(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 131 295 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.02.2023 Bulletin 2023/06

(21) Application number: **20928867.9**

(22) Date of filing: **31.03.2020**

(51) International Patent Classification (IPC):
H01F 7/16 *(1968.09)*

(52) Cooperative Patent Classification (CPC):
H01F 7/16

(86) International application number:
PCT/JP2020/014854

(87) International publication number:
WO 2021/199296 (07.10.2021 Gazette 2021/40)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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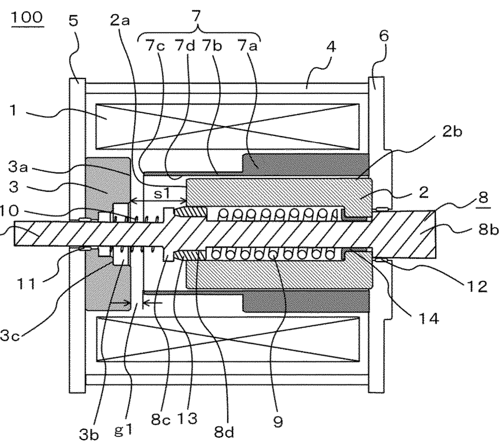
(54) **ELECTROMAGNETIC ACTUATOR AND CIRCUIT BREAKER USING SAME ELECTROMAGNETIC ACTUATOR**

(57) Provided is an electromagnetic actuator capable of maintaining a wipe amount during closing of a circuit breaker. The electromagnetic actuator according to the present disclosure includes: a tubular coil 1 generating a magnetic flux in an axial direction thereof when energized; a movable core 2 installed in a state where the movable core 2 can reciprocate in the axial direction of the coil 1; a shaft 8 surrounded by the movable core 2, performing an opening/closing operation between contacts of a circuit breaker, and movable together with the movable core 2; a tubular yoke pipe 4 surrounding the coil 1; a fixed-side lid plate 5 and a movable-side lid plate 6 disposed at both ends in the axial direction of the yoke pipe 4, respectively; a fixed core 3 disposed on the fixed-side lid plate 5 side on an inner circumferential side of the coil 1; and a yoke projection portion 7 disposed on the movable-side lid plate 6 side on the inner circumferential side of the coil 1. When the movable core 2 is excited by a current flowing through the coil 1, the movable core 2 moves together with the shaft 8 from an initial position to the fixed core 3 to bring the contacts of the circuit breaker into contact with each other to stop the shaft 8, and then moves relative to the shaft 8 to a position at which the movable core 2 comes into contact with the fixed core 3.

FIG.3



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an electromagnetic actuator used for a circuit breaker or the like capable of interrupting an electric path, and a circuit breaker using this electromagnetic actuator.

BACKGROUND ART

[0002] Generally, in a circuit breaker, an electromagnetic actuator is used for operating a contact opening/closing operation. In the electromagnetic actuator, when a current flows through a coil, a magnetic circuit is excited, a movable core inside the electromagnetic actuator is driven in the direction toward a fixed core, and a shaft connected to the movable core moves together with the movable core, thereby operating a contact closing operation of the circuit breaker.

[0003] As a technology related to the conventional electromagnetic actuator, for example, there is a technology described in Patent Document. In the electromagnetic actuator according to Patent Document 1, a shaft which is an operation shaft for operating a contact closing operation of a circuit breaker is firmly fastened and fixed to a movable core by a set screw for preventing loosening. Accordingly, when a coil is energized, the shaft and the movable core move together.

[0004] In addition to such a conventional electromagnetic actuator, a circuit breaker that constantly maintains a contact closed state thereof includes a pushing mechanism in which a movable contact, which is one contact, relatively applies a contact pressure to a fixed contact, which is another contact, during closing. Accordingly, a wipe amount which is the pushing amount of the contact pressure applied to the contact is maintained, and the contacts are brought into a stable contact state during closing.

CITATION LIST

PATENT DOCUMENT

[0005] Patent Document 1: Japanese Laid-Open Patent Publication No. 9-199320

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] However, the circuit breaker is required to be downsized, but there is a problem that the size of the circuit breaker becomes larger when the mechanism for maintaining the wipe amount between the contacts during closing is provided separately from the electromagnetic actuator.

[0007] The present disclosure has been made to solve the above-described problem, and an object of the present disclosure is to obtain an electromagnetic actuator capable of maintaining a wipe amount during closing of a circuit breaker, and a circuit breaker that eliminates the need for providing a mechanism for maintaining a wipe amount, separately from an electromagnetic actuator and can be further downsized.

SOLUTION TO THE PROBLEMS

[0008] An electromagnetic actuator according to the present disclosure includes: a tubular coil generating a magnetic flux in an axial direction thereof when a current flows therethrough; a movable core installed in a state where the movable core can reciprocate in the axial direction of the coil; a shaft surrounded by the movable core, performing an opening/closing operation between a movable-side contact and a fixed-side contact of a circuit breaker, and movable together with the movable core; a tubular yoke pipe surrounding the coil; a fixed-side lid plate disposed at one end of the yoke pipe in the axial direction of the coil; a movable-side lid plate disposed at another end of the yoke pipe in the axial direction of the coil; a fixed core disposed on an inner circumferential side of the coil from the fixed-side lid plate in a direction toward the movable-side lid plate; and a tubular yoke projection portion projecting on the inner circumferential side of the coil from the movable-side lid plate in a direction toward the fixed-side lid plate so as to face the fixed core. The movable core is disposed in a space on an inner circumferential side of the yoke projection portion, and when the movable core is excited by a current flowing through the coil, the movable core moves together with the shaft from an initial position in a direction toward the fixed core in the axial direction of the coil to bring the movable-side contact and the fixed-side contact into contact with each other to stop movement of the shaft, and then moves relative to the shaft to a position at which the movable core comes into contact with the fixed core in an excitation operation completion state.

[0009] A circuit breaker according to the present disclosure is a circuit breaker in which the electromagnetic actuator according to the present disclosure is used for operating an opening/closing operation between the movable-side contact and the fixed-side contact.

EFFECT OF THE INVENTION

[0010] In the electromagnetic actuator according to present disclosure, after the movement of the shaft is stopped by bringing the movable-side contact and the fixed-side contact into contact with each other, the movable core can move relative to the shaft toward the fixed core, and a wipe amount at the time of closing of the circuit breaker can be maintained by the operation of the electromagnetic actuator itself.

[0011] In the circuit breaker using the electromagnetic actuator according to present disclosure, it is not necessary to provide a mechanism for maintaining the wipe amount, separately from the electromagnetic actuator, so that the circuit breaker can be downsized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

[FIG. 1] FIG. 1 schematically shows a contact opened state of a circuit breaker using an electromagnetic actuator according to Embodiment 1.
[FIG. 2] FIG. 2 schematically shows a contact closed state of the circuit breaker using the electromagnetic actuator according to Embodiment 1.
[FIG. 3] FIG. 3 is a schematic cross-sectional view showing a demagnetized state of the electromagnetic actuator according to Embodiment 1.
[FIG. 4] FIG. 4 is a schematic cross-sectional view showing an excitation operation completion state of the electromagnetic actuator according to Embodiment 1.
[FIG. 5] FIG. 5 illustrates a magnetic circuit at an initial position of a movable core of the electromagnetic actuator according to Embodiment 1.
[FIG. 6] FIG. 6 is a schematic cross-sectional view showing a demagnetized state of an electromagnetic actuator according to Embodiment 2.
[FIG. 7] FIG. 7 is a schematic cross-sectional view showing an excitation operation completion state of the electromagnetic actuator according to Embodiment 2.
[FIG. 8] FIG. 8 illustrates a magnetic circuit at an initial position of a movable core of the electromagnetic actuator according to Embodiment 2.
[FIG. 9] FIG. 9 is a schematic cross-sectional view showing a demagnetized state of an electromagnetic actuator according to Embodiment 3.
[FIG. 10] FIG. 10 is a schematic cross-sectional view showing an excitation operation completion state of the electromagnetic actuator according to Embodiment 3.

DESCRIPTION OF EMBODIMENTS

[0013] Hereinafter, embodiments according to the present disclosure will be described with reference to the drawings. In the following embodiments, the same components are denoted by the same reference characters.

Embodiment 1

[0014] FIG. 1 and FIG. 2 schematically illustrate a circuit breaker 110 using an electromagnetic actuator according to Embodiment 1. FIG. 1 shows a contact opened state of the circuit breaker 110, and FIG. 2 shows a contact closed state of the circuit breaker 110.

[0015] The circuit breaker 110 according to Embodiment 1 is a circuit breaker that constantly maintains a contact closed state thereof by energizing a coil of an electromagnetic actuator. As shown in FIG. 1 and FIG. 2, the circuit breaker 110 has a movable-side contact 104 and a fixed-side contact 105 which are a pair of contacts, an electromagnetic actuator 100 provided with a shaft 8 for operating a contact opening/closing operation, and an arc extinguishing chamber 108.

[0016] A movable conductor 103, a flexible conductor 106, a lower conductor 101, and an opening spring 107 are provided on the movable-side contact 104 side. An upper conductor 102 is provided on the fixed-side contact 105 side.

[0017] In the arc extinguishing chamber 108, arc discharge which occurs when the movable-side contact 104 moves away from the fixed-side contact 105 at the time of an opening operation is extinguished.

[0018] The fixed-side contact 105, which is one of the pair of contacts, is joined to one end portion of the upper conductor 102 and electrically connected to the upper conductor 102.

[0019] The movable-side contact 104, which is the other of the pair of contacts, is joined to one end portion of the movable conductor 103 at a position facing the fixed-side contact 105. Another end portion of the movable conductor 103 is connected to the lower conductor 101 by the flexible conductor 106. The movable-side contact 104 is electrically connected to the lower conductor 101 via the movable conductor 103 and the flexible conductor 106.

[0020] The flexible conductor 106 is biased by the shaft 8 of the electromagnetic actuator 100 so as to open and close the movable-side contact 104 and the fixed-side contact 105.

[0021] The lower conductor 101, the upper conductor 102, the movable conductor 103, the movable-side contact 104, the fixed-side contact 105, and the flexible conductor 106 are composed of conductors.

[0022] The movable-side contact 104 and the fixed-side contact 105 are energized via the lower conductor 101 and the upper conductor 102, respectively. The movable-side contact 104 becomes connected to the fixed-side contact 105 by the movable conductor 103 moving toward the upper conductor 102. In addition, the movable-side contact 104 becomes disconnected from the fixed-side contact 105 by the movable conductor 103 moving in the direction away from the upper conductor 102.

[0023] A state where the movable-side contact 104 and the fixed-side contact 105 are connected to each other is a contact closed state, and a state where the movable-side contact 104 and the fixed-side contact 105 are separated from each other is a contact opened state.

[0024] In the circuit breaker 110, the movable-side contact 104 and the fixed-side contact 105 are made to be connected to each other by an excitation operation of the electromagnetic actuator 100, to bring about the contact closed state shown in FIG. 2. In this case, the lower conductor 101 and the upper conductor 102 are energized via the movable-side contact 104 and the fixed-side contact 105.

[0025] Moreover, in the circuit breaker 110, the movable-side contact 104 and the fixed-side contact 105 become separated from each other by a demagnetization operation of the electromagnetic actuator 100, to bring about the contact opened state shown in FIG. 1. In this case, the energization of the lower conductor 101 and the upper conductor 102 is stopped.

[0026] The opening spring 107 is connected to the movable conductor 103 and is provided so as to perform contact opening on the movable-side contact 104 side of the movable conductor 103. The opening spring 107 elastically stores a force that separates the movable-side contact 104 from the fixed-side contact 105. Contact opening and contact closing which are a contact opening operation and a contact closing operation are performed by the operation of the electromagnetic actuator 100. When the electromagnetic actuator 100 is driven for contact closing, contact closing is performed against the stored force of the opening spring 107.

[0027] The shaft 8 is disposed so as to pass through the axis center of the electromagnetic actuator 100. The movable conductor 103 is connected to the electromagnetic actuator 100 via the shaft 8. The electromagnetic actuator 100 operates the opening/closing operation between the contacts of the circuit breaker 110. The electromagnetic actuator 100 moves the movable conductor 103 via the shaft 8 to control the connection between the movable-side contact 104 and the fixed-side contact 105.

[0028] Next, the configuration of the electromagnetic actuator 100 shown in FIG. 3 and FIG. 4 will be described.

[0029] FIG. 3 corresponds to the opened state of the circuit breaker 110 shown in FIG. 1, and is a cross-sectional view showing a demagnetized state of the electromagnetic actuator 100 according to Embodiment 1. The demagnetized state of the electromagnetic actuator 100 shown in FIG. 3 is a state where a movable core 2 is located at an initial position.

[0030] FIG. 4 corresponds to the closed state of the circuit breaker 110 shown in FIG. 2, and is a cross-sectional view showing an excitation operation completion state of the electromagnetic actuator 100 according to Embodiment 1. The excitation operation completion state of the electromagnetic actuator 100 shown in FIG. 4 is a state where the movable core 2 is in contact with a fixed core 3.

[0031] The electromagnetic actuator 100 has a tubular coil 1 which generates a magnetic flux in an axial direction thereof when a current flows therethrough, the movable core 2 which is disposed in the axial direction of the coil 1 and is installed in a state where the movable core 2 can reciprocate in the axial direction of the coil 1, the shaft 8 which is surrounded by the movable core 2 and is movable together with the movable core 2, a tubular yoke pipe 4 which surrounds the coil 1, a fixed-side lid plate 5 which is disposed at one end of the yoke pipe 4 in the axial direction of the coil 1, a movable-side lid plate 6 which is disposed at the other end of the yoke pipe 4 in the axial direction of the coil 1, the fixed core 3 which is disposed on the inner circumferential side of the coil 1 from the fixed-side lid plate 5 in the direction toward the movable-side lid plate 6, and a tubular yoke projection portion 7 which projects on the inner circumferential side of the coil 1 from the movable-side lid plate 6 in the direction toward the fixed-side lid plate 5 so as to face the fixed core 3.

[0032] In the axial direction of the coil 1, the yoke pipe 4 is disposed between the fixed-side lid plate 5 and the movable-side lid plate 6, and the fixed-side lid plate 5 and the movable-side lid plate 6 are disposed so as to face each other. In the axial direction of the coil 1, the fixed core 3 faces the yoke projection portion 7 and the movable core 2 which is surrounded by the yoke projection portion 7.

[0033] Components including the yoke pipe 4, the fixed-side lid plate 5, the movable-side lid plate 6, the fixed core 3, and the yoke projection portion 7 are integrated with a step, and are made of a magnetic material. A typical magnetic material is, for example, iron.

[0034] Moreover, in the components including the yoke pipe 4, the fixed-side lid plate 5, the movable-side lid plate 6, the fixed core 3, and the yoke projection portion 7, a magnetic circuit is excited together with the movable core 2 by energizing the coil 1.

[0035] The coil 1 is housed in a tubular space which is formed by the yoke pipe 4, the fixed-side lid plate 5, the movable-side lid plate 6, the fixed core 3, and the yoke projection portion 7. In addition, the coil 1 has a tubular shape that surrounds the movable core 2, the yoke projection portion 7, and the fixed core 3.

[0036] The movable core 2 is disposed on the inner circumferential side of the yoke projection portion 7 so as to face the fixed core 3, and is installed in a state where the movable core 2 can reciprocate relative to the fixed core 3 in the axial direction of the coil 1. Specifically, when a current flows through the coil 1, the movable core 2 is driven so as to move toward the fixed core 3 in the axial direction of the coil 1. In this case, the movable core 2 moves from the initial position which is a position in the demagnetized state of the electromagnetic actuator 100 in which the contact opened state of the circuit breaker 110 shown in FIG. 3 is maintained, to a position at which the movable core 2 comes into contact with the fixed core 3 and which is a position in the excitation operation completion state of the electromagnetic actuator 100 in which the closed state of the circuit breaker 110 shown in FIG. 4 is maintained.

[0037] Moreover, in the axial direction of the coil 1, the length of the movable core 2 is longer than 1/2 of the length of the yoke pipe 4. At the initial position, a movable core end surface 2a of the movable core 2 is located on the fixed core 3 side with respect to the center position of the coil 1 in the axial direction. As the movable core 2 becomes longer, the facing area between the movable core 2 and the yoke projection portion 7 in the axial direction becomes larger.

[0038] The magnetic resistance of the magnetic circuit is reduced by increasing the magnetic path cross-sectional area corresponding to the facing area. By increasing the facing area between the movable core 2 and the yoke projection portion 7, the attractive force acting on the movable core 2 in an excitation maintained state can be further improved. Accordingly, the holding force between the main contacts in the closed state of the circuit breaker 110 can be improved.

[0039] The shaft 8 is surrounded by the movable core 2 and is disposed in the axial direction of the coil 1. The shaft 8 is made of a non-magnetic material.

[0040] In the axial direction of the coil 1, the shaft 8 penetrates the fixed-side lid plate 5, the fixed core 3, and the movable-side lid plate 6. The shaft 8 has a first shaft end portion 8a which is one end portion penetrating the fixed-side lid plate 5, and a second shaft end portion 8b which is another end portion penetrating the movable-side lid plate 6. The first shaft end portion 8a extends to the movable conductor 103 and is connected to the movable conductor 103. The second shaft end portion 8b is formed such that the outer diameter thereof is larger than that of a portion, of the shaft 8, which is inserted into the movable core 2.

[0041] Moreover, a shaft protrusion portion 8c and a shaft step portion 8d are formed on the shaft 8. The shaft protrusion portion 8c faces the fixed core 3, and the shaft step portion 8d is located at an end portion on the fixed-side lid plate 5 side of the movable core 2 so as to be adjacent to the shaft protrusion portion 8c. The shaft protrusion portion 8c and the shaft step portion 8d are formed such that the outer diameters thereof are larger than that of the portion, of the shaft 8, which is inserted into the movable core 2.

[0042] Between the movable core 2 and the shaft 8, a first movable core bearing 13 and a second movable core bearing 14, which are bearings for the movable core, are arranged at both ends in the axial direction of the movable core 2, respectively.

[0043] Specifically, the first movable core bearing 13 is provided on the shaft step portion 8d of the shaft 8 at an end portion position on the fixed-side lid plate 5 side of the movable core 2. The movable core 2 is supported by the first movable core bearing 13 so as to be movable relative to the shaft 8. By disposing the first movable core bearing 13 on the shaft 8 which is a non-magnetic component, the movable core 2 can be formed without decreasing the cross-sectional area thereof, and the attractive force can be ensured.

[0044] Moreover, the second movable core bearing 14 is provided at an end portion position on the movable-side lid plate 6 side of the movable core 2. The second movable core bearing 14 supports the movable core 2 so as to be movable together with the movable core 2 relative to the shaft 8.

[0045] A contact-pressure spring 9 is disposed between the movable core 2 and the shaft 8. The shaft 8 and the movable core 2 are connected via the contact-pressure spring 9. The contact-pressure spring 9 is provided in the movable core 2, and is located between the first movable core bearing 13 and the second movable core bearing 14 in the axial direction. The electromagnetic actuator 100 is made compact. By increasing the length of the movable core 2, it is possible to increase the length of the contact-pressure spring 9.

[0046] When the movable core 2 moves relative to the shaft 8 in the direction toward the fixed core 3, the contact-pressure spring 9 is compressed to store a force in a direction in which the movable core 2 is separated from the fixed core 3.

[0047] A return spring 10 is disposed between the shaft protrusion portion 8c and the fixed core 3. The shaft 8 and the fixed core 3 are connected via the return spring 10. The return spring 10 has a tubular shape that surrounds the shaft 8 and is surrounded by the fixed core 3. When the shaft 8 moves together with the movable core 2 in the direction toward the fixed core 3, the return spring 10 is compressed to store a force in a direction in which the contacts of the circuit breaker are separated from each other.

[0048] Moreover, shaft bearings which support movement of the shaft 8 are disposed at the fixed-side lid plate 5 and the movable-side lid plate 6, respectively, in the axial direction. Specifically, a first shaft bearing 11 is provided at a center portion of the fixed-side lid plate 5, and a second shaft bearing 12 is provided at a center portion of the movable-side lid plate 6. The first shaft bearing 11 is disposed between the fixed-side lid plate 5 and the first shaft end portion 8a of the shaft 8 which penetrates the fixed-side lid plate 5. The second shaft bearing 12 is disposed between the movable-side lid plate 6 and the second shaft end portion 8b of the shaft 8 which penetrates the movable-side lid plate 6. The shaft 8 can move in the axial direction of the coil 1 while being supported by the first shaft bearing 11 and the second shaft bearing 12.

[0049] Next, the structure of the fixed core 3 and the positional relationship of the fixed core 3 with the movable core 2 in the electromagnetic actuator 100 according to Embodiment 1 will be described.

[0050] The movable core 2 and the fixed core 3 each have a tubular shape that surrounds the shaft 8. In a direction perpendicular to the axial direction of the coil 1, the movable core 2 and the fixed core 3 have the movable core end surface 2a and a fixed core end surface 3a which face each other. The movable core end surface 2a is an annular surface facing the fixed core end surface 3a, and the fixed core end surface 3a is an annular surface facing the movable core end surface 2a.

[0051] At the initial position, a gap s1 having a predetermined distance is provided at the facing position between the movable core end surface 2a and the fixed core end surface 3a. The movable core 2 is excited and driven in the axial direction toward the fixed core 3, the gap s1 becomes smaller as the movable core 2 moves, and in the excitation operation completion state, the movable core end surface 2a comes into contact with the fixed core end surface 3a, so that the gap s1 becomes zero.

[0052] The fixed core end surface 3a is located on the fixed-side lid plate 5 side with respect to the center in the axial direction of the coil 1. A surface at which the movable core end surface 2a of the movable core 2 comes into contact with the fixed core end surface 3a of the fixed core 3 in the excitation operation completion state in which the movable core 2 has been excited and driven in the axial direction toward the fixed core 3, as shown in FIG. 4, is referred to as a contact surface 16.

[0053] The position of the contact surface 16 is the same as the position of the fixed core end surface 3a, and the contact surface 16 between the movable core 2 and the fixed core 3 in the excitation operation completion state is located on the movable core 2 moving direction side with respect to the center in the axial direction of the coil 1. That is, the contact surface 16 is located on the fixed-side lid plate 5 side with respect to the center in the axial direction of the coil 1.

[0054] Accordingly, a sufficient distance can be obtained between the contact surface 16 and the movable core end surface 2a at the initial position. In addition, it is possible to increase the length in the axial direction of the movable core 2, so that the facing area with the yoke projection portion 7 can be increased and the attractive force can be increased.

[0055] Moreover, as shown in FIG. 3, in the fixed core 3, a fixed core recess 3b which faces the shaft protrusion portion 8c of the shaft 8 and is recessed so as to house the shaft protrusion portion 8c and the return spring 10 is formed at a center portion in the axial direction of the fixed core end surface 3a. A fixed core step portion 3c is provided so as to be stepped on an inner wall surface of the fixed core recess 3b and face the shaft protrusion portion. In the excitation operation completion state shown in FIG. 4, the shaft protrusion portion 8c is surrounded by the fixed core recess 3b so as to be housed in the fixed core recess 3b, and contacts the fixed core 3 via the return spring 10.

[0056] Next, the structure of the yoke projection portion 7 and the position relationship of the yoke projection portion 7 with the movable core 2 and the fixed core 3 in the electromagnetic actuator 100 according to Embodiment 1 will be described.

[0057] In the electromagnetic actuator 100 according to Embodiment 1, the yoke projection portion 7 has a yoke main projection portion 7a which is disposed on the movable-side lid plate 6 side, and a yoke narrow projection portion 7b which extends from the yoke main projection portion 7a toward the fixed-side lid plate 5 side. The yoke projection portion 7 faces the fixed core 3, and is disposed such that the yoke narrow projection portion 7b extends in the direction toward the fixed core 3. A yoke projection portion distal end surface 7c which is an end surface, of the yoke projection portion 7, facing the fixed core 3 projects so as to be closer to the fixed core 3 than the movable core end surface 2a is at the initial position. A gap g1 having a predetermined distance is provided at the facing position between the yoke projection portion distal end surface 7c and the fixed core end surface 3a. The gap g1 is smaller than the gap s1 between the fixed core end surface 3a and the movable core end surface 2a at the initial position.

[0058] The inner diameter of the yoke main projection portion 7a and the inner diameter of the yoke narrow projection portion 7b are equal to each other, and the outer diameter of the yoke main projection portion 7a is larger than the outer diameter of the yoke narrow projection portion 7b. The yoke main projection portion 7a and the yoke narrow projection portion 7b may be integrally formed or may be formed as separate components. Both the yoke main projection portion 7a and the yoke narrow projection portion 7b have a yoke projection portion inner wall surface 7d which is an inner wall surface of the yoke projection portion 7. The characteristics of the attractive force applied to the movable core 2 can be adjusted by adjusting the configuration of the yoke projection portion 7 such as the outer diameter difference between the yoke main projection portion 7a and the yoke narrow projection portion 7b and the width of the yoke narrow projection portion 7b.

[0059] In the yoke projection portion 7, the yoke projection portion inner wall surface 7d faces a movable core outer wall surface 2b, which is an outer wall surface of the movable core 2, so as to surround the movable core 2. The yoke projection portion 7 has the yoke narrow projection portion 7b which extends from the yoke main projection portion 7a, and by increasing the length of the movable core 2, the facing area between the movable core 2 and the yoke projection portion 7 becomes larger, that is, the facing area between the movable core outer wall surface 2b and the yoke projection portion inner wall surface 7d becomes larger.

[0060] Next, the operation of the electromagnetic actuator 100 will be described.

[0061] By energizing the coil 1, the magnetic circuit composed of the movable core 2, the fixed core 3, the fixed-side lid plate 5, the yoke pipe 4, the movable-side lid plate 6, and the yoke projection portion 7 is excited, a magnetic attractive force acts on the movable core 2, and the movable core 2 is driven in the direction toward the fixed core 3. The movable core 2 shown in FIG. 3 is driven from the initial position to the position at which the movable core 2 comes into contact with the fixed core 3 and which is a position in the excitation operation completion state shown in FIG. 4. The circuit breaker 110 is brought into the closed state shown in FIG. 2 from the opened state shown in FIG. 1.

[0062] As the movable core 2 moves in the direction toward the fixed core 3 side, the contact-pressure spring 9 which connects the movable core 2 and the shaft 8 is pressed by the moving movable core 2, so that the shaft 8 moves together with the movable core 2 from the movable-side lid plate 6 side toward the fixed-side lid plate 5 side. The movable conductor 103 which is connected to the shaft 8 moves in the left direction on the drawing sheet in FIG. 1 so as to bring the movable-side contact 104 and the fixed-side contact 105 into contact with each other. The return spring 10 between the shaft protrusion portion 8c and the fixed core 3 is compressed to store a force. When the movable-side contact 104 and the fixed-side contact 105 come into contact with each other, the shaft 8 stops. After the movement of the shaft 8 is stopped, the movable core 2 is further driven in the direction toward the fixed core 3 relative to the shaft 8 by the magnetic attractive force. Then, the movable core end surface 2a of the movable core 2 and the fixed core end surface 3a of the fixed core 3 come into contact with each other to complete the excitation operation, and the circuit breaker is brought into the closed state.

[0063] After the movement of the shaft 8 is stopped by bringing the movable-side contact 104 and the fixed-side contact 105 into contact with each other, the movable core 2 moves relative to the shaft 8, thereby further applying a contact pressure to the movable-side contact 104 and the fixed-side contact 105 via the shaft 8. Accordingly, a wipe amount at the time of closing can be maintained by the operation of the electromagnetic actuator itself.

[0064] As shown in FIG. 4, in the excitation operation completion state in which the movable core 2 is in contact with the fixed core 3, the return spring 10 is compressed and the shaft 8 contacts the fixed core 3 via the return spring 10. At this time, the shaft protrusion portion 8c is surrounded by the fixed core recess 3b so as to be housed in the fixed core recess 3b, and does not completely contact the fixed core step portion 3c in the fixed core recess 3b, so that there is a gap 16a therebetween.

[0065] Since the gap 16a exists between the shaft protrusion portion 8c and the fixed core step portion 3c, the movable core 2 can apply a contact pressure between the contacts via the shaft 8.

[0066] Also in the excitation operation completion state, the shaft protrusion portion 8c contacts the fixed core step portion 3c via the return spring 10 such that the stored force of the contact-pressure spring 9 remains. Since the gap 16a exists, the stored force of the contact-pressure spring 9 can be released when the magnetic circuit is demagnetized. In the electromagnetic actuator, an attractive force may act between the movable core and the fixed core due to the influence of the residual magnetic field, and the movable core 2 can be separated from the fixed core 3 by using the stored force of the contact-pressure spring 9. Since the stored force of the contact-pressure spring 9 can be used, the size of the return spring 10 which is provided on the fixed core 3 side can be reduced, so that the return spring 10 can be downsized.

[0067] When the magnetic circuit is demagnetized by stopping the energization of the coil 1, the magnetic attractive force disappears, the contact-pressure spring 9 extends, and the movable core 2 moves in a direction opposite to a direction in which the fixed core 3 is disposed. The second shaft end portion 8b is brought into contact with the movable core 2, and the shaft 8 moves together with the movable core. The return spring 10 extends, and the movable conductor 103 which is connected to the shaft 8 moves in the right direction on the drawing sheet in FIG. 1 so as to separate the movable-side contact 104 and the fixed-side contact 105 from each other, so that the contacts are completely separated with the stored force of the opening spring 107. The movable core 2 returns to the initial position. Accordingly, the electromagnetic actuator 100 is brought into the demagnetized state, and the circuit breaker 110 is brought into the opened state shown in FIG. 1.

[0068] FIG. 5 illustrates the magnetic circuit at the initial position of the movable core 2 of the electromagnetic actuator 100 according to Embodiment 1.

[0069] As shown in FIG. 5, at the initial position, the gap g1 between the yoke projection portion distal end surface 7c and the fixed core end surface 3a is smaller than the gap s1 between the movable core end surface 2a and the fixed core end surface 3a. Therefore, a magnetic flux 24 in the axial direction which is generated in the magnetic circuit by energizing the coil 1 has a magnetic flux 24a which passes through the movable core 2, and a magnetic flux 24b which passes through the yoke projection portion 7. A part of the magnetic flux 24 in the axial direction flows from the yoke main projection portion 7a of the yoke projection portion 7 through the yoke narrow projection portion 7b to the fixed core 3, and the magnetic flux flowing through the movable core 2 becomes smaller. Until the position of the movable core end surface 2a of the movable core 2 moves past the yoke projection portion distal end surface 7c, the driving force applied to the movable core 2 is reduced, so that it is possible to slow down the excitation operation of the electromagnetic actuator 100. Accordingly, it is possible to close the contacts of the circuit breaker 110 at low speed.

[0070] Moreover, when the movable core 2 moves toward the fixed core 3 away from the movable-side lid plate 6, the magnetic flux passes through the movable core 2 and the fixed core 3 from the yoke projection portion 7. As the movable core 2 moves, the gap s1 between the movable core end surface 2a and the fixed core end surface 3a becomes smaller. When the position of the movable core end surface 2a of the movable core 2 moves past the yoke projection portion distal end surface 7c, the gap g1 between the yoke projection portion distal end surface 7c and the fixed core end surface 3a becomes larger than the gap s1 between the movable core end surface 2a and the fixed core end surface 3a, so that almost all of the magnetic flux in the axial direction passes through the movable core 2 from the yoke projection portion 7. In the maintained state where the excitation operation is completed, almost all of the magnetic flux in the axial direction passes through the movable core 2. Therefore, after the movable core end surface 2a of the movable core 2 moves past the yoke projection portion distal end surface 7c of the yoke projection portion 7, the driving force applied to the movable core 2 becomes larger, so that the attractive force in the excitation maintained state can be improved.

[0071] Also, as described above, the contact surface 16 between the movable core 2 and the fixed core 3 is located on the movable core 2 moving direction side with respect to the center in the axial direction of the coil 1, and by increasing the length of the movable core 2 and extending the yoke narrow projection portion 7b of the yoke projection portion 7 in the direction toward the fixed core 3, the facing area between the yoke projection portion 7 and the movable core 2 in the direction perpendicular to the axial direction becomes larger, so that the attractive force in the excitation maintained state can be further improved.

[0072] In the electromagnetic actuator according to Embodiment 1, after the movement of the shaft is stopped by bringing the movable-side contact and the fixed-side contact into contact with each other, the movable core can move relative to the shaft toward the fixed core, and a wipe amount at the time of closing of the circuit breaker can be maintained by the operation of the electromagnetic actuator itself.

[0073] In the circuit breaker using the electromagnetic actuator according to Embodiment 1, it is not necessary to provide a mechanism for maintaining the wipe amount, separately from the electromagnetic actuator, so that the circuit breaker can be downsized.

[0074] Moreover, in the electromagnetic actuator according to Embodiment 1, since the contact surface between the movable core and the fixed core is located on the movable core moving direction side with respect to the center position of the coil in the axial direction of the coil, the distance between the contact surface and the initial position can be ensured. Even when the length in the axial direction of the movable core is increased, the movable core can be formed without projecting outward from the movable-side lid plate at the initial position, so that it is possible to reduce the external dimensions of the electromagnetic actuator. Accordingly, the circuit breaker using the electromagnetic actuator can be downsized.

[0075] Furthermore, in the electromagnetic actuator according to Embodiment 1, owing to the configuration in which the yoke narrow projection portion is provided in the yoke projection portion, the effects of slowing down the excitation operation and improving the attractive force in the excitation maintained state are achieved. Accordingly, the contacts of the circuit breaker using the electromagnetic actuator can be closed at low speed, and the holding force between the contacts in the closed state can be improved.

Embodiment 2

[0076] FIGS. 6 and 7 are cross-sectional views of an electromagnetic actuator 200 according to Embodiment 2 of the present disclosure.

[0077] FIG. 6 is a cross-sectional view showing a demagnetized state of the electromagnetic actuator 200 according to Embodiment 2, corresponding to the opened state of the circuit breaker shown in FIG. 1. FIG. 6 is a cross-sectional view showing a state where a movable core 2 is at an initial position in the demagnetized state of the electromagnetic actuator 200.

[0078] FIG. 7 is a cross-sectional view showing an excitation operation completion state of the electromagnetic actuator 200 according to Embodiment 2, corresponding to the closed state of the circuit breaker shown in FIG. 2. The excitation operation completion state of the electromagnetic actuator 200 shown in FIG. 7 is a state where the movable core 2 is in contact with a fixed core 3.

[0079] Similar to the electromagnetic actuator 100 shown in FIG. 1 and FIG. 2, the electromagnetic actuator 200 serves to bias the movable contact of the circuit breaker in the closing direction and is used for operating an opening/closing operation between the contacts.

[0080] In Embodiment 2, the same components as those in Embodiment 1 of the present disclosure are denoted by the same reference characters, and the description of the same or corresponding parts is omitted. Hereinafter, the differences of the electromagnetic actuator 200 according to Embodiment 2 from Embodiment 1 will be described with reference to the drawings.

[0081] As shown in FIGS. 6 and 7, the electromagnetic actuator 200 has a tubular coil 1 which generates a magnetic flux in an axial direction thereof when a current flows therethrough, the movable core 2 which is disposed in the axial direction of the coil 1 and is installed in a state where the movable core 2 can reciprocate in the axial direction of the coil 1, a shaft 8 which is surrounded by the movable core 2 and is movable together with the movable core 2, a tubular yoke pipe 4 which surrounds the coil 1, a fixed-side lid plate 5 which is disposed at one end of the yoke pipe 4 in the axial direction of the coil 1, a movable-side lid plate 6 which is disposed at the other end of the yoke pipe 4 in the axial direction of the coil 1, the fixed core 23 which is disposed on the inner circumferential side of the coil 1 from the fixed-side lid plate 5 in the direction toward the movable-side lid plate 6, and a tubular yoke projection portion 27 which projects on the inner circumferential side of the coil 1 from the movable-side lid plate 6 in the direction toward the fixed-side lid plate 5 so as to face the fixed core 23.

[0082] Components including the yoke pipe 4, the fixed-side lid plate 5, the movable-side lid plate 6, the fixed core 23, and the yoke projection portion 27 are integrated with a step, and are made of a magnetic material. A typical magnetic material is, for example, iron.

[0083] Moreover, in the components including the yoke pipe 4, the fixed-side lid plate 5, the movable-side lid plate 6, the fixed core 23, and the yoke projection portion 27, a magnetic circuit is excited together with the movable core 2 by energizing the coil 1.

[0084] In Embodiment 2, the configurations of the fixed core 23 and the yoke projection portion 27 are different from the configurations of the fixed core 3 and the yoke projection portion 7 of Embodiment 1. In the electromagnetic actuator 200 according to Embodiment 2, the configuration other than the fixed core 23 and the tubular yoke projection portion 27 is the same as in Embodiment 1. The same advantageous effects are achieved.

[0085] Next, the structure of the tubular yoke projection portion 27 and the positional relationship of the tubular yoke projection portion 27 with the movable core 2 in the electromagnetic actuator 200 according to Embodiment 1 will be described.

[0086] The tubular yoke projection portion 27 projects from the movable-side lid plate 6 in the direction toward the fixed-side lid plate 5 so as to surround a part of the movable core 2 at the initial position, and both the outer diameter and the inner diameter of the tubular yoke projection portion 27 are uniform. The tubular yoke projection portion 27 has a yoke projection portion distal end surface 27a which is an annular end surface facing the fixed core 23, and a yoke projection portion inner wall surface 27b which faces a movable core outer wall surface 2b which is an outer wall surface of the movable core 2.

[0087] Next, the structure of the fixed core 23 and the positional relationship of the fixed core 23 with the movable core 2 and the tubular yoke projection portion 27 in the electromagnetic actuator 200 according to Embodiment 1 will be described.

[0088] The fixed core 23 has a fixed core base portion 23a which is disposed on the fixed-side lid plate 5 side, and a fixed core narrow projection portion 23b which extends from the fixed core base portion 23a in the direction toward the movable-side lid plate 6. The fixed core base portion 23a and the fixed core narrow projection portion 23b may be integrally formed or may be formed as separate components.

[0089] The fixed core base portion 23a is disposed so as to face the movable core 2 and the tubular yoke projection portion 27 which surrounds the movable core 2. The fixed core base portion 23a has a fixed core end surface 23c which is an end surface facing the movable core 2. The fixed core end surface 23c is an annular surface facing a movable core end surface 2a, and is located on the fixed-side lid plate 5 side with respect to the center in the axial direction of the coil 1.

[0090] At the initial position, a gap s2 having a predetermined distance is provided at the facing position between the movable core end surface 2a and the fixed core end surface 23c. The movable core 2 is excited and driven in the axial direction toward the fixed core 23, the gap s2 becomes smaller as the movable core 2 moves, and in the excitation operation completion state, the movable core end surface 2a comes into contact with the fixed core end surface 23c, so that the gap s2 becomes zero.

[0091] A surface at which the movable core end surface 2a of the movable core 2 comes into contact with the fixed core end surface 23c of the fixed core 23 in the excitation operation completion state as shown in FIG. 7, is referred to as a contact surface 26. The position of the contact surface 26 is the same as the position of the fixed core end surface 23c, and is located on the movable core 2 moving direction side with respect to the center position in the axial direction of the coil 1. That is, the contact surface 26 is located on the fixed-side lid plate 5 side with respect to the center in the axial direction of the coil 1.

[0092] Accordingly, a sufficient distance can be obtained between the contact surface 26 and the movable core end surface 2a at the initial position.

[0093] Moreover, as shown in FIG. 6, in the fixed core base portion 23a, a fixed core recess 23f which faces a shaft protrusion portion 8c of the shaft 8 and is recessed so as to house the shaft protrusion portion 8c and a return spring 10 is formed at a center portion in the axial direction of the fixed core end surface 23c. A fixed core step portion 23g is provided so as to be stepped on an inner wall surface of the fixed core recess 23f and face the shaft protrusion portion. In the excitation operation completion state shown in FIG. 7, the shaft protrusion portion 8c is surrounded by the fixed core step portion 23g so as to be housed in the fixed core step portion 23g.

[0094] The fixed core narrow projection portion 23b extends in the direction toward the movable core 2, and has a tubular shape that surrounds a movable core distal end portion 2c which is a distal end portion of the movable core 2 in a direction in which the movable core 2 moves toward the fixed core base portion 23a. The fixed core narrow projection portion 23b has a fixed core distal end surface 23d which is an annular end surface facing the tubular yoke projection portion 27, and a fixed core inner wall surface 23e which is an inner wall surface facing the movable core outer wall surface 2b. At the initial position, in the movable core 2, in the axial direction, the movable core distal end portion 2c is surrounded by the fixed core narrow projection portion 23b, and a portion on the movable-side lid plate 6 side other than the movable core distal end portion 2c is surrounded by the tubular yoke projection portion 27.

[0095] The fixed core distal end surface 23d projects so as to be closer to the tubular yoke projection portion 27 than the position of the movable core end surface 2a is at the initial position. A gap g2 having a predetermined distance is provided at the facing position between the yoke projection portion distal end surface 27a and the fixed core distal end surface 23d. The gap g2 is smaller than the gap s2 at the initial position.

[0096] Next, the operation of the electromagnetic actuator 200 will be described.

[0097] By energizing the coil 1, the magnetic circuit composed of the movable core 2, the fixed core 23, the fixed-side lid plate 5, the yoke pipe 4, the movable-side lid plate 6, and the yoke projection portion 27 is excited, a magnetic attractive force acts on the movable core 2, and the movable core 2 is driven in the direction toward the fixed core 23. The movable core 2 shown in FIG. 6 is driven from the initial position to the position at which the movable core 2 comes into contact with the fixed core 23 and which is a position in the excitation operation completion state shown in FIG. 7. The circuit breaker 110 is brought into the closed state shown in FIG. 2 from the opened state shown in FIG. 1.

[0098] As the movable core 2 moves in the direction toward the fixed core 23 side, the contact-pressure spring 9 which connects the movable core 2 and the shaft 8 is pressed by the moving movable core 2, so that the shaft 8 moves together with the movable core 2 in the axial direction from the movable-side lid plate 6 side toward the fixed-side lid plate 5 side. The contacts of the circuit breaker come into contact with each other via a movable conductor connected to the shaft 8. When the contacts come into contact with each other, the shaft 8 stops. After the movement of the shaft 8 is stopped, the movable core 2 is driven by the magnetic attractive force so as to further move relative to the shaft 8 to the position at which the movable core 2 comes into contact with the fixed core 23. Then, the movable core end surface 2a of the movable core 2 and the fixed core end surface 23c of the fixed core 23 come into contact with each other to complete the excitation operation, and the circuit breaker is brought into the closed state.

[0099] After the movement of the shaft 8 is stopped by bringing the contacts of the circuit breaker into contact with each other, the movable core 2 moves relative to the shaft 8, thereby further applying a contact pressure to the contacts of the circuit breaker via the shaft 8. Accordingly, a wipe amount at the time of closing can be maintained by the operation of the electromagnetic actuator itself.

[0100] As shown in FIG. 7, in the excitation operation completion state in which the movable core 2 is in contact with the fixed core 23, the return spring 10 is compressed and the shaft 8 contacts the fixed core 23 via the return spring 10. At this time, the shaft protrusion portion 8c is surrounded by the fixed core recess 23f so as to be housed in the fixed core recess 23f, and does not completely contact the fixed core step portion 23g in the fixed core recess 23f, so that there is a gap 26a therebetween.

[0101] Since the gap 26a exists between the shaft protrusion portion 8c and the fixed core step portion 23g, the movable core 2 can apply a contact pressure between the contacts via the shaft 8.

[0102] Also in the excitation operation completion state, the shaft protrusion portion 8c contacts the fixed core step portion 23g via the return spring 10 such that the stored force of the contact-pressure spring 9 remains. Since the gap 26a exists, the stored force of the contact-pressure spring 9 can be released when the magnetic circuit is demagnetized. In the electromagnetic actuator, an attractive force may act between the movable core and the fixed core due to the influence of the residual magnetic field, and the movable core 2 can be separated from the fixed core 23 by using the stored force of the contact-pressure spring 9. Since the stored force of the contact-pressure spring 9 can be used, the size of the return spring 10 which is provided on the fixed core 23 side can be reduced, so that the return spring 10 can be downsized.

[0103] When the magnetic circuit is demagnetized by stopping the energization of the coil 1, the magnetic attractive force disappears, the contact-pressure spring 9 extends, and the movable core 2 moves in a direction opposite to a direction in which the fixed core 23 is disposed. The movable core 2 is brought into contact with the second shaft end portion 8b, and the shaft 8 moves together with the movable core. The return spring 10 extends, and the movable conductor 103 which is connected to the shaft 8 moves in a direction in which the movable-side contact 104 and the fixed-side contact 105 are separated from each other, so that the contacts are completely separated with the stored force of an opening spring 107. The movable core 2 returns to the initial position. Accordingly, the electromagnetic actuator 200 is brought into the demagnetized state, and the circuit breaker is brought into the opened state.

[0104] FIG. 8 illustrates the magnetic circuit at the initial position of the movable core 2 of the electromagnetic actuator 200 according to Embodiment 2.

[0105] As shown in FIG. 8, at the initial position, the gap g2 between the yoke projection portion distal end surface 27a and the fixed core distal end surface 23d is smaller than the gap s2 between the movable core end surface 2a and the fixed core end surface 23c. Therefore, a magnetic flux 28 in the axial direction which is generated in the magnetic circuit by energizing the coil 1 has a magnetic flux 28a which passes through the movable core 2, and a magnetic flux 28b which passes through the fixed core narrow projection portion 23b from the tubular yoke projection portion 27. A part of the magnetic flux 28 in the axial direction flows from the tubular yoke projection portion 27 through the fixed core narrow projection portion 23b to the fixed core 23, and the magnetic flux flowing through the movable core 2 becomes smaller. The driving force applied to the movable core 2 is reduced, so that it is possible to slow down the excitation operation of the electromagnetic actuator 200. Accordingly, it is possible to close the contacts of the circuit breaker at low speed.

[0106] In the electromagnetic actuator according to Embodiment 2, after the movement of the shaft is stopped by bringing the movable-side contact and the fixed-side contact into contact with each other, the movable core can move relative to the shaft toward the fixed core, and a wipe amount at the time of closing of the circuit breaker can be maintained by the operation of the electromagnetic actuator itself.

[0107] In the circuit breaker using the electromagnetic actuator according to Embodiment 2, it is not necessary to provide a mechanism for maintaining the wipe amount, separately from the electromagnetic actuator, so that the circuit breaker can be downsized.

[0108] Moreover, in the electromagnetic actuator according to Embodiment 2, since the contact surface between the movable core and the fixed core is located on the movable core moving direction side with respect to the center position of the coil in the axial direction of the coil, the distance between the contact surface and the initial position can be ensured. Even when the length in the axial direction of the movable core is increased, the movable core can be formed without projecting outward from the movable-side lid plate at the initial position, so that it is possible to reduce the external dimensions of the electromagnetic actuator. Accordingly, the circuit breaker using the electromagnetic actuator can be downsized.

[0109] Furthermore, in the electromagnetic actuator according to Embodiment 2, owing to the configuration of the fixed core provided with the fixed core narrow projection portion, the slowdown of the excitation operation can be improved. Accordingly, it is possible to close the contacts of the circuit breaker, which uses this electromagnetic actuator, at low speed.

Embodiment 3

[0110] FIGS. 9 and 10 are cross-sectional views of an electromagnetic actuator 300 according to Embodiment 3 of the present disclosure.

[0111] FIG. 9 corresponds to the opened state of the circuit breaker 110 shown in FIG. 1, and is a cross-sectional view showing a demagnetized state of the electromagnetic actuator 300 according to Embodiment 3. The demagnetized state of the electromagnetic actuator 300 shown in FIG. 9 is a state where a movable core 2 of the electromagnetic actuator 300 is located at an initial position.

[0112] FIG. 10 corresponds to the closed state of the circuit breaker 110 shown in FIG. 2, and is a cross-sectional view showing an excitation operation completion state of the electromagnetic actuator 300 according to Embodiment 3. The excitation operation completion state of the electromagnetic actuator 300 shown in FIG. 10 is a state where the movable core 2 is in contact with a fixed core 3.

[0113] Similar to the electromagnetic actuator 100 shown in FIG. 1 and FIG. 2, the electromagnetic actuator 300 serves to bias the movable contact of the circuit breaker in the closing direction and is used for operating an opening/closing operation between the contacts.

[0114] In Embodiment 3, the same components as those in Embodiment 1 of the present disclosure are denoted by the same reference characters, and the description of the same or corresponding parts is omitted. Hereinafter, the differences of the electromagnetic actuator 300 according to Embodiment 3 from Embodiment 1 will be described with reference to the drawings.

[0115] As shown in FIGS. 9 and 10, the electromagnetic actuator 300 has a tubular coil 1 which generates a magnetic flux in an axial direction thereof when a current flows therethrough, the movable core 2 in which a tubular space for housing the coil is formed and which is disposed in the axial direction of the coil 1 and is installed in a state where the movable core 2 can reciprocate in the axial direction of the coil 1, a shaft 8 which is surrounded by the movable core 2 and is movable together with the movable core 2, a tubular yoke pipe 4 which surrounds the coil 1, a fixed-side lid plate 5 which is disposed at one end of the yoke pipe 4 in the axial direction of the coil 1, a movable-side lid plate 36 which is disposed at the other end of the yoke pipe 4 in the axial direction of the coil 1, the fixed core 3 which is disposed on the inner circumferential side of the coil 1 from the fixed-side lid plate 5 in the direction toward the movable-side lid plate 36, and a tubular yoke projection portion 7 which projects on the inner circumferential side of the coil 1 from the movable-side lid plate 36 in the direction toward the fixed-side lid plate 5 so as to face the fixed core 3.

[0116] Components including the yoke pipe 4, the fixed-side lid plate 5, the movable-side lid plate 36, the fixed core 3, and the yoke projection portion 7 are integrated with a step, and are made of a magnetic material. A typical magnetic material is, for example, iron.

[0117] Moreover, in the components including the yoke pipe 4, the fixed-side lid plate 5, the movable-side lid plate 36, the fixed core 3, and the yoke projection portion 7, a magnetic circuit is excited together with the movable core 2 by energizing the coil 1.

[0118] In Embodiment 3, the configuration of the movable-side lid plate 36 is different from the configuration of the movable-side lid plate 6 of Embodiment 1.

[0119] As shown in FIG. 9, in the movable-side lid plate 36, an air outlet 33 is provided at a portion surrounded by the yoke projection portion 7, so as to penetrate the movable-side lid plate 36.

[0120] Moreover, an airtight bearing which supports movement of the movable core 2 relative to the yoke projection portion 7 and blocks outflow of air is provided between the movable core 2 and the yoke projection portion 7. The airtight bearing is movable together with the movable core 2 and is disposed such that the air inside the electromagnetic actuator does not leak from between the movable core 2 and the yoke projection portion 7.

[0121] A plurality of airtight bearings can be provided between the movable core 2 and the yoke projection portion 7, and the airtightness and the holding stability of the movable core 2 can be improved.

[0122] As shown in FIG. 9 and FIG. 10, a third movable core bearing 31 and a fourth movable core bearing 32, which are airtight bearings, are provided at both end portions of the movable core 2, respectively. The third movable core bearing 31 and the fourth movable core bearing 32 have a hermetically sealed configuration such that the air inside the electromagnetic actuator does not leak from between the movable core 2 and the yoke projection portion 7, and support the movable core 2 so as to be movable together with the movable core 2 relative to the yoke projection portion 7.

[0123] Moreover, a spring pressing plate 34 is provided between the movable core 2 and a contact-pressure spring 9. When the movable core 2 moves in the direction toward the fixed core 3 side, the contact-pressure spring 9 is pressed by the moving movable core 2 via the spring pressing plate 34, and the shaft 8 moves together with the movable core 2 in the axial direction from the movable-side lid plate 6 side toward the fixed-side lid plate 5 side.

[0124] The spring pressing plate 34 is also in contact with the movable core 2 and the shaft 8, and also has a function of closing the gap between the movable core 2 and the shaft 8 such that the air inside the movable core 2 does not leak.

[0125] In the electromagnetic actuator 300 according to Embodiment 3, the configuration other than the configuration of the movable-side lid plate 36 and the airtight bearings between the movable core 2 and the yoke projection portion 7 is the same as in Embodiment 1. The same advantageous effects are achieved.

[0126] As for the operation of the electromagnetic actuator 300 according to Embodiment 3, the difference from Embodiment 1 will be described.

[0127] The electromagnetic actuator 300 is the same as in Embodiment 1, except that in the electromagnetic actuator 300, by stopping the energization of the coil 1, the magnetic circuit is demagnetized, and when the movable core 2 moves from the position at which the movable core 2 comes into contact with the fixed core 3, to the initial position, the movable core 2 discharges air through the air outlet 33.

[0128] When the magnetic circuit is demagnetized by stopping the energization of the coil 1, the magnetic attractive force disappears, the contact-pressure spring 9 extends, and the movable core 2 moves in a direction opposite to a direction in which the fixed core 3 is disposed. The movable core 2 is brought into contact with the second shaft end portion 8b, and the shaft 8 moves together with the movable core 2. The return spring 10 extends, and the movable conductor 103 which is connected to the shaft 8 moves in a direction in which the movable-side contact 104 and the fixed-side contact 105 are separated from each other, so that the contacts are completely separated with the stored force of an opening spring 107. The movable core 2 returns to the initial position. Accordingly, the electromagnetic actuator 300 is brought into the demagnetized state, and the circuit breaker is brought into the opened state.

[0129] In FIG. 10, when the movable core 2 and the shaft 8 move together in the direction toward the initial position, air A between the movable core 2 and the movable-side lid plate 36 inside the yoke projection portion 7 is discharged through the air outlet 33 to the outside of the electromagnetic actuator 300. An arrow 33a indicates the direction in which the air A inside the electromagnetic actuator 300 is discharged through the air outlet 33 to the outside of the electromagnetic actuator 300. The air A discharged through the air outlet 33 during a demagnetization operation can be used for extinguishing the arc of the circuit breaker.

[0130] With the demagnetization operation of the electromagnetic actuator, the contacts of the circuit breaker are separated from each other, and arc discharge occurs. The arc needs to be extinguished quickly. By blowing air to the arc generated between the contacts, the arc can be transferred to the arc extinguishing chamber side, extended, and extinguished. As the amount of air blown to the arc increases, the arc extinguishing efficiency tends to increase. By using the air A, which is discharged through the air outlet 33 at high speed during the demagnetization operation, for extinguishing the arc of the circuit breaker, the arc extinguishing efficiency at the time of arc generation can be improved.

[0131] The magnetic circuit in the electromagnetic actuator 300 according to Embodiment 3 is also the same as the magnetic circuit of Embodiment 1.

[0132] The electromagnetic actuator according to Embodiment 3 and the circuit breaker using this electromagnetic actuator have the same advantageous effects as those of the electromagnetic actuator according to Embodiment 1.

[0133] Furthermore, when the electromagnetic actuator is demagnetized, the air inside the electromagnetic actuator can be discharged through the air discharge port and used for extinguishing the arc of the circuit breaker, so that the arc extinguishing efficiency can be improved. In addition, since the air discharged from the electromagnetic actuator itself can be used for extinguishing the arc, the cost and the size of the circuit breaker can be reduced.

[0134] It is noted that, within the scope of the present disclosure, the embodiments described in the present disclosure may be combined with each other, or each of the embodiments may be modified or simplified as appropriate.

DESCRIPTION OF THE REFERENCE CHARACTERS

[0135]

1	coil
2	movable core
2a	movable core end surface
2b	movable core outer wall surface
2c	movable core distal end portion
3	fixed core
3a	fixed core end surface
3b	fixed core recess
3c	fixed core step portion
4	yoke pipe
5	fixed-side lid plate
6	movable-side lid plate
7	yoke projection portion
7a	yoke main projection portion
7b	yoke narrow projection portion
7c	yoke projection portion distal end surface
7d	yoke projection portion inner wall surface

8	shaft
8a	first shaft end portion
8b	second shaft end portion
9	contact-pressure spring
10	return spring
11	first shaft bearing
12	second shaft bearing
13	first movable core bearing
14	second movable core bearing
23	fixed core
23a	fixed core base portion
23b	fixed core narrow projection portion
23c	fixed core end surface
23d	fixed core distal end surface
23e	fixed core inner wall surface
23f	fixed core recess
23g	fixed core step portion
24	magnetic flux
27	yoke projection portion
27a	yoke projection portion distal end surface
27b	yoke projection portion inner wall surface
28	magnetic flux
31	third movable core bearing
32	fourth movable core bearing
33	air outlet
36	movable-side lid plate
100	electromagnetic actuator
110	circuit breaker
101	lower conductor
102	upper conductor
103	movable conductor
104	movable-side contact
105	fixed-side contact
106	flexible conductor
107	opening spring
108	arc extinguishing chamber
110	circuit breaker
200, 300	electromagnetic actuator

Claims

1. An electromagnetic actuator comprising:

a tubular coil generating a magnetic flux in an axial direction thereof when a current flows therethrough;
a movable core installed in a state where the movable core can reciprocate in the axial direction of the coil;
a shaft surrounded by the movable core, operating an opening/closing operation between a movable-side contact and a fixed-side contact of a circuit breaker, and movable together with the movable core;
a tubular yoke pipe surrounding the coil;
a fixed-side lid plate disposed at one end of the yoke pipe in the axial direction of the coil;
a movable-side lid plate disposed at another end of the yoke pipe in the axial direction of the coil;
a fixed core disposed on an inner circumferential side of the coil from the fixed-side lid plate in a direction toward the movable-side lid plate; and
a tubular yoke projection portion projecting on the inner circumferential side of the coil from the movable-side lid plate in a direction toward the fixed-side lid plate so as to face the fixed core, wherein
the movable core is disposed in a space on an inner circumferential side of the yoke projection portion, and
when the movable core is excited by a current flowing through the coil, the movable core moves together with the shaft from an initial position in a direction toward the fixed core in the axial direction of the coil to bring the movable-side contact and the fixed-side contact into contact with each other to stop movement of the shaft, and then moves relative to the shaft to a position at which the movable core comes into contact with the fixed core in an excitation operation completion state.

2. The electromagnetic actuator according to claim 1, wherein a contact surface at which the movable core and the fixed core come into contact with each other in the excitation operation completion state is located on the movable core moving direction side with respect to a center position of the coil in the axial direction of the coil.

3. The electromagnetic actuator according to claim 1 or 2, wherein, in the axial direction of the coil, a length of the movable core is longer than 1/2 of a length of the yoke pipe.

4. The electromagnetic actuator according to any one of claims 1 to 3, wherein, in the shaft, a shaft protrusion portion having a larger outer diameter than a portion, of the shaft, which is inserted into the movable core is provided at an end portion position on the fixed-side lid plate side of the movable core.

5. The electromagnetic actuator according to claim 4, wherein a fixed core recess which is recessed so as to house the shaft is formed on a fixed core end surface which is an end surface, of the fixed core, facing the movable core.

6. The electromagnetic actuator according to claim 5, wherein

a fixed core step portion is formed so as to be stepped on an inner wall surface of the fixed core recess and face the shaft protrusion portion, and in the excitation operation completion state, the shaft protrusion portion is surrounded by the fixed core recess so as to be housed in the fixed core recess, and there is a gap between the shaft protrusion portion and the fixed core step portion.

7. The electromagnetic actuator according to claim 5 or 6, wherein

a return spring is disposed between the shaft protrusion portion and the fixed core recess, and the shaft and the fixed core are connected via the return spring.

8. The electromagnetic actuator according to any one of claims 1 to 7, wherein

a contact-pressure spring is disposed between the movable core and the shaft, and
the movable core and the shaft are connected via the contact-pressure spring.

9. The electromagnetic actuator according to any one of claims 1 to 8, wherein, between the movable core and the shaft, a first movable core bearing which supports the movable core such that the movable core is movable relative to the shaft, is provided on the shaft at the end portion position on the fixed-side lid plate side of the movable core.

10. The electromagnetic actuator according to any one of claims 1 to 9, wherein, between the movable core and the shaft, a second movable core bearing which supports the movable core such that the second movable core bearing is movable together with the movable core relative to the shaft, is provided at an end portion position on the movable-side lid plate side of the movable core.

11. The electromagnetic actuator according to any one of claims 1 to 10, wherein

the shaft has

a first shaft end portion which is one end portion penetrating the fixed-side lid plate, and
a second shaft end portion which is another end portion penetrating the movable-side lid plate, and

the second shaft end portion is formed such that an outer diameter thereof is larger than that of the portion, of the shaft, which is inserted into the movable core.

12. The electromagnetic actuator according to claim 11, wherein

a first shaft bearing which supports movement of the shaft is provided between the fixed-side lid plate and the first shaft end portion, and
a second shaft bearing which supports movement of the shaft is provided between the movable-side lid plate and the second shaft end portion.

13. The electromagnetic actuator according to any one of claims 1 to 12, wherein the yoke projection portion has

a yoke main projection portion disposed on the movable-side lid plate side, and
a yoke narrow projection portion extending from the yoke main projection portion in the direction toward the fixed-side lid plate.

14. The electromagnetic actuator according to any one of claims 1 to 13, wherein

the fixed core has

a fixed core base portion disposed on the fixed-side lid plate side, and
a fixed core narrow projection portion extending from the fixed core base portion in the direction toward the movable-side lid plate,

the fixed core base portion has the fixed core end surface which is the end surface facing the movable core, and
the fixed core narrow projection portion has a tubular shape which surrounds a movable core distal end portion which is a distal end portion of the movable core in a direction in which the movable core moves toward the fixed core base portion.

15. The electromagnetic actuator according to any one of claims 1 to 14 wherein, in the movable-side lid plate, an air outlet is provided at a portion surrounded by the yoke projection portion, so as to penetrate the movable-side lid plate.

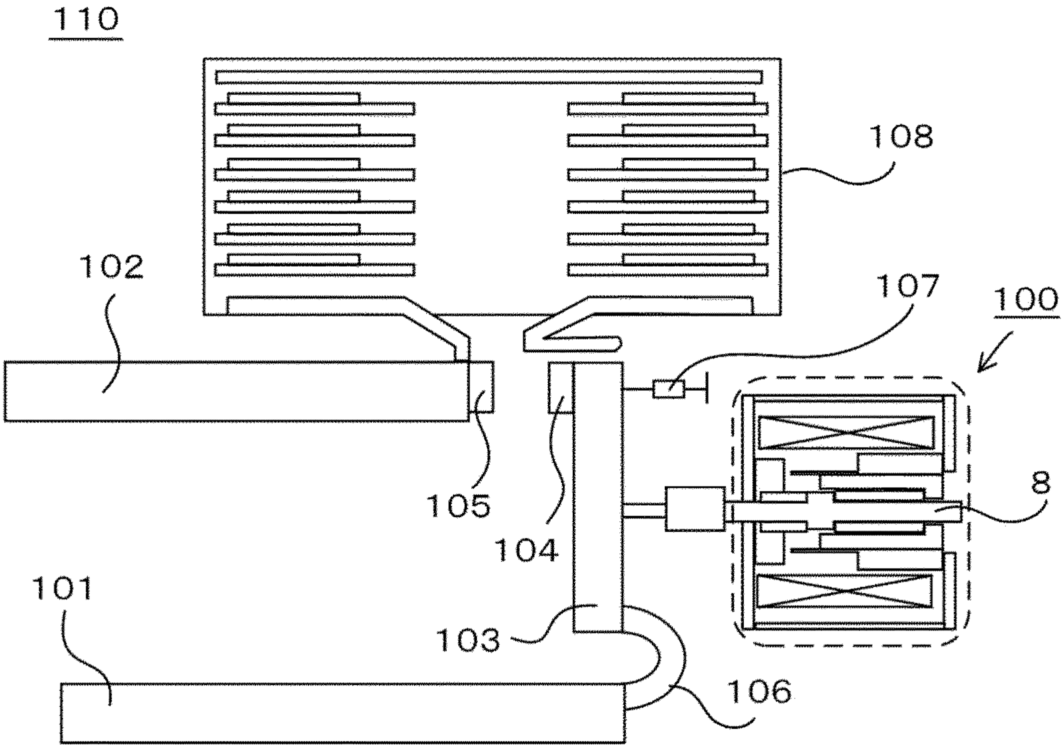
16. The electromagnetic actuator according to claim 15, wherein an airtight bearing which supports movement of the movable core relative to the yoke projection portion and blocks outflow of air is provided between the movable core and the yoke projection portion.

17. The electromagnetic actuator according to claim 16, wherein a plurality of the airtight bearings are provided.

18. The electromagnetic actuator according to any one of claims 15 to 17, wherein a spring pressing plate which closes a gap between the movable core and the shaft such that air inside the movable core does not leak, is provided.

19. A circuit breaker in which the electromagnetic actuator according to any one of claims 1 to 18 is used for operating an opening/closing operation between the movable-side contact and the fixed-side contact.

FIG.1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106

FIG.2

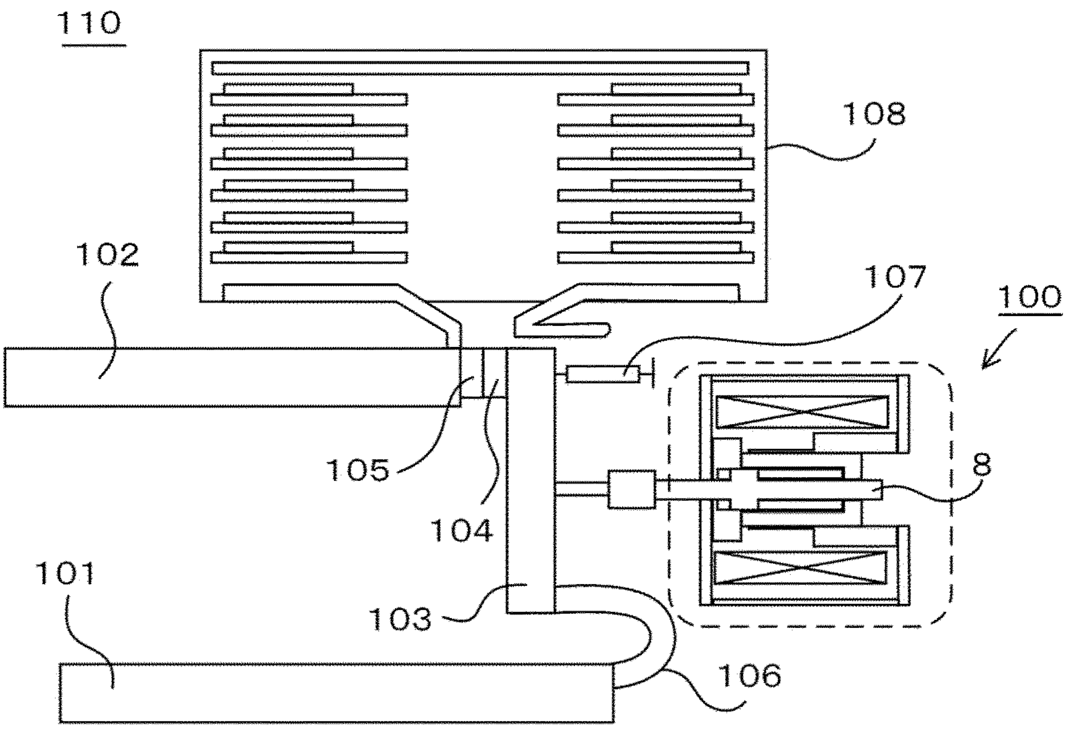
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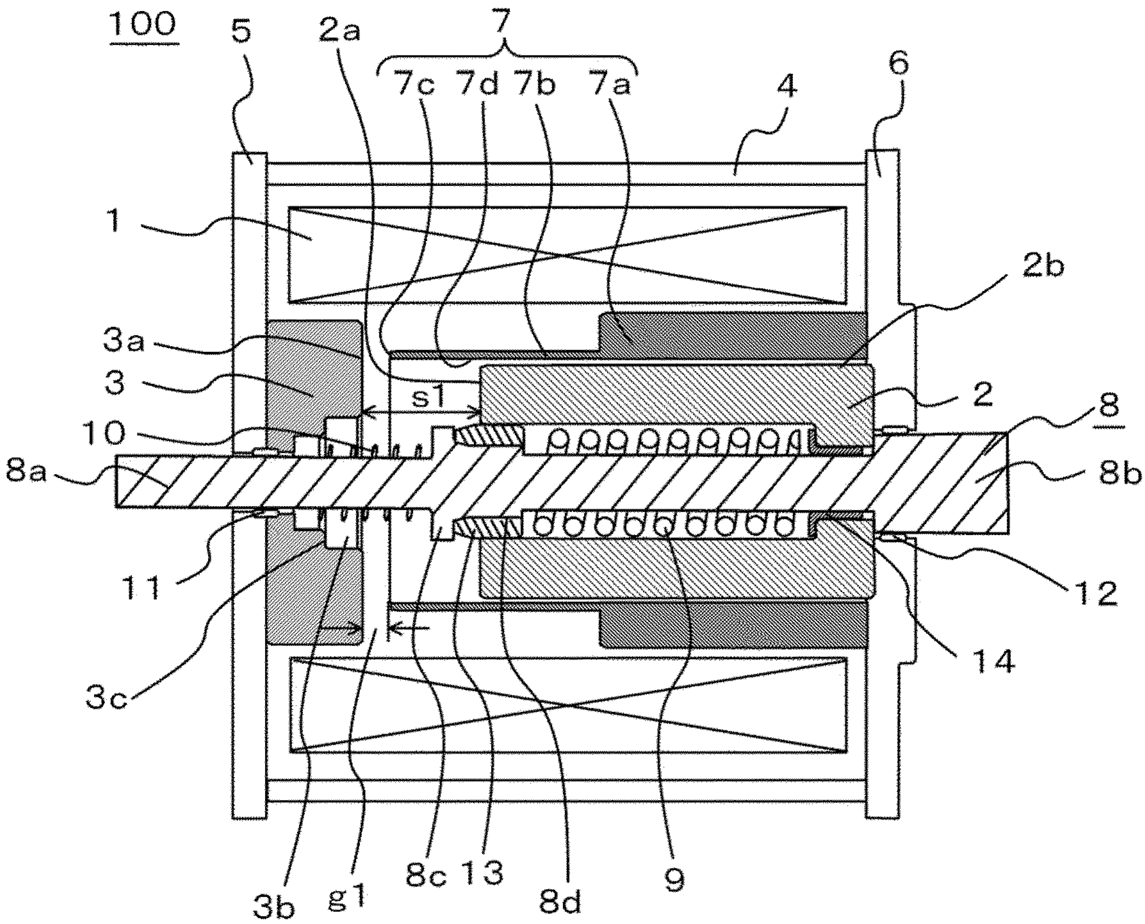
FIG.3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8d
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FIG.4

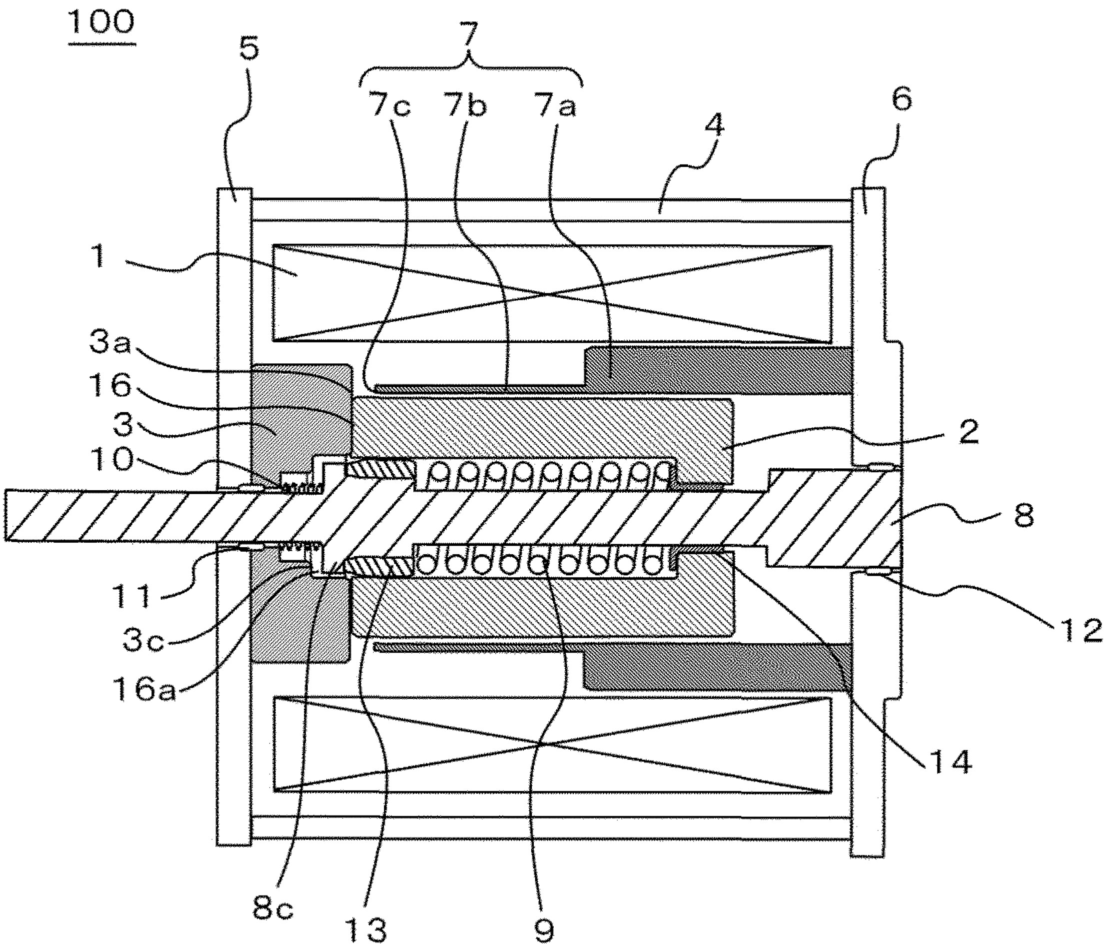

FIG.5

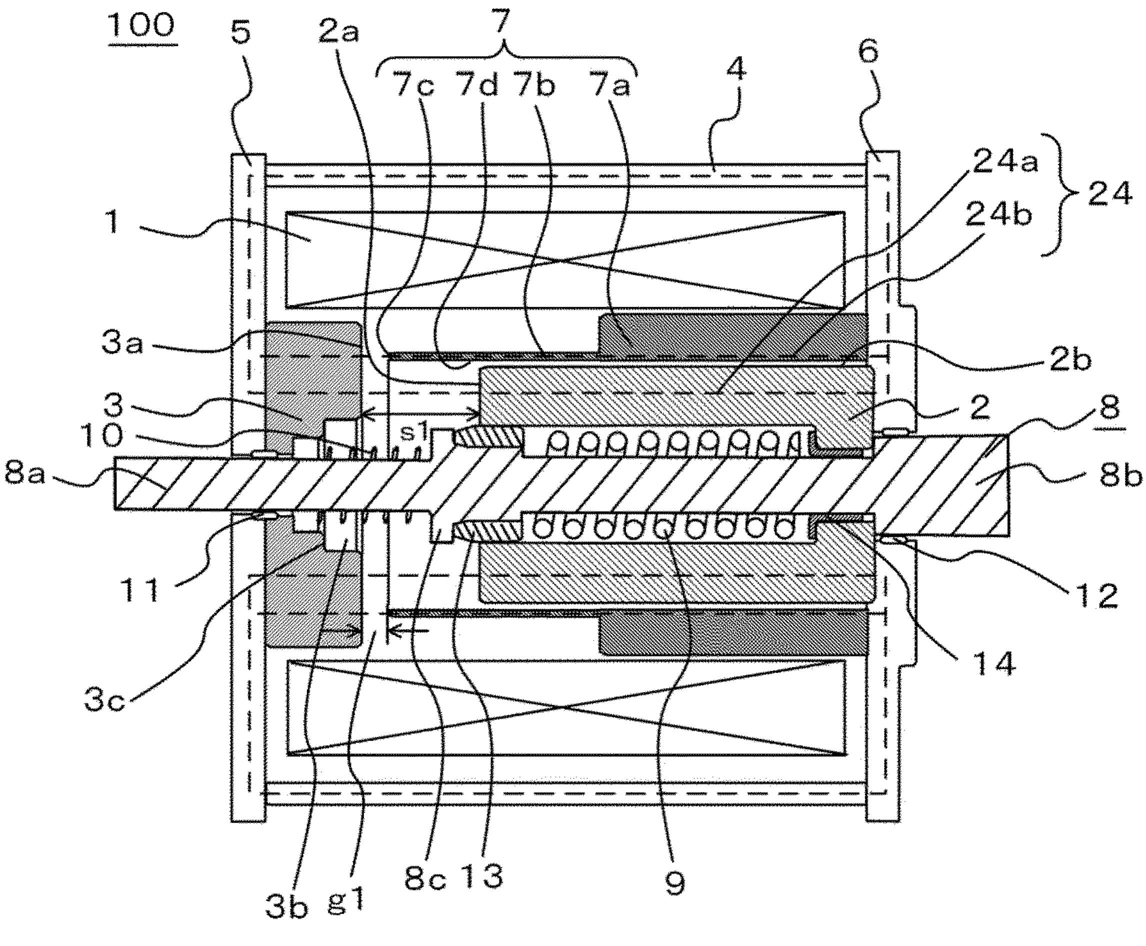
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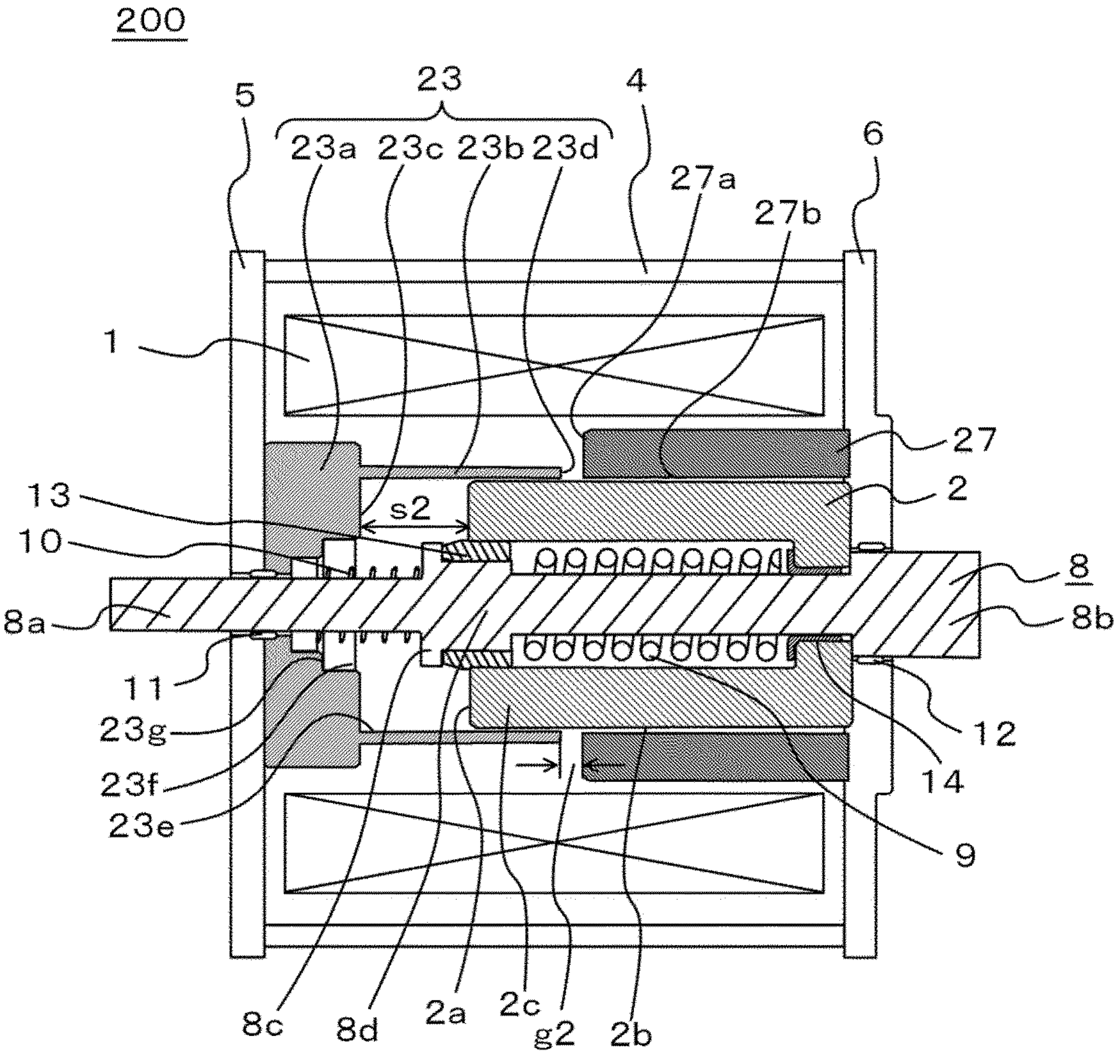
FIG.6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2c
g2
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FIG.7

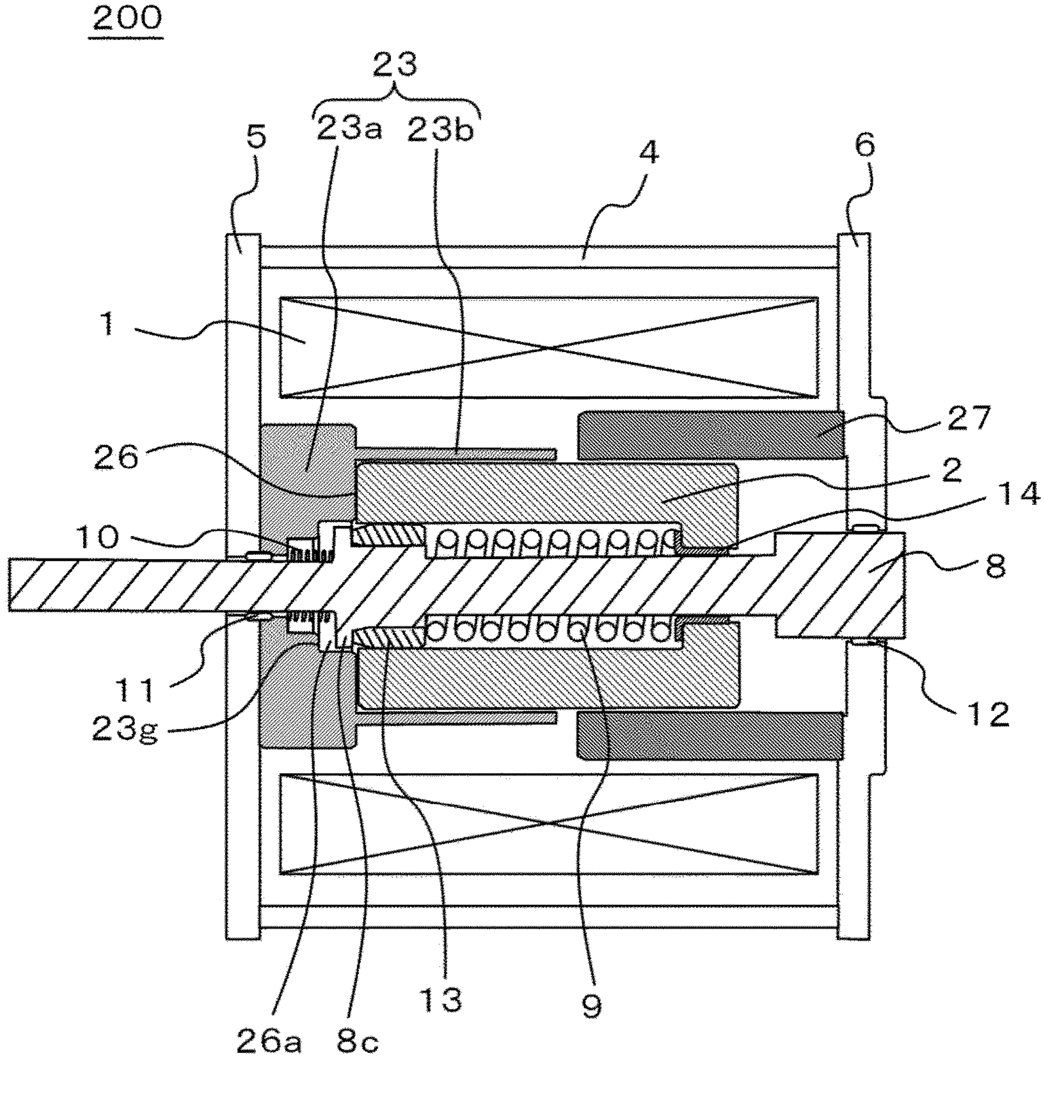

FIG.8

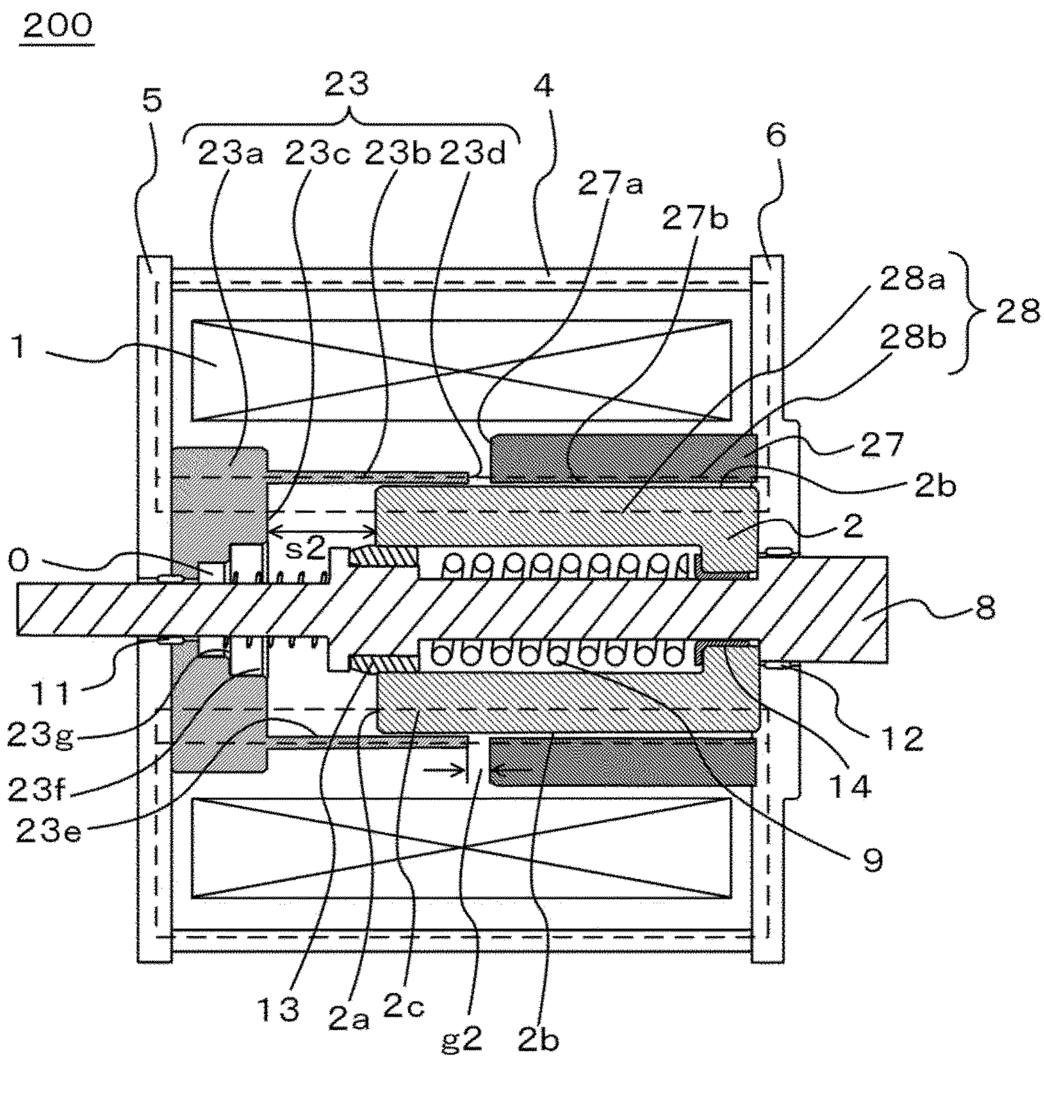
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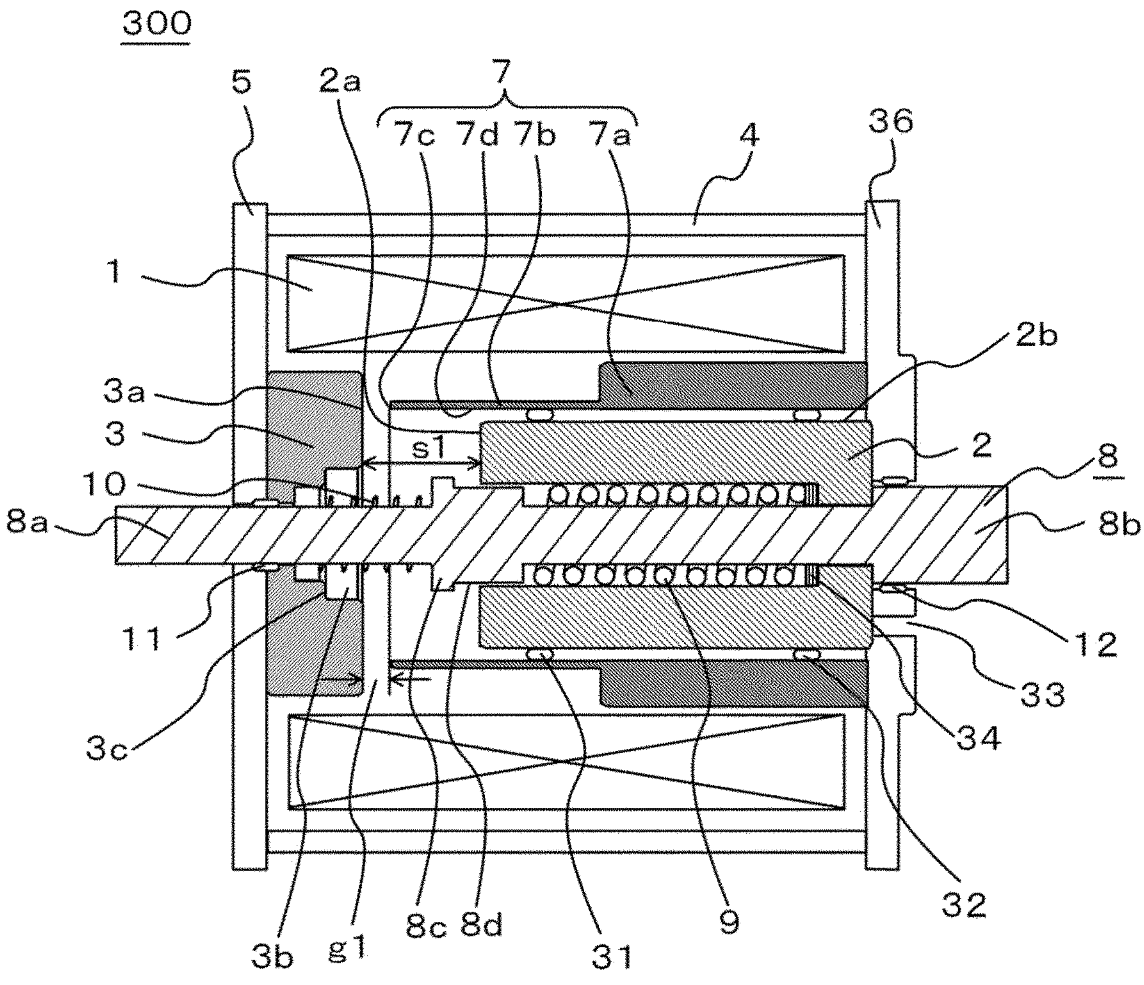
FIG.9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3c
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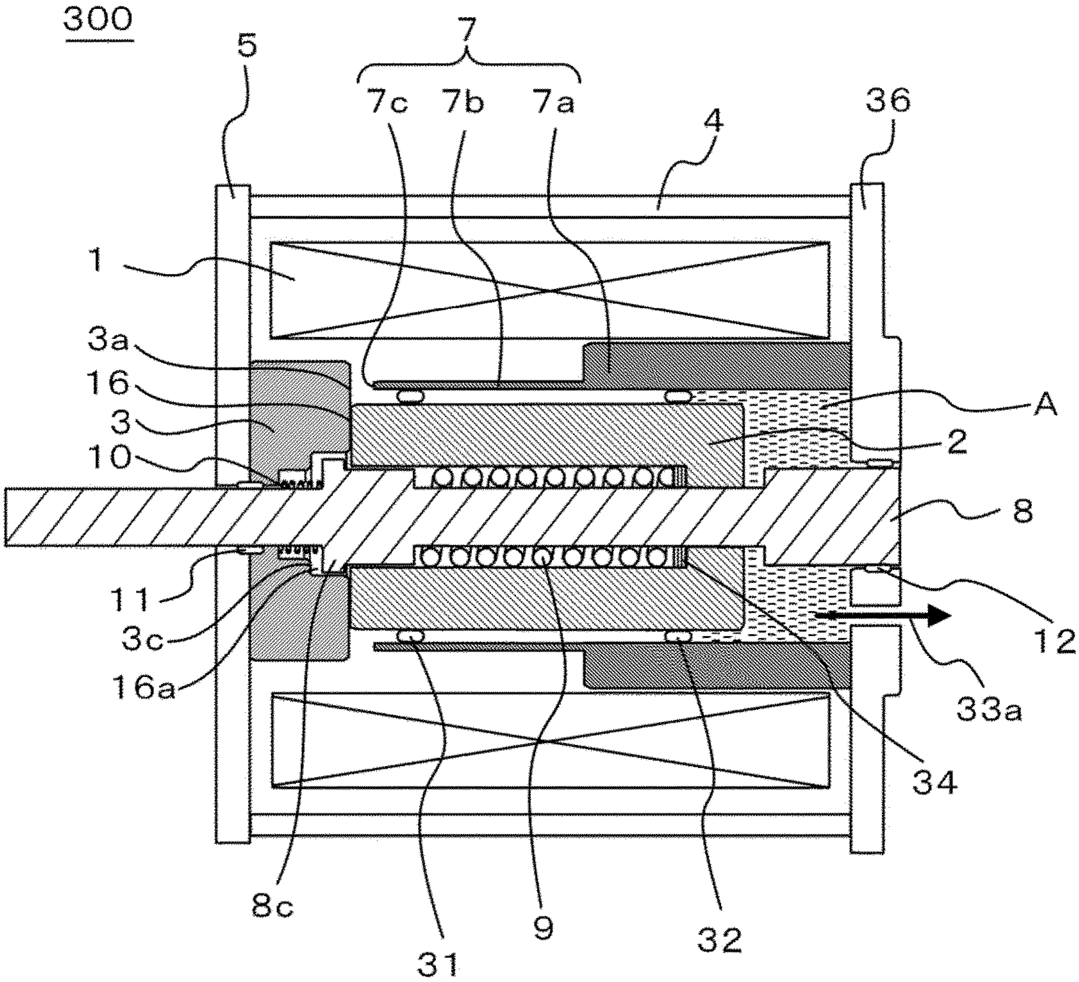
3b
g1
8c
8d
31
9

FIG.10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/014854

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. H01F7/16(2006.01)i
FI: H01F7/16 D

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. H01F7/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005-142257 A (SHINDENGEN MECHATRONICS CO., LTD.) 02 June 2005	1-19
A	JP 2003-163115 A (SHINDENGEN ELECTRIC MFG. CO., LTD.) 06 June 2003	1-19

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02.06.2020	16.06.2020

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/014854

Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
JP 2005-142257 A	02.06.2005	(Family: none)	
JP 2003-163115 A	06.06.2003	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 9199320 A **[0005]**