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(54) ELECTROMAGNETICALLY DRIVEN VALVE

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(57) **ABSTRACT**

An electromagnetically driven valve includes a drive valve that has a stem; an upper disk and a lower disk each of which has an arm portion, and each of which extends from a first end that is movably connected to the stem toward a second end that is movably supported by a disk supporting base; and an electromagnet. The electromagnet includes a core that is provided so as to face the arm portion, and a coil that is wound around the core. The electromagnet forms a magnetic circuit that passes through the core and the arm portion when an electric current is applied to the coil. The electromagnetically driven valve further includes a permanent magnet which has a magnetic axis along the magnetic circuit, and which is provided so as to act on a magnetic flux that flows through the magnetic circuit.

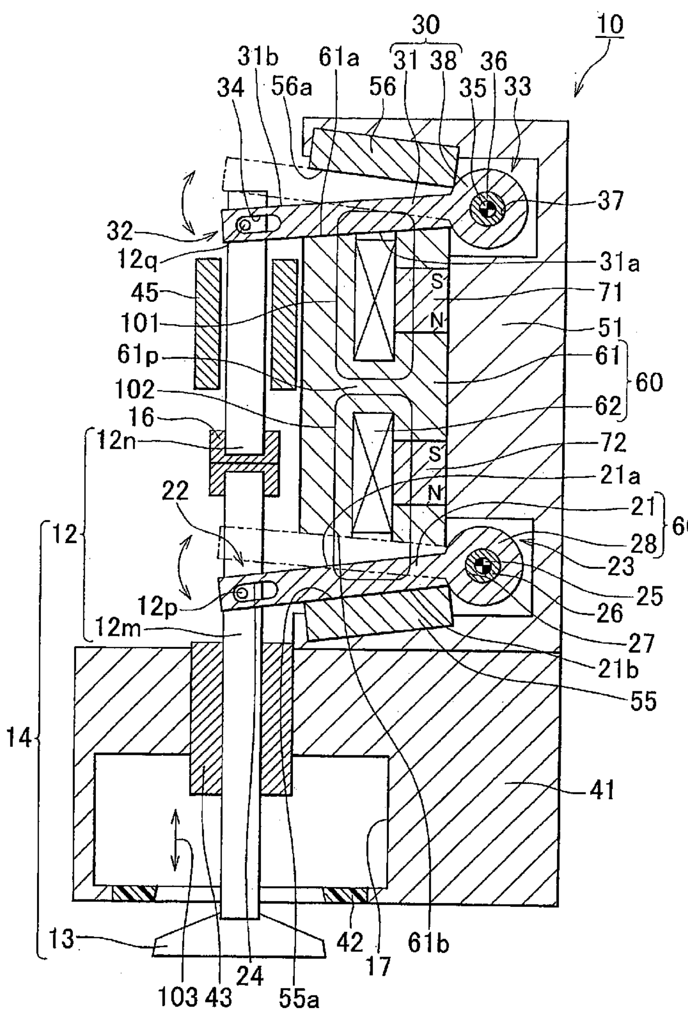
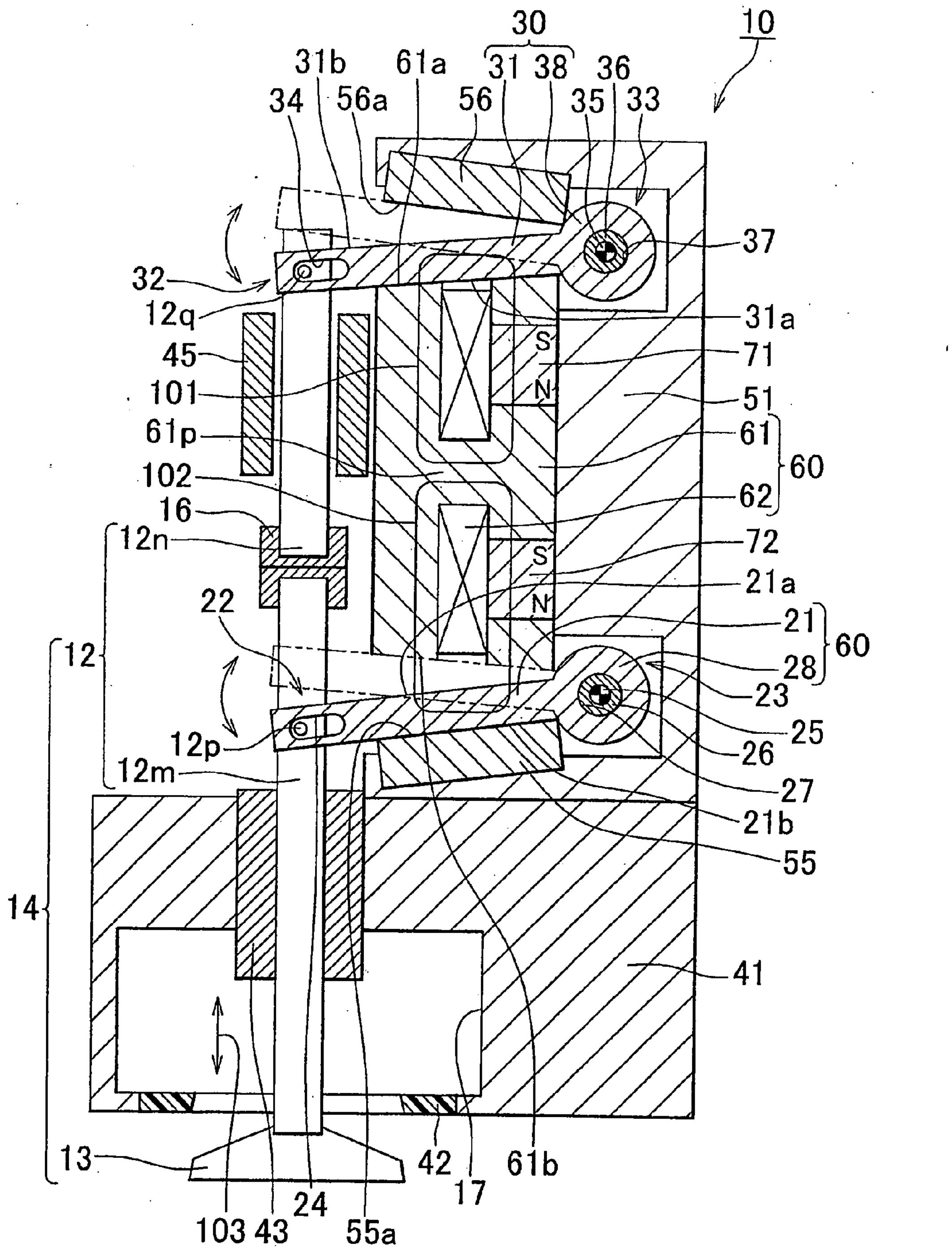


FIG. 1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10
31b
61a
31
38
36
34
56a
56
35
33
37
32
12q
31a
45
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71
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101
51
61p
61
60
102
62
16
12n
72
S
21a
22
N
21
60
12
28
23
22
25
12p
26
12m
27
21b
55
14
41
13
42
17
61b
103
43
24
55a

FIG. 2

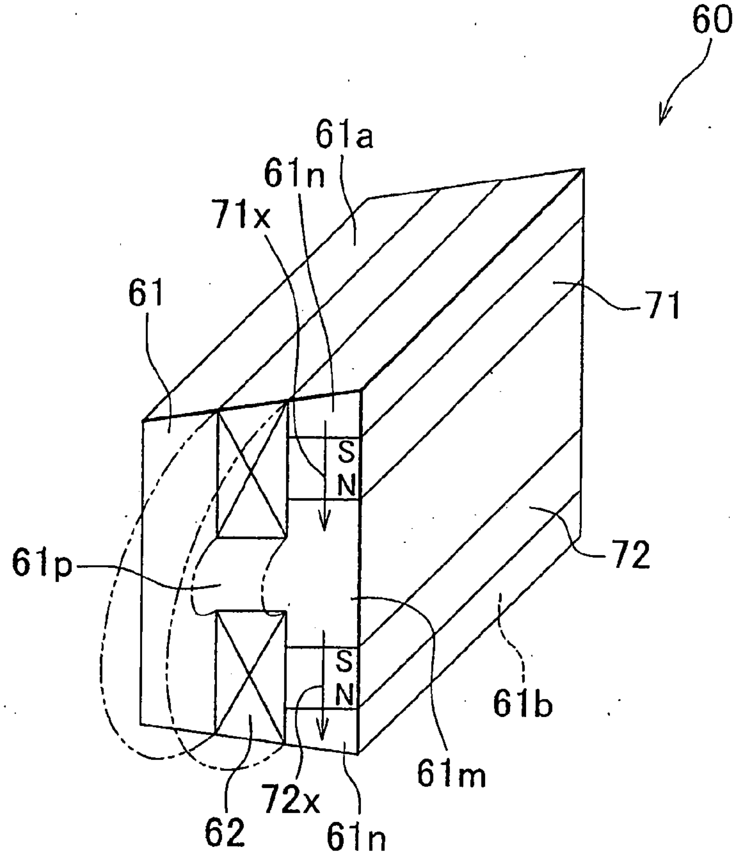

60
61a
61n
71x
61
71
S
N
61p
72
S
N
61b
61m
72x
62
61n

FIG. 3

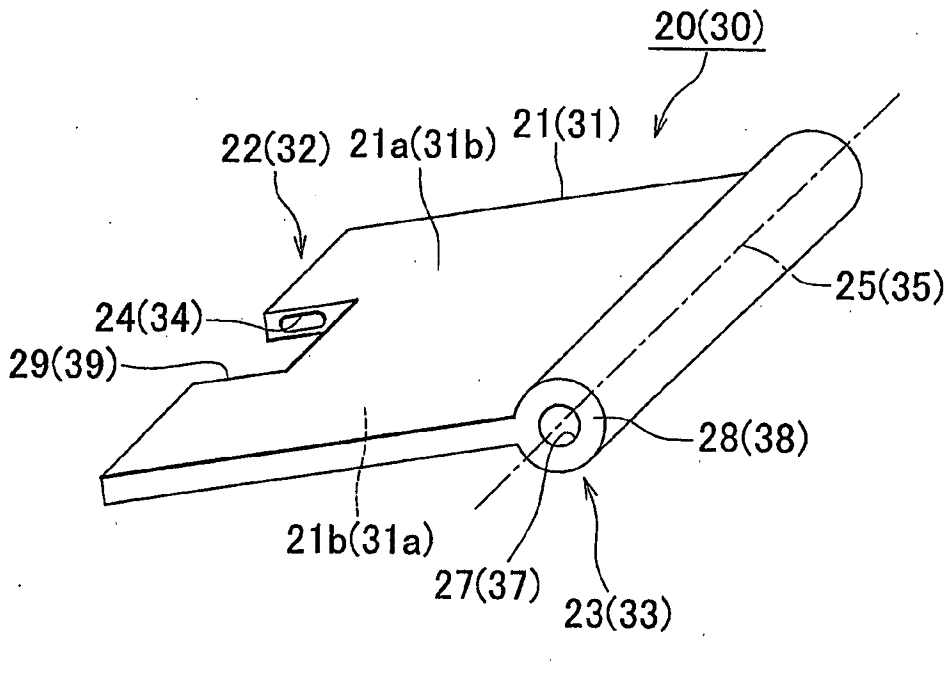

20(30)
22(32)
21a(31b)
21(31)
24(34)
25(35)
29(39)
28(38)
21b(31a)
27(37)
23(33)

FIG. 4

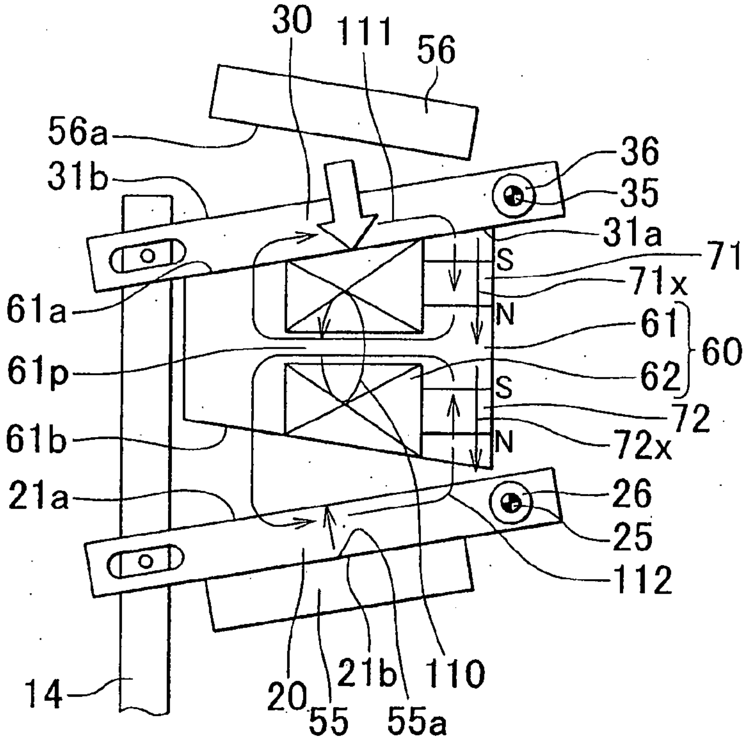

30
111
56
56a
31b
36
35
31a
71
71x
S
N
61a
61
60
61p
62
S
72
61b
72x
N
21a
26
25
112
14
20
55
21b
110
55a

FIG. 5

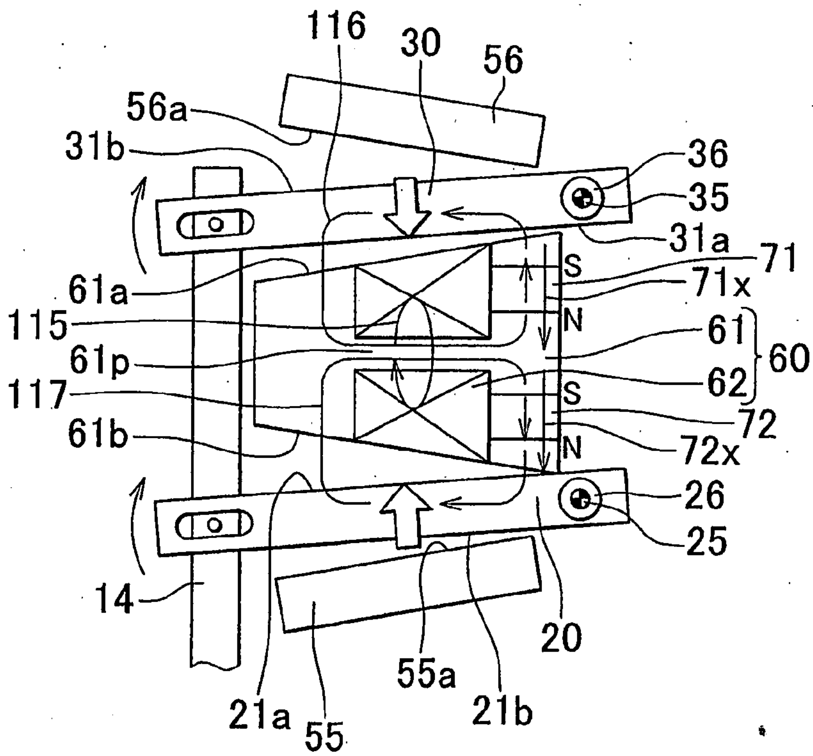
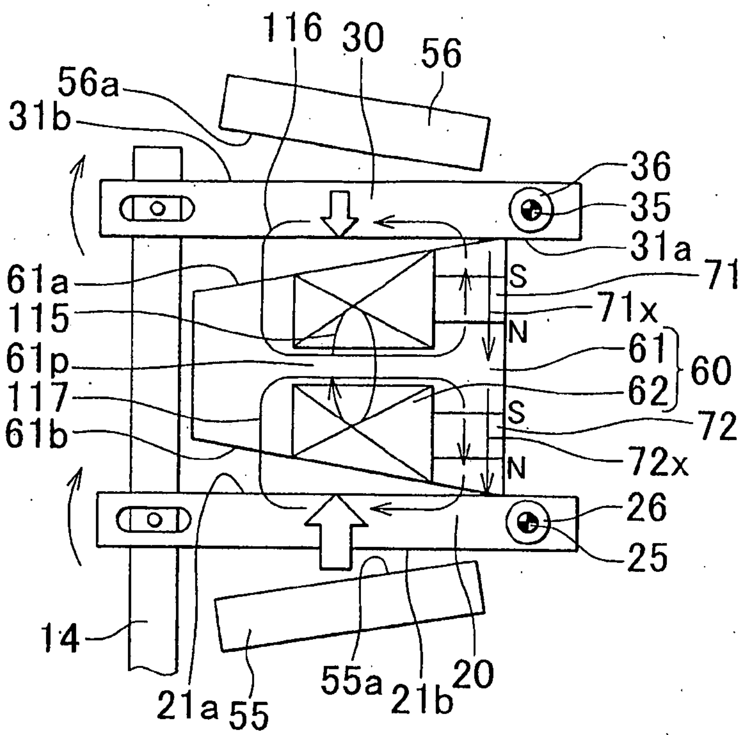

116
30
56
56a
31b
36
35
31a
71
71x
S
61a
115
N
61
60
61p
117
62
S
72
72x
61b
N
26
25
14
20
55a
21b
21a
55

FIG. 6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56a
31b
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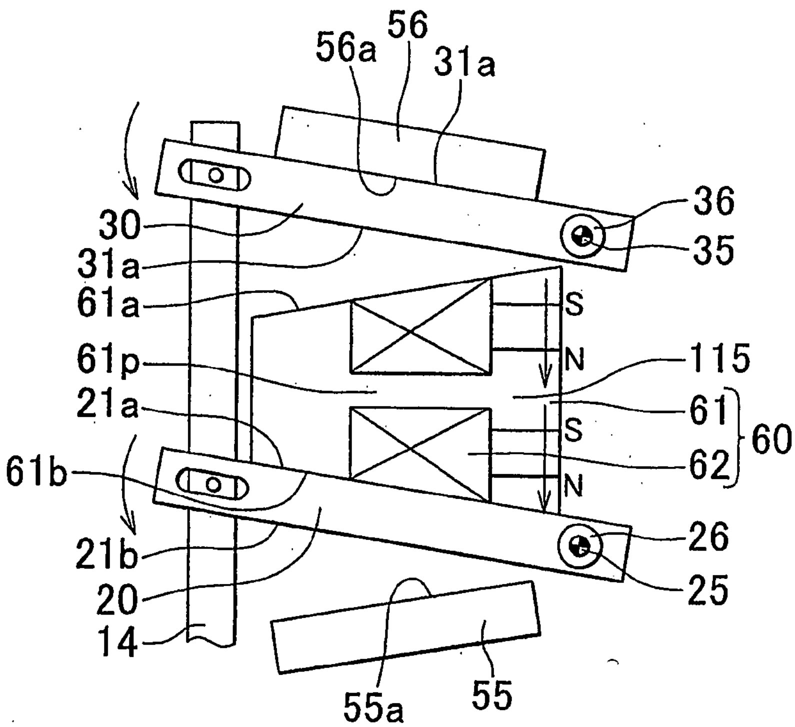
31a
71
61a
71x
115
61
61p
60
62
117
72
61b
72x
26
25
14
21a
55
55a
21b
20
S
N
S
N

FIG. 7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56
31a
36
30
35
31a
61a
S
61p
N
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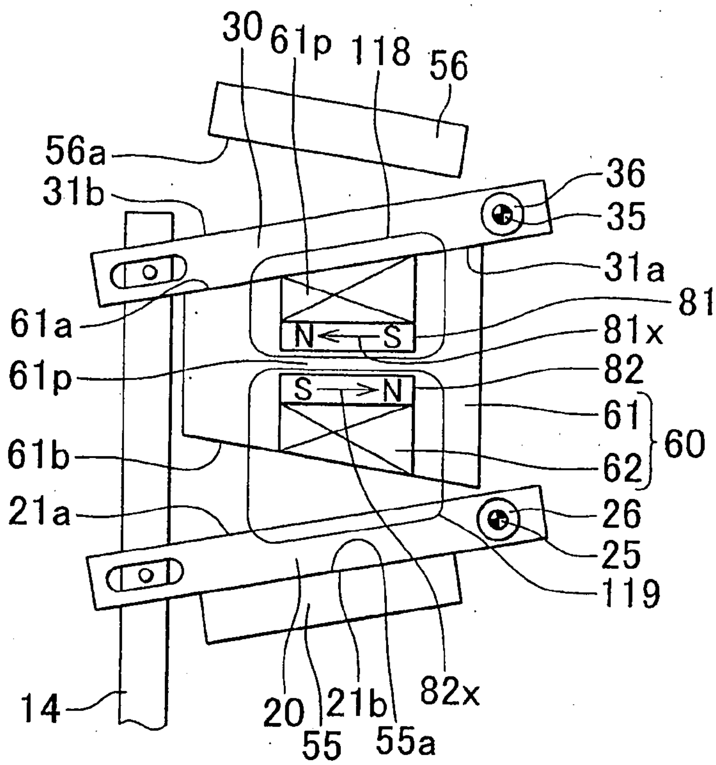
21a
61
S
60
61b
62
N
21b
26
20
25
14
55a
55

FIG. 8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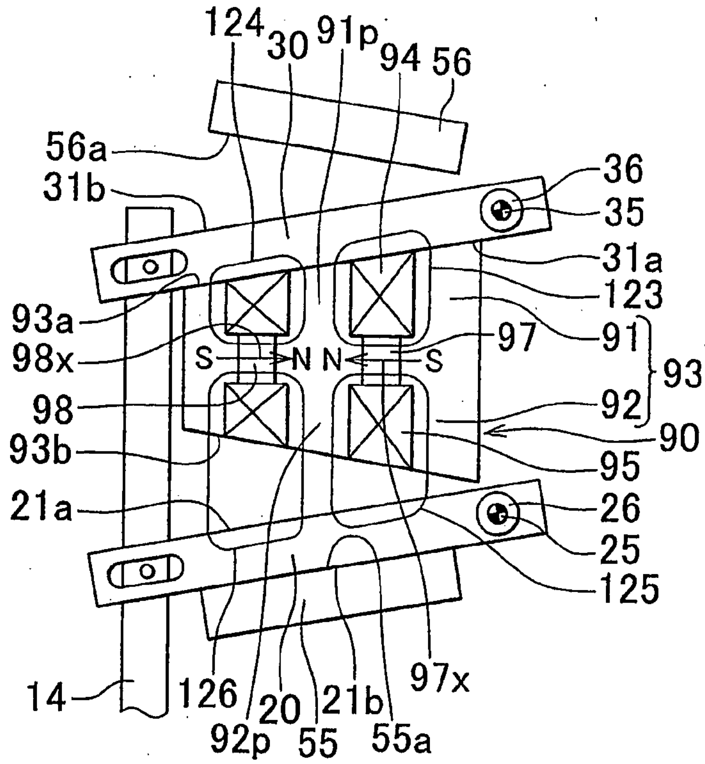
61p
118
56
56a
31b
36
35
31a
81
61a
81x
N
S
61p
82
S
N
61
60
61b
62
21a
26
25
119
14
20
55
21b
55a
82x

FIG. 9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30
91p
94
56
56a
31b
36
35
31a
123
93a
91
98x
97
S
N
N
S
93
98
92
93b
90
95
21a
26
25
125
14
126
92p
20
55
21b
55a
97x

ELECTROMAGNETICALLY DRIVEN VALVE

INCORPORATION BY REFERENCE

[0001] This is a 371 national phase application of PCT/IB2005/002503 filed 24 Aug. 2005, claiming priority to Japanese Patent Application No. 2004-251288 filed 31 Aug. 2004, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates generally to an electromagnetically driven valve. More specifically, the invention relates to a rotary driven type electromagnetically driven valve used for an internal combustion engine.

[0004] 2. Description of the Related Art

[0005] A conventional electromagnetically driven valve is disclosed in, for example, Japanese Patent Application Publication No. 11-350929 A. Japanese Patent Application Publication No. 11-350929 A discloses a so-called parallel driven type electromagnetically driven valve intended for reliably attracting an armature to an electromagnet and realizing low electric power consumption. The electromagnetically driven valve disclosed in Japanese Patent Application Publication No. 11-350929 A includes a valve stem formed integrally with a valve element.

[0006] The valve stem is provided with a collar-shaped armature that extends in the radius direction of the valve stem. A first electromagnet and a second electromagnet are arranged with the armature interposed therebetween. The electromagnetically driven valve further includes a lower spring that applies a force to the valve element in the direction in which the valve is closed, and an upper spring that applies a force to the valve element in the direction in which the valve is opened. The lower spring and the upper spring are provided in series in the axial direction of the valve stem. In the parallel driven type electromagnetically driven valve, an electromagnetic force generated by the first electromagnet and the second electromagnet, and an elastic force of the lower spring and the upper spring are directly applied to the valve stem, whereby the valve stem reciprocates between the valve opening position and the valve closing position. An assist magnet for generating a large amount of electromagnetic force is provided in a core forming the first electromagnet and the second electromagnet.

[0007] Japanese Patent Application Publication No. 04-276106 A discloses an electromagnetically driven valve intended for efficiently driving an electromagnetic valve. The electromagnetically driven valve disclosed in Japanese Patent Application Publication No. 04-276106 A is a parallel driven type electromagnetically driven valve, as in the case of the electromagnetically driven valve disclosed in Japanese Patent Application Publication No. 11-350929 A. The electromagnetically driven valve includes a valve mechanism which drives an electromagnetic valve by using an electromagnetic force. A permanent magnet portion is provided in a yoke forming the valve mechanism.

[0008] In the parallel driven type electromagnetically driven valve disclosed in Japanese Patent Application Publication No. 11-350929 A, a clearance is formed between the first electromagnet and the second electromagnet. The armature reciprocates in the clearance while being alternately attracted to the first electromagnet and the second electromagnet. The armature and each of the first electromagnet and the second electromagnet are uniformly apart from each other while the distance therebetween uniformly changes, except for the state where the valve stem is at one of the valve opening position and the valve closing position. However, an electromagnetic force acts at a higher degree at a position at which the distance from the electromagnet is shorter. Therefore, the electromagnetically driven valve disclosed in Japanese Patent Application Publication No. 11-350929 A has a problem that a sufficiently large amount of electromagnetic force cannot be applied to the armature, and, therefore, a large amount of driving force cannot be obtained. Such a problem also occurs in the parallel driven type electromagnetically driven valve disclosed in Japanese Patent Application Publication No. 04-276106 A.

[0009] Document FR 2 792 451 discloses an electromagnetic drive mechanism, wherein the electromagnetic drive mechanism has a flexible return section to move a valve between an open and closed position. The flexible return is made up of tongue sections pivoting about an axis which act on the valve spoke transforming movements to the valve movement plane.

[0010] Further, document EP 1 010 866 A2 discloses an electromagnetic actuating system having a valve member. The electromagnetic actuating system includes an armature which moves with the valve member, an electromagnet which attracts the armature in a direction of movement of the valve member by being supplied with a current, and a spring which presses the armature away from the electromagnet. A permanent magnet which can exert a magnetic attracting force between the armature and the electromagnet is provided. A current controller supplies a release current to the electromagnet so that magnetic flux is generated in a direction opposite to a direction of magnetic flux generated by the permanent magnet when the armature is released from the electromagnet. The valve member functions as an intake valve or an exhaust valve of an internal combustion engine, and the current controller controls an amount of said release current in accordance with an operating state of the internal combustion engine.

[0011] Finally, document DE 198 24 537 A1 discloses an electromagnetically driven device having a valve stem and that reciprocates in a direction in which the valve stem extends. Further, an oscillating member having an arm portion made of magnetic material extends from a first end and is movably supported by a supporting member. The arm is oscillated by means of an electromagnet that includes a core and a coil and forms a magnetic circuit.

SUMMARY OF THE INVENTION

[0012] The invention is made in light of the above-mentioned circumstances. It is, therefore, an object of the invention to provide an electromagnetically driven valve in which a sufficiently large amount of driving force can be obtained.

[0013] According to an aspect of the invention, there is provided an electromagnetically driven valve including a drive valve which has a valve stem; two oscillation members being formed of a first oscillation member and a second oscillation member, which have an arm portion made of magnetic material, and which extends from a first end that is movably connected to the valve stem toward a second end that is movably supported by a supporting member, respectively; and an electromagnet. The electromagnet includes a core that is provided so as to face the arm portion, and a coil that is wound around the core. The electromagnet forms two magnetic circuits which pass through the core and the arm portions when an electric current is applied to the coil for applying magnetism to the two oscillation members, respectively. The electromagnetically driven valve further includes a permanent magnet which has a magnetic axis along the magnetic circuits, and which is provided so as to act on a magnetic flux that flows through the magnetic circuits. The permanent magnet is disposed so as to balance out the magnetic flux that flows through the magnetic circuit acting on one of the two oscillation members, and to increase the magnetic flux that flows through the magnetic circuit acting on the other oscillation member. The oscillation members are oscillated by using the second end as a supporting point due to an electromagnetic force applied from the electromagnet. An oscillation motion of the oscillation member is transmitted to the drive valve via the first end, whereby the drive valve reciprocates in the direction in which the valve stem extends.

[0014] According to another aspect of the invention, there is provided a control method for an electromagnetically driven valve including a drive valve which has a valve stem and which reciprocates in a direction in which the valve stem extends; two oscillation members being formed of a first oscillation member and a second oscillation member which are movably connected to the valve stem; and an electromagnet which forms two magnetic circuits between the electromagnet and the oscillation members for applying magnetism to the two oscillation members, respectively, wherein the permanent magnet is disposed so as to balance out the magnetic flux that flows through the magnetic circuit acting on one of the two oscillation members, and to increase the magnetic flux that flows through the magnetic circuit acting on the other oscillation member. The control method includes a first step in which a supply of an electric current to the electromagnet is stopped, whereby the oscillation member, which is at a first position at which the oscillation members have been oscillated as much as possible so that the drive valve is moved in a first direction, are started to be oscillated toward a second position at which the oscillation members are to be oscillated as much as possible so that the drive valve is moved in a second direction that is opposite to the first direction; and a second step which is performed after the first step is completed, and in which the supply of the electric current to the electromagnet is started before the oscillation member reaches a center position that is a midpoint between the first position and the second position. In this case, the first position may be a position at which the oscillation member has been oscillated as much as possible so that the drive valve is opened, and the second position may be a position at which the oscillation member has been oscillated as much as possible so that the drive valve is closed. Alternatively, the first position may be a position at which the oscillation member has been oscillated as much as possible so that the drive valve is closed, and the second position may be a position at which the oscillation member has been oscillated as much as possible so that the drive valve is opened.

[0015] With the electromagnetically driven valve thus configured, when the direction in which the magnetic flux flows in the permanent magnet matches the direction in which the magnetic flux flows through the magnetic circuit, the strength of the magnetic flux flowing through the magnetic circuit is increased. On the other hand, when the direction in which the magnetic flux flows in the permanent magnet is opposite to the direction in which the magnetic flux flows through the magnetic circuit, the strength of the magnetic flux flowing through the magnetic circuit is decreased. Accordingly, appropriately selecting the direction of an electric current applied to the coil makes it possible to control the amount of electromagnetic force applied to the oscillation member so that an oscillation motion of the oscillation member is promoted. In addition, in the invention, a method in which the drive valve is reciprocated due to the oscillation motion of the oscillation member is used as the method for driving the electromagnetically driven valve. In this case, the distance between the arm portion and the electromagnet at a position near the second end movably supported by the supporting member is always shorter than the distance between the arm portion and the electromagnet at a position near the first end movably connected to the valve stem, regardless of the oscillation position of the oscillation member. Accordingly, a larger amount of electromagnetic force can be applied to the oscillation member. It is, therefore, possible to obtain a sufficiently large amount of driving force by providing the permanent magnet in the rotary driven type electromagnetically driven valve.

[0016] As mentioned above, when the direction in which the magnetic flux flows in the permanent magnet matches the direction in which the magnetic flux flows through the magnetic circuit, the strength of the magnetic flux flowing through the magnetic circuit is increased. On the other hand, when the direction in which the magnetic flux flows in the permanent magnet is opposite to the direction in which the magnetic flux flows through the magnetic circuit, the strength of the magnetic flux flowing through the magnetic circuit is decreased. Accordingly, it is possible to start the supply of electric current to the electromagnet before the oscillation member reaches the center position while reciprocating between the first position and the second position.

[0017] The permanent magnet may be provided in the core.

[0018] With the electromagnetically driven valve thus configured, it is possible to cause the magnetic flux formed in the permanent magnet to act on the magnetic flux flowing through the magnetic circuit more effectively.

[0019] The permanent magnet may be provided between the core and the coil.

[0020] With the electromagnetically driven valve thus configured, it is possible to avoid the situation where the core needs to be divided into two areas in order to provide the permanent magnet. As a result, the structure of the electromagnet can be simplified.

[0021] The permanent magnet may be embedded in the core, and the core may be divided into two areas by the permanent magnet on the magnetic circuit.

[0022] With the electromagnetically driven valve thus configured, it is possible to cause the magnetic flux flowing through the magnetic circuit to pass through the permanent magnet reliably. It is, therefore, possible to cause the magnetic flux formed in the permanent magnet to act on the magnetic flux flowing through the magnetic circuit more effectively.

[0023] As described so far, according to the invention, it is possible to provide the electromagnetically driven valve in which a sufficiently large amount of driving force can be obtained, and the control method thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The features, advantages thereof, technical and industrial significance of this invention will be better understood by reading the following detailed description of preferred embodiments of the invention, when considered in connection with the accompanying drawings, in which:

[0025] FIG. **1** illustrates a cross sectional view of an electromagnetically driven valve according to a first embodiment of the invention;

[0026] FIG. **2** illustrates a perspective view of an electromagnet in FIG. **1**;

[0027] FIG. **3** illustrates a perspective view of a lower disk (an upper disk) in FIG. **1**;

[0028] FIG. **4** illustrates a schematic view of the upper disk and the lower disk that have been oscillated as much as possible so that the valve is opened;

[0029] FIG. **5** illustrates a schematic view of the upper disk and the lower disk that are oscillating toward the center position from the position at which the upper disk and the lower disk have been oscillated as much as possible so that the valve is opened;

[0030] FIG. **6** illustrates a schematic view of the upper disk and the lower disk that are at the center position;

[0031] FIG. **7** illustrates a schematic view of the upper disk and the lower disk that have been oscillated as much as possible so that the valve is closed;

[0032] FIG. **8** illustrates a schematic view of an electromagnetically driven valve according to a second embodiment of the invention; and

[0033] FIG. **9** illustrates a schematic view of an electromagnetically driven valve according to a third embodiment of the invention.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0034] In the following description and the accompanying drawings, the invention will be described in more detail in terms of exemplary embodiments. Note that, the same reference numerals will be assigned to the same or equivalent components in the following description and the accompanying drawings.

[0035] FIG. **1** illustrates a cross sectional view of an electromagnetically driven valve according to a first embodiment of the invention. The electromagnetically driven valve according to the first embodiment forms an engine valve (an intake valve or an exhaust valve) of an internal combustion engine such as a gasoline engine or a diesel engine. In the first embodiment, the description will be made concerning the case where the electromagnetically driven valve forms an intake valve. Note that, in the case where the electromagnetically driven valve forms an exhaust valve, the same structure as that of the electromagnetically driven valve forming the intake valve is applied.

[0036] As shown in FIG. **1**, an electromagnetically driven valve **10** is a rotary driven type electromagnetically driven valve, and a parallel link mechanism is applied to a motion mechanism thereof.

[0037] The electromagnetically driven valve **10** includes a drive valve **14** having a stem **12** extending in one direction; a lower disk **20** and an upper disk **30** which are connected to the stem **12** at different positions, and which oscillates due to an electromagnetic force and an elastic force applied thereto; an open/close electromagnet **60** which generates the electromagnetic force (hereinafter, may be simply referred to as an "electromagnet **60**"); a lower torsion bar **26** which is provided in the lower disk **20** and which applies the elastic force to the lower disk **20**; and an upper torsion bar **36** which is provided in the upper disk **30** and which applies the elastic force to the upper disk **30**. Permanent magnets **71** and **72** are embedded in the electromagnet **60**. The drive valve **14** reciprocates in the direction in which the stem **12** extends (the direction shown by an arrow **103**) due to the oscillation motion of the lower disk **20** and the upper disk **30**.

[0038] The drive valve **14** is provided in a cylinder head **41** in which an intake port **17** is formed. A valve seat **42** is provided at a position at which the intake port **17** formed in the cylinder head **41** is communicated with a combustion chamber (not shown). The drive valve **14** further includes a bell portion **13** formed at an end of the stem **12**. As the drive valve **14** reciprocates, the bell portion **13** alternately contacts the valve seat **42** and moves away from the valve seat **42**, whereby the intake port **17** is alternately closed and opened. Namely, when the stem **12** moves upward, the drive valve **14** is moved toward the valve closing position, and when the stem **12** moves downward, the drive valve **14** is moved toward the valve opening position.

[0039] The stem **12** is formed of a lower stem **12*m*** that extends from the bell portion **13**, and an upper stem **12*n*** that is connected to the lower stem **12*m*** with a lash adjuster **16** interposed between the lower stem **12*m*** and the upper stem **12*n***. The lash adjuster **16** serves a buffering member located between the upper stem **12*n*** and the lower stem **12*m***, and is likely to shrink and unlikely to stretch. The lash adjuster **16** absorbs an error in positioning of the drive valve **14** at the valve closing position, and allows the bell portion **13** to reliably contact the valve seat **42**. A connection pin **12*p***, which protrude from the outer surface of the lower stem **12*m***, is provided for the lower stem **12*m***. A connection pin **12*q***, which protrudes from the outer surface of the upper stem **12*n***, is provided for the upper stem **12*n*** at a predetermined distance from the connection pin **12*p***.

[0040] A valve guide **43** is provided in the cylinder head **41** so as to slidably guide the lower stem **12*m*** in the axial direction. A stem guide **45** is provided so as to slidably guide the upper stem **12*n*** in the axial direction, at a position at a predetermined distance from the valve guide **43**. The valve guide **43** and the stem guide **45** are made of metal material such as stainless so as to endure sliding with the stem **12** at a high speed. A disk supporting base **51** is fitted on the top surface of the cylinder head **41**, at a predetermined distance from the stem **12**.

[**0041**] FIG. **2** illustrates a perspective view of the electromagnet **60** in FIG. **1**. As shown in FIGS. **1** and **2**, the electromagnet **60** is fitted to the disk supporting base **51**, at a position between the lower disk **20** and the upper disk **30**. The electromagnet **60** is formed of an open/close coil **62** (hereinafter, may be simply referred to as a "coil **62**"), and an open/close core **61** (hereinafter, may be simply referred to as a "core **61**") which has attraction surfaces **61***a* and **61***b*, and which is made of magnetic material. The core **61** has a shaft portion **61***p* extending in the direction perpendicular to the direction in which the stem **12** extends. The coil **62** is provided around the shaft portion **61***p*, and formed of a mono-coil (i.e., a coil formed of a piece of wire).

[**0042**] When an electric current is applied to the coil **62**, a magnetic flux flows between the core **61** and the lower disk **20**, whereby a magnetic circuit **102** is formed. Similarly, when the electric current is applied to the coil **62**, a magnetic flux flows between the core **61** and the upper disk **30**, whereby a magnetic circuit **101** is formed. In the core **61**, the permanent magnet **71** is provided so as to be located on the magnetic circuit **101**, and the permanent magnet **72** is provided so as to be located on the magnetic circuit **102**. The core **61** is divided, by the permanent magnets **71** and **72**, into a portion **61***m* including the shaft portion **61***p*, and portions **61***n* one of which faces the upper disk **30** and the other of which faces the lower disk **20**.

[**0043**] The permanent magnet **71** has the magnetic axis in the direction along the magnetic circuit **101**. The south pole is formed in the side of the permanent magnet **71**, which is close to the portion **61***n*. The north pole is formed in the side of the permanent magnet **71**, which is close to the portion **61***m*. With such a structure, the magnetic flux formed in the permanent magnet **71** flows from the side close to the portion **61***n* toward the side close to the portion **61***m* (in the direction shown by an arrow **71***x*) due to the magnetic poles. The permanent magnet **72** has the magnetic axis in the direction along the magnetic circuit **102**. The north pole is formed in the side of the permanent magnet **72**, which is close to the portion **61***n*. The south pole is formed in the side of the permanent magnet **72**, which is close to the portion **61***m*. With such a structure, the magnetic flux formed in the permanent magnet **72** flows from the side close to the portion **61***m* toward the side close to the portion **61***n* (in the direction shown by an arrow **72***x*) due to magnetic poles.

[**0044**] The disk supporting base **51** is further provided with a valve opening permanent magnet **55**, and a valve closing permanent magnet **56** that is opposed to the valve opening permanent magnet **55** with the electromagnet **60** interposed therebetween. The valve opening permanent magnet **55** has an attraction surface **55***a*. A space in which the lower disk **20** oscillates is defined between the attraction surface **55***a* of the valve opening permanent magnet **55** and the attraction surface **61***b* of the electromagnet **60**. Similarly, the valve closing permanent magnet **56** has an attraction surface **56***a*. A space in which the upper disk **30** oscillates is defined between the attraction surface **56***a* of the valve closing permanent magnet **56** and the attraction surface **61***a* of the electromagnet **60**.

[**0045**] FIG. **3** illustrates a perspective view of the lower disk **20** (upper disk **30**) in FIG. **1**. As shown in FIG. **1** and FIG. **3**, the lower disk **20** has a first end **22** and a second end **23**, and extends from the second end **23** toward the first end **22** in the direction that crosses the direction in which the stem **12** extends. The lower disk **20** is formed of an arm portion **21** that has rectangular surfaces **21***a* and **21***b* and that extends from the second end **23** toward the first end **22**, and a hollow cylindrical bearing portion **28** that is formed in the second end **23** side. The surface **21***a* faces the attraction surface **61***b* of the electromagnet **60**, and the surface **21***b* faces the attraction surface **55***a* of the valve opening permanent magnet **55**. The magnetic circuit **102** formed by applying an electric current to the coil **62** forms a closed-loop that passes through the shaft portion **61***p* of the core **61**, the permanent magnet **72**, and the arm portion **21**.

[**0046**] A notched portion **29** is formed in the arm portion **21** in the first end **22** side. A long hole **24** is formed in each of wall surfaces of the notched portion **29**, which face each other. In the second end **23** side, a central axis **25** is defined which extends in the direction perpendicular to the direction from the first end **22** toward the second end **23**. A through-hole **27** extending along the central axis **25** is formed in the bearing portion **28**.

[**0047**] The upper disk **30** has the same shape as that of the lower disk **20**. In the upper disk **30**, a first end **32**, a second end **33**, an arm portion **31**, a surface **31***b*, a surface **31***a*, a notched portion **39**, and a long hole **34**, a bearing portion **38**, a through-hole **37**, and a central axis **35** are formed, which correspond to the first end **22**, the second end **23**, the arm portion **21**, the surface **21***a*, the surface **21***b*, the notched portion **29**, the long hole **24**, the bearing portion **28**, the through-hole **27**, and the central axis **25** in the lower disk **20**, respectively. The surface **31***a* faces the attraction surface **61***a* of the electromagnet **60**, and the surface **31***b* faces the attraction surface **56***a* of the valve closing permanent magnet **56**. The lower disk **20** and the upper disk **30** are made of soft magnetic material. The magnetic circuit **101** formed by applying an electric current to the coil **62** forms a closed-loop that passes through the shaft portion **61***p* of the core **61**, the permanent magnet **71**, and the arm portion **31**.

[**0048**] The first end **22** of the lower disk **20** is movably connected to the lower stem **12***m*, when the connection pin **12***p* is inserted into the long holes **24**. Similarly, the first end **32** of the upper disk **30** is movably connected to the upper stem **12***n*, when the connection pin **12***q* is inserted into the long holes **34**. The second end **23** of the lower disk **20** is movably supported by the disk supporting base **51** via the lower torsion bar **26** inserted into the through-hole **27**. Similarly, the second end **33** of the upper disk **30** is movably supported by the disk supporting base **51** via the upper torsion bar **36** inserted into the through-hole **37**. With such a structure, the drive valve **14** can be reciprocated by oscillating the lower disk **20** with respect to the central axis **25**, and the upper disk **30** with respect to the central axis **35**.

[**0049**] An elastic force is applied to the lower disk **20** by the lower torsion bar **26** in the clockwise direction around the central axis **25**. An elastic force is applied to the upper disk **30** by the upper torsion bar **36** in the counterclockwise direction around the central axis **35**. In the state where an electromagnetic force is not applied from the electromagnet **60**, the lower disk **20** and the upper disk **30** are placed at the center position by the lower torsion bar **26** and the upper torsion bar **36**. The center position is the midpoint between the position at which the lower disk **20** and the upper disk **30** have been oscillated as much as possible so that the valve is opened, and the position at which the lower disk **20** and the upper disk **30** have been oscillated as much as possible so that the valve is closed.

[0050] FIG. **4** illustrates a schematic view of the upper disk **30** and the lower disk **20** that have been oscillated as much as possible so that the valve is opened. FIG. **5** illustrates a schematic view of the upper disk **30** and the lower disk **20** that are moving toward the center position from the position at which the upper disk **30** and the lower disk **20** have been oscillated as much as possible so that the valve is opened. FIG. **6** illustrates a schematic view of the upper disk **30** and the lower disk **20** that are at the center position. FIG. **7** illustrates the upper disk **30** and the lower disk **20** that have been oscillated as much as possible so that the valve is closed. Next, the operation of the electromagnetically driven valve **10** will be described in detail.

[0051] As shown in FIG. **4**, when the drive valve **14** is at the valve opening position, an electric current that flows around the shaft portion **61***p* of the core **61** in a direction shown by an arrow **110** is applied to the coil **62**. Thus, the upper disk **30** is attracted to the attraction surface **61***a* of the electromagnet **60** due to an electromagnetic force generated by the electromagnet **60**. Meanwhile, the lower disk **20** is attracted to the attraction surface **55***a* by the valve opening permanent magnet **55**. As a result, the upper disk **30** and the lower disk **20** are oscillated as much as possible so that the valve is opened and maintained in this state, against an elastic force of the lower torsion bar **26** provided around the central axis **25**.

[0052] When the supply of electric current to the coil **62** is stopped, the electromagnetic force generated by the electromagnet **60** disappears. Thus, the upper disk **30** and the lower disk **20** move away from the attraction surfaces **61***a* and **55***a*, respectively, and start to oscillate toward the center position due to the elastic force of the lower torsion bar **26**.

[0053] As shown in FIG. **5**, an electric current is applied to the coil **62** in the direction shown by an arrow **115**, before the lower disk **20** and the upper disk **30** reach the center position. Thus, a magnetic flux flows between the core **61** and the lower disk **20** in the direction shown by an arrow **117**, and an electromagnetic force for attracting the lower disk **20** to the attraction surface **61***b* of the electromagnet **60** is generated. Also, a magnetic flux flows between the core **61** and the upper disk **30** in the direction shown by an arrow **116**, and an electromagnetic force for attracting the upper disk **30** to the attraction surface **61***a* of the electromagnet **60** is generated.

[0054] Since the direction in which the magnetic flux flows between the core **61** and the lower disk **20** matches the direction in which the magnetic flux formed in the permanent magnet **72** flows, the strength of magnetic flux increases. Accordingly, the electromagnetic force for attracting the lower disk **20** to the attraction surface **61***b* increases. Meanwhile, since the direction in which the magnetic flux flows between the core **61** and the upper disk **30** is opposite to the direction in which the magnetic flux formed in the permanent magnet **71** flows, the magnetic flux flowing between the core **61** and the upper disk **30** and the magnetic flux formed in the permanent magnet **71** balance each other out, and, therefore, the strength of magnetic flux is decreased. Accordingly, the electromagnetic force for attracting the upper disk **30** to the attraction surface **61***a* is decreased.

[0055] As described so far, providing the permanent magnets **71** and **72** makes it possible to increases the electromagnetic force applied in the direction in which the lower disk **20** and the upper disk **30** oscillate, and to decrease the electromagnetic force applied in the direction opposite to the direction in which the lower disk **20** and the upper disk **30** oscillate. It is, therefore, possible to increase a force for closing the drive valve **14** obtained due to the oscillation motion of the lower disk **20** and the upper disk **30**.

[0056] As shown in FIG. **6**, after reaching the center position, the lower disk **20** and the upper disk **30** are oscillated from the center position toward the position at which the lower disk **20** and the upper disk **30** are to be oscillated as much as possible so that the valve is closed, due to the electromagnetic force of the electromagnet **60** for attracting the lower disk **20** to the attraction surface **61***b* and the magnetic force of the valve closing permanent magnet **56** for attracting the upper disk **30** to the attraction surface **56***a*. Providing the valve closing permanent magnet **56** makes it possible to compensate for the shortfall of the electromagnetic force, which is likely to occur particularly when the drive valve **14** is near the valve closing position. It is, therefore, possible to prevent the force for closing the drive valve **14** from decreasing.

[0057] As shown in FIG. **7**, when the lower disk **20** and the upper disk **30** have oscillated as much as possible so that the valve is closed, the supply of electric current to the coil **62** is stopped. Thus, the upper disk **30** and the lower disk **20** move away from the attraction surfaces **56***a* and **61***b*, respectively, and start to oscillate toward the center position again due to the elastic force of the upper torsion bar **36**.

[0058] As shown in FIG. **4**, an electric current is applied to the coil **62** in the direction shown by the arrow **110**, before the lower disk **20** and the upper disk **30** reach the center position. Thus, a magnetic flux flows between the core **61** and the upper disk **30** in the direction shown by an arrow **111**, and an electromagnetic force for attracting the upper disk **30** to the attraction surface **61***a* of the electromagnet **60** is generated. Also, a magnetic flux flows between the core **61** and the lower disk **20** in the direction shown by an arrow **112**, and an electromagnetic force for attracting the lower disk **20** to the attraction surface **61***b* of the electromagnet **60** is generated.

[0059] At this time, since the direction in which the magnetic flux flows between the core **61** and the upper disk **30** matches the direction in which the magnetic flux formed in the permanent magnet **71** flows, the strength of magnetic flux increases. Accordingly, the electromagnetic force for attracting the upper disk **30** to the attraction surface **61***a* increases. Meanwhile, since the direction in which the magnetic flux flows between the core **61** and the lower disk **20** is opposite to the direction in which the magnetic flux formed in the permanent magnet **72** flows, the magnetic flux flowing between the core **61** and the lower disk **20** and the magnetic flux formed in the permanent magnet **72** balance each other out, and, therefore, the strength of magnetic flux is decreased. Accordingly, the electromagnetic force for attracting the lower disk **20** to the attraction surface **61***b* is decreased. In this case as well, it is possible to increase the electromagnetic force applied in the direction in which the lower disk **20** and the upper disk **30** oscillate, and to decrease the electromagnetic force applied in the direction opposite to the direction in which the lower disk **20** and the upper disk **30** oscillate. It is, therefore, possible to increase the force for opening the drive valve **14**.

[**0060**] After reaching the center position, the lower disk **20** and the upper disk **30** are oscillated from the center position toward the position at which the lower disk **20** and the upper disk **30** are to be oscillated as much as possible so that the valve is opened due to the electromagnetic force of the electromagnet **60** for attracting the upper disk **30** to the attraction surface **61***a* and the magnetic force of the valve opening permanent magnet **55** for attracting the lower disk **20** to the attraction surface **55***a*. In this case, providing the valve opening permanent magnet **55** makes it possible to prevent the force for opening the drive valve **14** from decreasing particularly when the drive valve **14** is near the valve opening position.

[**0061**] Then, the supply of the electric current to the open/close coil **62** is repeatedly started and stopped at the above-mentioned timing. Thus, the upper disk **30** and the lower disk **20** are moved so as to be repeatedly oscillated as much as possible so that the valve is opened and oscillated as much as possible so that the valve is closed. The drive valve **14** are reciprocated due to this oscillation motion.

[**0062**] In the electromagnetically driven valve **10** according to the first embodiment, when the lower disk **20** and the upper disk **30** are oscillating, the distance between the electromagnet **60** and the lower disk **20** decreases from the first end **22** toward the second end **23**, and the distance between the electromagnet **60** and the upper disk **30** decreases from the first end **32** toward the second end **33**. In contrast to this, in the parallel driven type electromagnetically driven valve, the electromagnet and the armature of the drive valve to which the electromagnetic force is applied are uniformly apart from each other while the distance therebetween uniformly changes. At a position at which the distance from the electromagnet is shorter, a larger amount of electromagnetic force is applied. Therefore, in the rotary driven type electromagnetically driven valve **10**, a large amount of electromagnetic force can be applied to the drive valve **14**, as compared with the parallel driven type electromagnetically driven valve.

[**0063**] Further, in the electromagnetically driven valve **10**, the structure is such that the lower disk **20** and the upper disk **30** are movably supported by the disk supporting base **51** and the electromagnet **60** is provided between the lower disk **20** and the upper disk **30**. Therefore, the height of the electromagnetically driven valve **10** can be made low, as compared with the case where an electromagnet is provided above each disk and another electromagnet is provided below each disk. In addition, with such a structure, just providing the electromagnet **60** formed of a mono-coil makes it possible to oscillate the upper disk **30** and the lower disk **20**, and to reciprocate the drive valve **14**. As a result, the number of the components of the electromagnet, which are expensive, can be reduced, resulting in a remarkable cost reduction.

[**0064**] In the first embodiment, in the process shown in FIG. **5**, an electric current is applied to the coil **62** before the lower disk **20** and the upper disk **30** reach the center position. Note that, providing the permanent magnets **71** and **72** makes it possible to supply the electric current at this timing in the electromagnetically driven valve **10** using the electromagnet **60** formed of a mono-coil. The reason will be described as follows.

[**0065**] When the electromagnet **60** is formed of a mono-coil, the electromagnetic force generated by the electromagnet **60** is applied to the lower disk **20** and the upper disk **30** in the same manner. Namely, in the electromagnetically driven valve in which the permanent magnets **71** and **72** are not provided, if an electric force is applied to the electromagnet **60** when the lower disk **20** and the upper disk **30** are at the center position, as shown in FIG. **6**, the lower disk **20** is attracted to the attraction surface **61***b*, and the upper disk **30** is also attracted to the attraction surface **61***a* with the same amount of force for attracting the lower disk **20** to the attraction surface **61***b*.

[**0066**] Accordingly, in order to oscillate the lower disk **20** and the upper disk **30** against the elastic force of the lower torsion bar **26** and the upper torsion bar **36** for attempting to maintain the lower disk **20** and the upper disk **30** at the center position, it is necessary to start the supply of electric current to the coil **62** when the lower disk **20** and the upper disk **30** exceed the center position shown in FIG. **6**. In this case, since the electromagnetic force acts more strongly between the lower disk **20** and the electromagnet **60**, since the distance between the lower disk **20** and the electromagnet **60** is shorter than the distance between the upper disk **30** and the electromagnet **60**. Accordingly, the upper disk **30** and the lower disk **20** can be oscillated as much as possible so that the valve is closed, as shown in FIG. **7**.

[**0067**] As described above, however, providing the permanent magnets **71** and **72** makes it possible to flexibly increase/decrease the electromagnetic force applied to the lower disk **20** and the upper disk **30**. Accordingly, in the first embodiment, the time at which the supply of electric current to the coil **62** is started can be set to a time before the lower disk **20** and the upper disk **30** reach the center position. As a result, the electromagnetic force generated by the electromagnet **60** can be more effectively applied to the lower disk **20** and the upper disk **30**. It is, therefore, to increase the force for closing the drive valve **14** and the force for opening the drive valve **14**.

[**0068**] The electromagnetically driven valve **10** according to the first embodiment of the invention includes the drive valve **14** having the stem **12** serving as the valve stem; the lower disk **20** which serves as an oscillation member, which has the arm portion **21** made of magnetic material, and which extends from the first end **22** connected to the stem **12** toward the second end **23** movably supported by the disk supporting base **51** serving as a supporting member; the upper disk **30** which serves as an oscillation member, which has the arm portion **31** made of magnetic material, and which extends from the first end **32** connected to the stem **12** toward the second end **33** movably supported by the disk supporting base **51** serving as the supporting member; and the open/close electromagnet **60** serving as an electromagnet. The electromagnet **60** includes the open/close core **61** serving as a core provided so as to face the arm portions **21** and **31**; and the open/close coil **62** serving as a coil provided around the core **61**. When an electric current is applied to the coil **62**, the electromagnet **60** forms the magnetic circuit **102** which passes through the core **61** and the arm portion **21**, and the magnetic circuit **101** which passes through the core **61** and the arm portion **31**.

[0069] The electromagnetically driven valve **10** further includes the permanent magnet **72** that has the magnetic axis along the magnetic circuit **102** and that is provided so as to act on the magnetic flux flowing through the magnetic circuit **102**; and the permanent magnet **71** that has the magnetic axis along the magnetic circuit **101** and that is provided so as to act on the magnetic flux flowing through the magnetic circuit **101**. The lower disk **20** oscillates by using the second end **23** as a supporting point due to the electromagnetic force applied from the electromagnet **60**, and the upper disk **30** oscillates by using the second end **33** as a supporting point due to the electromagnetic force applied from the electromagnet **60**. The drive valve **14** reciprocates in the direction in which the stem **12** extends due to the oscillation motion of the lower disk **20** and the upper disk **30** transmitted to the drive valve **14** via the first ends **22** and **32**, respectively.

[0070] The lower disk **20** and the upper disk **30**, serving as the oscillation members, are provided in the direction in which the stem **12**, serving as the valve stem, extends, at a predetermined distance from each other. The electromagnet **60** is provided between the lower disk **20** and the upper disk **30**. The coil **62** is formed of a mono-coil.

[0071] The electromagnetically driven valve **10** further includes the valve opening permanent magnet **55** serving as a first permanent magnet provided so as to be opposed to the electromagnet **60** with the lower disk **20** interposed therebetween; and the valve closing permanent magnet **56** serving as a second permanent magnet provided so as to be opposed to the electromagnet **60** with the upper disk **30** interposed therebetween.

[0072] A control method of the electromagnetically driven valve according to the first embodiment of the invention is the control method of the above-mentioned electromagnetically driven valve **10**. The control method includes a step in which the lower disk **20** and the upper disk **30**, which have been oscillated as much as possible so that the valve is opened, are started to oscillate toward the position at which the lower disk **20** and the upper disk **30** are to be oscillated as much as possible so that the valve is closed, by stopping the supply of electric current to the electromagnet **60**; and a step which is performed after the above-mentioned step, and in which the supply of electric current to the electromagnet **60** is started before the lower disk **20** and the upper disk **30** reach the center position that is the midpoint between the position at which the lower disk **20** and the upper disk **30** have been oscillated as much as possible so that the valve is opened and the position at which the lower disk **20** and the upper disk **30** have been oscillated as much as possible so that the valve is closed.

[0073] Also, the control method includes a step in which the lower disk **20** and the upper disk **30**, which have been oscillated as much as possible so that the valve is closed, are started to oscillate toward the position at which the lower disk **20** and the upper disk **30** are to be oscillated as much as possible so that the valve is opened, by stopping the supply of electric current to the electromagnet **60**; and a step which is performed after the above-mentioned step, and in which the supply of electric current to the electromagnet **60** is started before the lower disk **20** and the upper disk **30** reach the center position that is the midpoint between the position at which the lower disk **20** and the upper disk **30** have been oscillated as much as possible so that the valve is closed and the position at which the lower disk **20** and the upper disk **30** have been oscillated as much as possible so that the valve is opened.

[0074] In the first embodiment, the permanent magnets **71** and **72** are provided in the core **61**. However, the invention is not limited to this. Each of the permanent magnets **71** and **72** may be provided at a position outside the core **61**, as long as the magnetic flux in the permanent magnet **71** formed due to the magnetic poles acts on the magnetic flux flowing through the magnetic circuit **101**, and the magnetic flux in the permanent magnet **72** formed due to the magnetic poles acts on the magnetic flux flowing through the magnetic circuit **102**. Also, the permanent magnet **71** may be provided in the arm portion **31** of the upper disk **30**, and the permanent magnet **72** may be provided in the arm portion **21** of the lower disk **20**.

[0075] With the thus configured electromagnetically driven valve **10** according to the first embodiment of the invention, providing the permanent magnets **71** and **72** in the rotary driven type electromagnetically driven valve makes it possible to increase the force for opening the valve and the force for closing the valve, and to obtain a sufficiently large amount of driving force. It is, therefore, possible to improve the performance of the engine including the electromagnetically driven valve **10**.

[0076] FIG. **8** illustrates a schematic view of an electromagnetically driven valve according to a second embodiment of the invention. Basically, the electromagnetically driven valve according to the second embodiment has the same structure as that of the electromagnetically driven valve **10** according to the first embodiment. Therefore, the description concerning the portions having the same structure as those in the first embodiment will not be made here.

[0077] As shown in FIG. **8**, in the second embodiment, permanent magnets **81** and **82** are provided in the electromagnet **60**, instead of the permanent magnets **71** and **72** in the first embodiment. Each of the permanent magnets **81** and **82** is located so as to be adjacent to the shaft portion **61***p*, and provided between the core **61** and the coil **62**. The permanent magnet **81** is provided so as to face the upper disk **30**, and the permanent magnet **82** is provided so as to face the lower disk **20**.

[0078] In the permanent magnet **81**, the magnetic axis is formed along a magnetic circuit **118** formed between the core **61** and the upper disk **30**, and the magnetic flux formed in the permanent magnet **81** due to the magnetic poles flows in the direction shown by an arrow **81***x*. Similarly, in the permanent magnet **82**, the magnetic axis is formed along a magnetic circuit **119** formed between the core **61** and the lower disk **20**, and the magnetic flux formed in the permanent magnet **82** due to the magnetic poles flows in the direction shown by an arrow **82***x* that is opposite to the direction shown by the arrow **81***x*.

[0079] With such a structure, when an electric current is applied to the coil **62** in the appropriate direction, the strength of magnetic flux flowing between the core **61** and the upper disk **30** is increased when the lower disk **20** and the upper disk **30** oscillate from the valve closing side toward the valve opening side, and is decreased when the lower disk **20** and the upper disk **30** oscillate from the valve opening side toward the valve closing side. Also, the strength of magnetic flux flowing between the core **61** and the lower disk **20** is decreased when the lower disk **20** and the upper disk **30** oscillate from the valve closing side toward the valve opening side, and is increased when the lower disk **20** and the upper disk **30** oscillate from the valve opening side toward the valve closing side.

[**0080**] With the thus configured electromagnetically driven valve according to the second embodiment of the invention, the same effects as those disclosed in the first embodiment can be obtained. In addition, since the permanent magnets **81** and **82** are not embedded in the core **61**, the electromagnetically driven valve **60** can be easily produced at low cost.

[**0081**] FIG. **9** illustrates a cross sectional view of an electromagnetically driven valve according to a third embodiment of the invention. Basically, the electromagnetically driven valve according to the third embodiment has the same structure as that of the electromagnetically driven valve **10** according to the first embodiment. Therefore, the description concerning the portions having the same structure as those in the first embodiment will not be made here.

[**0082**] As shown in FIG. **9**, in the third embodiment, an electromagnet **90** is provided instead of the electromagnet **60** in the first embodiment. The electromagnet **90** includes coils **94** and **95**, and a core **93** that has attraction surfaces **93***a* and **93***b*, and that is made of magnetic material. The core **93** has a shape obtained by combining a portion **91** and a portion **92** with each other, each of which has a cross sectional area having a substantially "E" shape. The portion **91** is positioned so as to face the upper disk **30**, and has a shaft portion **91***p* extending in the direction in which the stem **12** extends. The portion **92** is positioned so as to face the lower disk **20**, and has a shaft portion **92***p* extending in the direction in which the stem **12** extends. The coil **94** is provided so as to be around the shaft portion **91***p*, and the coil **95** is provided so as to be around the shaft portion **92***p*.

[**0083**] When an electric current is applied to the coil **94**, a magnetic flux flows between the portion **91** and the upper disk **30**, whereby magnetic circuits **123** and **124** are formed in the core **93**. When an electric current is applied to the coil **95**, a magnetic flux flows between the portion **92** and the lower disk **20**, whereby magnetic circuits **125** and **126** are formed in the core **93**. Permanent magnets **97** and **98** are embedded in the core **93**. The permanent magnet **97** has the magnetic axis along the magnetic circuits **123** and **125**, and the magnetic flux formed in the permanent magnet **97** due to the magnetic poles flows in the direction shown by an arrow **97***x*. The permanent magnet **98** has the magnetic axis along the magnetic circuits **124** and **126**, and the magnetic flux formed in the magnet due to the magnetic poles flows in the direction shown by an arrow **98***x* that is opposite to the direction shown by the arrow **97***x*.

[**0084**] With such a structure; when an electric current is supplied to each of the coils **94** and **95** in the appropriate direction, the strength of magnetic flux flowing between the core **93** and the upper disk **30** increases when the lower disk **20** and the upper disk **30** oscillate from the valve closing side toward the valve opening side, and decreases when the lower disk **20** and the upper disk **30** oscillate from the valve opening side toward the valve closing side. Also, the strength of magnetic flux flowing between the core **93** and the lower disk **20** decreases when the lower disk **20** and the upper disk **30** oscillate from the valve closing side toward the valve opening side, and increases when the lower disk **20** and the upper disk **30** oscillate from the valve opening side toward the valve closing side.

[**0085**] With the thus configured electromagnetically driven valve according to the third embodiment of the invention, the same effects as those disclosed in the first embodiment can be obtained.

[**0086**] In the first to third embodiments, the description has been made concerning the case where the parallel link mechanism is applied to the rotary driven type electromagnetically driven valve. However, the invention is not limited to this. The invention can be applied to a rotary driven type electromagnetically driven valve including a disk which is connected to the stem **12** at a first end and which is movably supported by the disk supporting base **51** at a second end; and multiple electromagnets which are provided above and below the disk and which alternately apply an electromagnetic force to the disk.

[**0087**] Thus, the embodiment of the invention that has been disclosed in the specification is to be considered in all respects as illustrative and not restrictive. The technical scope of the invention is defined by claims, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

1. An electromagnetically driven valve comprising:

a drive valve that has a valve stem and that reciprocates in a direction in which the valve stem extends,

two oscillation members being formed of a first oscillation member and a second oscillation member, which have an arm portion made of magnetic material, and which extends from a first end that is movably connected to the valve stem toward a second end that is movably supported by a supporting member, respectively;

an electromagnet which includes a core that is provided so as to face the arm portion, and a coil that is wound around the core, and which forms two magnetic circuits which pass through the core and the arm portions when an electric current is applied to the coil for applying magnetism to the two oscillation members, respectively; and

a permanent magnet which has a magnetic axis along the magnetic circuits, and which is provided so as to act on a magnetic flux that flows through the magnetic circuits, wherein

the permanent magnet is disposed so as to balance out the magnetic flux that flows through the magnetic circuit acting on one of the two oscillation members, and to increase the magnetic flux that flows through the magnetic circuit acting on the other oscillation member,

the oscillation members is are oscillated by using the second end as a supporting point due to an electromagnetic force applied from the electromagnet, and an oscillation motion of the oscillation members is transmitted to the drive valve via the first end, whereby the drive valve reciprocates in the direction in which the valve stem extends.

2. The electromagnetically driven valve according to claim 1, wherein

the permanent magnet is provided in the core.

3. The electromagnetically driven valve according to claim 1, wherein

the permanent magnet is provided between the core and the coil.

4. The electromagnetically driven valve according to claim 1, wherein

the permanent magnet is embedded in the core, and the core is divided into two areas by the electromagnet on the magnetic circuit.

5. The electromagnetically driven valve according to claim 4, wherein

the coil is formed of a first coil that faces the arm portion of the first oscillation member, and a second coil that faces the arm portion of the second oscillation member.

6. A control method for an electromagnetically driven valve including a drive valve that has a valve stem and that reciprocates in a direction in which the valve stem extends; two oscillation members being formed of a first oscillation member and a second oscillation member, which are movably connected to the valve stem; and an electromagnet that forms two magnetic circuits between the electromagnet and the oscillation members for applying magnetism to the two oscillation members, respectively, wherein the permanent magnet is disposed so as to balance out the magnetic flux that flows through the magnetic circuit acting on one of the two oscillation members, and to increase the magnetic flux that flows through the magnetic circuit acting on the other oscillation member, the method comprising:

a first step in which a supply of an electric current to the electromagnet is stopped, whereby the oscillation members, which are at a first position at which the oscillation members have been oscillated as much as possible so that the drive valve is moved in a first direction, are started to be oscillated toward a second position at which the oscillation members are to be oscillated as much as possible so that the drive valve is moved in a second direction that is opposite to the first direction; and

a second step which is performed after the first step is completed, and in which the supply of the electric current to the electromagnet is started before the oscillation members reach a center position that is a midpoint between the first position and the second position.

7. The control method for an electromagnetically driven valve according to claim 6, wherein

the first position is a position at which the oscillation members have been oscillated as much as possible so that the drive valve is opened; and

the second position is a position at which the oscillation members have been oscillated as much as possible so that the drive valve is closed.

8. The control method for an electromagnetically driven valve according to claim 6, wherein

the first position is a position at which the oscillation members have been oscillated as much as possible so that the drive valve is closed; and

the second position is a position at which the oscillation members have been oscillated as much as possible so that the drive valve is opened.

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