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(54) **VALVE DEVICE**

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(57) **ABSTRACT**

A valve device includes a drive device, a valve element, a housing main body, a main-body cover and a seal member. The housing main body has a main-body connecting portion and a main body fastening portion. The main-body cover has a cover connecting portion and a cover fastening portion. At least one of the housing main body and the main-body cover has a corresponding one of: a rigidity reducing structure that reduces a rigidity of the main-body connecting portion; and a rigidity reducing structure that reduces a rigidity of the cover connecting portion. The rigidity reducing structure is a space that reduces the rigidity.

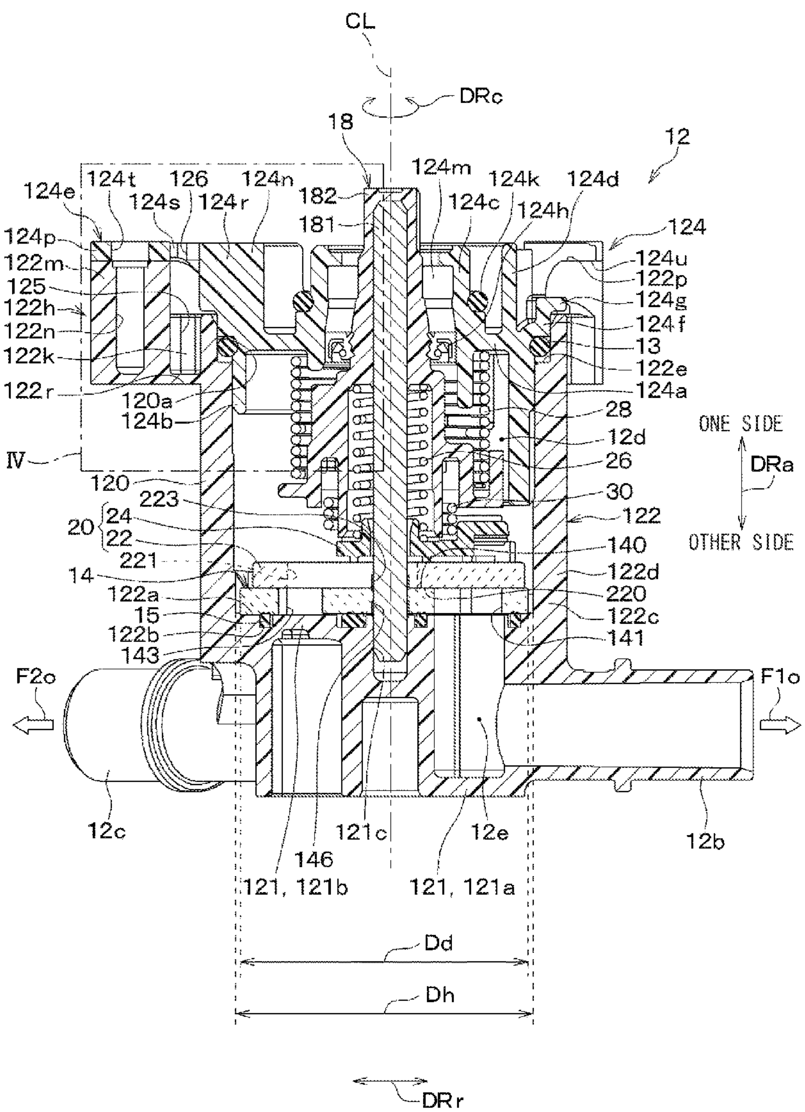
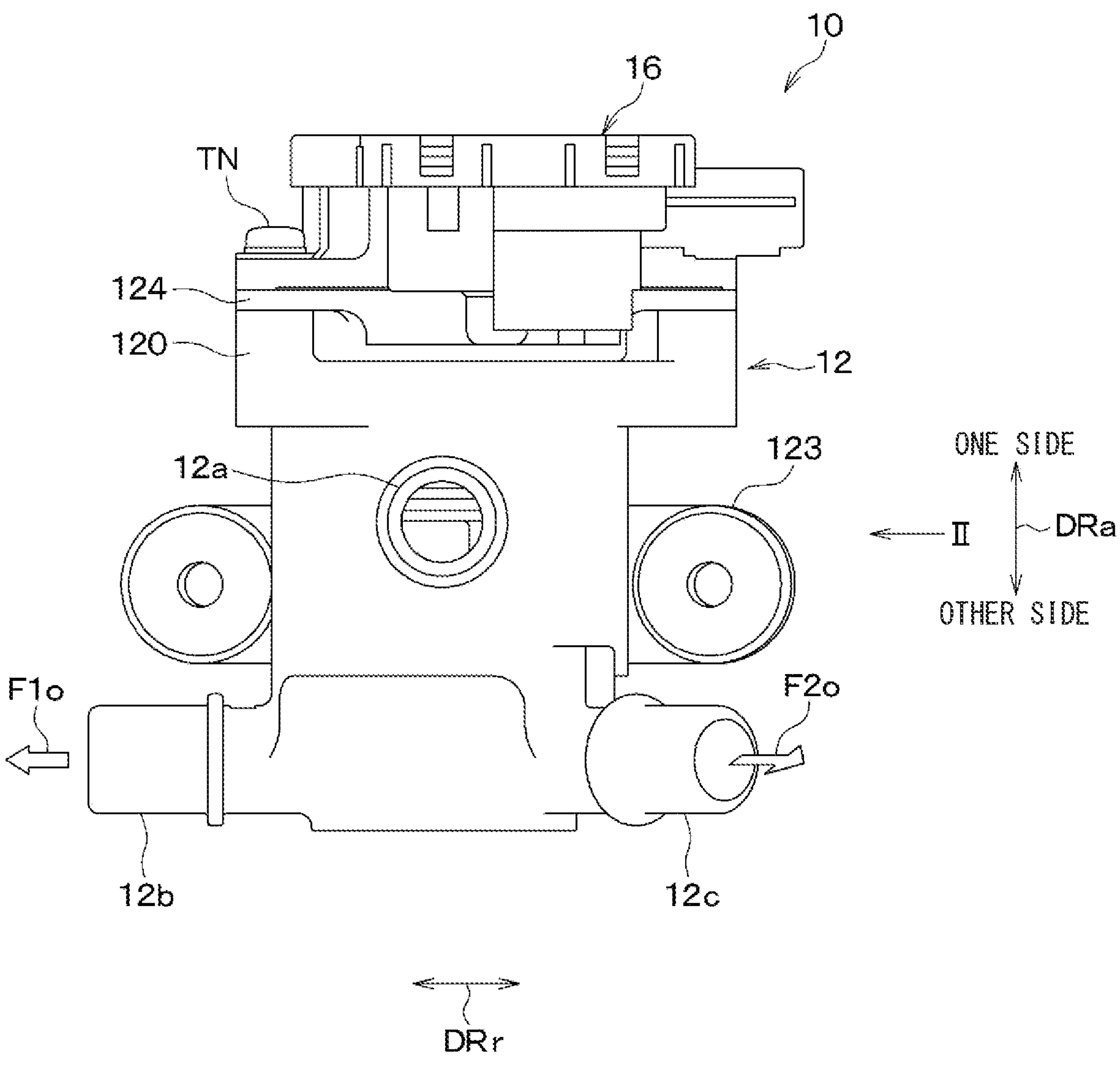


FIG. 1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12c
DRr

FIG. 2

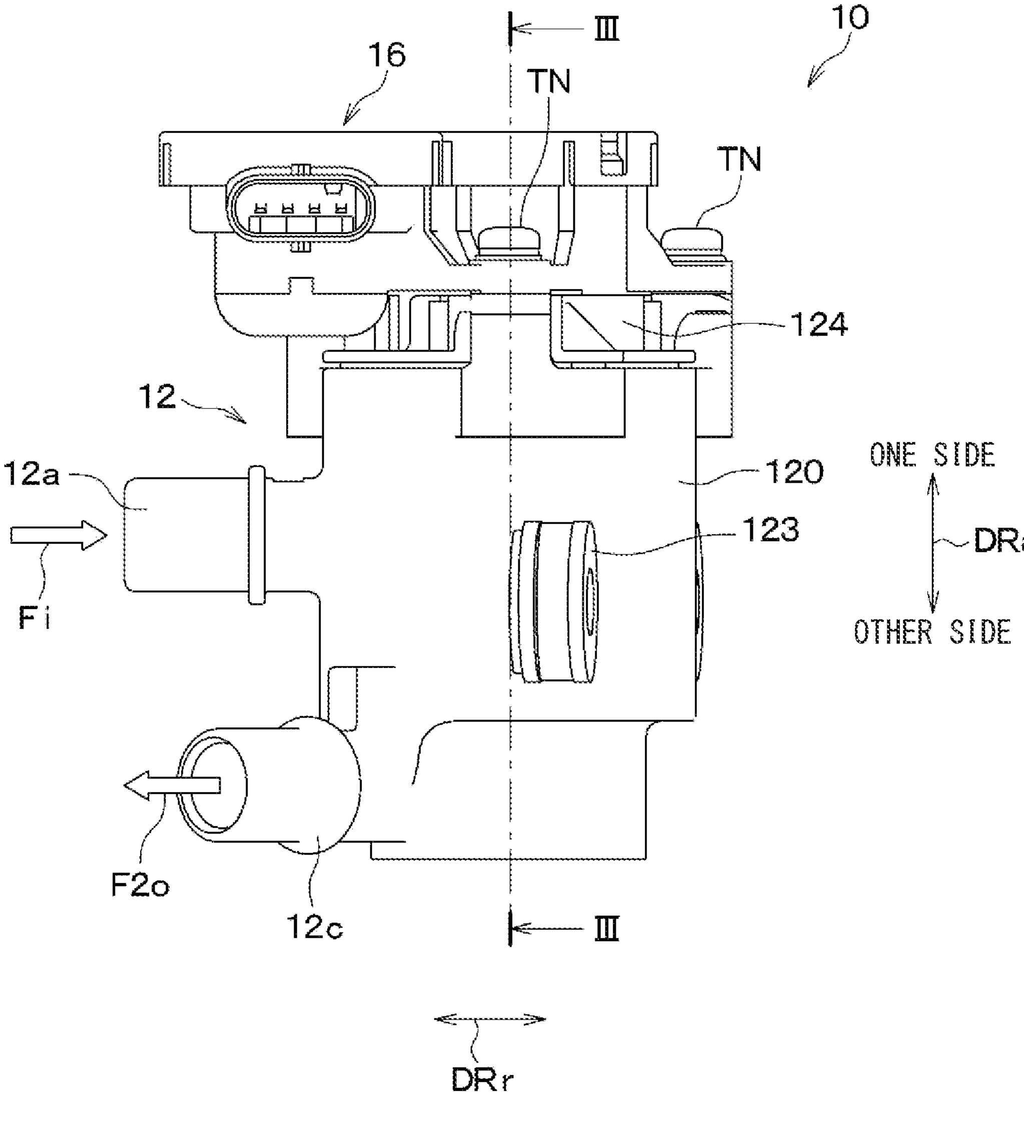
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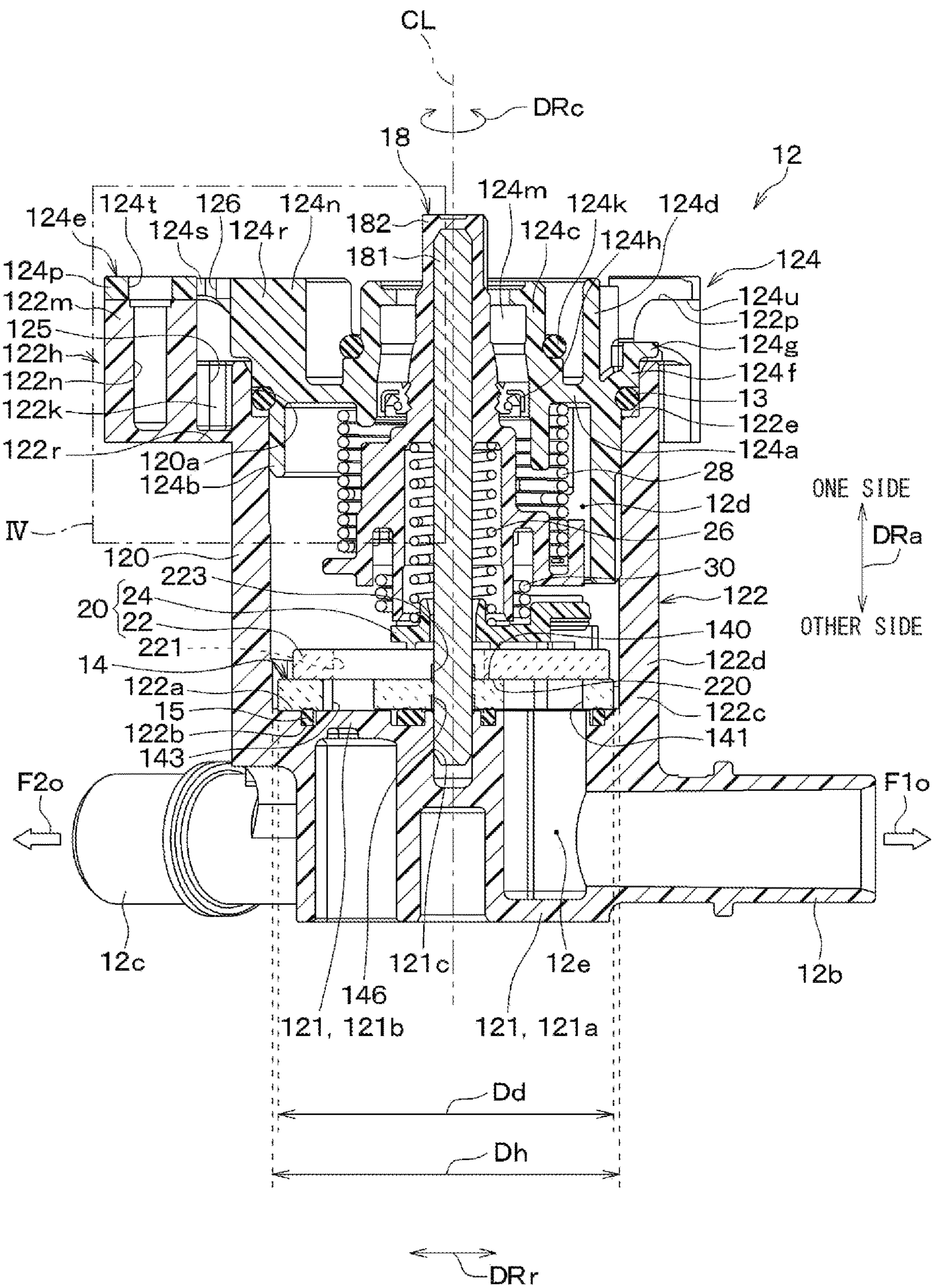
FIG. 3



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DRc
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124
122m
124u
122p
125
124g
122h
124f
122n
13
122k
122e
122r
124a
120a
124b
28
ONE SIDE
12d
DRa
IV
26
120
30
223
122
20
24
22
140
OTHER SIDE
221
14
122d
122a
220
15
122c
122b
141
143
F2o
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12c
121c
12e
12b
146
121, 121b
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Dd
Dh
DRr

FIG. 4

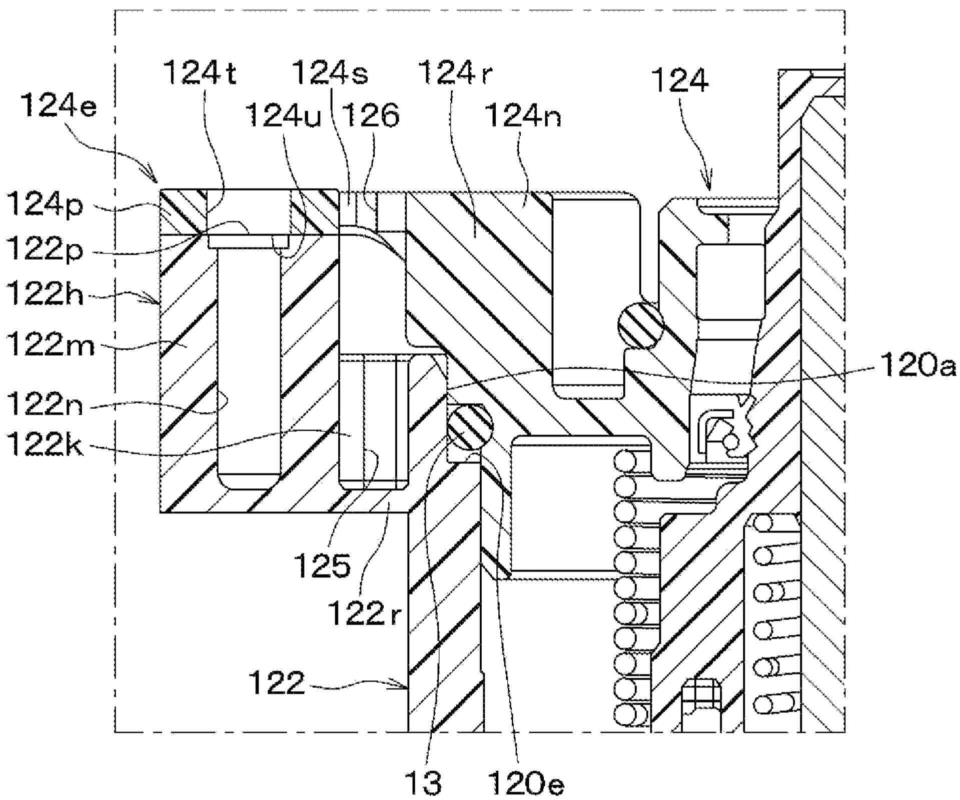
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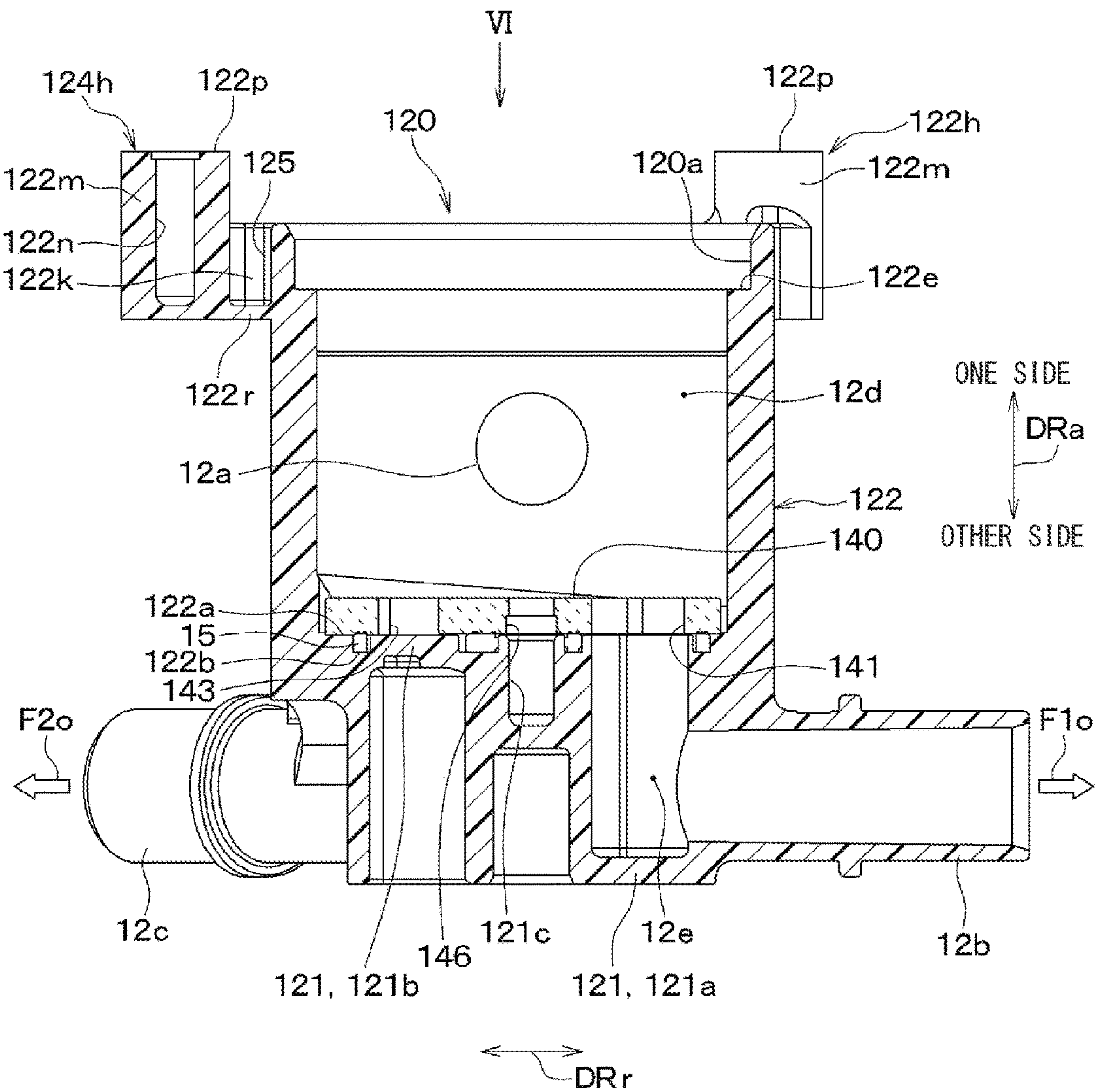
FIG. 5



VI
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DRr

FIG. 6

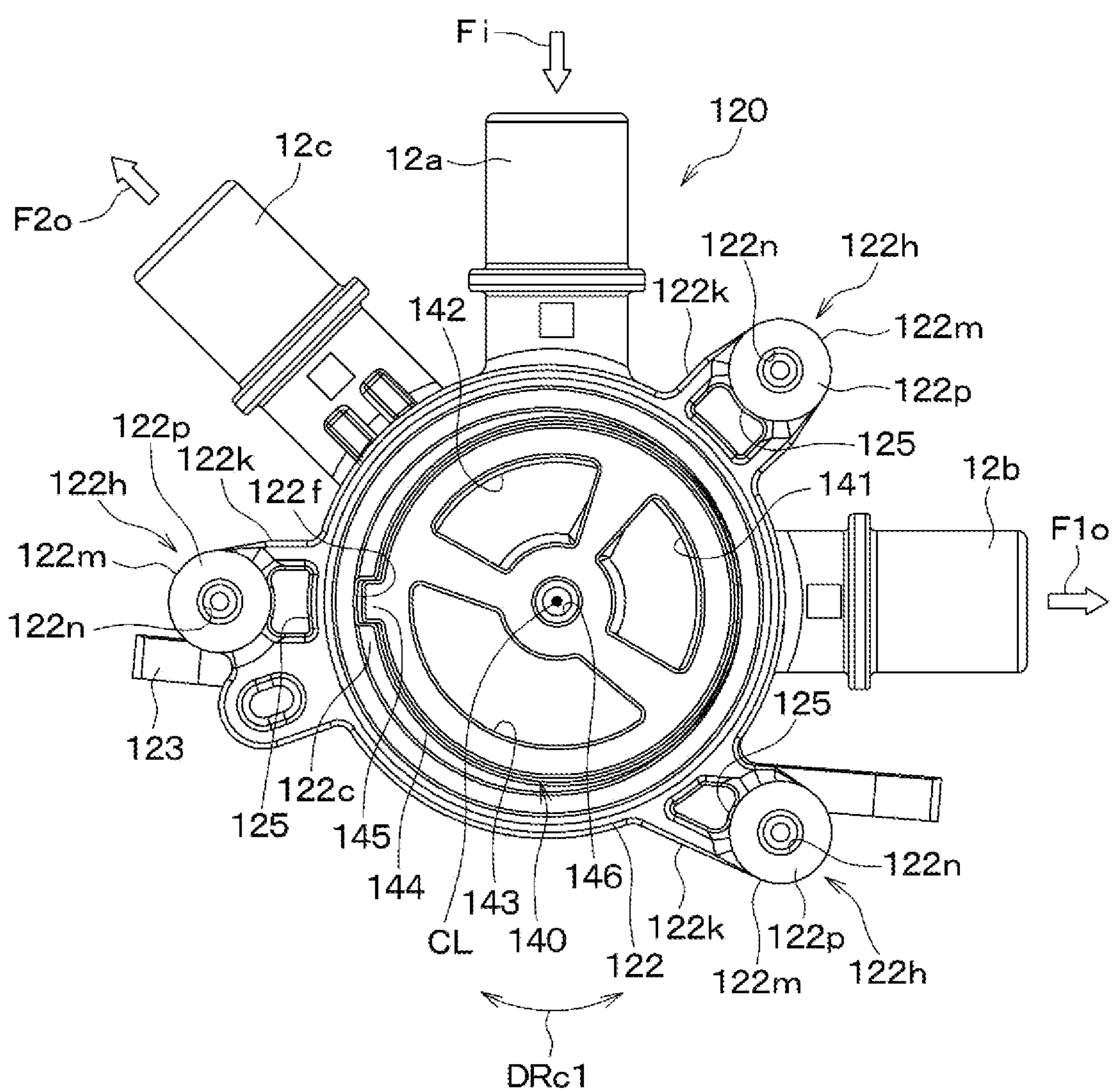
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FIG. 7

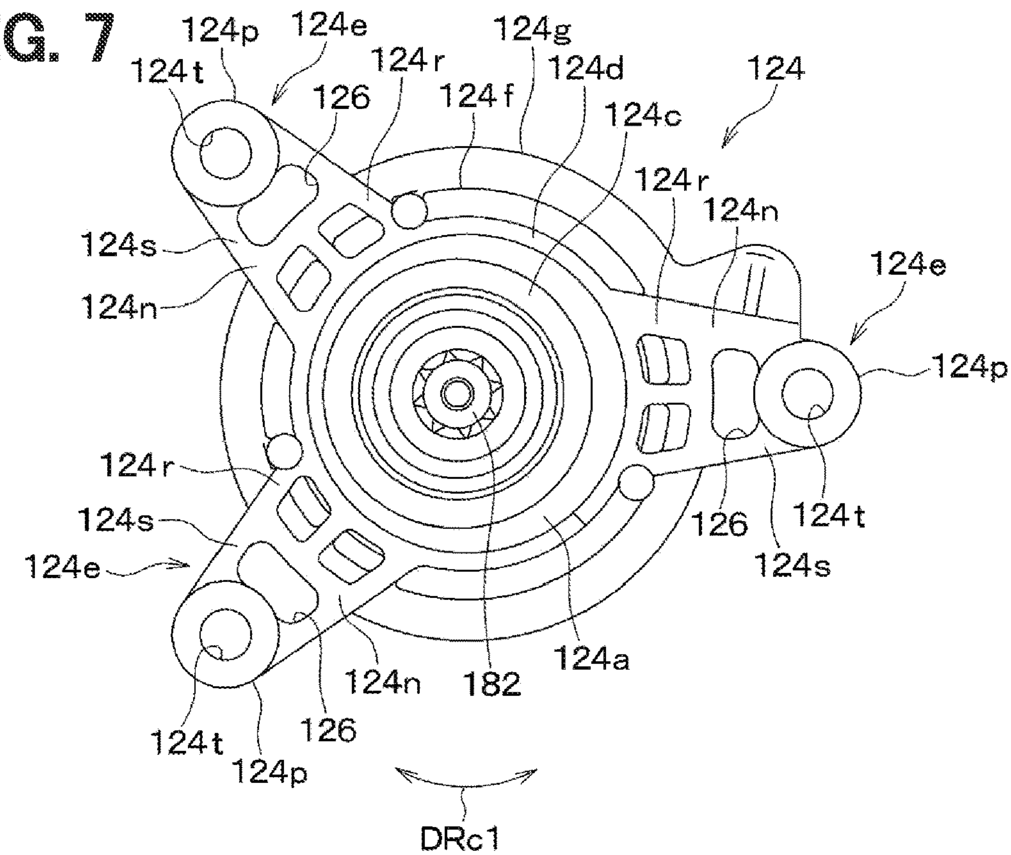
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FIG. 8

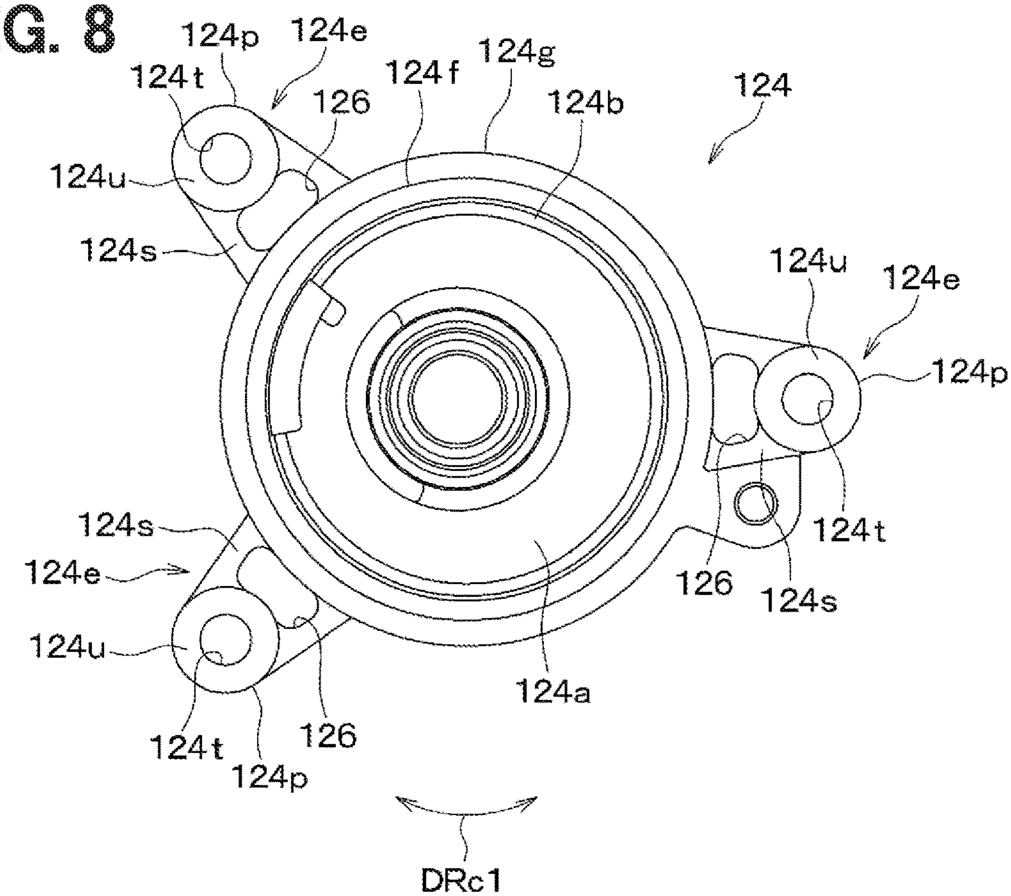
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FIG. 9

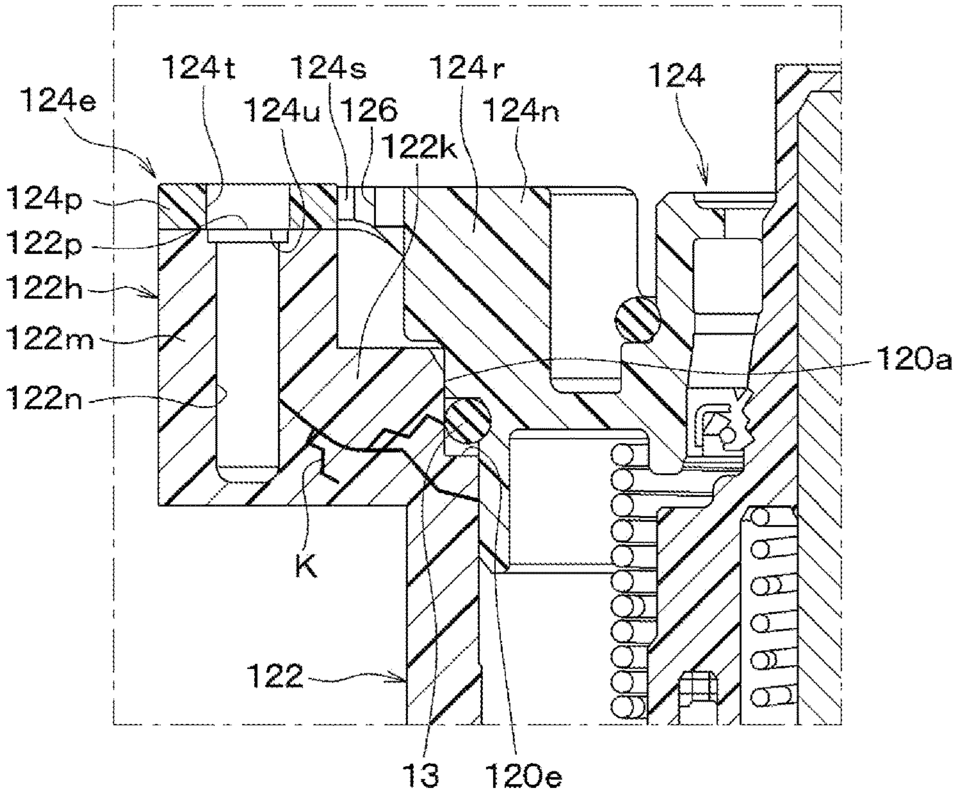

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FIG. 10

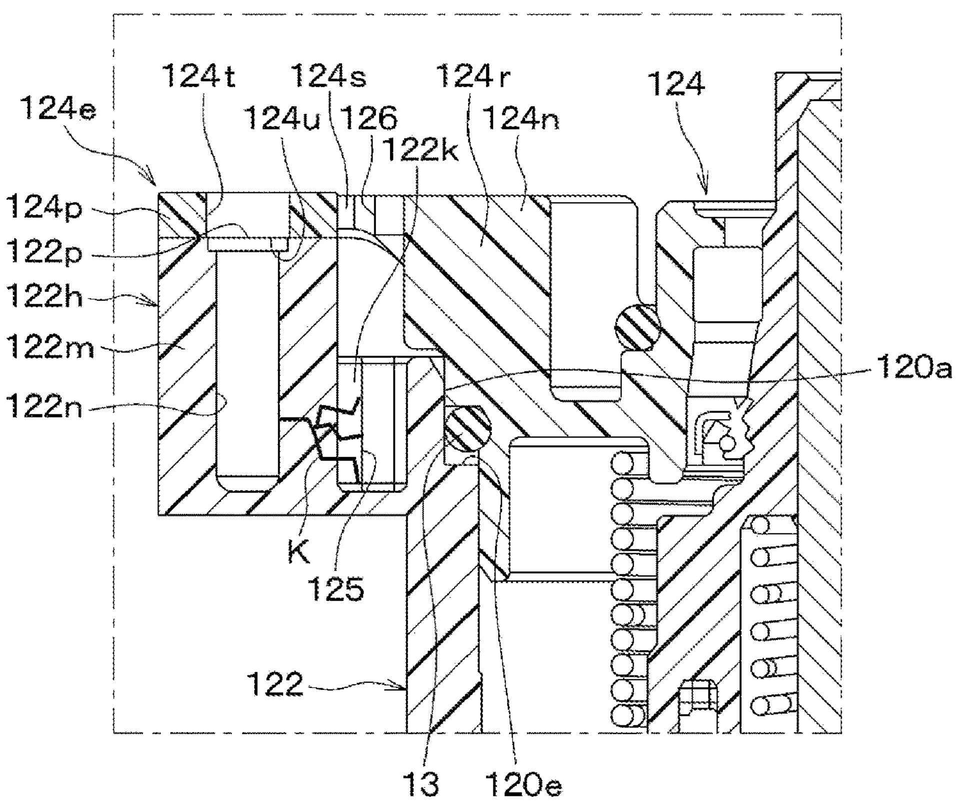

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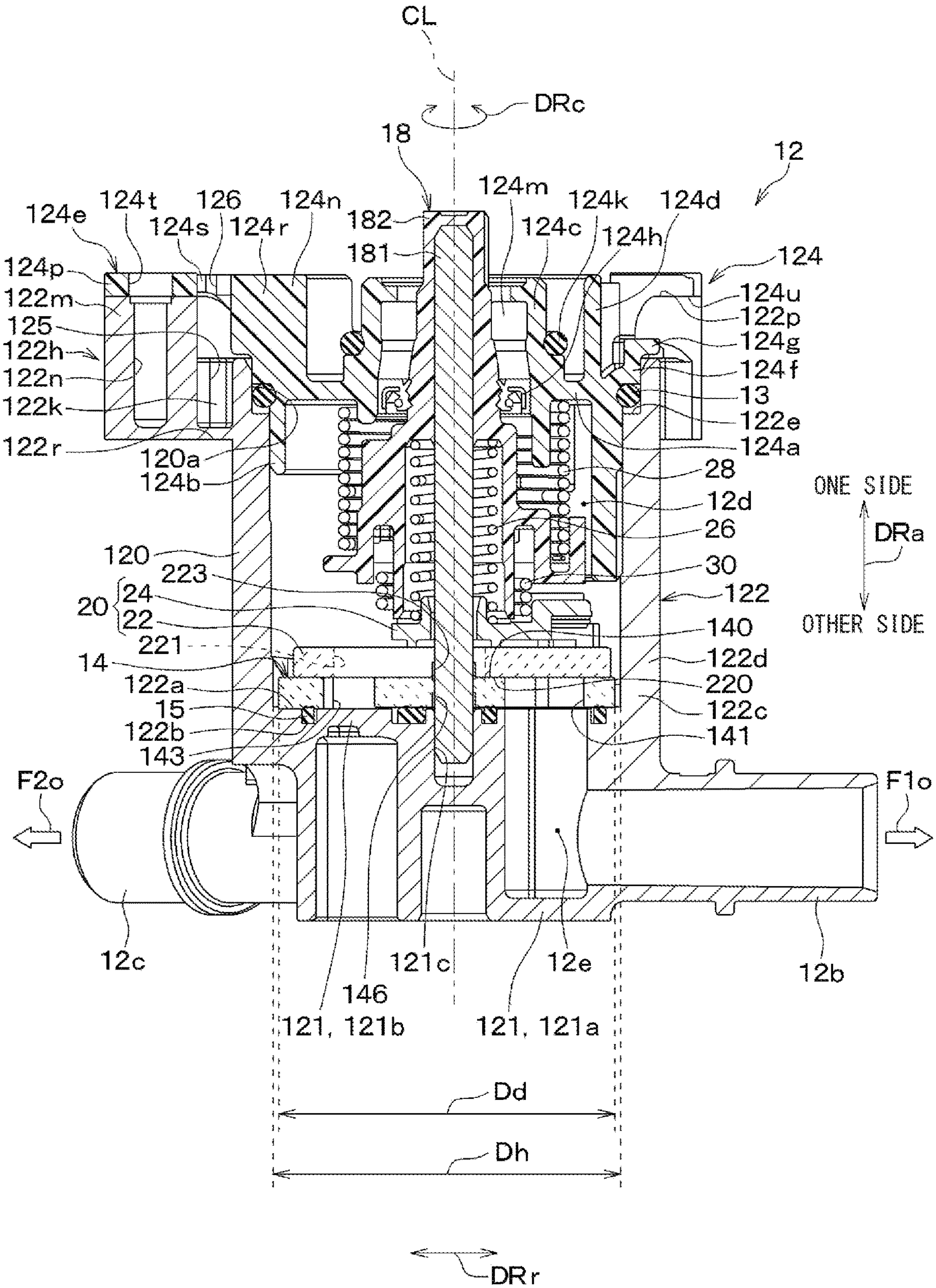
FIG. 11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121, 121a
Dd
Dh
DRr

VALVE DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation application of International Patent Application No. PCT/JP2022/015521 filed on Mar. 29, 2022, which designated the U.S. and claims the benefit of priority from Japanese Patent Application No. 2021-071791 filed on Apr. 21, 2021. The entire disclosures of all of the above applications are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to a valve device.

BACKGROUND

[0003] Previously, there is proposed a valve device that has: a shaft, which extends in an axial direction of a predetermined central axis; and a valve element while the shaft and the valve element are received at a receiving space formed by a housing main body and a main-body cover. In this valve device, the housing main body and the main-body cover are fastened together by a plurality of screws. Furthermore, in this valve device, a seal member, which is placed between the housing main body and the main-body cover, is resiliently deformed in the axial direction of the predetermined central axis to seal a gap between the housing main body and the main-body cover and thereby close between the receiving space and the outside of the valve device.

[0004] Each of the housing main body and the main-body cover of the valve device discussed above has a plurality of contact surfaces at portions thereof which are fastened with the screws. For instance, in a case where a degree of flatness of one or more of these contact surfaces is lower than a designed degree of flatness (designed accuracy) or a case where surface heights of these contact surfaces vary from each other, the housing main body and the main-body cover may be fastened together while at least one of the housing main body and the main-body cover is tilted relative to the axial direction of the predetermined central axis.

SUMMARY

[0005] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0006] According to one aspect of the present disclosure, there is provided a valve device that includes a drive device, a valve element, a housing main body, a main body cover and a seal member. The drive device is configured to output a rotational force. The valve element has a flow passage and is configured to adjust a flow rate of a fluid flowing in the flow passage when the valve element is rotated about a predetermined central axis by the rotational force outputted from the drive device. The housing main body has a main-body peripheral wall and an opening. The main-body peripheral wall surrounds the predetermined central axis and forms a receiving space which receives the valve element. The opening is formed at the housing main body on one side in an axial direction of the predetermined central axis. The main-body cover has a cover peripheral wall and is fastened to the housing main body and thereby closes the receiving space. The seal member is resiliently deformed between the housing main body and the main-body cover. The housing main body has a main-body connecting portion and a main-body fastening portion. The main-body connecting portion radially outwardly extends from the main-body peripheral wall to a location which is on a radially outer side of the seal member in a radial direction of the predetermined central axis. The main-body fastening portion is joined to a radially outer end part of the main-body connecting portion and has a fastening surface which contacts the main-body cover. The main-body cover has a cover connecting portion and a cover fastening portion. The cover connecting portion radially outwardly extends from the cover peripheral wall to a location which is on the radially outer side of the seal member in the radial direction of the predetermined central axis. The cover fastening portion is joined to a radially outer end part of the cover connecting portion and has a contact surface which contacts the fastening surface. At least one of the housing main body and the main-body cover has a corresponding one of: a rigidity reducing structure that includes a main-body rigidity reducing part that reduces a rigidity of the main-body connecting portion in comparison to a case where the main-body rigidity reducing part is absent at the main-body connecting portion; and a rigidity reducing structure that includes a cover rigidity reducing part that reduces a rigidity of the cover connecting portion in comparison to a case where the cover rigidity reducing part is absent at the cover connecting portion. At least one of the rigidity reducing structures is a structure that has a space which reduces the rigidity of a corresponding one of the main-body connecting portion and the cover connecting portion.

[0007] According to another aspect of the present disclosure, there is provided a valve device that includes a drive device, a valve element, a housing main body, a main-body cover and a seal member. The drive device is configured to output a rotational force. The valve element has a flow passage and is configured to adjust a flow rate of a fluid flowing in the flow passage when the valve element is rotated about a predetermined central axis by the rotational force outputted from the drive device. The housing main body receives the valve element at an inside of the housing main body and has an opening which is formed at the housing main body on one side in an axial direction of the predetermined central axis. The main-body cover is fastened to the housing main body and thereby closes the opening. The seal member is resiliently deformed between the housing main body and the main-body cover to seal a gap between the housing main body and the main-body cover. The housing main body has a main-body fastening portion. The main-body fastening portion is located on a radially outer side of the seal member in a radial direction of the predetermined central axis and has a fastening surface which contacts the main-body cover when the housing main body and the main-body cover are fastened together. The main-body cover has a cover fastening portion. The cover fastening portion is located on the radially outer side of the seal member in the radial direction of the predetermined central axis and has a contact surface which contacts the fastening surface. One of the housing main body and the main-body cover is formed by a member that has a lower rigidity in comparison to another one of the housing main body and the main-body cover.

BRIEF DESCRIPTION OF DRAWINGS

[0008] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0009] FIG. **1** is a front view of a valve device of an embodiment.

[0010] FIG. **2** is a side view of the valve device seen in a direction of an arrow II in FIG. **1**.

[0011] FIG. **3** is a cross-sectional view taken along line III-III in FIG. **2**.

[0012] FIG. **4** is an enlarged view of a portion IV in FIG. **3**.

[0013] FIG. **5** is a cross-sectional view of the valve device of the embodiment.

[0014] FIG. **6** is a top view of a main body seen in a direction of an arrow VI in FIG. **5**.

[0015] FIG. **7** is a top view of a main-body cover of the valve device of the embodiment.

[0016] FIG. **8** is a bottom view of the main-body cover of the valve device of the embodiment.

[0017] FIG. **9** is a diagram showing a state where a crack is generated at an inside of a valve device of a comparative example.

[0018] FIG. **10** is a diagram showing a state where a crack is generated at an inside of the valve device of the embodiment.

[0019] FIG. **11** is a cross-sectional view of a valve device of another embodiment.

DETAILED DESCRIPTION

[0020] Previously, there is proposed a valve device that has: a shaft, which extends in an axial direction of a predetermined central axis; and a valve element while the shaft and the valve element are received at a receiving space formed by a housing main body and a main-body cover. In this valve device, the housing main body and the main-body cover are fastened together by a plurality of screws. Furthermore, in this valve device, a seal member, which is placed between the housing main body and the main-body cover, is resiliently deformed in the axial direction of the predetermined central axis to seal a gap between the housing main body and the main-body cover and thereby close between the receiving space and the outside of the valve device.

[0021] Each of the housing main body and the main-body cover of the valve device discussed above has a plurality of contact surfaces at portions thereof which are fastened with the screws. For instance, in a case where a degree of flatness of one or more of these contact surfaces is lower than a designed degree of flatness (designed accuracy) or a case where surface heights of these contact surfaces vary from each other, the housing main body and the main-body cover may be fastened together while at least one of the housing main body and the main-body cover is tilted relative to the axial direction of the predetermined central axis. When the housing main body and the main-body cover are fastened together by the screws in the tilted state where at least one of the housing main body and the main-body cover is tilted relative to the axial direction of the predetermined central axis, an excessive load is applied to the contact surfaces of the housing main body and the main-body cover to cause deformation of at least one of the housing main body and the main-body cover.

[0022] As a result of extensive study conducted by the inventors of the present application, it is found that when at least one of the housing main body and the main body cover is deformed, a force for compressing the seal member is changed to cause a change in the amount of elastic deformation of the seal member as compared to a case where the housing main body and the main body cover are not deformed. Furthermore, it is also found that when the amount of deformation of the seal member is reduced in comparison to the case where the housing main body and the main-body cover are not deformed, the gap between the housing main body and the main-body cover may not be sealed by the seal member. This may result in that a required degree of sealing of the receiving space cannot be ensured, and thereby the fluid is leaked from the receiving space to the outside of the valve device.

[0023] According to one aspect of the present disclosure, there is provided a valve device including:

- **[0024]** a drive device that is configured to output a rotational force;
- **[0025]** a valve element that has a flow passage which is configured to conduct a fluid through the flow passage, wherein the valve element is configured to adjust a flow rate of the fluid flowing in the flow passage when the valve element is rotated about a predetermined central axis by the rotational force outputted from the drive device;
- **[0026]** a housing main body that has:
  - **[0027]** a main-body peripheral wall which surrounds the predetermined central axis and forms a receiving space, wherein the receiving space receives the valve element; and
  - **[0028]** an opening which is formed at the housing main body on one side in an axial direction of the predetermined central axis;
- **[0029]** a main-body cover that has a cover peripheral wall which surrounds the predetermined central axis, wherein the main-body cover is fastened to the housing main body and thereby closes the receiving space; and
- **[0030]** a seal member that is resiliently deformed between the housing main body and the main-body cover to seal a gap between the housing main body and the main-body cover, wherein:
- **[0031]** the housing main body has:
  - **[0032]** a main-body connecting portion that radially outwardly extends from the main-body peripheral wall to a location which is on a radially outer side of the seal member in a radial direction of the predetermined central axis; and
  - **[0033]** a main-body fastening portion that is joined to a radially outer end part of the main-body connecting portion and has a fastening surface which contacts the main-body cover;
- **[0034]** the main-body cover has:
  - **[0035]** a cover connecting portion that radially outwardly extends from the cover peripheral wall to a location which is on the radially outer side of the seal member in the radial direction of the predetermined central axis; and

[0036] a cover fastening portion that is joined to a radially outer end part of the cover connecting portion and has a contact surface which contacts the fastening surface;

[0037] at least one of the housing main body and the main-body cover has a corresponding one of:

[0038] a rigidity reducing structure that includes a main-body rigidity reducing part that reduces a rigidity of the main-body connecting portion in comparison to a case where the main-body rigidity reducing part is absent at the main-body connecting portion; and

[0039] a rigidity reducing structure that includes a cover rigidity reducing part that reduces a rigidity of the cover connecting portion in comparison to a case where the cover rigidity reducing part is absent at the cover connecting portion; and

[0040] at least one of the rigidity reducing structures is a structure that has a space which reduces the rigidity of a corresponding one of the main-body connecting portion and the cover connecting portion.

[0041] According to the above configuration, in the case where the space is formed at the main-body connecting portion, even when an excessive load is applied to the contact surface at the time of fastening the housing main body and the main-body cover due to a relatively low degree of flatness of at least one of the fastening surface and the contact surface, the main-body connecting portion is more likely to be deformed in comparison to a portion which is located on a radially inner side of the main-body connecting portion. Furthermore, in the case where the space is formed at the cover connecting portion, even when an excessive load is applied to the contact surface at the time of fastening the housing main body and the main-body cover due to a relatively low degree of flatness of at least one of the fastening surface and the contact surface, the cover connecting portion is more likely to be deformed in comparison to a portion which is located on a radially inner side of the cover connecting portion.

[0042] Therefore, it is possible to limit deformation of the portion of the housing main body and the portion of the main-body cover, which are located on the radially inner side of the main-body connecting portion and the cover connecting portion and compress the seal member. Therefore, it is possible to limit a decrease in the amount of resilient deformation of the seal member caused by the deformation of at least one of the housing main body and the main-body cover, and thereby it is possible to ensure the required degree of sealing of the receiving space.

[0043] According to another aspect of the present disclosure, there is provided a valve device including:

[0044] a drive device that is configured to output a rotational force;

[0045] a valve element that has a flow passage which is configured to conduct a fluid through the flow passage, wherein the valve element is configured to adjust a flow rate of the fluid flowing in the flow passage when the valve element is rotated about a predetermined central axis by the rotational force outputted from the drive device;

[0046] a housing main body that receives the valve element at an inside of the housing main body and has an opening which is formed at the housing main body on one side in an axial direction of the predetermined central axis;

[0047] a main-body cover that is fastened to the housing main body and thereby closes the opening;

[0048] a seal member that is resiliently deformed between the housing main body and the main-body cover to seal a gap between the housing main body and the main-body cover, wherein:

[0049] the housing main body has a main-body fastening portion, wherein the main-body fastening portion is located on a radially outer side of the seal member in a radial direction of the predetermined central axis and has a fastening surface which contacts the main-body cover when the housing main body and the main-body cover are fastened together;

[0050] the main-body cover has a cover fastening portion, wherein the cover fastening portion is located on the radially outer side of the seal member in the radial direction of the predetermined central axis and has a contact surface which contacts the fastening surface; and

[0051] one of the housing main body and the main-body cover is formed by a member that has a lower rigidity in comparison to another one of the housing main body and the main-body cover.

[0052] According to the above configuration, even when an excessive load is applied to the contact surface at the time of fastening the housing main body and the main-body cover due to a relatively low degree of flatness of at least one of the fastening surface and the contact surface, the another one of the housing main body and the main-body cover, which has the higher rigidity, is less likely to be deformed in comparison to the one of the housing main body and the main-body cover, which has the lower rigidity. Therefore, in comparison to the case where the housing main body and the main-body cover are respectively formed by members which have the same rigidity, it is possible to limit deformation of the other one of the housing main body and the main-body cover, which has the higher rigidity, in response to deformation of the one of the housing main body and the main-body cover, which has the lower rigidity. Thus, the required degree of sealing of the receiving space can be more easily ensured.

[0053] Hereinafter, an embodiment of the present disclosure will be described with reference to FIGS. **1** to **10**. In the present embodiment, there will be described an example where a valve device **10** of the present disclosure is applied to a temperature adjusting device that is for air conditioning of a vehicle cabin and is also for temperature control of a battery at an electric vehicle. The valve device **10**, which is used in the temperature adjusting device of the electric vehicle, is required to execute fine adjustment of the temperature according to a state of the vehicle cabin and a state of the battery and is required to accurately adjust a flow rate of a fluid in comparison to a coolant circuit of an internal combustion engine.

[0054] The valve device **10** shown in FIG. **1** is applied to a fluid circuit in which the fluid (in this example, coolant) for adjusting the temperature of the vehicle cabin and the temperature of the battery is circulated to adjust the temperature of the vehicle cabin and the temperature of the battery. The valve device **10** can increase or decrease the flow rate of the fluid in a flow path through the valve device

10 in the fluid circuit, and the valve device 10 can also shut off the flow of the fluid in the flow path. For example, an LLC, which contains ethylene glycol, is used as the fluid. Here, LLC stands for Long Life Coolant.

[0055] As sown in FIGS. 1 and 2, the valve device 10 includes a housing 12 that forms a fluid passage that is formed at an inside of the housing 12 and conducts the fluid through the fluid passage. The valve device 10 is a three-way valve and has an inlet 12*a* for inputting the fluid, a first outlet 12*b* for outputting the fluid, and a second outlet 12*c* for outputting the fluid while the inlet 12*a*, the first outlet 12*b* and the second outlet 12*c* are formed at the housing 12. The valve device 10 functions not only as a flow-path switching valve but also as a flow-rate adjusting valve for adjusting a flow rate ratio between the fluid flowing from the inlet 12*a* to the first outlet 12*b* and the fluid flowing from the inlet 12*a* to the second outlet 12*c*.

[0056] As shown in FIG. 3, the valve device 10 is a disc valve that performs a valve opening/closing operation by rotating a rotor, which is shaped in a form of a circular disk, around a central axis CL of a shaft 18 described later. In the present embodiment, the various structures will be described upon assuming that a direction, which is along the central axis CL of the shaft 18 described later, will be referred to as an axial direction DRa, and a direction, which is perpendicular to the axial direction DRa and radiates from the axial direction DRa, will be referred to as a radial direction DRr. Furthermore, in the present embodiment, the various structures will be described upon assuming that a direction, which is around the central axis CL, will be referred to as a circumferential direction DRc. In FIG. 3, a drive device 16 is omitted to make the drawing easy to see.

[0057] The valve device 10 includes a stationary disk 14, the shaft 18, a valve element 20, a compression spring 26, a first torsion spring 28 and a second torsion spring 30 which are received at the inside of the housing 12. Furthermore, the valve device 10 includes the drive device 16 which is placed at an outside of the housing 12.

[0058] The housing 12 is a non-rotatable member that is not rotated. The housing 12 is made of, for example, a resin material. The housing 12 includes a main body 120 and a main-body cover 124. The main body 120 is shaped in a bottomed tubular form and extends in the axial direction DRa. The main-body cover 124 closes an opening 120*a* of the main body 120 which is located on one side in the axial direction DRa. Each of the main body 120 and the main-body cover 124 is molded by injection molding, in which a resin material is filled into a mold and is solidified into a desired shape. The main body 120 serves as a housing main body.

[0059] The main body 120 has: a bottom wall 121 which forms a bottom surface; and a main-body peripheral wall 122 which surrounds the central axis CL. The main-body peripheral wall 122 cooperates with the main-body cover 124 to form a receiving space that receives the valve element 20. The bottom wall 121 and the main-body peripheral wall 122 are formed integrally in one-piece as an integral molded portion.

[0060] The bottom wall 121 has two recesses respectively formed by a step at two portions of the bottom wall 121, which respectively correspond to a first passage hole 141 and a second passage hole 142 of the stationary disk 14 described later. In contrast, the recess is not formed at another portion of the bottom wall 121, which is opposed to a third passage hole 143 of the stationary disk 14. Specifically, a distance between the main-body cover 124 and each of the two portions of the bottom wall 121, which are respectively opposed to the first passage hole 141 and the second passage hole 142 of the stationary disk 14, is larger than a distance between the main-body cover 124 and the other portion of the bottom wall 121, which is opposed to the third passage hole 143 of the stationary disk 14.

[0061] The bottom wall 121 has: two stepped portions 121*a* each of which has the recess formed by the step and is opposed to the corresponding one of the first passage hole 141 and the second passage hole 142 of the stationary disk 14; and a non-stepped portion 121*b*, which does not have the recess and is opposed to the third passage hole 143 of the stationary disk 14. In the bottom wall 121, each of the stepped portions 121*a* is largely spaced from the stationary disk 14, and the non-stepped portion 121*b* is close to the stationary disk 14.

[0062] At the main-body peripheral wall 122, the inlet 12*a* is formed at a location that is closer to the opening 120*a* than to the bottom wall 121, and the first outlet 12*b* and the second outlet 12*c* are formed at a location that is closer to the bottom wall 121 than to the opening 120*a*. The inlet 12*a*, the first outlet 12*b* and the second outlet 12*c* are respectively formed as a tubular member that has a flow passage at an inside thereof.

[0063] A mounting portion 122*a*, on which the stationary disk 14 is mounted, is formed at the inside of the main-body peripheral wall 122 at a location that is between the portion of the main-body peripheral wall 122, at which the inlet 12*a* is formed, and the other portion of the main-body peripheral wall 122, at which the outlets 12*b*, 12*c* are formed. The main-body peripheral wall 122 has: a first disk opposing portion 122*c* which is opposed to the stationary disk 14 in the radial direction DRr; and a second disk opposing portion 122*d* which is opposed to a drive disk 22 in the radial direction DRr.

[0064] Furthermore, at the inside of the main-body peripheral wall 122, a seal installation portion 122*e*, at which a seal member 13 described later is installed, is formed at a location which is closer to the opening 120*a* than to the first disk opposing portion 122*c* and the second disk opposing portion 122*d*. Furthermore, as shown in FIG. 6, a receiving groove 122*f*, which receives a rotation stop projection 145 of the stationary disk 14 described later, is formed at an inside of the first disk opposing portion 122*c* in the main-body peripheral wall 122.

[0065] A plurality of main-body attachment portions 122*h*, at which the main-body cover 124 is attached to the main body 120, and a plurality of installation portions 123, through which the valve device 10 is installed to the electric vehicle, are formed at the outside of the main-body peripheral wall 122. Each of the installation portions 123 is a portion that is coupled to the electric vehicle at the time of installing the valve device 10 to the electric vehicle, and the installation portion 123 has a through-hole through which a coupling member for coupling with the electric vehicle is inserted.

[0066] The mounting portion 122*a* is a portion that contacts a back surface of the stationary disk 14 which is opposite to an opening surface 140 of the stationary disk 14. The mounting portion 122*a* is formed at a location at which an inner diameter changes at the main-body peripheral wall 122. Specifically, the mounting portion 122*a* is a planar portion that extends in the radial direction DRr. The mounting portion **122***a* has a receiving groove **122***b* that receives a gasket **15** described later.

[0067] The first disk opposing portion **122***c* is formed such that an inner diameter Dh of the first disk opposing portion **122***c* without the receiving groove **122***f* is larger than an outer diameter Dd of the stationary disk **14** without the rotation stop projection **145**. With this configuration, in a state where the stationary disk **14** is installed to the mounting portion **122***a*, a gap is formed between the stationary disk **14** and the main-body peripheral wall **122**. In other words, the stationary disk **14** is not positioned by the main-body peripheral wall **122**.

[0068] The receiving groove **122***f* is formed by radially recessing the inside of the first disk opposing portion **122***c* away from the central axis CL. A portion of the first disk opposing portion **122***c*, at which the receiving groove **122***f* is formed, has a sufficient thickness in comparison to a radial depth of the receiving groove **122***f*. Furthermore, the receiving groove **122***f* is formed at a location that is circumferentially displaced from a location interposed between the central axis CL and the first outlet **12***b* in the radial direction DRr and is also circumferentially displaced from a location interposed between the central axis CL and the second outlet **12***c* in the radial direction DRr.

[0069] An inner diameter of the second disk opposing portion **122***d* is larger than an inner diameter of the first disk opposing portion **122***c*. Furthermore, the inner diameter of the second disk opposing portion **122***d* is larger than an outer diameter of the drive disk **22**. With this configuration, a gap is formed between the drive disk **22** and the main-body peripheral wall **122**. Specifically, the drive disk **22** does not contact the main-body peripheral wall **122** and is not positioned by the main-body peripheral wall **122**. The outer diameter of the drive disk **22** is substantially the same as the outer diameter Dd of the stationary disk **14**.

[0070] The inside of the housing **12** is partitioned into an inlet-side space **12***d* and an outlet-side space **12***e* by the stationary disk **14** while the inlet-side space **12***d* and the outlet-side space **12***e* are communicated with the first passage hole **141**. The inlet-side space **12***d* is a space communicated with the inlet **12***a* at the inside of the housing **12** and is also the receiving space which receives the valve element **20**. The outlet-side space **12***e* is a space communicated with the first outlet **12***b* and the second outlet **12***c* at the inside of the housing **12**.

[0071] Although not depicted in the drawing, the inside of the main body **120** is provided with a partition, which is shaped in a plate form and partitions between a first outlet-side space, which communicates the outlet-side space **12***e* to the first passage hole **141**, and a second outlet-side space, which communicates the outlet-side space **12***e* to the second passage hole **142**. This partition extends across the outlet-side space **12***e* in the radial direction DRr.

[0072] The seal installation portion **122***e* is formed by a planar portion which extends in the radial direction DRr and is formed by increasing an inner diameter of the end portion of the main-body peripheral wall **122**, which is adjacent to the opening **120***a*, in comparison to the other portion of the main-body peripheral wall **122**. The seal installation portion **122***e* is a portion at which the seal member **13** for sealing a gap between the main body **120** and the main-body cover **124** is installed.

[0073] Each of the main-body attachment portions **122***h* projects radially outward in the radial direction DRr from the end portion of the main-body peripheral wall **122** at which the opening **120***a* is formed. As shown in FIG. **6**, the number of the main-body attachment portions **122***h* is three, and these three main-body attachment portions **122***h* are arranged at predetermined intervals in the circumferential direction DRc.

[0074] Each of the three main-body attachment portions **122***h* has a main-body connecting portion **122***k* and a main-body fastening portion **122***m*. The main-body connecting portion **122***k* extends outward from the main-body peripheral wall **122** in the radial direction DRr. The main-body fastening portion **122***m* is joined to an end part of the main-body connecting portion **122***k* which is radially opposite to a part of the main-body connecting portion **122***k* that is joined to the main-body peripheral wall **122**. The main-body connecting portion **122***k* and the main-body fastening portion **122***m* are formed integrally in one-piece as an integral molded portion. As shown in FIGS. **4** to **6**, each of the three main-body attachment portions **122***h* has an identical basic structure. Therefore, only one of these three main-body attachment portions **122***h* will be described while description of the other two of the main-body attachment portions **122***h* is omitted. In FIG. **5**, various components received at the inside of the main body **120** are not depicted for the sake of simplicity.

[0075] The main-body connecting portion **122***k* joins between an outer periphery of the main-body peripheral wall **122** and the main-body fastening portion **122***m* and ensures a required distance between the outer periphery of the main-body peripheral wall **122** and the main-body fastening portion **122***m*. The main-body connecting portion **122***k* is shaped in a plate form, a thickness direction of which coincides with the axial direction DRa, and the main-body connecting portion **122***k* radially outwardly extends from the main-body peripheral wall **122** to a location which is on a radially outer side of the seal member **13** in the radial direction DRr. Furthermore, a radially inner end part of the main-body connecting portion **122***k* is joined to the outer periphery of the main-body peripheral wall **122**, and a radially outer end part of the main-body connecting portion **122***k* is joined to the main-body fastening portion **122***m*.

[0076] An axial size of the main-body connecting portion **122***k* measured in the axial direction DRa is larger than a radial size of the main-body connecting portion **122***k* measured in the radial direction DRr. Furthermore, a size of the main-body connecting portion **122***k*, which is measured in a perpendicular direction being perpendicular to the radial direction DRr and the axial direction DRa, is larger than the radial size of the main-body connecting portion **122***k* measured in the radial direction DRr.

[0077] The main-body connecting portion **122***k* has a rigidity reducing structure that includes a main-body rigidity reducing part **125** which reduces a rigidity of the main-body connecting portion **122***k*. The main-body rigidity reducing part **125** reduces the rigidity of the main-body connecting portion **122***k* in comparison to the main-body peripheral wall **122** and the main-body fastening portion **122***m*. The main-body rigidity reducing part **125** will be described later in detail.

[0078] The main-body fastening portion **122***m* is a portion to which a fastening member TN for fastening the main body **120** and the main-body cover **124** together is installed. The main-body fastening portion **122***m* is shaped in a tubular form and extends in the axial direction DRa, and the main-body fastening portion **122***m* is located on the radially outer side of the main-body connecting portion **122***k* in the radial direction DRr. An axial size of the main-body fastening portion **122***m*, which is measured in the axial direction DRa, is larger than the axial size of the main-body connecting portion **122***k*, which is measured in the axial direction DRa, and the main-body fastening portion **122***m* projects from the main-body connecting portion **122***k* toward the one side in the axial direction DRa.

[0079] Specifically, the one-side end of the main-body fastening portion **122***m*, which is located on the one side in the axial direction DRa, is placed at a location that is closer to the drive device **16** in comparison to one-side end of the main-body connecting portion **122***k*, which is located on the one side in the axial direction DRa. In contrast, a location of the other-side end of the main-body fastening portion **122***m*, which is located on the other side in the axial direction DRa, is the same as a location of the other-side end of the main-body connecting portion **122***k*, which is located on the other side in the axial direction DRa.

[0080] A main body insertion hole **122***n*, into which a fastening member TN for fastening the main-body cover **124** to the main body **120**, is formed at the main-body fastening portion **122***m* and extends in the axial direction DRa. When the fastening member TN is inserted into the main body insertion hole **122***n* and a cover insertion hole **124***t* described later, the main body **120** and the main-body cover **124** are fastened together. An inner diameter of the main body insertion hole **122***n* is slightly smaller than an outer diameter of a portion of the fastening member TN, which is inserted into the main body insertion hole **122***n*.

[0081] In the present embodiment, a tapping screw, which is made of a metal material, is used as the fastening member TN for fastening the main body **120** and the main-body cover **124** together. Therefore, the fastening member TN is threadably inserted into the main-body fastening portion **122***m* and is tightened at the time of fastening the main-body cover **124** to the main body **120**. The main-body fastening portion **122***m* has a fastening surface **122***p* which contacts the main-body cover **124** at the time of fastening the main body **120** and the main-body cover **124** together.

[0082] The fastening surface **122***p* is a planar surface part of the main-body fastening portion **122***m* located on the one side in the axial direction DRa. A location of the fastening surface **122***p* is displaced from an installation location of each of the seal member **13** and the main-body fastening portion **122***m* toward the one side in the axial direction DRa. In the valve device **10** of the present embodiment, the number of the fastening surfaces **122***p* which contact the main-body cover **124** at the time of fastening the main-body cover **124** to the main body **120**, is three.

[0083] The main-body cover **124** is a lid member that covers the opening **120***a* of the main body **120**. As shown in FIGS. **3**, **7** and **8**, the main-body cover **124** has a plate portion **124***a*, a rib portion **124***b*, a housing boss portion **124***c*, a cover peripheral wall **124***d* and a plurality of cover attachment portions **124***e*. The plate portion **124***a*, the rib portion **124***b*, the housing boss portion **124***c*, the cover peripheral wall **124***d* and the cover attachment portions **124***e* are formed integrally in one-piece as an integral molded portion.

[0084] The plate portion **124***a* is shaped in a circular ring form that extends in the radial direction DRr. In the main-body cover **124**, the plate portion **124***a* forms the inlet-side space **12***d* in corporation with the main-body peripheral wall **122** and the stationary disk **14**.

[0085] Furthermore, an outer diameter of the plate portion **124***a* is increased stepwise from the other side toward the one side in the axial direction DRa. Specifically, the plate portion **124***a* has: a seal support portion **124***f*, which is located on the other side in the axial direction DRa; and a lid portion **124***g*, which is connected to the seal support portion **124***f*. In the plate portion **124***a*, an outer diameter of the lid portion **124***g* is larger than an outer of the seal support portion **124***f*.

[0086] The seal support portion **124***f* is a portion for clamping the seal member **13** installed at the seal installation portion **122***e*. The outer diameter of the seal support portion **124***f* is slightly smaller than an inner diameter of the opening **120***a*. Therefore, a gap is formed between an inner periphery of the opening **120***a* and an outer periphery of the seal support portion **124***f*.

[0087] The seal support portion **124***f* clamps the seal member **13** between a surface of the seal support portion **124***f*, which is located on the other side in the axial direction DRa, and the seal installation portion **122***e* when the seal support portion **124***f* is inserted from the opening **120***a* into the inlet-side space **12***d*. Therefore, the gap between the inner periphery of the opening **120***a* and the outer periphery of the seal support portion **124***f* is sealed by the seal member **13**.

[0088] The lid portion **124***g* is a portion that closes the opening **120***a* at the time of fastening the main body **120** and the main-body cover **124** together. The lid portion **124***g* is located on the outer side of the seal support portion **124***f* in the radial direction DRr. The outer diameter of the lid portion **124***g* is larger than an inner diameter of the opening **120***a* of the main body **120**, so that the lid portion **124***g* cannot be inserted into the opening **120***a*. Furthermore, the outer diameter of the lid portion **124***g* is substantially the same as an outer diameter of the main-body peripheral wall **122**.

[0089] The seal member **13** is made of urethane rubber, which is an elastomer, and the seal member **13** is resiliently deformable in the axial direction DRa when the seal member **13** is clamped between the seal support portion **124***f* and the seal installation portion **122***e*. The seal member **13** is a member shaped in a ring form, a thickness direction of which coincides with the axial direction DRa. In the present embodiment, an O-ring is used as the seal member **13**.

[0090] An outer diameter of the seal member **13** is slightly smaller than an inner diameter of the opening **120***a*, and an inner diameter of the seal member **13** is slightly larger than an outer diameter of the rib portion **124***b*. In other words, the seal member **13** has: the outer diameter which is slightly smaller than the inner diameter of the opening **120***a* of the main body **120**; and the inner diameter which is slightly larger than the outer diameter of the rib portion **124***b*.

[0091] When the main body **120** and the main-body cover **124** are fastened together, the seal member **13** is clamped and is compressed in the axial direction DRa between the surface of the seal support portion **124***f* located on the other side in the axial direction DRa and the seal installation portion **122***e* and is resiliently deformed to a predetermined desirable shape.

[0092] The rib portion **124***b* is a portion of the main-body cover **124** which is inserted into the opening **120***a* of the main body **120**. The rib portion **124***b* is shaped in a tubular form and is located on the radially outer side of the plate portion **124***a*. The rib portion **124***b* projects from the plate portion **124***a* toward the bottom wall **121**.

[0093] The housing boss portion **124***c* is a portion through which the shaft **18** is inserted at the inside thereof. The housing boss portion **124***c* is shaped in a tubular form and is located on the radially inner side of the plate portion **124***a*. A shaft seal **124***h*, which is shaped in a circular ring form and seals a gap between the housing boss portion **124***c* and the shaft **18**, is installed at the inside of the housing boss portion **124***c*, and an O-ring **124***k*, which seals a gap between the housing boss portion **124***c* and the drive device **16**, is installed at the outside of the housing boss portion **124***c*. Furthermore, a bearing **124***m*, which rotatably supports the shaft **18**, is installed at the inside of the housing boss portion **124***c*. In the present embodiment, the housing boss portion **124***c* serves as a shaft support portion.

[0094] The drive device **16** is inserted at an inside of the cover peripheral wall **124***d*, and the cover peripheral wall **124***d* surrounds the central axis CL. The cover peripheral wall **124***d* is shaped in a tubular form and is located on the radially outer side of the housing boss portion **124***c*. The drive device **16** is inserted between an outer periphery of the housing boss portion **124***c* and an inner periphery of the cover peripheral wall **124***d*.

[0095] Each of the cover attachment portions **124***e* projects outward from an outer periphery of the cover peripheral wall **124***d* in the radial direction DRr. As shown in FIG. **7**, the number of the cover attachment portions **124***e* is three, and these three cover attachment portions **124***e* are located on the radially outer side of the cover peripheral wall **124***d* and are arranged at predetermined intervals in the circumferential direction DRc. Each of the cover attachment portions **124***e* is placed at a location that corresponds to a corresponding one of the main-body attachment portions **122***h*. Specifically, each of the cover attachment portions **124***e* is placed at the location at which the cover attachment portion **124***e* overlaps with the corresponding one of the main-body attachment portions **122***h* in the axial direction DRa.

[0096] Each of the cover attachment portions **124***e* has a cover connecting portion **124***n* and a cover fastening portion **124***p*. The cover connecting portion **124***n* extends outward from the cover peripheral wall **124***d* in the radial direction DRr. The cover fastening portion **124***p* is joined to an end part of the cover connecting portion **124***n* which is radially opposite to a part of the cover connecting portion **124***n* that is joined to the cover peripheral wall **124***d*. The cover connecting portion **124***n* and the cover fastening portion **124***p* are formed integrally in one-piece as an integral molded portion. Each of the three cover attachment portions **124***e* has an identical basic structure. Therefore, only one of these three cover attachment portions **124***e* will be described while description of the other two of the cover attachment portions **124***e* is omitted.

[0097] The cover connecting portion **124***n* is a portion that joins between the outer periphery of the cover peripheral wall **124***d* and the cover fastening portion **124***p*. The cover connecting portion **124***n* is shaped in a plate form, a thickness direction of which coincides with the axial direction DRa, and the cover connecting portion **124***n* extends outward from the cover peripheral wall **124***d* in the radial direction DRr to a location which is on the radially outer side of the seal member **13** in the radial direction DRr. Furthermore, the outer periphery of the cover peripheral wall **124***d* is joined to a radially inner end part of the cover connecting portion **124***n*, and the cover fastening portion **124***p* is joined to the radially outer end part of the cover connecting portion **124***n*.

[0098] A size of the cover connecting portion **124***n*, which is measured in the axial direction DRa, is reduced from the radially inner side toward the radially outer side in the radial direction DRr. Specifically, the cover connecting portion **124***n* has an inner connecting portion **124***r*, which is located on the inner side in the radial direction DRr, and an outer connecting portion **124***s* which is joined to the inner connecting portion **124***r*. In the cover connecting portion **124***n*, the size of the outer connecting portion **124***s*, which is measured in the axial direction DRa, is smaller than the size of the inner connecting portion **124***r*, which is measured in the axial direction DRa.

[0099] The inner connecting portion **124***r* is a portion of the cover connecting portion **124***n* which is located on the inner side of the outer periphery of the main-body peripheral wall **122** in the radial direction DRr. In contrast, the outer connecting portion **124***s* is a portion of the cover connecting portion **124***n*, which is located on the outer side of the outer periphery of the main-body peripheral wall **122** in the radial direction DRr. Specifically, the outer connecting portion **124***s* projects to a location which is on the radially outer side of the main-body peripheral wall **122** in the radial direction DRr. The outer connecting portion **124***s* is located on the radially outer side of the seal member **13** in the radial direction DRr.

[0100] The outer connecting portion **124***s* is opposed to the main-body connecting portion **122***k* in the axial direction DRa. The outer connecting portion **124***s* has a rigidity reducing structure that includes a cover rigidity reducing part **126** which reduces a rigidity of the cover connecting portion **124***n*. The cover rigidity reducing part **126** will be described later in detail.

[0101] The cover fastening portion **124***p* is a portion to which the fastening member TN for fastening the main body **120** and the main-body cover **124** together is installed. The cover fastening portion **124***p* is shaped in a circular disk form, a thickness direction of the which coincides with the axial direction DRa, and the cover fastening portion **124***p* is located on the radially outer side of the cover connecting portion **124***n* in the radial direction DRr. The size of the cover fastening portion **124***p* measured in the axial direction DRa is smaller than the size of the inner connecting portion **124***r* measured in the axial direction DRa and is substantially the same as the size of the outer connecting portion **124***s* measured in the axial direction DRa.

[0102] The cover fastening portion **124***p* has: the cover insertion hole **124***t*, into which the fastening member TN for fastening the main-body cover **124** to the main body **120** is inserted; and a contact surface **124***u*, which contacts the fastening surface **122***p* at the time of fastening the main-body cover **124** to the main body **120**. In the valve device **10** of the present embodiment, the number of contact surfaces **124***u* is three, and these three contact surfaces **124***u* are respectively placed at three locations which correspond to the three fastening surfaces **122***p*, respectively. The location of the contact surface **124***u* is displaced from the installation location of the seal member **13** toward the one side in the axial direction DRa.

[0103] The cover insertion hole **124***t* extends through the cover fastening portion **124***p* in the axial direction DRa from the one side to the other side of the cover fastening portion **124***p* in the axial direction DRa. The cover insertion hole **124***t* is placed at a location that corresponds to a location of the main body insertion hole **122***n*. In the present embodiment, the inner diameter of the cover insertion hole **124***t* is larger than the inner diameter of the main body insertion hole **122***n* and the outer diameter of the portion of the fastening member TN which is inserted into the main body insertion hole **122***n*. Therefore, at the time of fastening the main-body cover **124** to the main body **120**, the fastening member TN is not threaded into the main-body cover **124** and is just inserted through the cover insertion hole **124***t*.

[0104] When each of the fastening members TN is threadably inserted into the corresponding main body insertion hole **122***n* and is tightened to a position at which each of the fastening surfaces **122***p* contacts the corresponding contact surface **124***u*, the main body **120** and the main-body cover **124** are fastened together.

[0105] The stationary disk **14** is a circular disk member, a thickness direction of which coincides with the axial direction DRa. The stationary disk **14** has the opening surface **140** that is a front surface of the stationary disk **14** along which the drive disk **22** slides. The opening surface **140** is a contact surface that contacts a sliding surface **220** of the drive disk **22**.

[0106] Preferably, the stationary disk **14** is made of a material that has a smaller coefficient of linear expansion and superior wear resistance in comparison to the material of the housing **12**. The stationary disk **14** is made of a high-hardness material that has a hardness higher than that of the housing **12**. Specifically, the stationary disk **14** is made of ceramic. The stationary disk **14** is a powder molded product that is formed by molding ceramic powder into a desired shape with a press machine. Only a portion of the stationary disk **14**, which forms the opening surface **140**, may be made of the material, such as the ceramic, which has the smaller coefficient of linear expansion and the superior wear resistance in comparison to the material of the housing **12**.

[0107] Furthermore, as shown in FIG. **6**, the stationary disk **14** is a passage forming portion that forms the first passage hole **141** and the second passage hole **142** which conduct the fluid therethrough. Therefore, in the valve device **10** of the present embodiment, the stationary disk **14**, which is the passage forming portion, is formed as a separate member that is formed separately relative to the housing **12**.

[0108] Furthermore, the third passage hole **143**, which does not conduct the fluid, is formed at the stationary disk **14**. Furthermore, the stationary disk **14** has: a stationary outer periphery **144** which is opposed to the main-body peripheral wall **122**; and the rotation stop projection **145** which projects toward the main-body peripheral wall **122**.

[0109] Each of the passage holes **141**, **142**, **143** is formed at a corresponding location of the stationary disk **14** which is spaced from the central axis CL of the shaft **18**, so that each of the passage holes **141**, **142**, **143** does not overlap with the central axis CL of the shaft **18**. Each of the passage holes **141**, **142**, **143** is a through-hole that is shaped in a form of a sector. Each of the first passage hole **141** and the second passage hole **142** serve as a communication passage that communicates between the inlet-side space **12***d* and the outlet-side space **12***e*. In contrast, the other side of the third passage hole **143**, which is located on the other side in the axial direction DRa, is closed by the non-stepped portion **121***b*, so that the third passage hole **143** does not function as a communication passage that communicates between the inlet-side space **12***d* and the outlet-side space **12***e*. The shape of each of the passage holes **141**, **142**, **143** may be in another form, such as a form of circle, a form of ellipse instead of the form of sector.

[0110] Specifically, the first passage hole **141** is formed at a corresponding location of the stationary disk **14**, which corresponds to the first outlet-side space, to enable communication of the first passage hole **141** with the first outlet-side space. Specifically, the second passage hole **142** is formed at a corresponding location of the stationary disk **14**, which corresponds to the second outlet-side space, to enable communication of the second passage hole **142** with the second outlet-side space. The third passage hole **143** is placed at a location that corresponds to the non-stepped portion **121***b*, so that the third passage hole **143** is not communicated with the first outlet-side space and the second outlet-side space.

[0111] A stationary disk hole **146** is formed at generally a center part of the stationary disk **14**. The stationary disk hole **146** is a stationary-side through-hole, through which the shaft **18** is inserted. An inner diameter of the stationary disk hole **146** is larger than the diameter of the shaft **18**, so that the shaft **18** does not slide relative to the stationary disk hole **146**. Specifically, a size of the stationary disk hole **146** is set such that a predetermined gap is formed between an inner periphery of the stationary disk hole **146** and the outer periphery of the shaft **18** to enable tilting of the shaft **18** in a state where the shaft **18** is inserted through the stationary disk hole **146**.

[0112] The stationary outer periphery **144** forms an outer contour of the stationary disk **14**. A portion of the stationary outer periphery **144**, which forms the rotation stop projection **145**, is opposed to the receiving groove **122***f*.

[0113] The rotation stop projection **145** is a rotation limiting portion that is fitted into the receiving groove **122***f* to limit rotation of the stationary disk **14** in the circumferential direction DRc. The rotation stop projection **145** is formed at a location that corresponds to the receiving groove **122***f* in the radial direction DRr at the time of placing the stationary disk **14** at the inside of the main body **120**. The rotation stop projection **145** is formed such that the portion of the stationary outer periphery **144**, which forms the rotation stop projection **145**, projects further toward the radially outer side in the radial direction DRr in comparison to another portion of the stationary outer periphery **144**, which does not form the rotation stop projection **145**, and thereby the portion of the stationary outer periphery **144**, which forms the rotation stop projection **145**, projects away from the central axis CL.

[0114] The gasket **15**, which seals a gap between the stationary disk **14** and the mounting portion **122***a*, is placed between the stationary disk **14** and the mounting portion **122***a*. The gasket **15** is made of rubber. The gasket **15** is received in the receiving groove **122***b* formed at the mounting portion **122***a*. The gasket **15** has at least two projections at a seal surface opposed to the stationary disk **14** and at least two projections at another seal surface opposed to the mounting portion **122***a*. Specifically, the gasket **15** has two projections that project in the axial direction DRa. Such a gasket **15** can be obtained by a simple method, for example, by forming recesses at a flat seal surface.

[0115] The drive device **16** is a device for outputting the rotational force. Although not depicted in the drawings, the drive device **16** includes: an electric motor which serves as a drive power source; and a gear arrangement which serves as a drive force transmission member and transmits the output of the electric motor to the shaft **18**. For example, a servomotor or a brushless motor is used as the electric motor. The gear arrangement is formed by a gear mechanism that includes, for example, a helical gear or a spur gear. Although not depicted in the drawings, the electric motor is rotated according to a control signal outputted from a valve controller unit that is electrically connected to the electric motor. The valve controller unit is a computer that includes a memory (a non-transitory tangible storage medium) and a processor. The valve controller unit executes a computer program stored in the memory and also executes various control processes according to the computer program.

[0116] The shaft **18** is a rotatable column that is rotated about the predetermined central axis CL by the rotational force outputted from the drive device **16**. The shaft **18** extends in the axial direction DRa. Two axial sides of the shaft **18**, which are opposite to each other in the axial direction DRa, are rotatably supported by the housing **12**. Specifically, the shaft **18** has a both-ends supported structure. The shaft **18** extends through the stationary disk **14** and the drive disk **22** and is rotatably supported related to the housing **12**.

[0117] Specifically, at the inside of the main-body cover **124**, one side of the shaft **18**, which is located on the one side in the axial direction DRa, is rotatably supported by the bearing **124***m*, which is located on the radially inner side of the cover rigidity reducing parts **126** in the radial direction DRr. Furthermore, the other side of the shaft **18** in the axial direction DRa is supported by a bearing hole **121***c* formed at the bottom wall **121** of the main body **120**. The bearing hole **121***c* is formed by a plain bearing. The bearing hole **121***c* may be formed by a ball bearing or the like instead of the plain bearing.

[0118] The shaft **18** includes: a shaft core **181** made of metal; and a holder **182** made of resin and is coupled to the shaft core **181**. The shaft core **181** is coupled to the holder **182** such that the shaft core **181** is rotatable integrally with the holder **182**. The shaft core **181** and the holder **182** are formed as an insert molded product that is formed integrally by insert molding.

[0119] The shaft core **181** includes the central axis CL of the shaft **18** and extends in the axial direction DRa. The shaft core **181** is a portion that becomes a center of rotation of the valve element **20**. The shaft core **181** is formed by a rod member made of the metal to ensure a required degree of straightness of the shaft core **181**.

[0120] The holder **182** is coupled to the one side of the shaft core **181**, which is located on the one side in the axial direction DRa. The holder **182** is shaped in a bottomed tubular form. The shaft core **181** is coupled to an inside of a distal end part of the holder **182** which is located on the one side in the axial direction DRa. Furthermore, the distal end part of the holder **182**, which projects to the outside of the housing **12**, is coupled to the gear arrangement of the drive device **16**.

[0121] The valve element **20** is rotated by the output of the drive device **16** about the central axis CL of the shaft **18**. The valve element **20** increases or decreases an opening degree of each of the passage holes **141**, **142** of the stationary disk **14** in response to the rotation of the shaft **18**. As shown in FIG. **3**, the valve element **20** includes: the drive disk **22**, which serves as a rotor; and a lever **24**, which couples the drive disk **22** to the shaft **18**.

[0122] The drive disk **22** is the rotor which increases or decreases the opening degree of the first passage hole **141** and the opening degree of the second passage hole **142** in response to the rotation of the shaft **18**. The opening degree of the first passage hole **141** is a degree of opening of the first passage hole **141**. Here, the opening degree of the first passage hole **141** in a full-opening state thereof is indicated as 100%, and the opening degree of the first passage hole **141** in a full-closing state thereof is indicated as 0%. The full-opening state of the first passage hole **141** is a state where the first passage hole **141** is not closed by the drive disk **22** at all. The full-closing state of the first passage hole **141** is a state where a whole of the first passage hole **141** is closed by the drive disk **22**. The opening degree of the second passage hole **142** is the same as the opening degree of the first passage hole **141**.

[0123] The drive disk **22** is a circular disk member, a thickness direction of which coincides with the axial direction DRa. The drive disk **22** is placed in the inlet-side space **12***d* such that the drive disk **22** is opposed to the stationary disk **14** in the axial direction DRa. The drive disk **22** has the sliding surface **220** that is opposed to the opening surface **140** of the stationary disk **14**. The sliding surface **220** is a seal surface that seals the opening surface **140** of the stationary disk **14**.

[0124] Preferably, the drive disk **22** is made of a material that has a smaller coefficient of linear expansion and superior wear resistance in comparison to the material of the housing **12**. The drive disk **22** is made of a high-hardness material that has a hardness higher than that of the housing **12**. Specifically, the drive disk **22** is made of ceramic. The drive disk **22** is a powder molded product that is formed by molding ceramic powder into a desired shape with a press machine. Only a portion of the drive disk **22**, which forms the sliding surface **220**, may be made of the material, such as the ceramic, which has the smaller coefficient of linear expansion and the superior wear resistance in comparison to the material of the housing **12**.

[0125] Here, the ceramic is a material that has a small coefficient of linear expansion and shows little dimensional change upon absorption of water, and has excellent wear resistance. When the drive disk **22** is made of the ceramic, the positional relationship between the drive disk **22** and the shaft **18**, and the positional relationship between the drive disk **22** and the housing **12** are stabilized. As a result, a required accuracy of the flow rate control can be ensured, and unintended fluid leakage can be limited.

[0126] Furthermore, the drive disk **22** has a rotor hole **221** that is placed at a location which is eccentric to the central axis CL of the shaft **18**. The rotor hole **221** is a through-hole that extends through the drive disk **22** in the axial direction DRa, and the rotor hole **221** serves as a flow passage through which the fluid is conducted. The rotor hole **221** is formed at the location which overlaps with the first passage hole **141** and the second passage hole **142** in the axial direction DRa when the drive disk **22** is rotated about the central axis CL of the shaft **18**.

[0127] The drive disk **22** has a shaft insertion hole **223** at a substantially center of the drive disk **22**. The shaft insertion hole **223** is a drive-side insertion hole through which the shaft **18** is inserted. An inner diameter of the shaft insertion hole **223** is larger than a diameter of the shaft **18**, so that the shaft **18** does not slide relative to the shaft insertion hole **223**. Specifically, a predetermined gap is formed between an inner periphery of the shaft insertion hole **223** and the outer periphery of the shaft **18** to enable tilting of the shaft **18** in a state where the shaft **18** is inserted through the shaft insertion hole **223**.

[0128] In the valve device **10**, when the drive disk **22** is rotated to a position, at which the rotor hole **221** overlaps with the first passage hole **141** in the axial direction DRa, the first passage hole **141** is opened. Also, in the valve device **10**, when the drive disk **22** is rotated to a position, at which the rotor hole **221** overlaps with the second passage hole **142** in the axial direction DRa, the second passage hole **142** is opened.

[0129] The drive disk **22** is configured to adjust a flow rate ratio between the fluid, which passes through the first passage hole **141**, and the fluid, which passes through the second passage hole **142**. That is, the drive disk **22** is configured such that when the opening degree of the first passage hole **141** is increased, the opening degree of the second passage hole **142** is decreased.

[0130] The lever **24** is a coupling member that couples between the shaft **18** and the drive disk **22**. The lever **24** is fixed to the drive disk **22** and couples between the drive disk **22** and the shaft **18** such that the drive disk **22** and the shaft **18** are integrally rotatable in a state where the drive disk **22** is displaceable in the axial direction DRa.

[0131] The compression spring **26** is an urging member that urges the valve element **20** to the stationary disk **14**. The compression spring **26** is resiliently deformed in the axial direction DRa of the shaft **18**. The compression spring **26** is placed at the inside of the housing **12** in a state where the compression spring **26** is compressed in the axial direction DRa such that one end part of the compression spring **26**, which is located on the one side in the axial direction DRa, contacts the shaft **18**, and the other end part of the compression spring **26**, which is located on the other side in the axial direction DRa, contacts the valve element **20**. Specifically, the compression spring **26** is placed such that the one end part of the compression spring **26**, which is located on the one side in the axial direction DRa, contacts an inside of the holder **182**, and the other end part of the compression spring **26**, which is located on the other side in the axial direction DRa, contacts the lever **24**. The compression spring **26** is not fixed to at least one of the valve element **20** and the shaft **18**, so that compression spring **26** does not function as a torsion spring.

[0132] The valve element **20** is urged against the stationary disk **14** by the compression spring **26**, so that a contact state, in which the opening surface **140** of the stationary disk **14** and the sliding surface **220** of the drive disk **22** contact with each other, is maintained. This contact state is a state where the opening surface **140** of the stationary disk **14** and the sliding surface **220** of the drive disk **22** make surface-to-surface contact with each other. That is, the valve device **10** can maintain the orientation of the drive disk **22** such that the drive disk **22** is kept in contact with the stationary disk **14**.

[0133] Specifically, the compression spring **26** is arranged to surround the central axis CL of the shaft **18**. In other words, the shaft **18** is placed at an inside of the compression spring **26**. With this configuration, it is possible to limit uneven distribution of the load of the compression spring **26** against the drive disk **22** in the circumferential direction DRc of the shaft **18**, and thereby the contact state of the sliding surface **220** relative to the opening surface **140** can be easily maintained.

[0134] The first torsion spring **28** is a spring that urges the shaft **18** against the housing **12** in the circumferential direction DRc around the central axis CL of the shaft **18**. The first torsion spring **28** is placed between the housing **12** and the shaft **18**.

[0135] Basically, the first torsion spring **28** is used in a state where the first torsion spring **28** is twisted in the circumferential direction DRc and is thereby resiliently deformed. An urging force of the first torsion spring **28** is applied to the shaft **18** in both a rotating state, in which the shaft **18** is rotated, and a stop state, in which the shaft **18** is not rotated. The urging force of the first torsion spring **28** is transmitted as a rotational force from the gear arrangement of the drive device **16** to the electric motor through the shaft **18**. Therefore, by placing the first torsion spring **28** between the housing **12** and the shaft **18**, rattling in the circumferential direction DRc between the drive device **16** and the shaft **18** is limited. The first torsion spring **28** is merely twisted in the circumferential direction DRc and is not compressed in the axial direction DRa.

[0136] The second torsion spring **30** is a spring that urges the lever **24** against the shaft **18** in the circumferential direction DRc. The second torsion spring **30** is placed between the shaft **18** and the lever **24**. An axial dimension of the second torsion spring **30** measured in the axial direction DRa is smaller than that of the first torsion spring **28**, and a radial dimension of the second torsion spring **30** measured in the radial direction DRr is smaller than that of the first torsion spring **28**.

[0137] Basically, the second torsion spring **30** is used in a state where the second torsion spring **30** is twisted in the circumferential direction DRc and is thereby resiliently deformed. An urging force of the second torsion spring **30** is applied to the lever **24** in both a rotating state, in which the shaft **18** is rotated, and a stop state, in which the shaft **18** is not rotated. The urging force of the second torsion spring **30** is transmitted to the drive disk **22** as a rotational force through the lever **24**. Therefore, by placing the second torsion spring **30** between the shaft **18** and the lever **24**, rattling in the circumferential direction DRc between the shaft **18** and the lever **24** is limited. Furthermore, since the lever **24** is fixed to the drive disk **22**, rattling in the circumferential direction between the shaft **18** and the drive disk **22** is limited by the second torsion spring **30**. The second torsion spring **30** is merely twisted in the circumferential direction DRc and is not compressed in the axial direction DRa.

[0138] In the valve device **10**, the shaft **18**, the lever **24** and the shaft **18** are assembled as a sub-assembly by engaging the shaft **18** to the lever **24** in a state where the second torsion spring **30** is interposed between the shaft **18** and the lever **24**.

[0139] Next, details of each main-body rigidity reducing part **125** and each cover rigidity reducing part **126** will be described. The main-body rigidity reducing part **125** of the present embodiment is formed by one space (single space) that is formed at the main-body connecting portion **122***k*. Specifically, the one main-body rigidity reducing part **125** is formed at the main-body connecting portion **122***k*, so that the space is formed at the inside of the main-body connecting portion **122***k*.

[0140] The space, which is formed by the main-body rigidity reducing part **125**, is a space that is filled with the air. In this way, the rigidity of the main-body connecting portion **122***k* is reduced in comparison to a case where the main-body rigidity reducing part **125** is absent at the main-body connecting portion **122***k*.

[0141] Furthermore, the cover rigidity reducing part **126** of the present embodiment is formed by one space (single space) that is formed at the cover connecting portion **124***n*. Specifically, the one cover rigidity reducing part **126** is formed at the cover connecting portion **124***n*, so that the space is formed at the inside of the cover connecting portion **124***n*.

[0142] The space, which is formed by the cover rigidity reducing part **126**, is a space that is filled with the air. Therefore, the rigidity of the cover connecting portion **124***n* is reduced in comparison to a case where the cover rigidity reducing part **126** is absent at the cover connecting portion **124***n*.

[0143] The main-body rigidity reducing part **125** extends from one end of the main-body connecting portion **122***k*, which is located on the one side in the axial direction DRa, toward the other end of the main-body connecting portion **122***k*, which is located on the other side in the axial direction DRa, without penetrating through the other end part of the main-body connecting portion **122***k*. Specifically, the main-body rigidity reducing part **125** is shaped in a bottomed tubular form (bottomed form) and has an opening on the one side in the axial direction DRa and a closed bottom on the other side in the axial direction DRa.

[0144] A cross-section of the main-body connecting portion **122***k*, which is perpendicular to the axial direction DRa, is set such that a cross-sectional area of a portion of the main-body connecting portion **122***k*, at which the main-body rigidity reducing part **125** is formed, is larger than a cross-sectional area of another portion of the main-body connecting portion **122***k*, at which the main-body rigidity reducing part **125** is absent. Specifically, the cross-section of the main-body connecting portion **122***k*, which is perpendicular to the axial direction DRa, is set such that an opening cross-sectional area of the main-body rigidity reducing part **125** is larger than the cross-sectional area of the other portion, at which the main-body rigidity reducing part **125** is absent. The main-body rigidity reducing part **125** is formed such that the opening cross-sectional area of the main-body rigidity reducing part **125** is constant along the main-body rigidity reducing part **125** from the one side to the other side in the axial direction DRa.

[0145] It is desirable that in the main-body connecting portion **122***k*, a depth of the main-body rigidity reducing part **125** is larger than a bottom thickness of a connecting bottom portion **122***r*, which is a portion located on the other side of the main-body rigidity reducing part **125** in the axial direction DRa. Specifically, it is desirable that a size of the main-body rigidity reducing part **125** measured in the axial direction DRa is at least twice larger than a size of the connecting bottom portion **122***r* measured in the axial direction DRa. In the present embodiment, the main-body rigidity reducing part **125** is formed such that a ratio of the size of the main-body rigidity reducing part **125** measured in the axial direction DRa relative to the size of the connecting bottom portion **122***r* measured in the axial direction DRa is at least four times.

[0146] The cover rigidity reducing part **126** extends through the cover connecting portion **124***n* from one end of the cover connecting portion **124***n*, which is located on the one side in the axial direction DRa, to the other end of the cover connecting portion **124***n*, which is located on the other side in the axial direction DRa. Specifically, the cover rigidity reducing part **126** extends through the outer connecting portion **124***s* from one end of the outer connecting portion **124***s*, which is located on the one side in the axial direction DRa, to the other end of the outer connecting portion **124***s*, which is located on the other side in the axial direction DRa. That is, the cover rigidity reducing part **126** is a through-hole that extends through the outer connecting portion **124***s*.

[0147] The cover rigidity reducing part **126** is formed at a location, at which the cover rigidity reducing part **126** overlaps with the main-body rigidity reducing part **125** in the axial direction DRa. Furthermore, the size of the cover rigidity reducing part **126** is set such that the cover rigidity reducing part **126** overlaps with the main-body rigidity reducing part **125** in the axial direction DRa.

[0148] Furthermore, a cross-section of the outer connecting portion **124***s*, which is perpendicular to the axial direction DRa, is set such that a cross-sectional area of a portion of the outer connecting portion **124***s*, at which the cover rigidity reducing part **126** is formed, is larger than a cross-sectional area of another portion of the outer connecting portion **124***s*, at which the cover rigidity reducing part **126** is absent. Specifically, the cross-section of the outer connecting portion **124***s*, which is perpendicular to the axial direction DRa, is set such that an opening cross-sectional area of the cover rigidity reducing part **126** is larger than the cross-sectional area of the other portion, at which the cover rigidity reducing part **126** is absent. The cover rigidity reducing part **126** is formed such that the opening cross-sectional area of the cover rigidity reducing part **126** is constant along the cover rigidity reducing part **126** from the one side to the other side in the axial direction DRa.

[0149] Next, an operation of the valve device **10** of the present embodiment will be described. As shown in FIGS. **1** to **4**, in the valve device **10**, the fluid flows from the inlet **12***a* into the inlet-side space **12***d*, as indicated by an arrow Fi. Then, in a case where the first passage hole **141** is opened, the fluid flows from the inlet-side space **12***d* to the first outlet-side space through the first passage hole **141**. The fluid, which flows into the first outlet-side space, flows from the first outlet-side space to the outside of the valve device **10** through the first outlet **12***b*, as indicated by an arrow Flo. In this case, the flow rate of the fluid, which passes through the first passage hole **141**, is determined according to the opening degree of the first passage hole **141**. That is, the flow rate of the fluid, which flows from the inlet **12***a* to the first outlet **12***b* through the first passage hole **141**, is increased when the opening degree of the first passage hole **141** is increased.

[0150] In contrast, in another case where the second passage hole **142** is opened, the fluid flows from the inlet-side space **12***d* to the second outlet-side space through the second passage hole **142**. The fluid, which flows into the second outlet-side space, flows from the second outlet-side space to the outside of the valve device **10** through the second outlet **12***c*, as indicated by an arrow F2o. In this case, the flow rate of the fluid, which passes through the second passage hole **142**, is determined according to the opening degree of the second passage hole **142**. That is, the flow rate of the fluid, which flows from the inlet **12***a* to the second outlet **12***c* through the second passage hole **142**, is increased when the opening degree of the second passage hole **142** is increased.

[0151] Next, fastening between the main body **120** and the main-body cover **124** will be described. As described above, the main body **120** and the main-body cover **124** are made of the resin material. In contrast, the tapping screws made of the metal material are respectively used as the fastening members TN, which fasten the main-body cover **124** to the main body **120**. When each of the fastening members TN is threadably inserted into the corresponding main body insertion hole **122***n* and is tightened to a position at which each of the fastening surfaces **122***p* contacts the corresponding contact surface **124***u*, the main body **120** and the main-body cover **124** are fastened together.

[0152] Now, there will be described influences on the fastening between the main body **120** and the main-body cover **124** in a case where a degree of flatness of one or more of the three fastening surfaces **122***p* and the three contact surfaces **124***u* is lower than a designed degree of flatness (designed accuracy) and a case where surface heights of the three fastening surfaces **122***p* and surface heights of the three contact surfaces **124***u* vary from each other.

[0153] In a case where the degree of flatness of the fastening surface **122***p* and/or the contact surface **124***u* is lower than the designed degree of flatness (designed accuracy), the main body **120** and the main-body cover **124** may possibly be assembled together such that at least one of the main body **120** and the main-body cover **124** is tilted relative to the axial direction DRa at the time of fastening the fastening member TN until the fastening surface **122***p* and the contact surface **124***u* contact each other. Furthermore, in the case where the surface heights of the three fastening surfaces **122***p* and the surface heights of the three contact surfaces **124***u* vary from each other, the main body **120** and the main-body cover **124** may possibly be assembled in a state where at least one of the main body **120** and the main-body cover **124** is tilted such that a portion of one of the fastening surface **122***p* and the contact surface **124***u* opposed to each other is positioned on the lower side of a portion of the other one of the fastening surface **122***p* and the contact surface **124***u*.

[0154] When the fastening members TN are tightened in the state where at least one of the main body **120** and the main-body cover **124** is tilted relative to the axial direction DRa, an excessive load is applied to the fastening surface **122***p* and the contact surface **124***u*. Thereby, at least one of the main body **120** and the main-body cover **124** may possibly be deformed along the tilting direction of the at least one of the main body **120** and the main-body cover **124**. In the present embodiment, the main body **120** and the main-body cover **124**, which are made of the resin material, are fastened by the fastening members TN, which are made of the metal material. Therefore, the main body **120** and the main-body cover **124** are more likely to be deformed than the fastening members TN.

[0155] When a distance between the seal installation portion **122***e* and the seal support portion **124***f*, which resiliently deform the seal member **13** in the axial direction DRa, is increased in response to deformation of at least one of the main body **120** and the main-body cover **124** in comparison to the distance between the seal installation portion **122***e* and the seal support portion **124***f* before the time of deformation, the amount of resilient deformation of the seal member **13** is reduced. In this case, when the seal member **13** cannot be resiliently deformed to the shape for sealing between the main body **120** and the main-body cover **124**, the gap between the main body **120** and the main-body cover **124** may not be sealed. Therefore, the inlet-side space **12***d* cannot be closed relative to the outside of the valve device **10**, and thereby it is difficult ensure the required degree of sealing of the inlet-side space **12***d*.

[0156] Furthermore, when the main body **120** and the main-body cover **124** are fastened by fastening the screws in the state where at least one of the main body **120** and the main-body cover **124** is tilted relative to the axial direction DRa, a crack may possibly be generated at least one of the main body **120** and the main-body cover **124**, which are made of the resin. When the crack is generated to extend from the outside to the inside of the main-body peripheral wall **122**, it is difficult to ensure the required degree of sealing of the inlet-side space **12***d*.

[0157] The valve device **10** needs to accurately adjust the flow rate of the fluid, so that the required degree of sealing of the inlet-side space **12***d* needs to be ensured. However, it is difficult to ensure the required degree of sealing of the inlet-side space **12***d* in the case where the degree of flatness of one or more of the three fastening surfaces **122***p* and the three contact surfaces **124***u* is lower than the designed degree of flatness (designed accuracy) or the case where surface heights of the three fastening surfaces **122***p* and surface heights of the three contact surfaces **124***u* vary from each other.

[0158] The main body **120** and the main-body cover **124** are injection molded by filling the resin material into the mold and solidifying the resin material into the desired shape, so that it is difficult for the main body **120** and the main-body cover **124** to achieve a high degree of flatness or uniform surface heights in comparison with the case of processing the metal material.

[0159] In contrast, in the present embodiment, in the valve device **10**, the main-body rigidity reducing part **125** is formed at each of the main-body connecting portions **122***k*. Furthermore, the cover rigidity reducing part **126** is formed at each of the cover connecting portions **124***n*. Therefore, the main-body connecting portion **122***k* tends to be deformed when the excessive load is applied to the fastening surface **122***p* at the time of fastening the main body **120** and the main-body cover **124** together in the case where the degree of flatness of one or more of the three fastening surfaces **122***p* and the three contact surfaces **124***u* is lower than the designed degree of flatness (designed accuracy) or the case where surface heights of the fastening surfaces **122***p* and surface heights of the contact surfaces **124***u* vary from each other. Likewise, when the excessive load is applied to the contact surface **124***u*, the cover connecting portion **124***n* tends to be deformed.

[0160] In contrast, at the main body **120**, the main-body peripheral wall **122**, which is located on the radially inner side of the main-body connecting portion **122***k*, is less likely to be deformed. Furthermore, at the main-body cover **124**, the plate portion **124**a and the rib portion **124**b, which are located on the radially inner side of the cover connecting portions **124**n in the radial direction DRr, is less likely to be deformed. Therefore, it is possible to limit an increase in the distance between the seal installation portion **122**e and the seal support portion **124**f caused by the deformation of at least one of the main body **120** and the main-body cover **124**. Therefore, it is possible to limit the decrease in the amount of resilient deformation of the seal member **13** caused by the deformation of at least one of the main body **120** and the main-body cover **124**, and thereby it is possible to ensure the required degree of sealing of the inlet-side space **12**d.

[0161] Furthermore, the valve device **10** of the present embodiment can achieve the following advantages.

[0162] (1) The rigidity reducing structures are implemented by providing the main-body rigidity reducing part **125** and the cover rigidity reducing part **126**, each of which is the space, to the main-body connecting portion **122**k and the cover connecting portion **124**n, respectively. In this way, the rigidity reducing structures can be more easily implemented in comparison to a case where each of the main-body rigidity reducing parts **125** is formed by a member, which has a lower rigidity in comparison to the main-body peripheral wall **122**, or a case where each of the cover rigidity reducing parts **126** is formed by a member, which has a lower rigidity in comparison to the cover peripheral wall **124**d.

[0163] (2) The location of each of the fastening surfaces **122**p is displaced from the installation location of the seal member **13** toward the one side in the axial direction DRa. According to this, the distance between the seal member **13** and the fastening surface **122**p in the axial direction DRa can be increased in comparison to a case where the fastening surface **122**p is placed at the same location as the installation location of the seal member **13**. Therefore, even when at least one of the main body **120** and the main-body cover **124** is deformed in response to application of the excessive load to the fastening surface **122**p and the contact surface **124**u, the seal member **13** is less likely to be deformed.

[0164] (3) The location of the fastening surface **122**p is displaced from the installation location of the main-body connecting portion **122**k toward the one side in the axial direction DRa. According to this, the distance between the main-body connecting portion **122**k and the fastening surface **122**p in the axial direction DRa can be increased in comparison to a case where the fastening surface **122**p is placed at the same location as the installation location of the main-body connecting portion **122**k.

[0165] Thus, at the time of applying the excessive load to the fastening surface **122**p, the main-body connecting portion **122**k is more easily deformed in comparison to the case where the above-described configuration is absent. Therefore, the excessive load can be allowed by the main-body connecting portion **122**k. Therefore, even in the case where the excessive load is applied to the fastening surface **122**p, the portion of the main body **120**, which is located on the radially inner side of the main-body connecting portion **122**k in the radial direction DRr, is less likely to be deformed.

[0166] (4) The valve device **10** includes the shaft **18** that is rotated integrally with the valve element **20**. Furthermore, the main-body cover **124** has the housing boss portion **124**c. The housing boss portion **124**c rotatably supports the one axial side of the shaft **18** located on the one side in the axial direction DRa in the state where the shaft **18** is inserted through the housing boss portion **124**c. The housing boss portion **124**c is located on the radially inner side of the cover rigidity reducing part **126** in the radial direction DRr. Furthermore, the main-body cover **124** has the shaft seal **124**h which seals the gap between the outer periphery of the shaft **18** and the inner periphery of the housing boss portion **124**c.

[0167] In a case where the main-body cover **124** is fastened in the state where the main-body cover **124** is tilted relative to the axial direction DRa, the shaft **18**, which is supported by the main-body cover **124**, may possibly be tilted relative to the shaft seal **124**h. In this case, uneven wearing of the shaft seal **124**h caused by the rotation of the shaft **18** may possibly occur. However, according to the present embodiment, in the valve device **10**, the main-body rigidity reducing part **125** is formed at each of the main-body connecting portions **122**k, and the cover rigidity reducing part **126** is formed at each of the cover connecting portions **124**n. Therefore, In the case where the main-body cover **124** is fastened in the state where the main-body cover **124** is tilted relative to the axial direction DRa, the tilting of the shaft **18** relative to the shaft seal **124**h is limited. Thus, uneven wearing of the shaft seal **124**h caused by the rotation of the shaft **18** is limited.

[0168] (5) The predetermined gap is formed between the inner periphery of the shaft insertion hole **223** and the outer periphery of the shaft **18** to enable tilting of the shaft **18** in the state where the shaft **18** is inserted through the shaft insertion hole **223**.

[0169] In a case where the main-body cover **124** is fastened in the state where the main-body cover **124** is tilted relative to the axial direction DRa, the shaft **18**, which is supported by the main-body cover **124**, may possibly be tilted relative to the axial direction DRa. Furthermore, in order to avoid interference between the inner periphery of the shaft insertion hole **223** and the outer periphery of the shaft **18**, it is necessary to increase the predetermined gap between the inner periphery of the shaft insertion hole **223** and the outer periphery of the shaft **18** when the amount of tilt of the shaft **18** is increased.

[0170] However, according to the present embodiment, in the valve device **10**, the main-body rigidity reducing part **125** is formed at each of the main-body connecting portions **122**k, and the cover rigidity reducing part **126** is formed at each of the cover connecting portions **124**n. Therefore, in the case where the main-body cover **124** is fastened in the state where the main-body cover **124** is tilted relative to the axial direction DRa, the tilting of the shaft **18** relative to the shaft seal **124**h is limited.

[0171] Therefore, it is no longer required to unnecessarily increase the predetermined gap between the inner periphery of the shaft insertion hole **223** and the outer periphery of the shaft **18** to avoid the interference between the shaft insertion hole **223** and the shaft **18**.

[0172] Thus, in comparison to the case where the gap between the shaft **18** and the shaft insertion hole **223** is unnecessarily increased, it is possible to limit a positional deviation between the rotor hole **221** of the drive disk **22** and the first passage hole **141** and the second passage hole **142** of the stationary disk **14**. In this way, the flow rate of the fluid, which flows in the first passage hole **141**, and the flow rate of the fluid, which flows in the second passage hole **142**, can be accurately adjusted.

[0173] (6) In the present embodiment, the tapping screw, which is made of the metal material, is used as the fastening member TN for fastening the main body **120** and the main-body cover **124** together. In the case where the main body **120** and the main-body cover **124** are fastened together by threadably inserting the tapping screw into the main-body fastening portion **122***m*, the crack may possibly be generated at the main-body fastening portion **122***m*.

[0174] Here, it is assumed that a crack K is generated from the main-body fastening portion **122***m* to the main-body peripheral wall **122** through the main-body connecting portion **122***k* in a case where the main-body rigidity reducing part **125**, which is formed by the space, is not present at the main-body connecting portion **122***k*, as shown in FIG. **9**. When the crack K is generated and extends from the outside to the inside of the main-body peripheral wall **122**, it is difficult to ensure the required degree of sealing of the inlet-side space **12***d*.

[0175] In contrast, in the valve device **10** of the present embodiment, the main-body rigidity reducing part **125**, which is formed by the space, is provided at each of the main-body connecting portions **122***k*. Therefore, even when the crack K is generated from the main-body fastening portion **122***m* toward the main-body peripheral wall **122** through the main-body connecting portion **122***k* in response to the threadably inserting of the tapping screw, the crack K is less likely to be generated beyond the main-body rigidity reducing part **125** toward the inner side in the radial direction DRr, as shown in FIG. **10**. Thus, even when the crack is generated at the main-body fastening portion **122***m* by the threadably inserting of the tapping screw, it is possible to limit the leakage of the fluid to the outside of the valve device **10** through the crack.

[0176] (7) The main body **120** and the main-body cover **124** are made of the resin. Furthermore, the main-body rigidity reducing part **125** is shaped in the bottomed tubular form and has the opening on the one side in the axial direction DRa and the closed bottom on the other side in the axial direction DRa. With this configuration, at the time of manufacturing the main body **120** by the rein molding, the mold can be easily removed from the main body **120**. Therefore, generation of burrs at the time of the resin molding can be limited.

OTHER EMBODIMENTS

[0177] Although the representative embodiment of the present disclosure has been described above, the present disclosure is not limited to the above-described embodiment and can be variously modified, for example, as follows.

[0178] In the embodiment described above, there is described the example where both of the main body **120** and the main-body cover **124** are made of the resin. However, the present disclosure is not limited to this. For example, the main body **120** and the main-body cover **124** may be formed by different types of members such that the rigidity of one of the main body **120** and the main-body cover **124** is smaller than the rigidity of the other one of the main body **120** and the main-body cover **124**. Specifically, for example, as shown in FIG. **11**, the main body **120** may be made of metal, and the main-body cover **124** may be made of resin that has the rigidity lower than that of the metal.

[0179] In this way, even when the excessive load is applied to the fastening surface **122***p* and the contact surface **124***u* at the time of fastening the main body **120** and the main-body cover **124** together, the main body **120** is less likely to be deformed in comparison to the main-body cover **124** which has the lower rigidity. Therefore, in comparison to the case where the main body **120** and the main-body cover **124** are respectively formed by the members which have the same rigidity, it is possible to limit deformation of the other one, which has the higher rigidity, in response to deformation of the one, which has the lower rigidity. Thus, the required degree of sealing of the receiving space can be more easily ensured.

[0180] In the embodiment described above, there is described the example where main-body rigidity reducing part **125** is formed as the rigidity reducing structure at each of the main-body connecting portions **122***k*, and the cover rigidity reducing part **126** is formed as the rigidity reducing structure at each of the cover connecting portions **124***n*. However, the present disclosure is not limited to this. For example, the rigidity reducing structure may be configured such that the main-body rigidity reducing part **125** is formed only at each of the main-body connecting portions **122***k*, and the cover rigidity reducing part **126** is not formed at each of the cover connecting portions **124***n*. Furthermore, the rigidity reducing structure may be configured such that the main-body rigidity reducing part **125** is not formed at each of the main-body connecting portions **122***k*, and the cover rigidity reducing part **126** is formed only at each of the cover connecting portions **124***n*.

[0181] In the embodiment described above, there is described the example where the space is formed at each of the main-body rigidity reducing parts **125** and the cover rigidity reducing parts **126** while the inside of the space is empty. For example, the main-body rigidity reducing part **125** may be configured such that the inside of the space, which is formed by the main-body rigidity reducing part **125**, is filed with a member which has a rigidity that is lower than the rigidity of the main-body connecting portion **122***k*. Furthermore, the cover rigidity reducing part **126** may be configured such that the inside of the space, which is formed by the cover rigidity reducing part **126**, is filed with a member which has a rigidity that is lower than the rigidity of the cover connecting portion **124***n*.

[0182] In the embodiment described above, there is described the example where the main-body rigidity reducing part **125** is the one bottomed tubular hole (single bottomed tubular hole) formed at the main-body connecting portion **122***k*. However, the present disclosure is not limited to this. Furthermore, there is described the example where the cover rigidity reducing part **126** is the one through-hole (single bottomed tubular hole) formed at the cover connecting portion **124***n*. However, the present disclosure is not limited to this.

[0183] The main-body rigidity reducing part **125** may be appropriately changed as long as the main-body rigidity reducing part **125** reduces the rigidity of the main-body connecting portion **122***k*. The cover rigidity reducing part **126** may be appropriately changed as long as the cover rigidity reducing part **126** reduces the rigidity of the cover connecting portion **124***n*.

[0184] For example, each of the main-body rigidity reducing part **125** and the cover rigidity reducing part **126** may be formed by a plurality of through-holes. Each of the main-body rigidity reducing part **125** and the cover rigidity reducing part **126** may be formed by a space where the opening cross-sectional area is not constant along the space from the one side to the other side in the axial direction DRa. Furthermore, the cover rigidity reducing part **126** may be shaped in a bottomed tubular form ((bottomed form) and has an opening on the one side in the axial direction DRa and a closed bottom on the other side in the axial direction DRa.

[0185] Needless to say, in the above-described embodiments, the elements of each embodiment are not necessarily essential except when it is clearly indicated that they are essential and when they are clearly considered to be essential in principle.

[0186] In each of the above embodiments, when a numerical value such as the number, numerical value, amount, range or the like of the constituent elements of the embodiment is mentioned, the present disclosure should not be limited to such a numerical value unless it is clearly stated that it is essential and/or it is required in principle.

[0187] In each of the above embodiments, when the shape, positional relationship or the like of the constituent elements of the embodiment is mentioned, the present disclosure should not be limited such a shape or positional relationship unless it is clearly stated that it is essential and/or it is required in principle.

What is claimed is:

1. A valve device comprising:

a drive device that is configured to output a rotational force;

a valve element that has a flow passage which is configured to conduct a fluid through the flow passage, wherein the valve element is configured to adjust a flow rate of the fluid flowing in the flow passage when the valve element is rotated about a predetermined central axis by the rotational force outputted from the drive device;

a housing main body that has:

a main-body peripheral wall which surrounds the predetermined central axis and forms a receiving space, wherein the receiving space receives the valve element; and

an opening which is formed at the housing main body on one side in an axial direction of the predetermined central axis;

a main-body cover that has a cover peripheral wall which surrounds the predetermined central axis, wherein the main-body cover is fastened to the housing main body and thereby closes the receiving space; and

a seal member that is resiliently deformed between the housing main body and the main-body cover to seal a gap between the housing main body and the main-body cover, wherein:

the housing main body has:

a main-body connecting portion that radially outwardly extends from the main-body peripheral wall to a location which is on a radially outer side of the seal member in a radial direction of the predetermined central axis; and

a main-body fastening portion that is joined to a radially outer end part of the main-body connecting portion and has a fastening surface which contacts the main-body cover;

the main-body cover has:

a cover connecting portion that radially outwardly extends from the cover peripheral wall to a location which is on the radially outer side of the seal member in the radial direction of the predetermined central axis; and

a cover fastening portion that is joined to a radially outer end part of the cover connecting portion and has a contact surface which contacts the fastening surface;

at least one of the housing main body and the main-body cover has a corresponding one of:

a rigidity reducing structure that includes a main-body rigidity reducing part that reduces a rigidity of the main-body connecting portion in comparison to a case where the main-body rigidity reducing part is absent at the main-body connecting portion; and

a rigidity reducing structure that includes a cover rigidity reducing part that reduces a rigidity of the cover connecting portion in comparison to a case where the cover rigidity reducing part is absent at the cover connecting portion;

at least one of the rigidity reducing structures is a structure that has a space which reduces the rigidity of a corresponding one of the main-body connecting portion and the cover connecting portion; and

a location of the fastening surface is displaced from an installation location of the seal member in the axial direction of the predetermined central axis.

2. The valve device according to claim **1**, comprising a shaft that is configured to be rotated integrally with the valve element about the predetermined central axis, wherein:

the main-body cover has:

a shaft support portion that is located on a radially inner side of the cover rigidity reducing part in the radial direction of the predetermined central axis and rotatably supports one axial side of the shaft located on the one side in the axial direction in a state where the shaft is inserted through the shaft support portion; and

a shaft seal that seals a gap between an outer periphery of the shaft and an inner periphery of the shaft support portion.

3. The valve device according to claim **2**, comprising a stationary disk that has at least one passage hole which is configured to conduct the fluid through the at least one passage hole, wherein:

the valve element includes a rotor that has:

the flow passage which is placed at a location that overlaps with the at least one passage hole in the axial direction of the predetermined central axis; and

a shaft insertion hole through which the shaft is inserted, wherein the rotor is configured to adjust a flow rate of the fluid, which flows in the at least one passage hole, when the rotor is rotated about the predetermined central axis in response to rotation of the shaft to change an overlapping range between the at least one passage hole and the flow passage; and

a predetermined gap is formed between an inner periphery of the shaft insertion hole and the outer periphery of the shaft.

4. The valve device according to claim **1**, wherein the housing main body and the main-body cover are fastened together by a tapping screw that is inserted into the main-body fastening portion and the cover fastening portion.

5. The valve device according to claim **1**, wherein:
the housing main body and the main-body cover are made of resin; and
at least one of the main-body rigidity reducing part and the cover rigidity reducing part is in a bottomed form and has an opening on one side and a closed bottom on an opposite side that is opposite to the one side.

6. A valve device comprising:
a drive device that is configured to output a rotational force;
a valve element that has a flow passage which is configured to conduct a fluid through the flow passage, wherein the valve element is configured to adjust a flow rate of the fluid flowing in the flow passage when the valve element is rotated about a predetermined central axis by the rotational force outputted from the drive device;
a housing main body that has:
a main-body peripheral wall which surrounds the predetermined central axis and forms a receiving space, wherein the receiving space receives the valve element; and
an opening which is formed at the housing main body on one side in an axial direction of the predetermined central axis;
a main-body cover that has a cover peripheral wall which surrounds the predetermined central axis, wherein the main-body cover is fastened to the housing main body and thereby closes the receiving space; and
a seal member that is resiliently deformed between the housing main body and the main-body cover to seal a gap between the housing main body and the main-body cover, wherein:
the housing main body has:
a main-body connecting portion that radially outwardly extends from the main-body peripheral wall to a location which is on a radially outer side of the seal member in a radial direction of the predetermined central axis; and
a main-body fastening portion that is joined to a radially outer end part of the main-body connecting portion and has a fastening surface which contacts the main-body cover;
the main-body cover has:
a cover connecting portion that radially outwardly extends from the cover peripheral wall to a location which is on the radially outer side of the seal member in the radial direction of the predetermined central axis; and
a cover fastening portion that is joined to a radially outer end part of the cover connecting portion and has a contact surface which contacts the fastening surface;
at least one of the housing main body and the main-body cover has a corresponding one of:
a rigidity reducing structure that includes a main-body rigidity reducing part that reduces a rigidity of the main-body connecting portion in comparison to a case where the main-body rigidity reducing part is absent at the main-body connecting portion; and
a rigidity reducing structure that includes a cover rigidity reducing part that reduces a rigidity of the cover connecting portion in comparison to a case where the cover rigidity reducing part is absent at the cover connecting portion;
at least one of the rigidity reducing structures is a structure that has a space which reduces the rigidity of a corresponding one of the main-body connecting portion and the cover connecting portion; and
a location of the fastening surface is displaced from an installation location of the main-body connecting portion in the axial direction of the predetermined central axis.

7. A valve device comprising:
a drive device that is configured to output a rotational force;
a valve element that has a flow passage which is configured to conduct a fluid through the flow passage, wherein the valve element is configured to adjust a flow rate of the fluid flowing in the flow passage when the valve element is rotated about a predetermined central axis by the rotational force outputted from the drive device;
a housing main body that has:
a main-body peripheral wall which surrounds the predetermined central axis and forms a receiving space, wherein the receiving space receives the valve element; and
an opening which is formed at the housing main body on one side in an axial direction of the predetermined central axis;
a main-body cover that has a cover peripheral wall which surrounds the predetermined central axis, wherein the main-body cover is fastened to the housing main body and thereby closes the receiving space; and
a seal member that is resiliently deformed between the housing main body and the main-body cover to seal a gap between the housing main body and the main-body cover, wherein:
the housing main body has:
a main-body connecting portion that radially outwardly extends from the main-body peripheral wall to a location which is on a radially outer side of the seal member in a radial direction of the predetermined central axis; and
a main-body fastening portion that is joined to a radially outer end part of the main-body connecting portion and has a fastening surface which contacts the main-body cover;
the main-body cover has:
a cover connecting portion that radially outwardly extends from the cover peripheral wall to a location which is on the radially outer side of the seal member in the radial direction of the predetermined central axis; and
a cover fastening portion that is joined to a radially outer end part of the cover connecting portion and has a contact surface which contacts the fastening surface;
at least one of the housing main body and the main-body cover has a corresponding one of:
a rigidity reducing structure that includes a main-body rigidity reducing part that reduces a rigidity of the main-body connecting portion in comparison to a case where the main-body rigidity reducing part is absent at the main-body connecting portion; and

a rigidity reducing structure that includes a cover rigidity reducing part that reduces a rigidity of the cover connecting portion in comparison to a case where the cover rigidity reducing part is absent at the cover connecting portion;

at least one of the rigidity reducing structures is a structure that has a space which reduces the rigidity of a corresponding one of the main-body connecting portion and the cover connecting portion;

the housing main body and the main-body cover are made of resin; and

at least one of the main-body rigidity reducing part and the cover rigidity reducing part is in a bottomed form and has an opening on one side and a closed bottom on an opposite side that is opposite to the one side.

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