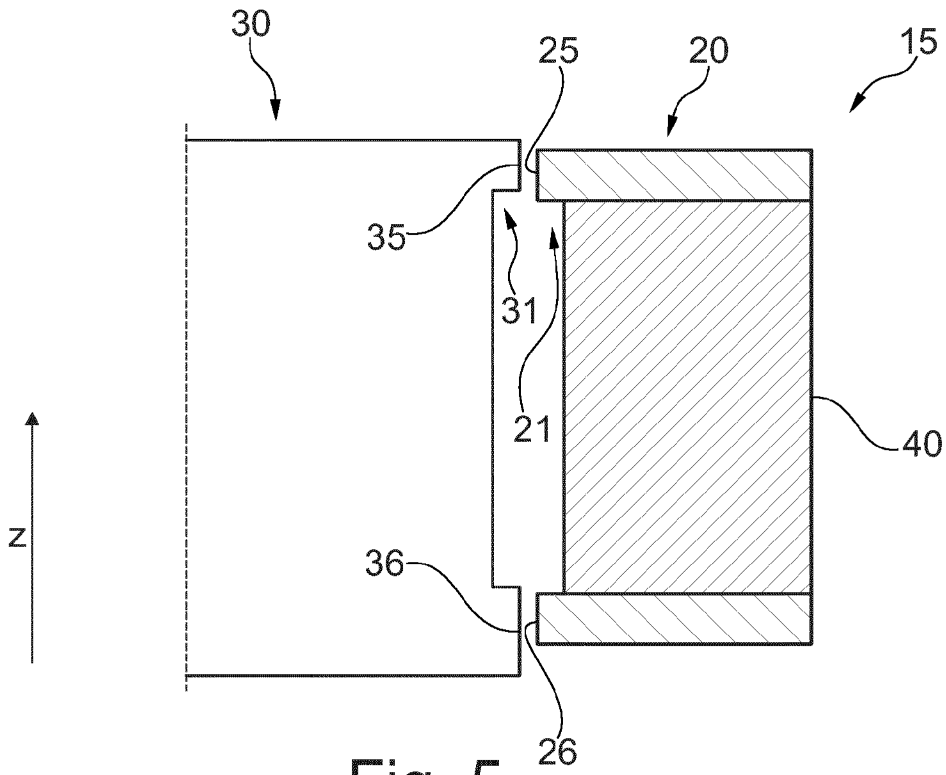
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Fig. 5

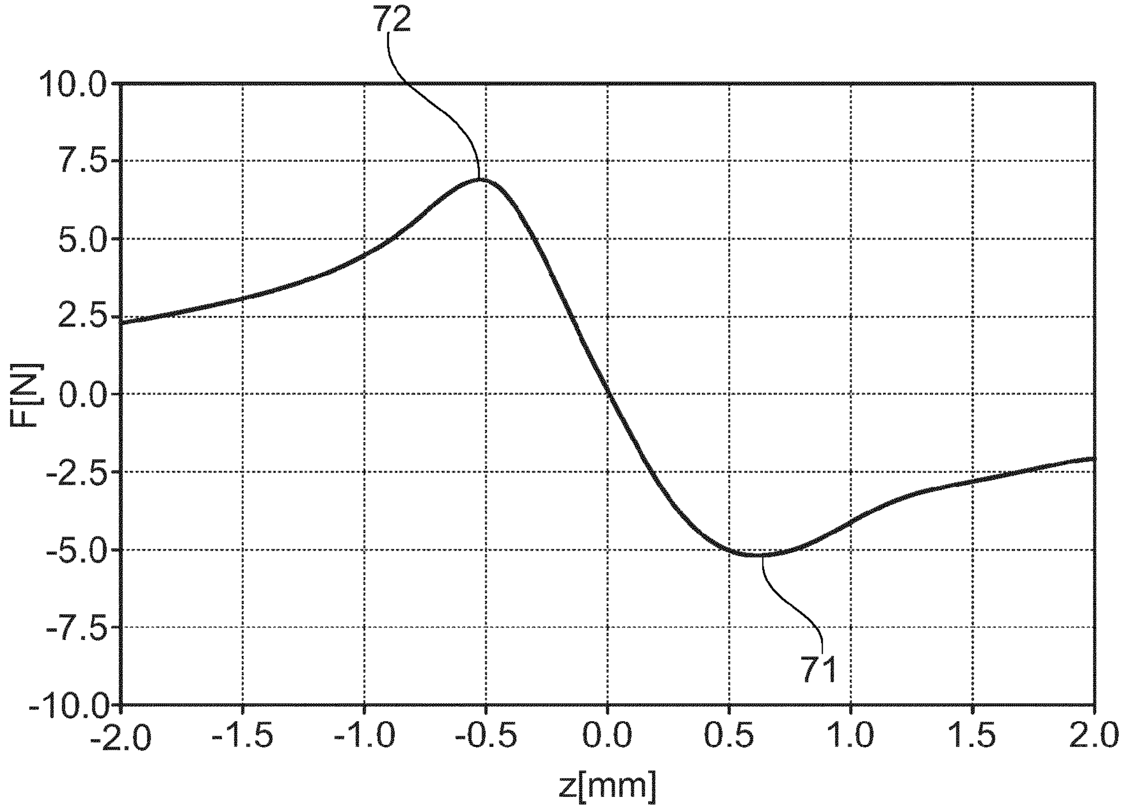
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Fig. 6

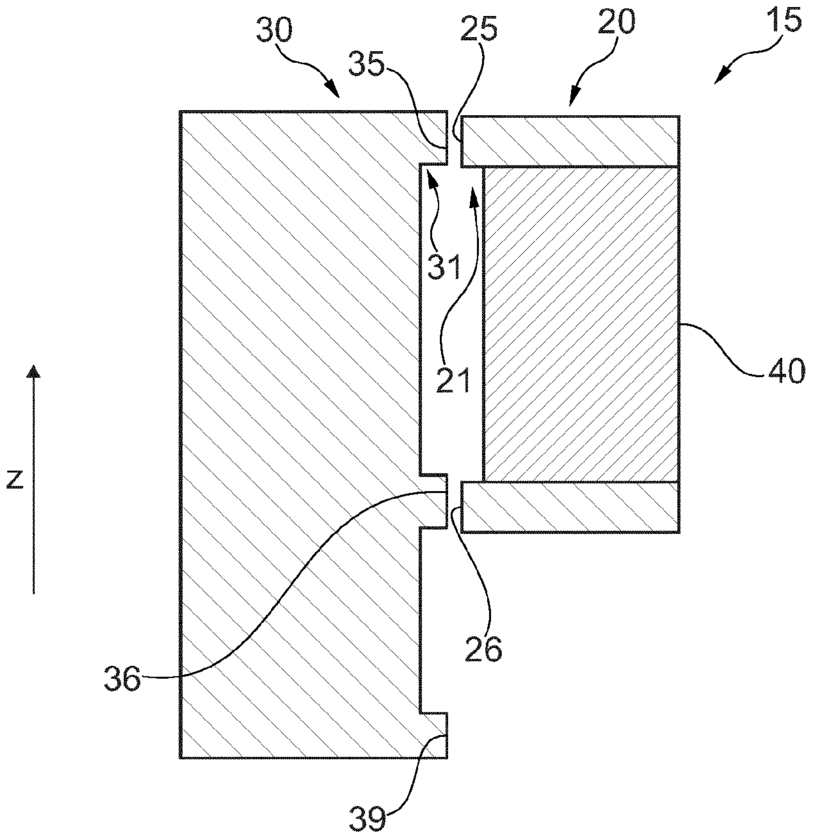
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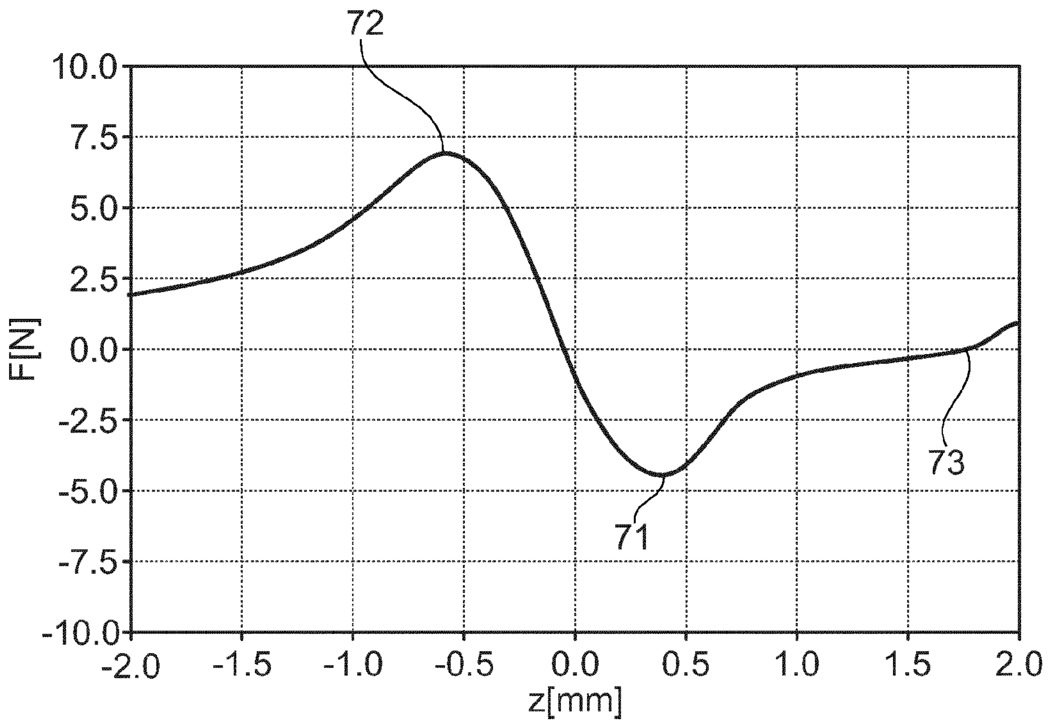
Fig. 7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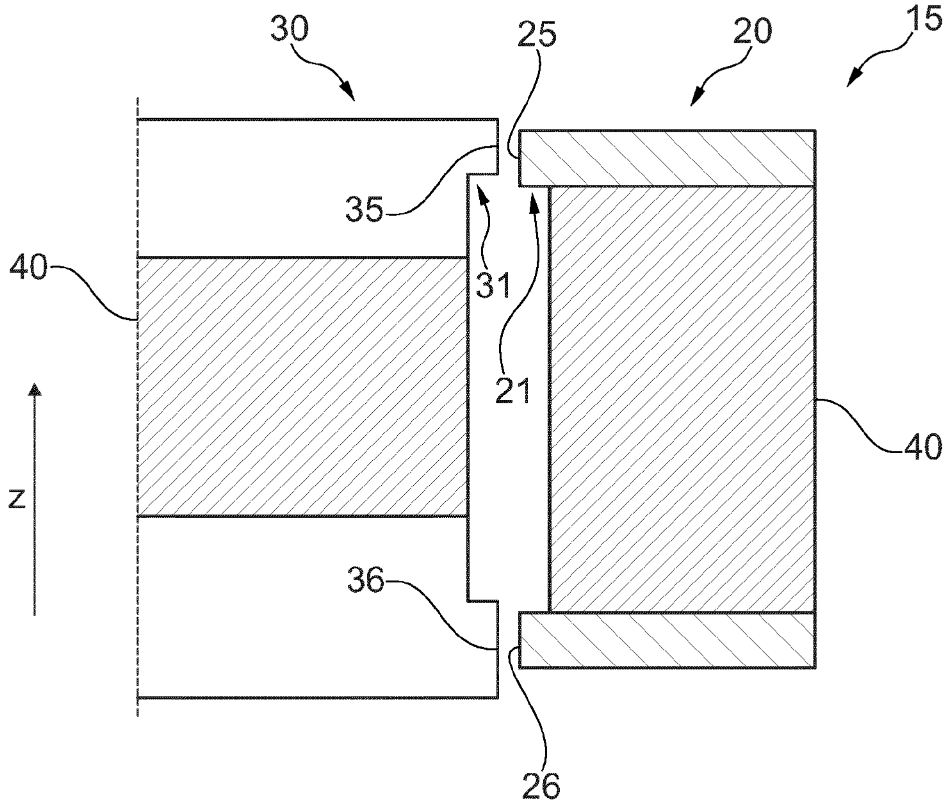
73

Fig. 8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26

Fig. 9

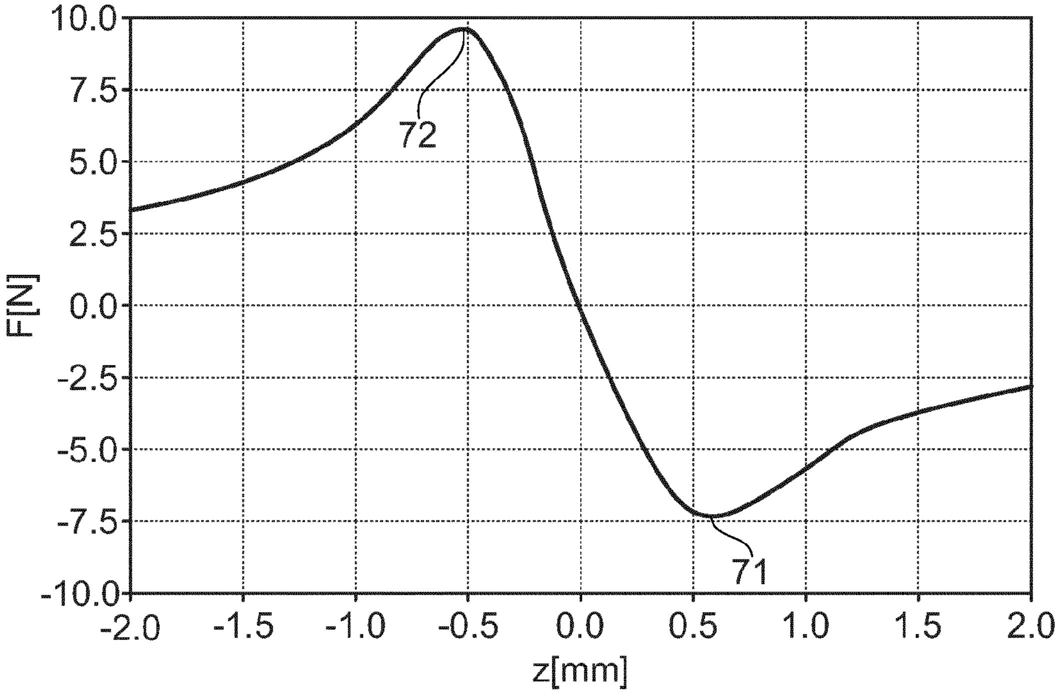
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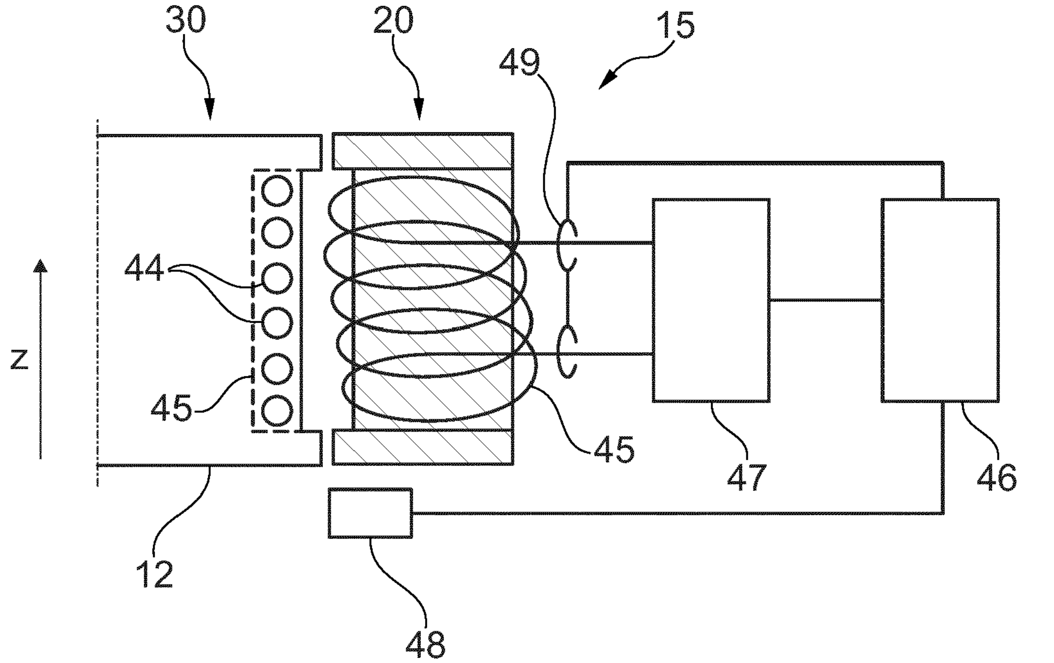
Fig. 10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44
z
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47
46
12
48

Fig. 11

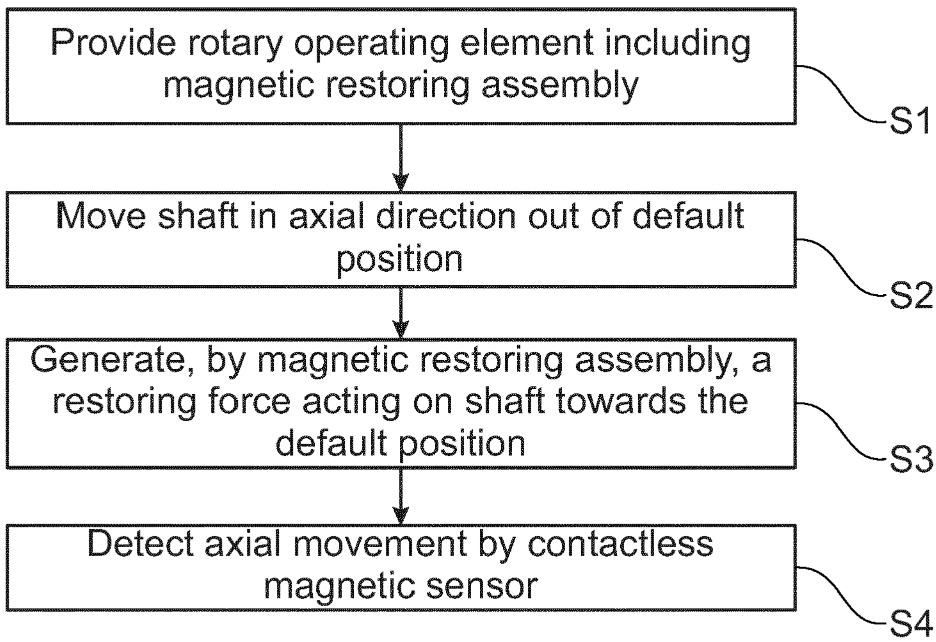
Provide rotary operating element including magnetic restoring assembly
S1
Move shaft in axial direction out of default position
S2
Generate, by magnetic restoring assembly, a restoring force acting on shaft towards the default position
S3
Detect axial movement by contactless magnetic sensor
S4

Fig. 12

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 8597

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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G05G

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	28 April 2024	Huyge, Kevin

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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