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(54) **FUEL INJECTION VALVE**

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F02M 51/06 (2006.01)

(52) **U.S. Cl.**
CPC ... ***F02M 51/061*** (2013.01); *F02M 2200/8061* (2013.01); *F02M 2200/90* (2013.01)

(58) **Field of Classification Search**
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USPC 239/585
See application file for complete search history.

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(57) **ABSTRACT**

A movable core is driven by a magnetic attraction force with a fixed core to move a valve body to inject fuel. A yoke accommodates the fixed core. A coil is in a coil chamber between the fixed core and the yoke. The coil chamber is filled with a filling resin member being electrically insulative. The fixed core has a core facing surface facing the movable core and includes a protruding portion that protrudes radially outer side and is in contact with the yoke to conduct the magnetic flux. A resin molding flow channel is formed in the protruding portion to cause molten resin serving as the filling resin member to flow into the coil chamber. A length of the protruding portion along a cylinder center line is set to be shorter toward a radially outer side.

10 Claims, 8 Drawing Sheets

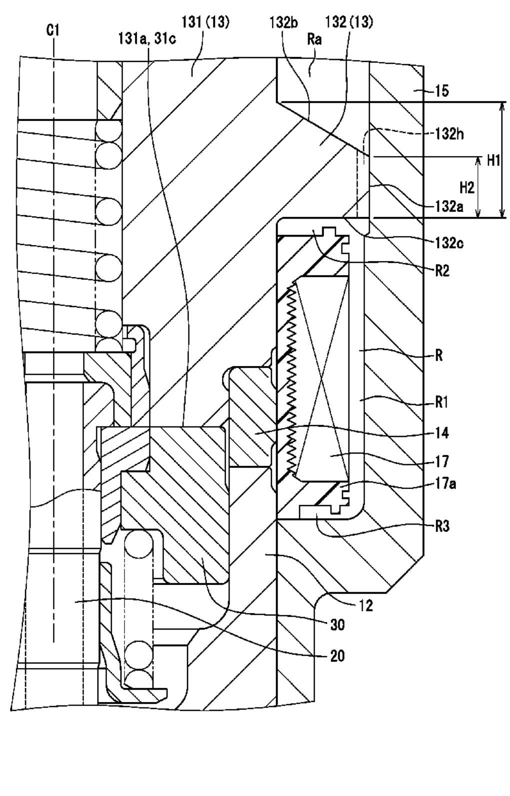
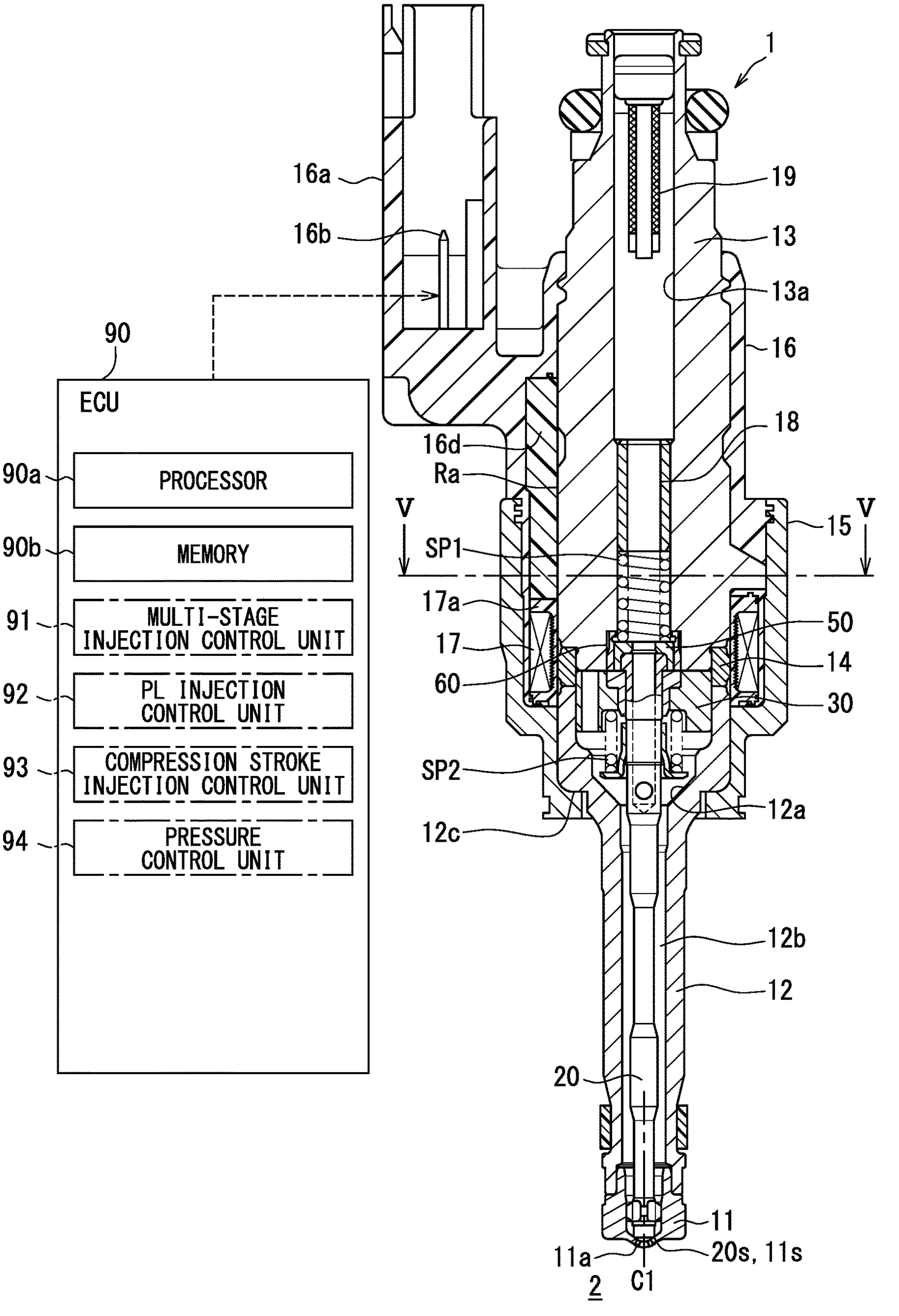
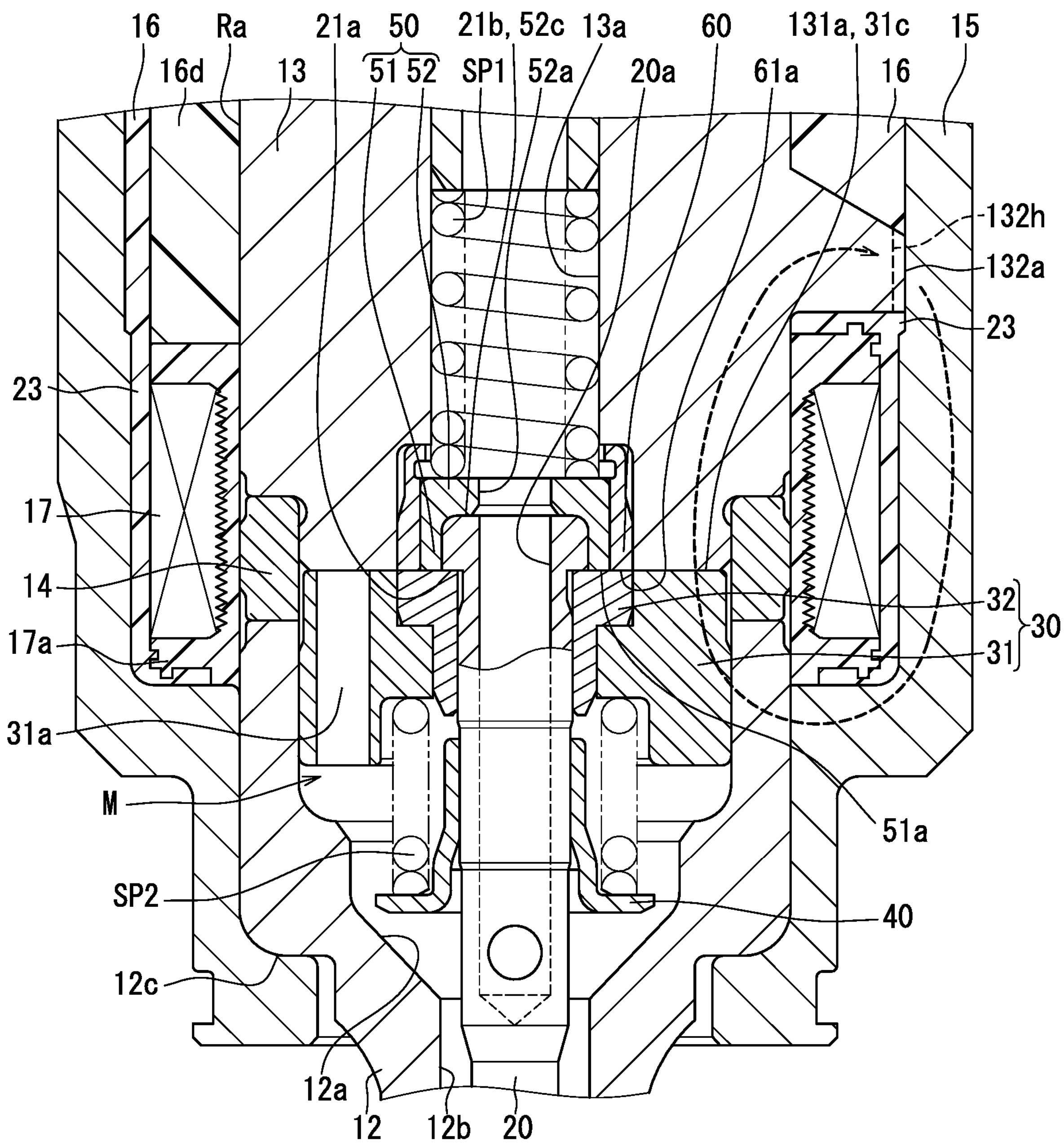


FIG. 1



1
16a
19
16b
13
13a
16
90
ECU
18
16d
Ra
90a
PROCESSOR
V
15
V
90b
MEMORY
SP1
17a
91
MULTI-STAGE INJECTION CONTROL UNIT
50
17
14
60
92
PL INJECTION CONTROL UNIT
30
SP2
93
COMPRESSION STROKE INJECTION CONTROL UNIT
12a
12c
94
PRESSURE CONTROL UNIT
12b
12
20
11
11a
20s, 11s
2
C1

FIG. 2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Ra
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50
21b, 52c
13a
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131a, 31c
15
16d
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51 52
SP1
52a
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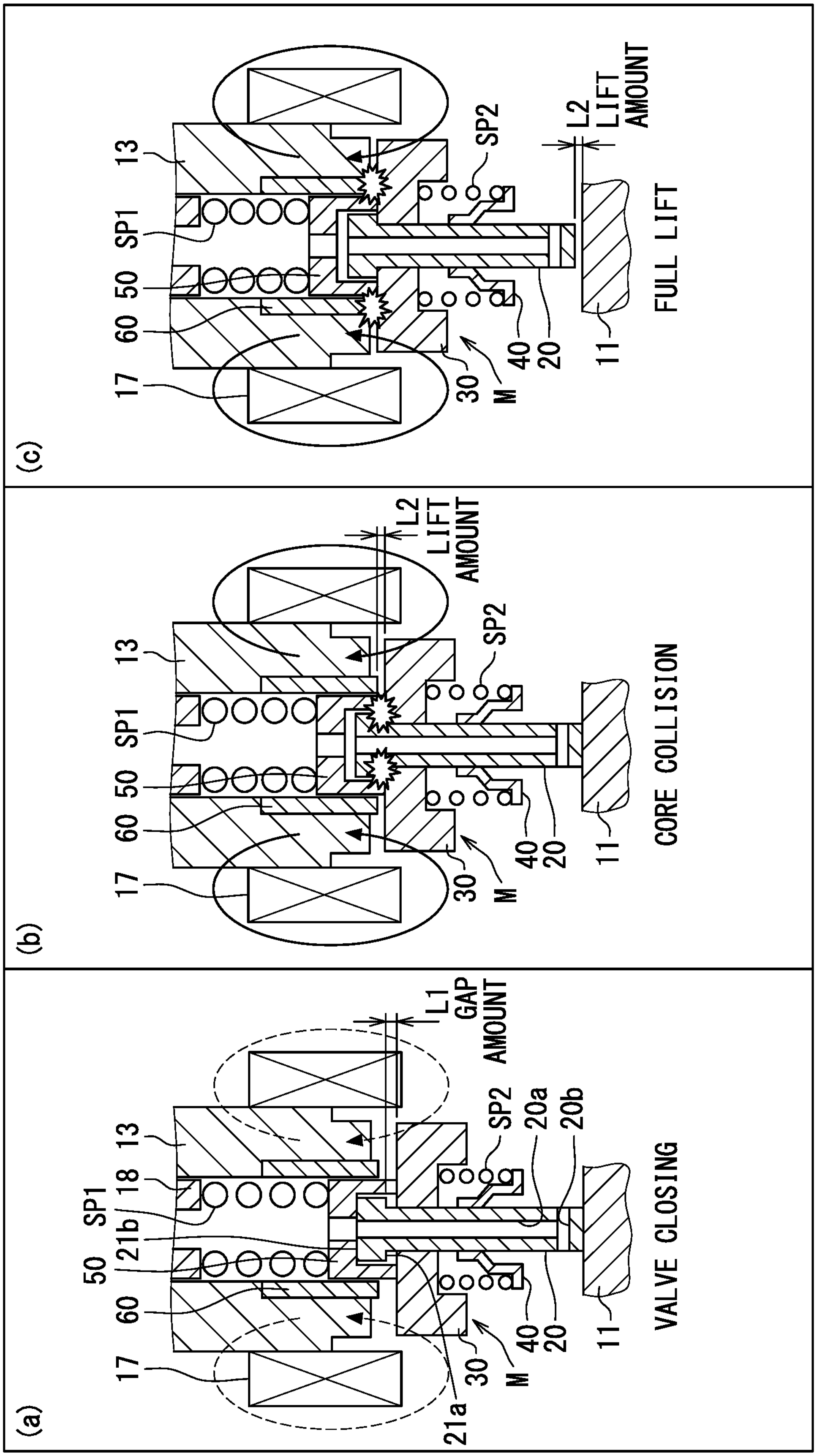
16
132h
132a
23
23
17
14
32
30
31
17a
31a
M
51a
SP2
40
12c
12a
12
12b
20

FIG. 3


(a)
17
60
50
SP1
21b
18
13
SP2
20a
20b
L1
GAP AMOUNT
21a
30
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40
20
11
VALVE CLOSING
(b)
17
60
50
SP1
13
SP2
L2
LIFT AMOUNT
30
M
40
20
11
CORE COLLISION
(c)
17
60
50
SP1
13
SP2
L2
LIFT AMOUNT
30
M
40
20
11
FULL LIFT

FIG. 4

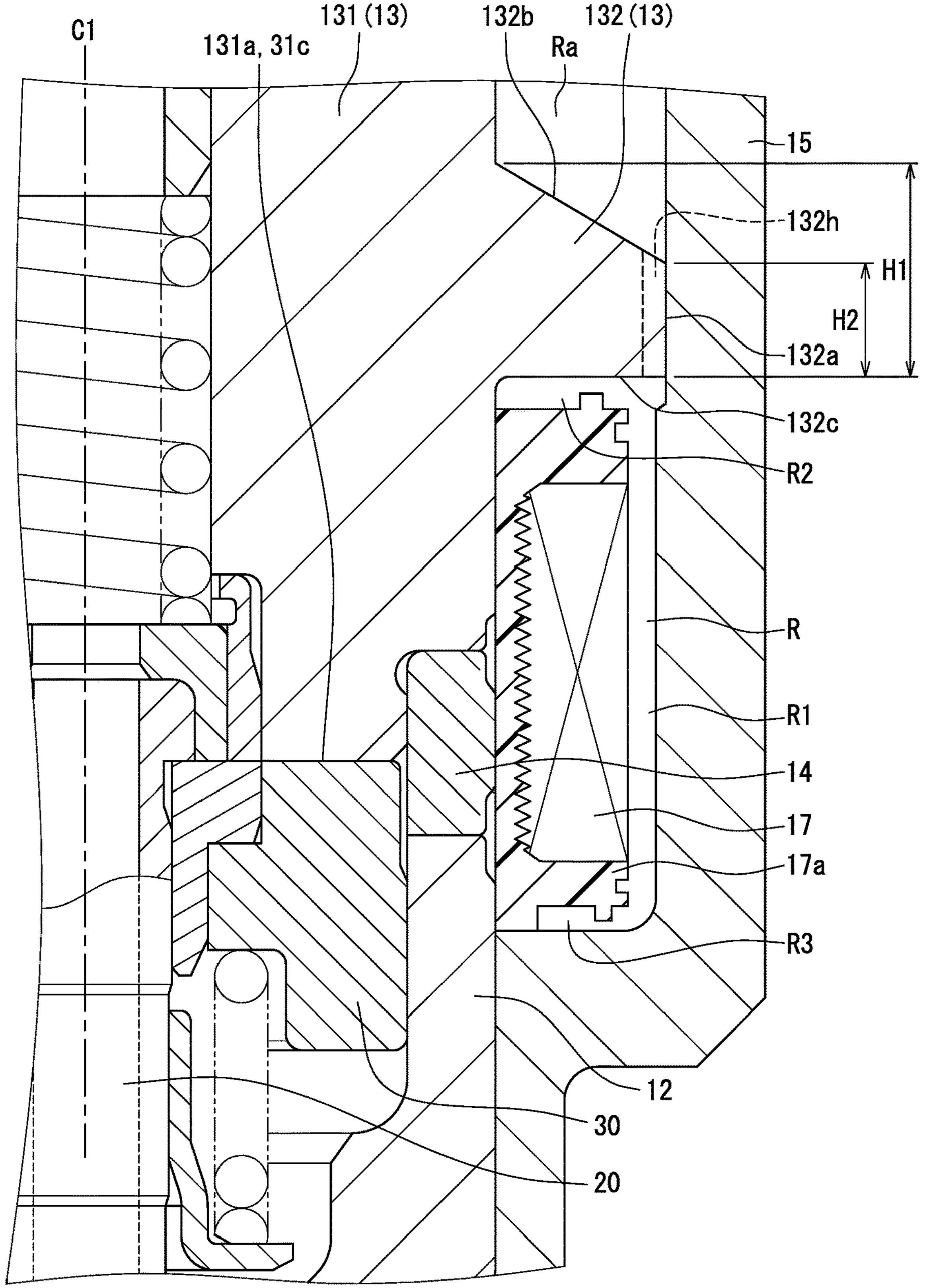
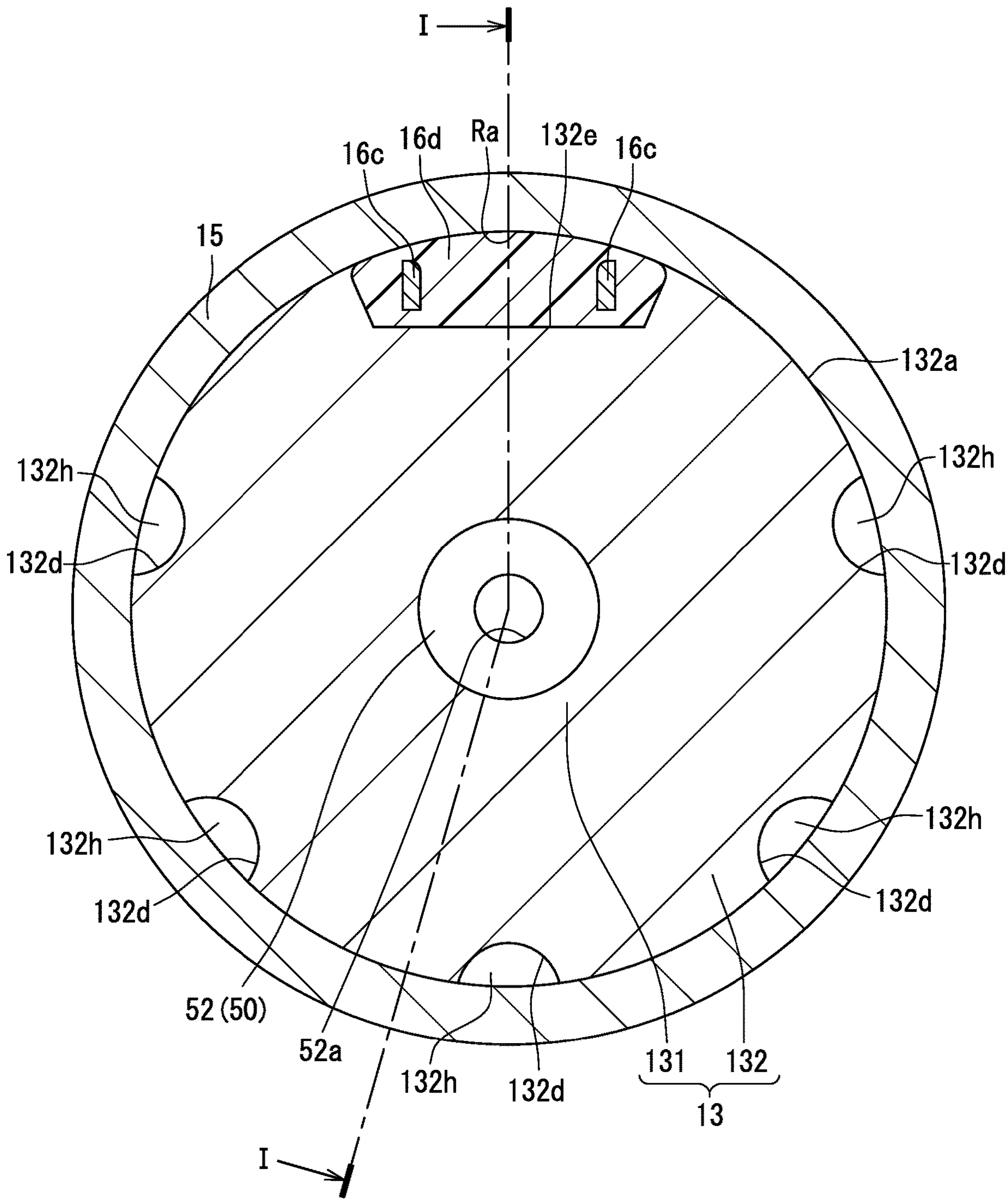
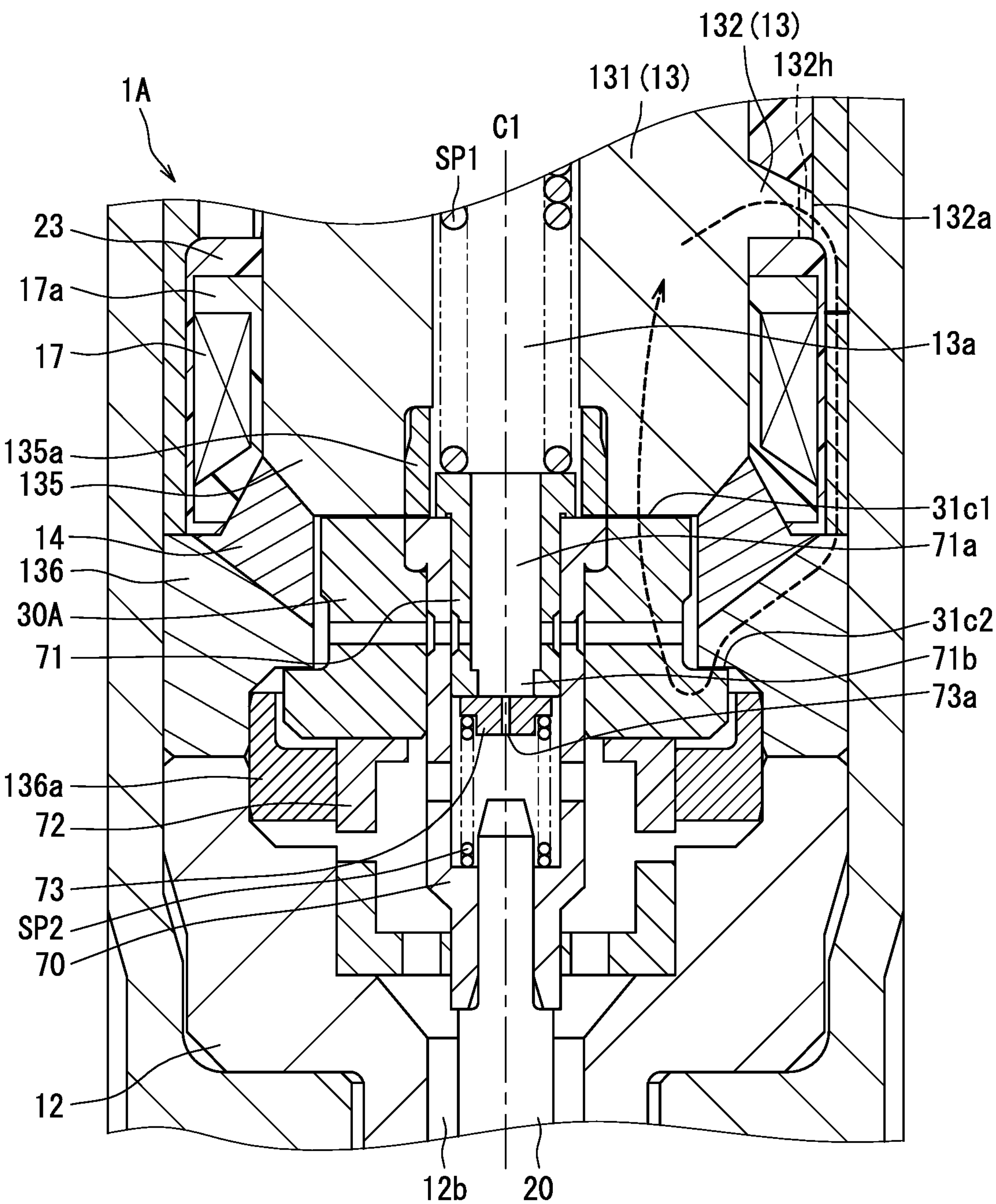

C1
131a, 31c
131 (13)
132b
Ra
132 (13)
15
132h
H1
H2
132a
132c
R2
R
R1
14
17
17a
R3
12
30
20

FIG. 5



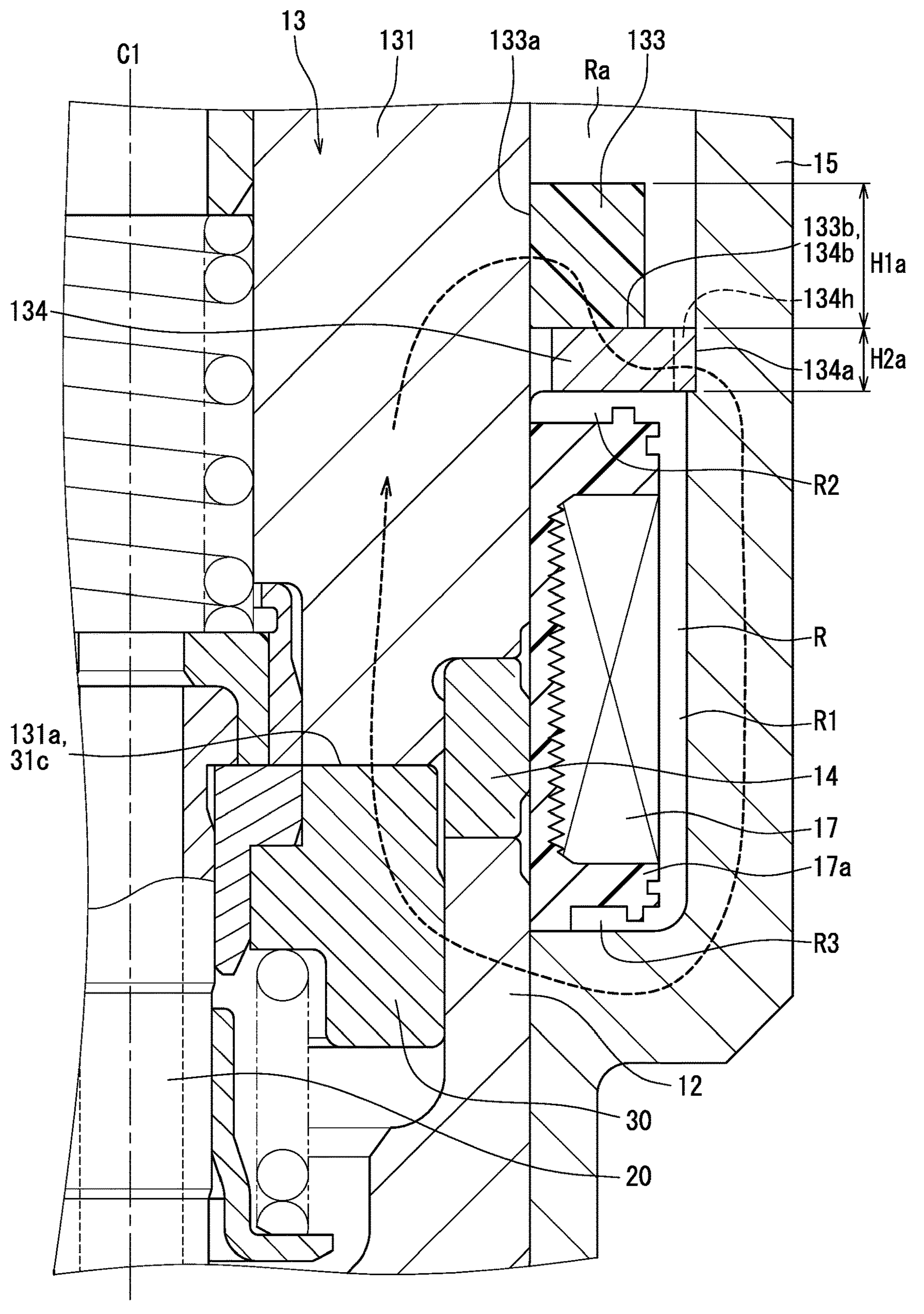
I
16c
16d
Ra
132e
16c
15
132a
132h
132h
132d
132d
132h
132h
132d
132d
52 (50)
52a
132h
132d
131
132
13
I

FIG. 6



1A
C1
SP1
131 (13)
132 (13)
132h
132a
13a
23
17a
17
135a
135
14
136
30A
71
31c1
71a
31c2
71b
73a
136a
72
73
SP2
70
12
12b
20

FIG. 7



13
131
133a
133
C1
Ra
15
133b,
134b
H1a
134h
134
134a
H2a
R2
R
R1
131a,
31c
14
17
17a
R3
12
30
20

FIG. 8

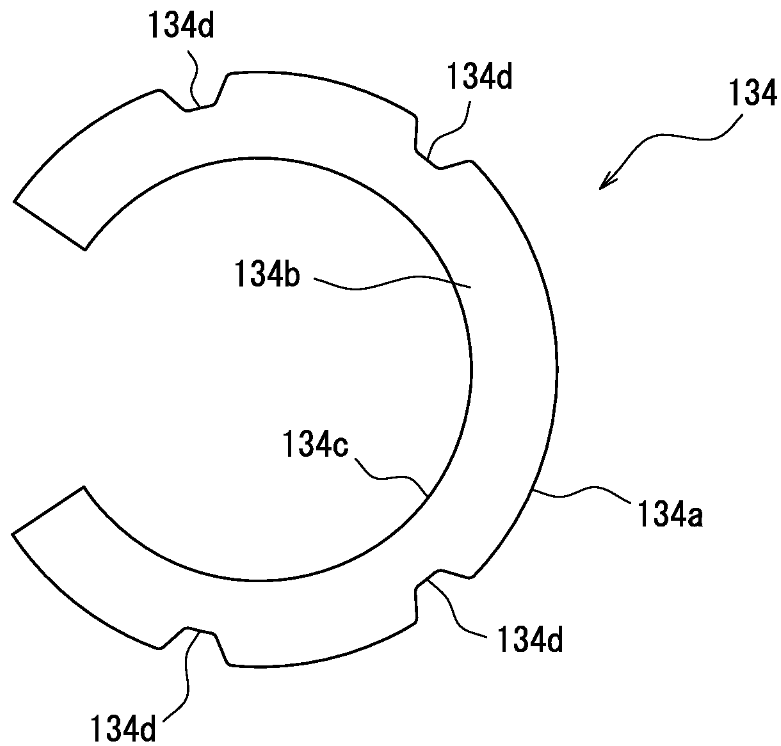
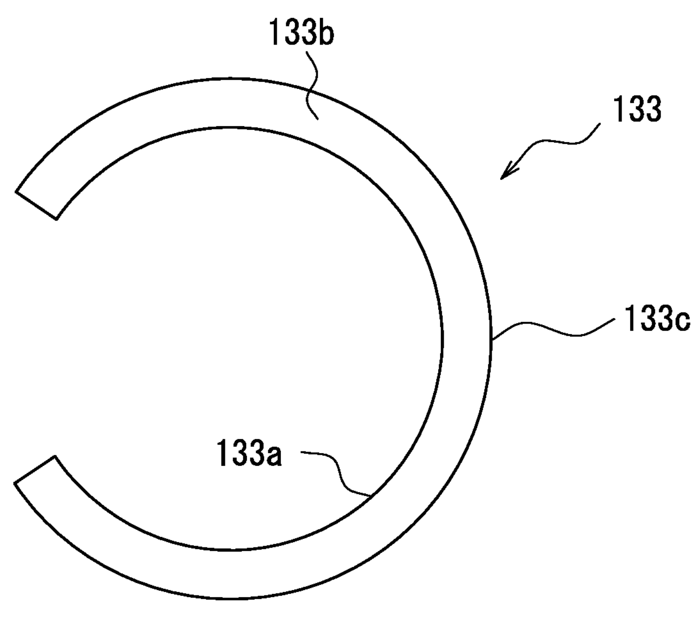


FIG. 9



FUEL INJECTION VALVE

CROSS REFERENCE TO RELATED APPLICATION

The present application is a continuation application of International Patent Application No. PCT/JP2019/050361 filed on Dec. 23, 2019, which designated the U.S. and claims the benefit of priority from Japanese Patent Application No. 2019-006270 filed on Jan. 17, 2019. The entire disclosures of all of the above applications are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to a fuel injection valve.

BACKGROUND

A known fuel injection valve includes a fixed core, a movable core, a valve body, a yoke, and a coil. The movable core is driven by a magnetic attraction force on energization of the coil to manipulate the valve body to inject fuel.

SUMMARY

A fuel injection valve according to a first aspect of the present disclosure comprises: a fixed core configured to form a part of a magnetic circuit that is to cause a magnetic flux to flow therethrough; a movable core configured to form a part of the magnetic circuit and configured to be driven by a magnetic attraction force generated in a gap between the movable core and the fixed core; a valve body configured to perform a valve opening operation caused by driving the movable core to open a nozzle hole to inject fuel; a yoke configured to form a part of the magnetic circuit and accommodating the fixed core; a coil placed in a coil chamber between the fixed core and the yoke and configured to generate the magnetic flux on energization; and a filling resin member with which the coil chamber is filled and having an electrical insulation property.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. **1** is a cross-sectional view of a fuel injection valve according to a first embodiment.

FIG. **2** is an enlarged view of a portion of a magnetic circuit of FIG. **1**.

FIG. **3** is a schematic view illustrating an operation of the fuel injection valve according to the first embodiment, in the drawing, column (a) illustrates a valve close state, column (b) illustrates a state where a movable core that is moved by a magnetic attraction force collides with a valve body, and column (c) illustrates a state where the movable core that is further moved by the magnetic attraction force collides with a guide member.

FIG. **4** is an enlarged view of a portion of the magnetic circuit of FIG. **2**.

FIG. **5** is a cross-sectional view which is taken along line V-V of FIG. **1**.

FIG. **6** is a cross-sectional view of a fuel injection valve according to a second embodiment.

FIG. **7** is a cross-sectional view of a fuel injection valve according to a third embodiment.

FIG. **8** is a top view of an outer protruding portion illustrated in FIG. **7** as seen from a side opposite to a nozzle hole.

FIG. **9** is a bottom view of an inner protruding portion illustrated in FIG. **7** as seen from a nozzle hole side.

DETAILED DESCRIPTION

As follows, examples of the present disclosure will be described.

According to an example of the present disclosure, a fuel injection valve includes a fixed core, a movable core, a valve body, a yoke, and a coil. The fixed core, the movable core, and the yoke form a magnetic circuit through which a magnetic flux generated by energization of the coil flows. The movable core is driven by a magnetic attraction force generated in a gap provided between the movable core and the fixed core to perform the valve opening operation in a valve body, whereby fuel is injected from a nozzle hole.

According to an example of the present disclosure, the fixed core has a cylindrical main body portion having a cylindrical shape and a protruding portion protruding a radially outer side from an outer peripheral surface of the cylindrical main body portion and being in contact with the yoke. The coil is placed in a coil chamber formed between the fixed core and the yoke. The coil chamber is filled with a filling resin member having an electrical insulation property.

According to an example of the present disclosure, a resin molding flow channel is formed in the protruding portion. The coil chamber is filled with the molten resin through the flow channel, and the molten resin is solidified. In this way, the filling resin member can be resin molded. In this configuration, in a case where a length (height dimension) of the protruding portion of the fixed core in a cylinder center line direction is shortened, the resin molding flow channel is shortened. Therefore, pressure loss of the molten resin in the flow channel can be reduced, and as a result, an injection pressure of the molten resin to be filled can be reduced. By shortening the length of the protruding portion, there are advantages in that the resin molding flow channel can be easily processed, and heat transfer of the molten resin which is lost on a flow channel wall surface can be restricted.

However, on the contrary, in the case where the height dimension of the protruding portion is reduced, a magnetic path cross-sectional area of a magnetic circuit in the protruding portion is reduced, so that the magnetic attraction force that drives the movable core is reduced.

According to an example of the present disclosure, a fuel injection valve comprises: a fixed core configured to form a part of a magnetic circuit that is to cause a magnetic flux to flow therethrough; a movable core configured to form a part of the magnetic circuit and configured to be driven by a magnetic attraction force generated in a gap between the movable core and the fixed core; a valve body configured to perform a valve opening operation caused by driving the movable core to open a nozzle hole to inject fuel; a yoke configured to form a part of the magnetic circuit and accommodating the fixed core; a coil placed in a coil chamber between the fixed core and the yoke and configured to generate the magnetic flux on energization; and a filling resin member with which the coil chamber is filled and having an electrical insulation property. The fixed core includes: a cylindrical main body portion that has a core facing surface facing the movable core; and a protruding portion that protrudes radially outward from an outer peripheral surface of the cylindrical main body portion and is in contact with the yoke to cause the magnetic flux to pass therethrough. The protruding portion defines a resin molding flow channel to cause molten resin serving as the filling resin member to flow into the coil chamber. A length (height dimension) of the protruding portion in a direction of a cylinder center line of the fixed core is set to be shorter toward a radially outer side of the fixed core.

The smaller the height dimension of the protruding portion at a certain diameter, the smaller the magnetic path cross-sectional area of the protruding portion is. On the other hand, since the circumferential length becomes longer as the portion is located on radially outer side of the protruding portion, if the height dimension is the same regardless of the position in the radial direction, the magnetic path cross-sectional area is larger as the portion is on the radially outer side. Therefore, a sufficient magnetic path cross-sectional area can be secured even if the height dimension is shortened by an amount corresponding to the increase in the circumferential length toward the radially outer side. In the fuel injection valve focused on this point, since the height dimension of the protruding portion is shorter toward the radially outer side, the length of the resin molding flow channel in the cylinder center line direction is shorter than the height dimension of the base end portion of the protruding portion. Therefore, the pressure loss and the heat loss of the molten resin when the molten resin flows through the resin molding flow channel can be reduced by the shortened amount.

Since the circumferential length of the magnetic path cross-sectional area at the protruding portion becomes longer toward the radially outer side of the fixed core, even if the height dimension is smaller toward the radially outer side, the minimum value of the magnetic path cross-sectional area inside the protruding portion can be kept unchanged. Therefore, it is possible to realize a reduction of injection pressure of the molten resin serving as the filling resin member and a reduction of heat loss of the molten resin while restricting a reduction of magnetic attraction force for driving the movable core.

Hereinafter, multiple embodiments of the present disclosure will be described with reference to the drawings. Duplicate description may be omitted by assigning the same reference numerals to the corresponding configuration elements in each embodiment. In a case where only a part of the configuration is described in each embodiment, the configurations of the other embodiments described above can be applied to the other parts of the configuration.

First Embodiment

A fuel injection valve **1** illustrated in FIG. **1** is a direct injection type which is attached to a cylinder head of an ignition type internal combustion engine mounted on a vehicle to directly inject fuel into a combustion chamber **2** of the internal combustion engine. Liquid gasoline fuel stored in an in-vehicle fuel tank is pressurized by a fuel pump (not illustrated) and supplied to the fuel injection valve **1**, and the supplied high-pressure fuel is injected into the combustion chamber **2** from a nozzle hole **11***a* formed in the fuel injection valve **1**.

The fuel injection valve **1** is of a center disposition type disposed at a center of the combustion chamber **2**. Specifically, the nozzle hole **11** a is located between an intake port and an exhaust port when viewed in an axis line direction of a piston of the internal combustion engine. The fuel injection valve **1** is attached to a cylinder head such that the axis line direction (vertical direction in FIG. **1**) of the fuel injection valve **1** is parallel to the axis line direction of the piston. The fuel injection valve **1** is located on the axis line of the piston or in the vicinity of an ignition plug located on the axis line of the piston.

An operation of the fuel injection valve **1** is controlled by a control device **90** mounted on the vehicle. The control device **90** has at least one calculation processing device (processor **90***a*) and at least one storage device (memory **90***b*) as a storage medium for storing a program executed by the processor **90***a* and data. The fuel injection valve **1** and the control device **90** provide a fuel injection system.

The control device and a method thereof described in the present disclosure may be implemented by a dedicated computer configuring a processor programmed to perform one or more functions embodied by a computer program. Alternatively, the control device and the method thereof described in the present disclosure may be implemented by a dedicated hardware logic circuit. Alternatively, the control device and the method thereof described in the present disclosure may be implemented by one or more dedicated computers configured by a combination of a processor executing a computer program and one or more hardware logic circuits. The computer program may also be stored in a computer-readable non-transitory tangible recording medium as instructions to be executed by a computer.

The fuel injection valve **1** includes a nozzle hole body **11**, a main body **12**, a fixed core **13**, a non-magnetic member **14**, a coil **17**, a support member **18**, a filter **19**, a first spring member SP**1** (elastic member), a cup **50**, a guide member **60**, a movable portion M (see FIGS. **2** and **3**), and the like. The movable portion M is an assembly in which a needle **20** (valve body), a movable core **30**, a second spring member SP**2**, a sleeve **40**, and the cup **50** are assembled. The nozzle hole body **11**, the main body **12**, the fixed core **13**, the support member **18**, the needle **20**, the movable core **30**, the sleeve **40**, the cup **50**, and the guide member **60** are made of metal.

The nozzle hole body **11** has multiple nozzle holes **11***a* for injecting fuel. The nozzle hole **11***a* is formed by performing a laser process on the nozzle hole body **11**. The needle **20** is located inside the nozzle hole body **11**. A fuel passage communicating with an inflow port of the nozzle hole **11***a* is formed between an outer surface of the needle **20** and an inner surface of the nozzle hole body **11**.

A seating surface **11***s* where a seat surface **20***s* formed on the needle **20** unseats from and seats on is formed on an inner peripheral surface of the nozzle hole body **11**. The seat surface **20***s* and the seating surface **11***s* have a shape extending annularly around a center axis line (axis line C**1**) of the needle **20**. When the needle **20** is unseated from and seated on the seating surface **11***s*, the fuel passage is opened and closed, and the nozzle hole **11***a* is opened and closed. The needle **20** corresponds to a “valve body” that opens and closes the nozzle hole **11***a* by opening and closing the fuel passage, is formed of martensitic stainless or the like, and has a shape extending in the axis line C**1** direction.

When the needle **20** performs the valve closing operation and the seat surface **20***s* comes into contact with the seating surface **11***s*, the seat surface **20***s* and the seating surface **11***s* come into line abut against each other. After that, when the seat surface **20***s* is pressed against the seating surface **11***s* by an elastic force of the first spring member SP**1**, the needle **20** and the nozzle hole body **11** are elastically deformed by the pressing force and come into surface abut against each other. A value obtained by dividing the pressing force by a surface-contacting area is a seat surface pressure, and the first spring member SP**1** is set such that the seat surface pressure equal to or higher than a predetermined value is secured.

The main body **12** and the non-magnetic member **14** have a cylindrical shape. A cylindrical end portion of the main body **12**, which is a portion on a side (nozzle hole side) closer to the nozzle hole **11***a*, is welded to be fixed to the nozzle hole body **11**. A cylindrical end portion of the main body **12** on a side (side opposite to the nozzle hole) away from the nozzle hole **11***a* is welded to be fixed to the cylindrical end portion of the non-magnetic member **14**. A cylindrical end portion of the non-magnetic member **14** on the side opposite to the nozzle hole is welded to be fixed to the fixed core **13**.

An outer peripheral surface of the fixed core **13** is press-fitted and fixed to an inner peripheral surface of the yoke **15** in a state where the yoke **15** is locked to a locking portion **12***c* of the main body **12**. An axial force generated by this press-fit generates a surface pressure that presses the yoke **15**, the main body **12**, the non-magnetic member **14**, and the fixed core **13** against each other in the axis line C**1** direction (vertical direction in FIG. **1**).

The main body **12** is formed of a magnetic material such as stainless steel, and has a flow channel **12***b* for causing the fuel to flow to the nozzle hole **11***a*. In the flow channel **12***b*, the needle **20** is accommodated in a movable state in the axis line C**1** direction. In the movable chamber **12***a*, the movable portion M (see FIGS. **2** and **3**) which is the assembly in which the needle **20**, the movable core **30**, the second spring member SP**2**, the sleeve **40**, and the cup **50** are assembled is accommodated in a movable state.

The flow channel **12***b* communicates with a downstream side of the movable chamber **12***a* and has a shape extending in the axis line C**1** direction. A center line of the flow channel **12***b* and the movable chamber **12***a* coincides with the cylinder center line (axis line C**1**) of the main body **12**. A portion of the needle **20** on the nozzle hole side is slidably supported by an inner wall surface **11***c* of the nozzle hole body **11**, and a portion of the needle **20** on the side opposite to the nozzle hole is slidably supported by an inner wall surface of the cup **50**. As described above, by slidably supporting two positions of an upstream end portion and a downstream end portion of the needle **20**, a movement of the needle **20** in a radial direction is regulated, and a tilt of the needle **20** with respect to the axis line C**1** of the main body **12** is regulated.

The cup **50** has a disk portion **52** in a disk shape and a cylindrical portion **51** in a cylindrical shape. The disk portion **52** has a through-hole **52***a* penetrating in the axis line C**1** direction. A surface of the disk portion **52** on the side opposite to the nozzle hole functions as a spring abutment surface that abuts against the first spring member SP**1**. A surface of the disk portion **52** on the nozzle hole side functions as a valve closing force transmission abutment surface **52***c* that abuts against the needle **20** and transmits a first elastic force (valve closing elastic force). The cylindrical portion **51** has a cylindrical shape extending from an outer peripheral end of the disk portion **52** to the nozzle hole side. A nozzle hole-side end surface of the cylindrical portion **51** functions as a core abutment end surface **51***a* that abuts against the movable core **30**. An inner wall surface of the cylindrical portion **51** slides with an outer peripheral surface of the needle **20**.

The fixed core **13** is formed of a magnetic material such as stainless steel, and has a flow channel **13***a* on an inside thereof for causing the fuel to flow to the nozzle hole **11***a*.

The flow channel **13***a* communicates with an upstream side of an internal passage **20***a* (see FIG. **2**) formed inside the needle **20** and the movable chamber **12***a*, and has a shape extending in the axis line C**1** direction. The guide member **60**, the first spring member SP**1**, and the support member **18** are accommodated in the flow channel **13***a*.

The support member **18** has a cylindrical shape or a C-shaped cross section with a notch, and is press-fitted and fixed to the inner wall surface of the fixed core **13**. The first spring member SP**1** is a coil spring disposed on the downstream side of the support member **18**, and is elastically deformed in the axis line C**1** direction. An upstream-side end surface of the first spring member SP**1** is supported by the support member **18**, and a downstream-side end surface of the first spring member SP**1** is supported by the cup **50**. The cup **50** is urged to the downstream side by a force (first elastic force) generated by the elastic deformation of the first spring member SP**1**. By adjusting a press-fit amount of the support member **18** in the axis line C**1** direction, a size (first set load) of the elastic force for urging the cup **50** is adjusted.

The filter **19** captures foreign matter contained in the fuel supplied to the fuel injection valve **1**. The filter **19** is press-fitted and fixed to an upstream-side portion of the support member **18** in the inner wall surface of the fixed core **13**.

As illustrated in FIG. **2**, the guide member **60** has a cylindrical shape formed of martensitic stainless or the like, and is press-fitted and fixed to the fixed core **13**. A nozzle hole-side end surface of the guide member **60** on functions as a stopper abutment end surface **61***a* that abuts against the movable core **30**. An inner wall surface of the guide member **60** slides with an outer peripheral surface **51***d* of the cylindrical portion **51** of the cup **50**. In short, the guide member **60** has a guide function of sliding the outer peripheral surface of the cup **50** moving in the axis line C**1** direction and a stopper function of restricting the movement of the movable core **30** toward the side opposite to the nozzle hole by abutting against the movable core **30** which moves in the axis line C**1** direction.

A resin member **16** is provided on the outer peripheral surface of the fixed core **13**. The resin member **16** has a connector housing **16***a*, and a terminal **16***b* is accommodated inside the connector housing **16***a*. The terminal **16***b* is electrically connected to the coil **17**. An external connector (not illustrated) is connected to the connector housing **16***a*, and power is supplied to the coil **17** through the terminal **16***b*. The coil **17** is wound around a bobbin **17***a* having an electrical insulation property to form a cylindrical shape, and is disposed radially outer side of the fixed core **13**, the non-magnetic member **14**, and the movable core **30**. The fixed core **13**, the yoke **15**, the main body **12**, and the movable core **30** form a magnetic circuit through which a magnetic flux generated with supply of power (energization) to the coil **17** flows (see a dotted arrow in FIG. **2**).

The coil **17** is disposed in a coil chamber R together with the bobbin **17***a*. The coil chamber R has a cylindrical shape formed by being surrounded by the fixed core **13**, the yoke **15**, the main body **12**, and the non-magnetic member **14**. The coil chamber R in which the coil **17** and the bobbin **17***a* are disposed is filled with a filling resin member **23** having the electrical insulation property.

As illustrated in FIG. **2**, the movable core **30** is disposed on the nozzle hole side with respect to the fixed core **13**, and is accommodated in the movable chamber **12***a* in a movable state in the axis line C**1** direction. The movable core **30** has an outer core **31** and an inner core **32**. The outer core **31** has a cylindrical shape formed of a magnetic material such as stainless, and the inner core **32** has a cylindrical shape formed of martensitic stainless or the like. The outer core **31** is press-fitted and fixed to an outer peripheral surface of the inner core **32**. Multiple through-holes **31***a* are formed in the outer core **31** (see FIG. **2**). The through-holes **31***a* have a circular shaped cross section extending in the axis line C**1** direction, and these through-holes **31***a* are disposed at equal intervals in a circumferential direction around the axis line C**1**.

The needle **20** is inserted to be disposed inside the cylinder of the inner core **32**. The inner core **32** is assembled to the needle **20** in a slidable state in the axis line C**1** direction with respect to the needle **20**. The inner core **32** abuts against the guide member **60** as a stopper member, the cup **50**, and the needle **20**. Therefore, a material having a higher hardness than that of the outer core **31** is used for the inner core **32**. The outer core **31** has a core facing surface **31***c* facing the fixed core **13**, and a gap is formed between the core facing surface **31***c* and the fixed core **13**. Therefore, in a state where the magnetic flux flows by energizing the coil **17** as described above, the magnetic attraction force attracted to the fixed core **13** acts on the outer core **31** by forming the gap.

The sleeve **40** is press-fitted and fixed to the needle **20**, and supports the nozzle hole-side end surface of the second spring member SP**2**. The second spring member SP**2** is a coil spring elastically deformed in the axis line C**1** direction. The opposite nozzle hole-side end surface of the second spring member SP**2** of the nozzle hole is supported by the outer core **31**. The outer core **31** is urged to the side opposite to the nozzle hole by a force (second elastic force) generated by the elastic deformation of the second spring member SP**2**. By adjusting a press-fit amount of the sleeve **40** in the axis line C**1** direction, a size of the second elastic force (second set load) for urging the movable core **30** at the time of valve closing is adjusted. The second set load of the second spring member SP**2** is smaller than the first set load of the first spring member SP**1**.

<Description of Operation>

Next, an operation of the fuel injection valve **1** will be described with reference to FIG. **3**.

As illustrated in column (a) in FIG. **3**, the magnetic attraction force is not generated in a state where the energization of the coil **17** is turned off, so that the magnetic attraction force urged toward the valve opening side does not act on the movable core **30**. The cup **50** urged to the side of the valve closing by the first elastic force of the first spring member SP**1** abuts against the valve body abutment surface **21***b* (see FIG. **2**) of the needle **20** at the time of valve closing and the inner core **32**, and transmits the first elastic force.

The movable core **30** is urged toward the valve closing side by the first elastic force of the first spring member SP**1** transmitted from the cup **50**, and is urged toward the valve opening side by the second elastic force of the second spring member SP**2**. Since the first elastic force is larger than the second elastic force, the movable core **30** is in a state of being pushed by the cup **50** and moved (lifted down) toward the nozzle hole. The needle **20** is urged toward the valve closing side by the first elastic force transmitted from the cup **50**, and is in a state of being pushed by the cup **50** and moved (lifted down) toward the nozzle hole, that is, in a state of being seated on the seating surface **11***s* to close the valve. In this valve close state, a gap is formed between the valve body abutment surface **21***a* (see FIG. **2**) of the needle **20** when the valve is opened and the inner core **32**, and a length of the gap in the axis line C**1** direction in the valve close state is referred to as a gap amount L**1**.

As illustrated in column (b) in FIG. **3**, in a state immediately after the energization of the coil **17** is switched from off to on, the magnetic attraction force urged toward the valve opening side acts on the movable core **30**, so that the movable core **30** initiates movement to the valve opening side. When the movable core **30** moves while pushing up the cup **50** and an amount of the movement thereof reaches the gap amount L**1**, the inner core **32** collides with the valve body abutment surface **21***a* of the needle **20** when the valve is opened. At the time of the collision, a gap is formed between the guide member **60** and the inner core **32**, and a length of the gap in the axis line C**1** direction is referred to as a lift amount L**2**.

During a period up to the time of the collision, a valve closing force by a fuel pressure applied to the needle **20** is not applied to the movable core **30**, so that a collision speed of the movable core **30** can be increased accordingly. Since such a collision force is added to the magnetic attraction force and used as the valve opening force of the needle **20**, the needle **20** can perform the valve opening operation even with the high-pressure fuel while restricting an increase in the magnetic attraction force required for valve opening.

After the collision, the movable core **30** further continues to move by the magnetic attraction force, and when the amount of the movement after the collision reaches the lift amount L**2**, as illustrated in column (c) in FIG. **3**, the inner core **32** collides with the guide member **60** to stop the movement. A separation distance between the seating surface **11***s* and the seat surface **20***s* in the axis line C**1** direction at the time of the stop of this movement corresponds to a full lift amount of the needle **20**, and coincides with the lift amount L**2** described above.

After that, when the energization of the coil **17** is switched from on to off, the magnetic attraction force also decreases as a drive current decreases, and the movable core **30** initiates the movement to the valve closing side together with the cup **50**. The needle **20** is pushed by the pressure of the fuel filled between the needle **20** and the cup **50** to initiate the lift-down (valve closing operation) simultaneously with the initiation of the movement of the movable core **30**.

After that, when the needle **20** is lifted down by the lift amount L**2**, the seat surface **20***s* is seated on the seating surface **11***s*, and the nozzle hole **11***a* is closed. After that, the movable core **30** continues to move toward the valve closing side together with the cup **50**, and when the cup **50** abuts against the needle **20**, the movement of the cup **50** toward the valve closing side stops. After that, the movable core **30** further continues to move toward the valve closing side (inertial movement) by an inertial force, and then moves (rebounds) toward the valve opening side by the elastic force of the second spring member SP**2**. After that, the movable core **30** collides with the cup **50** and moves (rebounds) toward the valve opening side together with the cup **50**, but is quickly pushed back by the valve closing elastic force to converge to an initial state illustrated in column (a) in FIG. **3**.

Therefore, the smaller the rebound and the shorter the time required for convergence, the shorter the time to return to the initial state from the end of injection is. Therefore, when executing multi-stage injection in which fuel is injected multiple times per combustion cycle of the internal combustion engine, an interval between injections can be shortened and the number of injections included in the multi-stage injection can be increased. By shortening the convergence time as described above, it is possible to control the injection amount with high accuracy in a case where partial lift injection described below is executed. The partial lift injection is injection of a minute amount at a short valve opening time by stopping the energization to the coil **17** and initiating the valve closing operation before the needle **20** that performs the valve opening operation reaches the full lift position (maximum valve opening position).

The above-described energization on/off is controlled by the processor **90***a* executing a program stored in the memory **90***b*. Basically, based on the load and the rotation speed of the internal combustion engine, the fuel injection amount, the injection timing, and the number of injections relating to the multi-stage injection in one combustion cycle are calculated by the processor **90***a*. The processor **90***a* executes various programs to execute multi-stage injection control, partial lift injection control (PL injection control), compression stroke injection control, and pressure control which are described below. The control device **90** when executing these controls corresponds to a multi-stage injection control unit **91**, a partial lift injection control unit (PL injection control unit **92**), a compression stroke injection control unit **93**, and a pressure control unit **94** illustrated in FIG. **1**.

The multi-stage injection control unit **91** controls the energization on/off of the coil **17** so as to inject fuel from the nozzle hole **11** a multiple times during one combustion cycle of the internal combustion engine. The PL injection control unit **92** controls the energization on/off of the coil **17** so that the valve closing operation is initiated after the needle **20** is unseated from the seating surface **11***s* and before the needle **20** reaches the full lift position. For example, as the number of multi-stage injections increases, the injection amount of one injection becomes very small, and therefore, in a case of such a small amount of injection, the PL injection control is executed.

The compression stroke injection control unit **93** controls the energization on/off of the coil **17** so as to inject the fuel from the nozzle hole **11***a* in a period including a part of the compression stroke period of the internal combustion engine. In a case where the fuel is injected into the combustion chamber **2** in the compression stroke period, the time from the injection start timing to the ignition timing is short, so that the time for sufficiently mixing the fuel and air is short. Therefore, the fuel injection valve **1** of this type is required to inject the fuel from the nozzle hole **11***a* in a state of high penetration force in order to promote a mixing property of the fuel and air. It is also required to increase the injection pressure in order to break up the spray in a short time.

The pressure control unit **94** controls the pressure (supply fuel pressure) of the fuel supplied to the fuel injection valve **1** to an optional target pressure within a predetermined range. Specifically, the supply fuel pressure is controlled by controlling the fuel discharge amount by the above-described fuel pump.

<Detailed Description of Fixed Core **13**>

Hereinafter, the fixed core **13** will be explained in detail with reference to FIGS. **4** and **5**. FIGS. **4** and **5** illustrate the fuel injection valve **1** in a state where the resin member **16** and the filling resin member **23** are not provided.

The fixed core **13** has a cylindrical main body portion **131** and a protruding portion **132**. The cylindrical main body portion **131** has a cylindrical shape extending in the driving direction of the movable core **30**, that is, in the axis line C1 direction. The first spring member SP**1**, the support member **18**, and the filter **19** are disposed inside a cylinder of the cylindrical main body portion **131**. A cylinder end surface of the cylindrical main body portion **131** has a core facing surface **131***a* facing the core facing surface **31***c* of the movable core **30**. A gap is provided between the core facing surfaces **31***c* and **131***a* of the movable core **30** and the fixed core **13**, and the movable core **30** is attracted to the fixed core **13** and driven by a magnetic attraction force generated in the gap.

The protruding portion **132** protrudes to the radially outer side from an outer peripheral surface of the cylindrical main body portion **131** and abuts against the yoke **15**. Therefore, a magnetic flux communicates between the fixed core **13** and the yoke **15**. The protruding portion **132** does not protrude from the entire outer peripheral surface of the cylindrical main body portion **131** in the axis line C**1** direction, but protrudes from a part of the outer peripheral surface thereof (see FIG. **4**). The protruding portion **132** does not protrude from the entire outer peripheral surface of the cylindrical main body portion **131** in the circumferential direction, but protrudes from a portion excluding a terminal chamber Ra in which a terminal extending portion **16***c* and an insulation member **16***d* are disposed (see FIG. **5**).

The terminal extending portion **16***c* is a portion of the terminal **16***b* extending in the axis line C**1** direction, is a portion connected to the coil **17**, and is covered with the insulation member **16***d* made of resin. A part of the terminal chamber Ra is provided between the outer peripheral surface of the cylindrical main body portion **131** of the fixed core **13** and the inner peripheral surface of the yoke **15**. A portion of the insulation member **16***d* located outside the terminal chamber Ra is covered with the fixed core **13** and the resin member **16**.

The protruding end surface **132***a*, which is the outer peripheral surface of the protruding portion **132**, is press-fitted into the inner peripheral surface of the yoke **15**. The protruding end surface **132***a* has a shape extending in parallel with the axis line C**1** direction. A protruding upper surface **132***b* of the protruding portion **132**, which is a surface (upper surface) on the side opposite to the coil chamber R, has a tapered shape linearly extending in a direction inclining with respect to the axis line C**1** in a cross-sectional view including the axis line C**1**. A protruding bottom surface **132***c* of the protruding portion **132**, which is a surface (bottom surface) on the side on which the coil chamber R is formed, has a horizontal shape linearly extending in a direction orthogonal to the axis line C**1** in a cross-sectional view including the axis line C**1**.

The height dimension, which is the length of the protruding portion **132** in the axis line C**1** direction, is shorter toward the radially outer side of the fixed core **13**. Therefore, a height dimension H**2** of the protruding end surface **132***a* is smaller than a height dimension H**1** of a boundary portion (base end portion) of the protruding portion **132** with the cylindrical main body portion **131**.

The coil chamber R and the terminal chamber Ra are partitioned by the protruding portion **132**. The protruding portion **132** is formed with a resin molding flow channel **132***h* for causing the molten resin serving as the filling resin member **23** to flow into the coil chamber R. The resin molding flow channel **132***h* has a shape extending in parallel with the axis line C**1** direction. The resin molding flow channel **132***h* is partitioned between a notch portion **132***d* provided in the protruding end surface **132***a* of the protruding portion **132** and the inner peripheral surface of the yoke **15**.

Multiple resin molding flow channels **132***h* are provided around the axis line C**1**. Multiple resin molding flow channels **132***h* are disposed at equal intervals around the axis line C**1**. Specifically, as illustrated in FIG. **5**, multiple resin molding flow channels **132***h* are disposed at equal intervals in the circumferential direction in a region where the protruding portion **132** is provided in a region excluding the terminal chamber Ra. The shape of the resin molding flow channel **132***h* in a cross section perpendicular to the axis line C**1** direction is a semicircular shape as illustrated in FIG. **5**. That is, the notch portion **132***d* has an arc shape in the cross-sectional view.

The inner peripheral surface of the bobbin **17***a* disposed in the coil chamber R is disposed so as to face the outer peripheral surfaces of the cylindrical main body portion **131**, the non-magnetic member **14**, and the main body **12**. In the coil chamber R, a first region R**1** is defined between the outer peripheral surfaces of the bobbin **17***a* and the coil **17**, and the inner peripheral surface of the yoke **15**, a second region R**2** is defined between the upper surface of the bobbin **17***a* and the protruding bottom surface **132***c*, and a third region R**3** is defined between the bottom surface of the bobbin **17***a* and the yoke **15**. The first region R**1**, the second region R**2**, and the third region R**3** are filled with the filling resin member **23**. The resin molding flow channel **132***h* is disposed at a position overlapping with the first region R**1** when viewed in the axis line C**1** direction.

<Definition of Magnetic Path Cross-Sectional Area>

Next, the magnetic path cross-sectional area of each portion forming the magnetic circuit will be explained. A magnetic path cross-sectional area is an area of a surface perpendicular to the magnetic flow direction, and, for example, an area (tip area) of the protruding end surface **132***a* of the fixed core **13** corresponds to the magnetic path cross-sectional area. An area of the notch portion **132***d* is not included in the magnetic path cross-sectional area because it is not in contact with the yoke **15**, and an area of a portion of the protruding portion **132** that is in contact with the yoke **15** by press-fit corresponds to the magnetic path cross-sectional area. An area of the boundary portion of the protruding portion **132** with the cylindrical main body portion **131**, that is, the area (base end area) at the portion of the height dimension H**1** illustrated in FIG. **4** corresponds to the magnetic path cross-sectional area.

A tip area is set larger than the base end area. These areas are specified by the height dimensions H**1** and H**2**, and the circumferential length. The circumferential length of the tip area is longer than the circumferential length of the base end area, and the height dimension H**2** of the tip area is smaller than the height dimension H**1** of the base end area. The circumferential length of the tip area does not include a portion that is not in contact with the yoke **15**. Specifically, since a groove **132***e* and the notch portion **132***d* forming the terminal chamber Ra are not in contact with the yoke **15**, they are not included in the circumferential length of the tip area. A portion of the protruding portion **132** which is in contact with the yoke **15** by press-fit is an object of the above-mentioned circumferential length.

The area of the core facing surface **31***c* of the movable core **30** and the area (core facing area) of the core facing surface **131***a* of the fixed core **13** correspond to the magnetic path cross-sectional area. In the area of the core facing surface **131***a*, an area of a portion excluding the through-hole **31***a* of the movable core **30** is not included in the magnetic path cross-sectional area because of not facing the movable core **30**. The magnetic path cross-sectional area (tip area) of the protruding end surface **132***a* is set to be larger than the magnetic path cross-sectional area of the core facing surface **131***a* of the fixed core **13**.

<Description of Manufacturing Method>

Next, a manufacturing method of the fuel injection valve **1** will be explained.

First, the needle **20**, the movable core **30**, the second spring member SP**2**, the sleeve **40**, and the cup **50** are assembled to form the movable portion M. After the non-magnetic member **14** and the nozzle hole body **11** are welded to the main body **12**, the movable portion M is incorporated into the main body **12**, and then the main body **12** and the fixed core **13** are assembled and welded.

On the other hand, the coil **17** is wound around the bobbin **17***a*, the end portion of the coil **17** is connected to the terminal extending portion **16***c*, and the insulation member **16***d* is assembled to the terminal extending portion **16***c* to form a coil assembly. The coil assembly is assembled to the fixed core **13** after the welding, and then the yoke **15** is press-fitted into the fixed core **13**.

After that, a mold for forming the resin member **16** is assembled to the fixed core **13** after press-fit, and molten resin is injected between the mold and the fixed core **13** at a predetermined pressure. The molten resin thus injected flows into the terminal chamber Ra, and then into the coil chamber R through the resin molding flow channel **132***h*. After that, the molten resin is cooled and solidified, and the mold is removed. Therefore, the coil chamber R is filled with the filling resin member **23**, and the resin molding flow channel **132***h* and the terminal chamber Ra are also filled with the resin member.

Next, the first spring member SP**1** and the support member **18** are assembled to adjust the first set load, and then the filter **19** is assembled to the fixed core **13**. As described above, the fuel injection valve **1** is manufactured.

<Effects>

According to the present embodiment, the fixed core **13** has the cylindrical main body portion **131** formed with the core facing surface **131***a* facing the movable core **30**, and the protruding portion **132** protruding radially outer side from the outer peripheral surface of the cylindrical main body portion **131** and abutting against the yoke **15**. The protruding portion **132** is formed with a resin molding flow channel **132***h* for causing the molten resin serving as the filling resin member **23** to flow into the coil chamber R. The length (height dimension) of the protruding portion **132** in the direction of the cylinder center line (direction of the axis line C**1**) of the fixed core **13** is shorter (smaller) toward the radially outer side of the fixed core **13**. Therefore, the length of the resin molding flow channel **132***h* in the axis line C**1** direction is shorter than the height dimension H**1** of the base end portion of the protruding portion **132**. Therefore, the pressure loss when the molten resin flows through the resin molding flow channel **132***h* can be reduced by the shortened amount, and further, the heat loss of the molten resin that is transferred on the wall surface of the resin molding flow channel **132***h* can be reduced.

Since the diameter of the magnetic path cross-sectional area at the protruding portion **132** increases toward the radially outer side of the fixed core **13** increases, even if the height dimension decreases toward the radially outer side, a minimum value of the magnetic path cross-sectional area inside the protruding portion **132** can be kept unchanged. Therefore, the reduction of the injection pressure of the molten resin can be realized while restricting the reduction of the magnetic attraction force for driving the movable core **30**.

In the present embodiment, the protruding portion **132** is press-fitted into the yoke **15**. Specifically, the protruding end surface **132***a* is press-fitted into the inner peripheral surface of the yoke **15**. Therefore, according to the above-described configuration in which the height dimension of the protruding portion **132** is set to be smaller toward the radially outer side, the length of the protruding end surface **132***a* in the axis line C**1** direction, which is the surface to be press-fitted, is shorter than the height dimension H**1** of the base end portion of the protruding portion **132**. Therefore, the load required for the press-fit can be reduced by the shortened amount.

In the present embodiment, the length of the protruding portion **132** in the axis line C**1** direction gradually decreases from radially inner side to the outer side of the fixed core **13**. Therefore, the molten resin easily moves in the radial direction along the protruding portion **132**. Therefore, it is possible to promote the injection pressure drop of the molten resin.

In the present embodiment, the resin molding flow channel **132***h* is formed between the yoke **15** and the notch portion **132***d* provided on the protruding end surface **132***a* of the protruding portion **132**. Therefore, a process required for the protruding portion **132** can be facilitated as compared with a case where a through-hole is formed in the protruding portion **132** and the through-hole becomes a resin molding flow channel. In the present embodiment, of the magnetic path cross-sectional area of the magnetic circuit, the magnetic path cross-sectional area (tip area) at the contact portion between the protruding portion **132** and the yoke **15** is larger than the magnetic path cross-sectional area (core facing area) on the core facing surface **131***a*. Therefore, the magnetic flux can be restricted from being throttled by the tip area in the entire magnetic circuit. That is, it is possible to avoid a situation in which the magnetic flux does not saturate on the core facing surface **131***a* and the magnetic flux saturates on the protruding end surface **132***a*. Therefore, it is possible to prevent the magnetic attraction force from reducing due to decreasing the height dimension of the protruding portion **132**.

In the present embodiment, multiple resin molding flow channels **132***h* are disposed at equal intervals around the cylindrical main body portion **131** in the direction of the cylinder center line (direction of the axis line C**1**). Therefore, when the molten resin is distributed to multiple resin molding flow channels **132***h*, it is possible to promote the uniform distribution of the molten resin.

Second Embodiment

The fuel injection valve **1** according to the first embodiment includes the movable core **30** having one core facing surface **31***c* (see FIG. **2**). Due to this configuration, the magnetic flux (incoming magnetic flux) entering the movable core **30** and the magnetic flux (outgoing magnetic flux) exiting the movable core **30** are oriented in different directions (see the dotted arrow in FIG. **2**). That is, one of the incoming magnetic flux and the outgoing magnetic flux is a magnetic flux that enters and exits in the axis line C**1** direction to apply a valve opening force to the movable core **30**, while the other of the incoming magnetic flux and the outgoing magnetic flux is a magnetic flux that enters and exits in the radial direction of the movable core **30** and does not contribute as the valve opening force.

On the other hand, a fuel injection valve **1**A of the present embodiment illustrated in FIG. **6** includes a movable core **30**A having two core facing surfaces, that is, a first core facing surface **31***c***1** and a second core facing surface **31***c***2**. The fuel injection valve **1**A further includes a first fixed core **135** having an attracting surface facing the first core facing surface **31***c***1**, and a second fixed core **136** having an attracting surface facing the second core facing surface **31***c***2**. A non-magnetic member **14** is disposed between the first fixed core **135** and the second fixed core **136**. With this configuration, both of the incoming magnetic flux and the outgoing magnetic flux enter and exit in the axis line C**1** direction to become a magnetic flux that causes the valve opening force to act on the movable core **30**A (see a dotted arrow in FIG. **6**). The movable core **30**A and the needle **20** are connected by a coupling member **70**, and an orifice member **71** is attached to the coupling member **70**.

When the coil **17** is energized to cause the needle **20** to perform the valve opening operation, the movable core **30**A is attracted to the fixed cores **135** and **136** by both the first core facing surface **31***c***1** and the second core facing surface **31***c***2**. Therefore, the needle **20** performs the valve opening operation together with the movable core **30**A, the coupling member **70**, and the orifice member **71**. At the full lift position of the needle **20**, the coupling member **70** abuts against the stopper **135***a* fixed to the first fixed core **135**, and the first core facing surface **31***c***1** and the second core facing surface **31***c***2** do not abut against the fixed cores **135** and **136**.

When the energization of the coil **17** is stopped to cause the needle **20** to perform valve closing operation, the elastic force of the second spring member SP**2** applied to the movable core **30** is applied to the orifice member **71**. Therefore, the needle **20** performs the valve closing operation together with the movable core **30**A, the coupling member **70**, and the orifice member **71**.

The slide member **72** is attached to the movable core **30**A and operates for opening and closing together with the movable core **30**A. The slide member **72** slides in the axis line C**1** direction with respect to the cover **136***a* fixed to the second fixed core **136**. In short, it can be said that the needle **20**, which operates for opening and closing together with the movable core **30**A, the slide member **72**, the coupling member **70**, and the orifice member **71**, is supported by the slide member **72** in the radial direction.

The fuel flowing into the flow channel **13***a* formed inside the fixed core **13** flows through an internal passage **71***a* of the orifice member **71**, an orifice **71***b* formed in the orifice member **71**, and an orifice **73***a* formed in the moving member **73** in this order, and flows into the flow channel **12***b*. The moving member **73** is a member that moves in the axis line C**1** direction so as to open and close the orifice **71***b*, and when the moving member **73** opens and closes the orifice **71***b*, a degree of throttling of the flow channel between the flow channel **13***a* and the flow channel **12***b* is changed.

Also in the fuel injection valve **1**A according to the present embodiment, the length (height dimension) of the protruding portion **132** in the axis line C**1** direction is set to be shorter toward the radially outer side of the fixed core **13**. Therefore, the reduction of the injection pressure of the molten resin can be realized while restricting the reduction of the magnetic attraction force. Since the protruding end surface **132***a* of the protruding portion **132** is press-fitted into the yoke **15**, the reduction of the press-fit load can also be realized while restricting the reduction of the magnetic attraction force.

In the present embodiment, the magnetic path cross-sectional area (tip area) at the contact portion between the protruding portion **132** and the yoke **15** is larger than the magnetic path cross-sectional area in the first core facing surface **31***c***1**. The tip area is larger than the magnetic path cross-sectional area in the second core facing surface **31***c***2**. Therefore, the magnetic flux can be restricted from being throttled by the tip area in the entire magnetic circuit.

Third Embodiment

In the fuel injection valve **1** according to the first embodiment, the cylindrical main body portion **131** and the protruding portion **132** are integrally formed. Specifically, one base material is cut to form the cylindrical main body portion **131** and the protruding portion **132** which are integrated with each other. On the other hand, in the present embodiment, as illustrated in FIG. **7**, the cylindrical main body portion **131** and the protruding portion are formed separately, and the protruding portion is assembled to the cylindrical main body portion **131**. The protruding portion is formed by combining two members. One is an outer protruding portion **134** illustrated in FIG. **8** and the other is an inner protruding portion **133** illustrated in FIG. **9**.

The inner protruding portion **133** and the outer protruding portion **134** are made of the same material, and these protruding portions are made of the same material as that of the cylindrical main body portion **131**. The inner protruding portion **133** and the outer protruding portion **134** do not have a shape extending in an annular shape around the axis line C**1**, but have a shape extending in an arc shape at a portion excluding the terminal chamber Ra (see FIGS. **8** and **9**). The length (height dimension) of the inner protruding portion **133** and the outer protruding portion **134** in the axis line C**1** direction is constant regardless of the position in the radial direction.

The inner protruding portion **133** is press-fitted into the cylindrical main body portion **131**. By this press-fit, the inner protruding portion **133** is supported and fixed to the cylindrical main body portion **131**, and is positioned with respect to the cylindrical main body portion **131**. An inner peripheral surface **133***a* of the inner protruding portion **133** is in close contact with an outer peripheral surface of the cylindrical main body portion **131**. An outer peripheral surface **133***c* of the inner protruding portion **133** is separated from the inner peripheral surface of the yoke **15**.

The outer protruding portion **134** is press-fitted into the yoke **15**. By this press-fit, the outer protruding portion **134** is supported and fixed to the yoke **15**, and is positioned with respect to the yoke **15**. An outer peripheral surface **134***a* of the outer protruding portion **134** is in close contact with the inner peripheral surface of the yoke **15**. An inner peripheral surface **134***c* of the outer protruding portion **134** is separated from the outer peripheral surface of the cylindrical main body portion **131**.

The outer protruding portion **134** is formed with a resin molding flow channel **134***h* for causing the molten resin serving as the filling resin member **23** to flow into the coil chamber R. The resin molding flow channel **134***h* has a shape extending in parallel with the axis line C**1** direction. The resin molding flow channel **134***h* is partitioned between a notch portion **134***d* provided on the outer peripheral surface **134***a* of the outer protruding portion **134** and the inner peripheral surface of the yoke **15**.

In the axis line C**1** direction, the inner protruding portion **133** is disposed on the side opposite to the nozzle hole of the outer protruding portion **134**. A bottom surface **133***b* of the inner protruding portion **133** is in close contact with an upper surface **134***b* of the outer protruding portion **134**.

The cylindrical main body portion **131**, the inner protruding portion **133**, the outer protruding portion **134**, and the yoke **15** are in close contact with each other as described above, thereby forming a magnetic circuit through which a magnetic flux flows (see a dotted arrow in FIG. **7**). The areas of the portions in close contact with each other correspond to the magnetic path cross-sectional area defined above. That is, the area (base end area) of the inner peripheral surface **133***a* of the inner protruding portion **133** and the area (tip area) of the outer peripheral surface **134***a* of the outer protruding portion **134** correspond to the magnetic path cross-sectional area. Of the bottom surface **133***b* of the inner protruding portion **133** and the upper surface **134***b* of the outer protruding portion **134**, an area (intermediate area) of portions which are in close contact with each other also corresponds to the magnetic path cross-sectional area.

The circumferential length of the tip area does not include a portion that is not in contact with the yoke **15**. Specifically, since a portion forming the terminal chamber Ra and the notch portion **134***d* are not in contact with the yoke **15**, they are not included in the circumferential length of the tip area. A portion of the outer protruding portion **134**, which is in contact with the yoke **15** by press-fit, is the target of the above-mentioned circumferential length.

A tip area is set larger than the base end area. These areas are specified by the height dimensions H**1***a* and H**2***a*, and the circumferential length. The circumferential length of the tip area is longer than the circumferential length of the base end area, and the height dimension H**2***a* of the tip area is smaller than the height dimension H**1***a* of the base end area. The tip area is set larger than the intermediate area.

In the axis line C**1** direction, the length (height dimension) of the inner peripheral surface **133***a* of the inner protruding portion **133** is shorter (smaller) than the length (height dimension) of the outer peripheral surface **134***a* of the outer protruding portion **134**. Therefore, the pressure loss when the molten resin flows through the resin molding flow channel **134***h* can be reduced by the shortening, and further, the heat loss of the molten resin that is transferred on the wall surface of the resin molding flow channel **134***h* can be reduced.

Furthermore, the diameter of the magnetic path cross-sectional area at the protruding portion formed by the inner protruding portion **133** and the outer protruding portion **134** increases toward the radially outer side of the fixed core **13**. Therefore, even if the height dimension is reduced toward the radially outer side, the minimum value of the magnetic path cross-sectional area in the entire protruding portion can be kept unchanged. Therefore, the reduction of the injection pressure of the molten resin can be realized while restricting the reduction of the magnetic attraction force for driving the movable core **30**.

Other Embodiments

Although multiple embodiments of the present disclosure have been described above, not only the combinations of the configurations explicitly illustrated in the description of each embodiment, but also the configurations of multiple embodiments can be partially combined even if they are not explicitly illustrated if there is no problem in the combination in particular. Unspecified combinations of the configurations described in multiple embodiments and the modifications are also disclosed in the following description.

In each of the above-described embodiments, the resin molding flow channel **132***h* is provided by the notch portion **132***d* formed in the protruding end surface **132***a*. On the other hand, the notch portion **132***d* may be eliminated, a through-hole extending in the axis line C**1** direction may be formed in the protruding portion **132**, and this through-hole may be used as the resin molding flow channel **132***h*.

In the first embodiment, the tip area of the protruding portion **132** is set larger than the base end area. On the other hand, the tip area may be the same as the base end area, or the tip area may be smaller than the base end area.

In the example illustrated in FIG. **2**, the through-hole **31***a* is formed in the movable core **30**, but the through-hole **31***a* may be eliminated. In the example illustrated in FIG. **5**, the notch portion **132***d* has an arc shape when viewed in the axis line C**1** direction, but may have a triangular shape or a quadrangular shape.

In the example illustrated in FIG. **4**, the protruding upper surface **132***b* has a tapered shape, and the protruding bottom surface **132***c* has a horizontal shape. On the other hand, the protruding upper surface **132***b* may have a horizontal shape, and the protruding bottom surface **132***c* may have a tapered shape.

In the example illustrated in FIG. **4**, the fixed core **13** is press-fitted and fixed to the yoke **15**, but may be fixed by screw fastening instead of the press-fit. For example, each of the inner peripheral surface of the yoke **15** and the protruding end surface **132***a* may be threaded and screw fastened together.

In the first embodiment, the length of the protruding portion **132** gradually decreases from radially inner side to the outer side of the fixed core **13**. On the other hand, a structure in which a size is reduced in a stepwise manner may be employed. For example, instead of forming the protruding upper surface **132***b* in a tapered shape, the protruding upper surface **132***b* may be formed in a step shape. In a case of such a step shape, as illustrated in FIG. **7**, it may be realized by a protruding portion which is separate from the cylindrical main body portion **131**, or may be realized by a protruding portion which is formed integrally with the cylindrical main body portion **131**.

In the example illustrated in FIG. **7**, the protruding portion formed separately from the cylindrical main body portion **131** is configured of two members. On the other hand, the protruding portion separate from the cylindrical main body portion **131** may be formed of one member. In the example illustrated in FIG. **7**, the inner protruding portion **133** is disposed on the side opposite to the nozzle hole of the outer protruding portion **134**, but the inner protruding portion **133** may be disposed on the nozzle hole side of the outer protruding portion **134** by reversing this disposition.

The resin molding flow channel **134***h* may be formed at a portion where the inner protruding portion **133** and the outer protruding portion **134** are in close contact with each other. Specifically, a notch may be formed in one of the bottom surface **133***b* of the inner protruding portion **133** and the upper surface **134***b* of the outer protruding portion **134**, and a resin molding flow channel may be formed by the notch. Alternatively, in addition to the resin molding flow channel **134***h* being formed on the outer peripheral surface **134***a* of the outer protruding portion **134**, a resin molding flow channel may be formed at a portion where the inner protruding portion **133** and the outer protruding portion **134** are in close contact with each other. Even in this case, it is desirable to set the tip area to be larger than the intermediate area.

In the first embodiment, the magnetic path cross-sectional area at the contact portion between the protruding portion **132** and the yoke **15** is larger than the magnetic path cross-sectional area in the core facing surface **131***a*, but the magnitude relationship may be reversed.

In the example illustrated in FIG. **5**, the resin molding flow channels **132***h* are disposed at equal intervals in the circumferential direction, but may be disposed at unequal intervals. The number of the resin molding flow channels **132***h* is not limited to multiple, and may be one.

In the first embodiment, the movable portion M is supported in the radial direction at two positions of the portion (needle tip portion) of the needle **20** facing the inner wall surface **11***c* of the nozzle hole body **11**, and the outer peripheral surface **51***d* of the cup **50**. On the other hand, the movable portion M may be supported in the radial direction at two positions of the outer peripheral surface of the movable core **30** and the needle tip portion.

In the first embodiment, the inner core **32** is formed of the non-magnetic material, but may be formed of the magnetic material. In a case where the inner core **32** is formed of the magnetic material, the inner core **32** may be formed of a weak magnetic material that is weaker in magnetism than that of the outer core **31**. Similarly, the needle **20** and the guide member **60** may be formed of a weak magnetic material that is weaker in magnetism than that of the outer core **31**.

In the first embodiment, when the movable core **30** is moved by a predetermined amount, the cup **50** is interposed between the first spring member SP**1** and the movable core **30** in order to realize the core boost structure in which the movable core **30** abuts against the needle **20** to initiate the valve opening operation. On the other hand, the cup **50** may be eliminated, a third spring member different from the first spring member SP**1** may be provided, and a core boost structure may be employed in which the movable core **30** is urged to the nozzle hole side by the third spring member.

In each of the above embodiments, the needle **20** is configured to be movable with respect to the movable core **30**, but the movable core **30** and the needle **20** may be integrally configured so as not to be movable relative to each other. When the second and subsequent injections of the divided injection are performed, it is necessary for the movable core **30** to return to the initial position. However, in a case where the movable core **30** and the needle **20** are integrally formed as described above, the needle **20** becomes heavy, and the valve closing bounce becomes easy. Therefore, the effect of restricting bounce by setting the seat angle θ to 90 degrees or less is suitably exhibited in the case of the above-mentioned integrated structure.

In the first embodiment, the fuel injection valve **1** is of the center disposition type which is attached to a portion of the cylinder head located at the center of the combustion chamber **2** to inject the fuel from above the combustion chamber **2** in the center line direction of the piston. On the other hand, the fuel injection valve may be a side disposition type fuel injection valve which is attached to a portion of the cylinder block located on the side of the combustion chamber **2** to inject the fuel from the side of the combustion chamber **2**.

What is claimed is:

1. A fuel injection valve comprising:

a fixed core configured to form a part of a magnetic circuit that is to cause a magnetic flux to flow therethrough;

a movable core configured to form a part of the magnetic circuit and configured to be driven by a magnetic attraction force generated in a gap between the movable core and the fixed core;

a valve body configured to perform a valve opening operation caused by driving the movable core to open a nozzle hole to inject fuel;

a yoke configured to form a part of the magnetic circuit and accommodating the fixed core;

a coil placed in a coil chamber between the fixed core and the yoke and configured to generate the magnetic flux on energization; and

a filling resin member with which the coil chamber is filled and having an electrical insulation property, wherein

the fixed core includes:

a cylindrical main body portion that has a core facing surface facing the movable core; and a protruding portion that protrudes radially outward from an outer peripheral surface of the cylindrical main body portion and is in contact with the yoke to cause the magnetic flux to pass therethrough,

the protruding portion defines a resin molding flow channel to cause molten resin serving as the filling resin member to flow into the coil chamber,

a length of the protruding portion in a direction of a cylinder center line of the fixed core is set to be shorter toward a radially outer side of the fixed core,

the protruding portion includes

a base portion that is located on a side closer to the cylindrical main body portion and that does not define the resin molding flow channel, and

an end portion that is located on a side closer to the yoke and that defines the resin molding flow channel, and

the length of the base portion of the protruding portion in the direction of the cylinder center line gradually decreases from a radially inner side to the radially outer side of the fixed core.

2. The fuel injection valve according to claim **1**, wherein the protruding portion is press-fitted to the yoke in a direction of the driving.

3. The fuel injection valve according to claim **1**, wherein the resin molding flow channel is formed between a notch portion, which is in a protruding end surface of the protruding portion, and the yoke.

4. The fuel injection valve according to claim **1**, wherein a magnetic path cross-sectional area of the magnetic circuit at a contact portion between the protruding portion and the yoke is larger than a magnetic path cross-sectional area of the magnetic circuit in the core facing surface.

5. The fuel injection valve according to claim **1**, wherein the resin molding flow channel includes a plurality of the resin molding flow channels placed at equal intervals around the cylinder center line of the cylindrical main body portion.

6. The fuel injection valve according to claim **1**, wherein the length of the protruding portion in the direction of the cylinder center line gradually decreases from the base portion to the end portion.

7. The fuel injection valve according to claim **1**, wherein the protruding portion has a protruding upper surface on a side opposite to the coil chamber, and

the protruding upper surface, in a cross-sectional view including the cylinder center line, has a tapered shape linearly extending from the base portion to the end portion in a direction inclining with respect to the cylinder center.

8. The fuel injection valve according to claim **3**, wherein the end portion defines the protruding end surface of the protruding portion.

9. The fuel injection valve according to claim **1**, wherein a width of the protruding portion in a direction perpendicular to the cylinder center line overlaps with a width of the coil in the direction perpendicular to the cylinder center line.

10. The fuel injection valve according to claim **1**, wherein the protruding portion has a protruding upper surface on a side opposite to the coil chamber, and

a resin member is provided on an outer peripheral surface of the fixed core and on the protruding upper surface of the protruding portion of the fixed core.

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