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

(11) EP 4 361 444 A1

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

(43) Date of publication:
01.05.2024 Bulletin 2024/18

(21) Application number: **21946952.5**

(22) Date of filing: **21.06.2021**

(51) International Patent Classification (IPC):
F04C 18/52 *(2006.01)* ***F04C 29/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04C 18/52; F04C 29/00

(86) International application number:
PCT/JP2021/023329

(87) International publication number:
WO 2022/269661 (29.12.2022 Gazette 2022/52)

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

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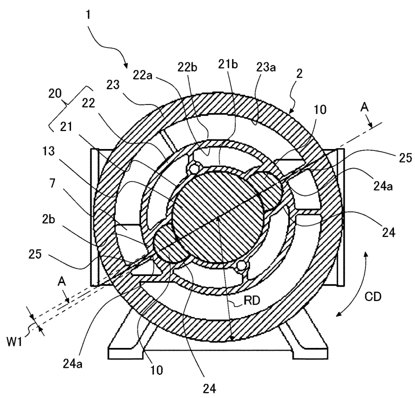
(54) SCREW COMPRESSOR

(57) A screw compressor includes a casing, a screw rotor, a gate rotor, and a slide valve. The casing includes an inner cylindrical portion having a hollow cylindrical shape and housing the screw rotor, an intermediate inner cylindrical portion having a hollow cylindrical shape such that an inner circumferential wall of the intermediate inner cylindrical portion faces an outer circumferential wall of the inner cylindrical portion at an end portion of the casing on one side in the axial direction of the rotating shaft, an outer cylindrical portion having a hollow cylindrical shape such that an inner circumferential wall of the outer cylindrical portion faces an outer circumferential wall of the intermediate inner cylindrical portion at the end portion of the casing on the one side in the axial direction of the rotating shaft and formed in the axial direction of the rotating shaft, a semicylindrical portion serving as a wall portion forming a semicylindrical groove inside the intermediate inner cylindrical portion, the semicylindrical portion being formed integrally with the inner cylindrical portion and the intermediate inner cylindrical portion and housing the slide valve inside the semicylindrical portion, and a protruding portion serving as a wall extending in a radial direction of the rotating shaft and in the axial direction of the rotating shaft, the protruding portion protruding from the outer circumferential wall of the intermediate inner cylindrical portion at a position where the semicylindrical portion and the intermediate inner cylindrical portion are integrated to each other.

FIG. 1



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Description

Technical Field

[0001] The present disclosure relates to a screw compressor used for, for example, refrigerant compression of a refrigerator.

Background Art

[0002] Some screw compressor includes one screw rotor and two gate rotors. The screw rotor and the gate rotors of such a screw compressor are accommodated in a casing. The screw rotor has a helical groove referred to as a screw groove. Such screw grooves mesh with and are engaged with the paired gate rotors disposed in radial directions of the screw rotor, thereby forming compression chambers. A slide valve is disposed beside the outer circumference of the screw rotor such that the slide valve is movable in the rotational axis direction of the screw rotor, and the internal volume ratio can be adjusted by adjusting the discharge timing of the fluid compressed in each of the compression chambers. In addition, by shifting the timing of the completion of closure of the compression chamber, the slide valve can also serve as a capacity control mechanism that can adjust the compression capacity.

[0003] The casing of the screw compressor has a cylindrical wall for housing the screw rotor and a semicylindrical wall for housing the slide valve. The casing, with the cylindrical wall, the semicylindrical wall, and a pair of compression chambers, forms a flow passage of the compressed refrigerant gas. High pressure is applied to an inner wall of the casing of the screw compressor during the operation of the compressor or a pressure resistance test conducted in which the inside of the screw compressor is pressurized. At this time, in the screw compressor, for example, stress is concentrated locally on the semicylindrical wall housing the slide valve because of the applied pressure and plastically deforms the material, and permanent strain may thereby remain in the casing after the load is removed. As a result, in the screw compressor, a gap cannot be kept constant in size between the cylindrical wall that has been deformed into, for example, an oval shape and the outer circumferential surface of the screw rotor, and leakage of the refrigerant gas from the compression chamber during the operation of the compressor thereby increases. Thus, the performance of the compressor may be decreased.

[0004] Thus, there is proposed a method for reducing the amount of deformation of the cylindrical wall due to permanent strain by providing, prior to a finish processing of the cylindrical wall of the casing, a preliminary pressurizing process in which a pressure larger than a design pressure is applied (for example, refer to Patent Literature 1).

Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2009-243412

Summary of Invention

Technical Problem

[0006] However, in the method of Patent Literature 1, because the preliminary pressurizing test is conducted, processes such as assembly of contour components, the preliminary pressurizing test, and disassembly of the contour components are required, and there may thus be an increase in time and cost of manufacturing products. In addition, in the method of Patent Literature 1, during the operation of the compressor, elastic deformation due to a pressure difference between the inside and the outside of the compressor is inevitable, and the gap between the outer circumferential surface of the screw rotor and the cylindrical wall may thereby be widened.

[0007] The present disclosure has been made to solve such above-described problems, and an object of the present disclosure is to provide a screw compressor with which plastic deformation caused by a pressure resistance test or elastic deformation caused during the operation of the compressor can be prevented or reduced, and permanent strain that remains in a casing after a load is removed can be reduced.

Solution to Problem

[0008] A screw compressor according to an embodiment of the present disclosure includes a casing forming a contour, a screw rotor accommodated inside the casing such that the screw rotor is movable and having an outer circumferential wall having a helical groove, a gate rotor accommodated inside the casing and having a tooth that meshes with the helical groove of the screw rotor, and a slide valve accommodated inside the casing and disposed such that the slide valve is slidable in an axial direction of a rotating shaft of the screw rotor. The casing includes an inner cylindrical portion having a hollow cylindrical shape and housing the screw rotor, an intermediate inner cylindrical portion having a hollow cylindrical shape such that an inner circumferential wall of the intermediate inner cylindrical portion faces an outer circumferential wall of the inner cylindrical portion at an end portion of the casing on one side in the axial direction of the rotating shaft, an outer cylindrical portion having a hollow cylindrical shape such that an inner circumferential wall of the outer cylindrical portion faces an outer circumferential wall of the intermediate inner cylindrical portion at the end portion of the casing on the one side in the axial direction of the rotating shaft and formed in the axial direction of the rotating shaft, a semicylindrical portion serving as a wall portion forming a semicylindrical groove inside the intermediate inner cylindrical portion, the semicylindrical portion being formed integrally with the inner cylindrical portion and the intermediate inner cylindrical portion and housing the slide valve inside the semicylindrical portion, and a protruding portion serving as a wall extending in a radial direction of the rotating shaft and in the axial direction of the rotating shaft, the protruding portion protruding from the outer circumferential wall of the intermediate inner cylindrical portion at a position where the semicylindrical portion and the intermediate inner cylindrical portion are integrated to each other.

Advantageous Effects of Invention

[0009] With the screw compressor according to an embodiment of the present disclosure, local stress concentration on the semicylindrical portion is reduced because of the rigidity of the protruding portion when internal pressure is applied to the casing, and the inner cylindrical portion and the intermediate inner cylindrical portion, which are formed integrally with the semicylindrical portion, are thereby prevented from being displaced. That is, the roundness can be prevented from increasing. Thus, with the screw compressor, when internal pressure is applied to the casing, plastic deformation caused by a pressure resistance test or elastic deformation caused during the operation of the compressor can be prevented or reduced, and permanent strain that remains in the casing after the load is removed can be reduced.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a front view of a screw compressor according to Embodiment 1.

[Fig. 2] Fig. 2 illustrates schematically a configuration of the screw compressor according to Embodiment 1 and is a sectional view at the position of line A-A of Fig. 1.

[Fig. 3] Fig. 3 illustrates schematically another configuration of the screw compressor according to Embodiment 1 and is a sectional view at the position of line A-A of Fig. 1.

[Fig. 4] Fig. 4 is a front view of the structure of an end portion, on one side in the longitudinal direction, of the screw compressor according to Embodiment 1.

[Fig. 5] Fig. 5 is a schematic side view illustrating schematically a side face of the screw compressor according to Embodiment 1.

[Fig. 6] Fig. 6 illustrates schematically the section of the screw compressor according to Embodiment 1 at the position of line B-B in Fig. 2.

[Fig. 7] Fig. 7 illustrates the compression principle of the operation of the screw compressor according to Embodiment 1.

[Fig. 8] Fig. 8 is a conceptual view applied with the analytical results of a part, of a casing of a screw compressor according to a comparative example, on which stress concentrates.

[Fig. 9] Fig. 9 is a conceptual view of a form of deformation of the casing of the screw compressor according to the comparative example when a pressure exceeding the design pressure is applied.

[Fig. 10] Fig. 10 illustrates schematically a configuration of a screw compressor according to Embodiment 2 and is a sectional view at the position of line A-A of Fig. 1.

[Fig. 11] Fig. 11 is a front view of a screw compressor according to Embodiment 3.

[Fig. 12] Fig. 12 illustrates schematically a configuration of the screw compressor according to Embodiment 3 and is an enlarged sectional view at the position of line D-D of Fig. 11.

[Fig. 13] Fig. 13 is a schematic top view illustrating schematically a top face of a casing of a screw compressor according to Embodiment 4.

[Fig. 14] Fig. 14 is a schematic side view illustrating schematically a side face of the casing of the screw compressor according to Embodiment 4.

[Fig. 15] Fig. 15 is a schematic top view illustrating schematically a top face of a casing of a screw compressor according to Embodiment 5.

[Fig. 16] Fig. 16 is a schematic top view illustrating schematically a top face of a casing of a screw compressor according to Embodiment 6.

[Fig. 17] Fig. 17 is a schematic side view illustrating schematically a side face of the casing of the screw compressor according to Embodiment 6.

[Fig. 18] Fig. 18 is a schematic side view illustrating schematically a side face of a casing of a screw compressor according to Embodiment 7.

Description of Embodiments

[0011] Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. Here, parts denoted by the same reference signs in the following figures including Fig. 1 are the same or equivalent to one another, and the same applies throughout the entire description of the embodiments below. In addition, in each of the embodiments, the parts that are the same or equivalent to the particulars described in a preceding embodiment are denoted by the same reference signs, and description of the parts may be omitted. The forms of the configuration elements represented in the entirety of the description are merely examples, and the configuration elements are not limited to the forms described in the description. In addition, the following embodiments may be partially combined, even when no specification is provided, within the range where there is no specific difficulty in combining the embodiments.

Embodiment 1

(Description of Configuration of Screw Compressor)

[0012] Fig. 1 is a front view of a screw compressor 1 according to Embodiment 1. Fig. 2 illustrates schematically a configuration of the screw compressor 1 according to Embodiment 1 and is a sectional view at the position of line A-A of Fig. 1. Fig. 3 illustrates schematically another configuration of the screw compressor 1 according to Embodiment 1 and is a sectional view at the position of line A-A of Fig. 1. Fig. 4 is a front view of the structure of an end portion 2a, on one side in the longitudinal direction, of the screw compressor 1 according to Embodiment 1. Fig. 5 is a schematic side view illustrating schematically a side face of the screw compressor 1 according to Embodiment 1. Note that, in Fig. 1, a slide-valve driving mechanism 11 illustrated in Fig. 2 is removed for the purpose of illustration of a wall of a casing 2. Regarding the screw compressor 1, what makes Fig. 2 different from Fig. 3 is a structure of protruding portions 25. The configurations of the screw compressors 1 will be described with reference to Figs. 1 to 5.

[0013] As Figs. 1 and 2 illustrate, the screw compressor 1 includes the casing 2 forming the contour, a screw rotor 3, gate rotors 6, and slide valves 10. The screw compressor 1 further includes a motor 4, which drives and rotates the screw rotor 3.

[0014] The casing 2 houses the screw rotor 3, the gate rotors 6, and the slide valves 10 inside the casing 2. The casing 2 further houses the motor 4 inside the casing 2. As Figs. 1 and 4 illustrate, the casing 2 includes an inner cylindrical portion 21, an intermediate inner cylindrical portion 22, an outer cylindrical portion 23, semicylindrical portions 24, and the protruding portions 25.

[0015] The inner cylindrical portion 21 has a hollow cylindrical shape and houses the screw rotor 3 inside the inner cylindrical portion 21. An inner circumferential wall 21a of the inner cylindrical portion 21 faces the screw rotor 3 or a rotating shaft 5, which will be described later. The inner cylindrical portion 21 is formed such that the inner cylindrical portion 21 extends in an axial direction AD of the rotating shaft 5.

[0016] As Fig. 4 illustrates, the inner cylindrical portion 21 has inside through holes 21c, which are through holes, and, through the inside through holes 21c, the space defined by the inner cylindrical portion 21 and the spaces defined by the semicylindrical portions 24 communicate with one another. The inner cylindrical portion 21 further has a through hole (not illustrated) communicating with spaces in which the gate rotors 6 is disposed.

[0017] At the end portion 2a on one side in the axial direction AD of the rotating shaft 5, the intermediate inner cylindrical portion 22 has a hollow cylindrical shape such that an inner circumferential wall 22a of the intermediate inner cylindrical portion 22 faces an outer circumferential wall 21b of the inner cylindrical portion 21. The intermediate inner cylindrical portion 22 is formed such that the intermediate inner cylindrical portion 22 extends in the axial direction AD of the rotating shaft 5. A part of an outer circumferential wall 22b of the intermediate inner cylindrical portion 22 is exposed outside the casing 2 and forms a part of the contour of the casing 2, between the outer cylindrical portion 23 and a motor accommodation portion 27, which will be described later. Note that the above-described structure is one form of the casing 2, and the casing 2 may have a structure in which the outer circumferential wall 22b of the intermediate inner cylindrical portion 22 and the contour of the casing 2 are separated structures, and there may be a difference in diameter between the outer circumferential wall 22b of the intermediate inner cylindrical portion 22 and the contour of the casing 2. The inner cylindrical portion 21 and the intermediate inner cylindrical portion 22 form a cylindrical portion 20. Thus, the cylindrical portion 20 has a hollow cylindrical shape such that the cylindrical portion 20 extends in the axial direction AD of the rotating shaft 5.

[0018] At the end portion 2a on one side in the axial direction AD of the rotating shaft 5, the outer cylindrical portion 23 has a hollow cylindrical shape such that an inner circumferential wall 23a of the outer cylindrical portion 23 faces the outer circumferential wall 22b of the intermediate inner cylindrical portion 22. The outer cylindrical portion 23 is formed such that the outer cylindrical portion 23 extends in the axial direction AD of the rotating shaft 5. The outer cylindrical portion 23 has a length smaller than the length of the intermediate inner cylindrical portion 22 in the axial direction AD of the rotating shaft 5. Note that the above-described structure is one form of the casing 2, and the outer cylindrical portion 23 may have, in the axial direction AD of the rotating shaft 5, a length equal to or a length larger than the length of the intermediate inner cylindrical portion 22. The outer cylindrical portion 23 includes a bottom wall portion 23c closer to an end portion 2b on the other side than the end portion 2a on one side in the axial direction AD of the rotating shaft 5, and the bottom wall portion 23c is connected to the outer circumferential wall 22b of the intermediate inner cylindrical portion 22.

[0019] The semicylindrical portions 24 each have a semicylindrical shape such that the semicylindrical portion 24 bulges outward from the inner cylindrical portion 21 in a radial direction RD of the rotating shaft 5, and an apex portion 24a of the semicylindrical portion 24 is formed integrally with the intermediate inner cylindrical portion 22. The semicylindrical portions 24 are formed in the cylindrical portion 20 formed by the inner cylindrical portion 21 and the intermediate inner cylindrical portion 22.

[0020] The semicylindrical portions 24 are each a wall portion forming a semicylindrical groove inside the intermediate inner cylindrical portion 22. The semicylindrical portions 24 are each formed integrally with the inner cylindrical portion 21 and the intermediate inner cylindrical portion 22 and each house the slide valve 10 inside the semicylindrical portion 24. The semicylindrical grooves each serve as a slide-valve accommodation groove 24b. The slide valves 10 are accommodated in the slide-valve accommodation grooves 24b such that the slide valves 10 are slidable along the slide-valve accommodation grooves 24b.

[0021] The semicylindrical portions 24 and the slide-valve accommodation grooves 24b are each formed such that the semicylindrical portion 24 and the slide-valve accommodation groove 24b extend in the axial direction AD of the rotating shaft 5. Sets of the semicylindrical portions 24 and the respective slide-valve accommodation grooves 24b are point symmetric about the rotating shaft 5 and formed at positions on both respective sides of the screw rotor 3.

[0022] The protruding portions 25 are each a wall extending in a radial direction RD of the rotating shaft 5 and in the axial direction AD of the rotating shaft 5 and protrude from the outer circumferential wall 22b of the intermediate inner cylindrical portion 22 at respective positions where the semicylindrical portions 24 and the intermediate inner cylindrical portion 22 are integrated to each other. That is, the protruding portions 25 are each formed on the corresponding one of the bulging apex portions 24a of the semicylindrical portions 24 and extend outward from the semicylindrical portions 24 in radial directions RD of the rotating shaft 5. Note that, because the semicylindrical portions 24 are formed in the cylindrical portion 20, the protruding portions 25 are formed, in the cylindrical portion 20, on parts of the semicylindrical portions 24.

[0023] The protruding portions 25 are each a part of the casing 2 and each have the same length as the semicylindrical portions 24 in the axial direction AD of the rotating shaft 5 as Fig. 2 illustrates. In addition, in a radial direction RD of the rotating shaft 5, the length of the protruding portions 25 to the inner circumferential wall 23a of the outer cylindrical portion 23 is the maximum possible length of the protruding portions 25.

[0024] A width W1 (refer to Fig. 1) of the protruding portions 25 in a circumferential direction CD of the rotating shaft 5 is smaller than a length L1 (refer to Fig. 2) of the protruding portions 25 in the axial direction AD of the rotating shaft 5.

[0025] The protruding portions 25 may each have a columnar shape or a rib shape. As Fig. 2 illustrates, such columnar-shaped protruding portions 25 are each formed such that, in a radial direction RD of the rotating shaft 5, an end portion of the protruding portion 25 on one side is formed integrally with the intermediate inner cylindrical portion 22, and an end portion of the protruding portion 25 on the other side is formed integrally with the outer cylindrical portion 23. The columnar-shaped protruding portions 25 are each formed such that the protruding portion 25 connects the intermediate inner cylindrical portion 22 and the outer cylindrical portion 23 to one another.

[0026] As Fig. 3 illustrates, such rib-shaped protruding portions 25 are each formed such that, in a radial direction RD of the rotating shaft 5, an end portion of the protruding portion 25 on one side is formed integrally with the intermediate inner cylindrical portion 22, and at least a part of an end portion of the protruding portion 25 on the other side faces the inner circumferential wall 23a of the outer cylindrical portion 23.

[0027] The inside of the casing 2 is divided by a partition (not illustrated) into a low-pressure side, which is the suction side of refrigerant, and a high-pressure side, which is the discharge side of refrigerant. A space on the low-pressure side serves as a low-pressure chamber 15 having a suction-pressure atmosphere. In addition, a space on the high-pressure side serves as a high-pressure chamber 16 having a discharge-pressure atmosphere. Note that, in the following description, in the axial direction AD of the rotating shaft 5, the suction-pressure side, which is one end side, may be referred to as an axial-direction suction side, and the discharge-pressure side, which is the other end side, may be referred to as an axial-direction discharge side.

[0028] In a part of the casing 2 on the discharge-pressure side, a discharge flow passage 7 and an inlet portion 7a, which is opened to the discharge flow passage 7, are formed. The discharge flow passage 7 is formed by walls forming the casing 2 and forms a part of the high-pressure chamber 16. As Fig. 2 illustrates, the inlet portion 7a serving as an entrance part of the discharge flow passage 7 for the compressed refrigerant is formed in the semicylindrical portions 24 and is formed such that the inlet portion 7a faces the slide valves 10. An outlet portion 7b serving as an exit part of the discharge flow passage 7 for the compressed refrigerant is formed between the intermediate inner cylindrical portion 22 and the outer cylindrical portion 23 in a radial direction RD of the rotating shaft 5. That is, the opening face of the inlet portion 7a faces in a radial direction RD of the rotating shaft 5, and the opening face of the outlet portion 7b faces in the axial direction AD of the rotating shaft 5.

[0029] Note that there may be an instance where the casing 2 is subjected to a pressure resistance test in which the inside of the casing 2 is pressurized. In the pressure resistance test, a pressure exceeding the design pressure is applied to the casing 2.

[0030] Fig. 6 illustrates schematically the section of the screw compressor 1 according to Embodiment 1 at the position of line B-B in Fig. 2. The internal structure of the casing 2 will further be described with reference to Figs. 2 and 6. The screw rotor 3 is accommodated inside the casing 2 such that the screw rotor 3 is movable. The screw rotor 3 has a columnar shape and has an outer circumferential wall having plural screw grooves 3a, which are helical grooves. The screw grooves 3a mesh with and are engaged with a pair of gate rotors 6 disposed in a radial direction RD from the screw rotor 3 and form compression chambers 14. In the screw rotor 3, one end is the suction side of fluid, and the other end is the discharge side.

[0031] The screw rotor 3 is disposed around and fixed to the rotating shaft 5 (refer to Fig. 2). A motor rotor 4b of the motor 4 is also fixed to the rotating shaft 5. The screw rotor 3 is rotated with the rotation of the rotating shaft 5 caused by the rotation of the motor rotor 4b fixed to the rotating shaft 5. When the screw rotor 3 is driven to rotate by the motor 4, the fluid in the low-pressure space is sucked into the compression chambers 14 and compressed, and the fluid that has been compressed in the compression chambers 14 passes through a discharge port 8, which will be described later, and is discharged into the high-pressure space.

[0032] An end portion of the rotating shaft 5 on the discharge side (on the AD1 side in Fig. 2) is supported by a bearing housing 13 such that the end portion of the rotating shaft 5 is movable. The bearing housing 13 supports the rotating shaft 5 with a main bearing 12 interposed between the bearing housing 13 and the rotating shaft 5. The bearing housing 13 is provided in the inner cylindrical portion 21 at the end portion of the rotating shaft 5 on the discharge side (on the AD1 side in Fig. 2). In addition, an end portion of the rotating shaft 5 on the suction side (on the AD2 side in Fig. 2) is supported by a sub-bearing (not illustrated) such that the end portion of the rotating shaft 5 is movable.

[0033] As Figs. 2 and 6 illustrate, the screw compressor 1 includes two gate rotors 6. The two gate rotors 6 are point symmetric about the rotating shaft 5 and disposed at positions on both respective sides of the screw rotor 3. Each of the gate rotors 6 is accommodated inside the casing 2 and includes gate-rotor teeth 6a, which mesh with the screw grooves 3a, which are helical grooves of the screw rotor 3.

[0034] The gate rotors 6 each have a disk shape and each include the plural gate-rotor teeth 6a provided in the outer circumferential surface of the gate rotor 6 and arranged in the circumferential direction. The gate-rotor teeth 6a of the gate rotors 6 mesh with the screw grooves 3a. Spaces surrounded by the gate-rotor teeth 6a of the gate rotors 6, the screw grooves 3a, and the inner circumferential wall 21a of the inner cylindrical portion 21 of the casing 2 form the compression chambers 14 in which refrigerant is compressed.

[0035] The compression chambers 14 are formed by the screw rotor 3, the gate rotors 6, the casing 2, and the slide valves 10, and a narrow gap is left between each of the components. The compressed gas leaks from such gaps during compression, and widening gaps thereby cause reduction in the performance of the compressor. In addition, during a normal operation, the slide valves 10 are moved by a load being exerted outward in radial directions due to a difference in pressure between the inside of the compression chambers 14 and the low-pressure chamber 15, which is the low-pressure space. Thus, widening of the gap between the screw rotor 3 and the slide valves 10 causes reduction in the performance of the compressor.

[0036] The plural compression chambers 14 are formed at positions where the plural compression chambers 14 are point symmetric about the center, in radial directions RD, of the screw rotor 3. Note that the screw compressor 1 may be of a type including one gate rotor 6, which meshes with one screw rotor 3 and thus forms a compression chamber 14. The gate rotors 6 are each supported by the corresponding one of gate-rotor supports 6b of metal at the side of the gate rotor 6 opposite to the other side that faces the compression chambers 14 to resist the pressure of the compression chambers 14.

[0037] Each of the slide valves 10 is accommodated inside the casing 2 and disposed such that a narrow gap is ensured between the slide valve 10 and the outer circumference of the screw rotor 3. The slide valves 10 are each disposed such that the slide valve 10 is slidable in the axial direction AD of the rotating shaft 5 of the screw rotor 3. The slide valves 10 each slide along the outer circumferential surface of the screw rotor 3 in the axial direction AD.

[0038] The slide valves 10 and the casing 2 are integrated to each other and together form the compression chambers 14. The slide valves 10 form the discharge port 8, and the timing of opening of the discharge port 8, that is, the timing at which the compression chambers 14 communicate with the discharge flow passage 7 changes depending on the positions of the slide valves 10.

[0039] In the screw compressor 1, the internal volume ratio of the screw rotor 3 is adjusted by changing the timing of opening of the discharge port 8 as described above. The internal volume ratio refers to a value obtained by dividing the volume of the compression chambers 14 when suction is completed by the volume of the compression chambers 14 when discharge is started.

[0040] The slide valves 10 each have a columnar shape and each include a valve body portion 10c, a guide portion 10a, and a coupling portion 10b. The valve body portions 10c each face the screw rotor 3 and form the compression chambers 14 together with the screw rotor 3. In addition, the valve body portions 10c have the discharge port 8, which is a through hole passing through in a radial direction RD of the rotating shaft 5. The discharge port 8 allows the discharge flow passage 7 and the compression chambers 14 to communicate with one another at a position where the pressure of the compression chambers 14 is high, and the discharge port 8 forms a flow passage through which refrigerant is moved from the compression chambers 14 to the discharge flow passage 7.

[0041] The guide portions 10a each have a columnar shape and each guide the movement of the corresponding one of the valve body portions 10c. The guide portions 10a each have a guide surface facing the bearing housing 13. The coupling portions 10b each couple one of the valve body portions 10c and the corresponding one of the guide portions 10a to one another.

[0042] The slide-valve driving mechanism 11, which causes the slide valves 10 to slide in the rotational axis direction of the screw rotor 3, is disposed at an end portion of the screw rotor 3 on the opposite side from the motor 4. The slide valves 10 are connected to the slide-valve driving mechanism 11 by use of a coupling rod 10d. The slide-valve driving mechanism 11 allows the slide valves 10 to slide in the axial direction AD of the rotating shaft 5 of the screw rotor 3.

[0043] In the screw compressor 1, for example, two-level adjustment of the internal volume ratio of the refrigerant gas that is compressed in the compression chambers 14 is enabled by the slide-valve driving mechanism 11 causing the slide valves 10 to slide in the axial direction AD. In addition, the slide-valve driving mechanism 11 can also serve as a capacity control mechanism that can adjust the compression capacity by shifting the timing of closure completion of the compression chambers 14, and the compression capacity can be adjusted by the slide valves 10 sliding in the axial direction AD.

[0044] Examples of a power source for the slide-valve driving mechanism 11, which drives the slide valves 10, include, but not limited to, power sources using gas pressure, oil pressure, and, for example, a motor other than a piston.

[0045] As Fig. 2 illustrates, the motor 4 includes a stator 4a inscribed in and fixed to the casing 2 and the motor rotor 4b disposed inside the stator 4a. When the motor 4 is controlled by use of an inverter system, a controller (not illustrated) controls the rotation frequency of the motor 4. The screw compressor 1 enables the adjustment of the compression capacity by controlling the rotation frequency of the motor 4. The screw rotor 3 and the motor rotor 4b are both disposed on the same axis and both fixed to the rotating shaft 5. The screw rotor 3 of the screw compressor 1 is rotated by being driven by the motor 4.

(Description of Operation of Screw Compressor 1)

[0046] Fig. 7 illustrates the compression principle of the operation of the screw compressor 1 according to Embodiment 1. A suction stroke is illustrated in (a), a compression stroke is illustrated in (b), and a discharge stroke is illustrated in (c). Next, an operation of the screw compressor 1 according to Embodiment 1 will be described with reference to Fig. 7.

[0047] As Fig. 7 illustrates, the screw rotor 3 is rotated by the motor 4 (refer to Fig. 2) through the rotating shaft 5 (refer to Fig. 2), and the gate-rotor teeth 6a thereby move relatively to each other inside the compression chambers 14. Thus, in the compression chambers 14, the suction stroke, the compression stroke, and the discharge stroke are counted as one cycle, and the cycle is repeated. Here, each of the strokes will be described while one of the compression chambers 14 illustrated by dots in Fig. 7 is focused.

[0048] The state of the focused one of the compression chambers 14 in the suction stroke is illustrated in (a). The screw rotor 3 is driven by the motor 4, thereby rotating in a direction of the solid-line arrow. Thus, as in (b), the volume of the focused compression chamber 14 is reduced.

[0049] When the screw rotor 3 continues rotating, as illustrated in (c), the focused compression chamber 14 comes to communicate with the discharge port 8 formed in the valve body portions 10c of the slide valves 10. Thus, the high-pressure refrigerant gas that has been compressed in the focused compression chamber 14 passes through the inside through holes 21c, the discharge port 8, and the inlet portion 7a (refer to Fig. 2), flows into the discharge flow passage 7, passes through the discharge flow passage 7, and is discharged outside the compressor. Then, similar compression is performed again at the back of the screw rotor 3. Due to the above-described operation, the inside of the casing 2 is divided into the low-pressure chamber 15, which is a low-pressure space, and the high-pressure chamber 16, which is a high-pressure space.

(Description of Load Applied to Casing)

[0050] As Figs. 2 and 4 illustrate, the screw compressor 1 according to Embodiment 1 has the inside through holes 21c provided in respective parts, of the inner cylindrical portion 21 housing the screw rotor 3, at which the slide valves 10 are disposed, and the respective parts thus have no walls of the inner cylindrical portion 21. In addition, the inner cylindrical portion 21 is connected to the semicylindrical portions 24 housing the slide valves 10.

[0051] Fig. 8 is a conceptual view applied with the analytical results of a part, of a casing 2 of a screw compressor 1L according to a comparative example, on which stress concentrates. Fig. 9 is a conceptual view of a form of deformation of the casing 2 of the screw compressor 1L according to the comparative example when a pressure exceeding the design pressure is applied. The screw compressor 1L according to the comparative example is a compressor having no protruding portions 25 and has the same structure as the screw compressor according to Embodiment 1 except for such absence of the protruding portions 25.

[0052] As described above, a single screw compressor is typically subjected to a pressure resistance test determined by the laws and regulations regarding high-pressure gas. Such a pressure resistance test is conducted on a contour component of the single screw compressor, and the inside of the casing is applied with a pressure exceeding a design pressure.

[0053] The results of the analysis conducted by the inventors revealed that, in the screw compressor 1L according to the comparative example, local stress concentration on the semicylindrical portions 24 caused by internal pressure strains the inner cylindrical portion 21 when the pressure resistance test or the operation of the compressor is performed. Parts P illustrated in Fig. 8 represent parts of the casing 2 to which local stress is applied.

[0054] Thus, when a pressure exceeding the design pressure is applied, in the screw compressor 1L according to the comparative example, the shapes of the intermediate inner cylindrical portion 22 and the inner cylindrical portion 21, which are integrated with the semicylindrical portions 24, are also changed through the above-described mechanism, and the roundness of each of the intermediate inner cylindrical portion 22 and the inner cylindrical portion 21 may thereby increase. The casing 2 is strained when the roundness of each of the intermediate inner cylindrical portion 22 and the inner cylindrical portion 21 increases. For example, as Fig. 9 illustrates, each of the inner cylindrical portion 21 and the intermediate inner cylindrical portion 22 of the screw compressor 1L according to the comparative example is deformed into an oval shape whose minor radius is an axis connecting the center of the cylindrical portion 20 and each of the centers of the semicylindrical portions 24 to one another.

(Functions and Effects of Screw Compressor 1)

[0055] The casing 2 of the screw compressor 1 includes the protruding portions 25, which are each a wall extending in a radial direction RD of the rotating shaft 5 and in the axial direction AD of the rotating shaft 5 and protrude from the outer circumferential wall 22b of the intermediate inner cylindrical portion 22 at respective positions where the semicylindrical portions 24 and the intermediate inner cylindrical portion 22 are integrated to each other. As evidenced by comparing Figs. 4 and 8, the positions where the semicylindrical portions 24 and the intermediate inner cylindrical portion 22 are integrated to each other are equivalent to respective positions of the parts P of the casing 2 to which local stress is applied. That is, the positions where the protruding portions 25 are formed is the respective positions of the parts P in the casing 2 to which local stress is applied. Thus, in the screw compressor 1, when internal pressure is applied to the casing 2, the rigidity is ensured by the presence of the protruding portions 25, and the local stress concentration on the semicylindrical portions 24 is thereby reduced.

[0056] In the screw compressor 1, when internal pressure is applied to the casing 2, the local stress concentration on the semicylindrical portions 24 is reduced by the protruding portions 25, and displacement of each of the inner cylindrical portion 21, which is formed integrally with the semicylindrical portions 24, and the intermediate inner cylindrical portion 22 is thereby prevented or reduced. That is, each roundness is prevented from increasing. Thus, in the screw compressor 1, when internal pressure is applied to the casing 2, plastic deformation caused by the pressure resistance test or elastic deformation caused during the operation of the compressor can be prevented or reduced, and permanent strain that remains in the casing 2 after the load is removed can be reduced.

[0057] In addition, in the screw compressor 1, when internal pressure is applied to the casing 2, the roundness of each of the inner cylindrical portion 21, which is formed integrally with the semicylindrical portions 24, and the intermediate inner cylindrical portion 22 is prevented from increasing by the protruding portions 25. Thus, because the gap between the intermediate inner cylindrical portion 22 or the cylindrical portion 20 and the outer cylindrical portion 23 is prevented from widening in the screw compressor 1, reduction of leak of the refrigerant gas that leaks from the compression chambers 14 during the operation of the compressor is enabled, and there can be provided such a high-performance screw compressor. That is, the gap between the cylindrical portion 20 and the outer circumferential surface of the screw rotor 3 can be kept constant in the screw compressor 1, and such a high-performance screw compressor can thus be provided.

[0058] In addition, during the operation of the screw compressor 1, a load is applied to the slide valves 10 such that the slide valves 10 move outward in radial directions of the screw rotor 3 because of the pressure from the compression chambers 14, and the slide valves 10 come into contact with the semicylindrical portions 24. As a result, in the screw compressor 1L having no protruding portions 25 according to the comparative example, the gap between the outer circumferential surface of the screw rotor 3 and the slide valves 10 widens. In contrast, in the screw compressor 1 according to Embodiment 1, the degree of deformation of the inner cylindrical portion 21 is prevented from increasing by the protruding portions 25. Thus, in the screw compressor 1, the amount of movement of the slide valves 10 in radial directions is prevented or reduced, and the gap between the outer circumferential surface of the screw rotor 3 and the slide valves 10 can be prevented from widening.

[0059] In addition, with the screw compressor 1 having the protruding portions 25, elastic deformation of the cylindrical portion 20 caused by the internal pressure of the casing 2 during the operation of the compressor can also be prevented or reduced. Thus, the performance reduction of the screw compressor 1 due to widening of the gap between the cylindrical portion 20 and the outer circumferential surface of the screw rotor 3 can be prevented or reduced. Or, with the screw compressor 1 having the protruding portions 25, elastic deformation of the cylindrical portion 20 caused by the internal pressure of the casing 2 during the operation of the compressor can also be prevented or reduced. Thus, with the screw compressor 1, seizing of the screw rotor 3 with the casing 2 due to narrowing of the gap between the cylindrical portion 20 and the outer circumferential surface of the screw rotor 3 can be prevented or reduced.

[0060] In addition, with the screw compressor 1 having the protruding portions 25, the semicylindrical portions 24 of the casing 2 can also be prevented from being deformed. Thus, in the screw compressor 1, the amount of movement of the slide valves 10, which are moved outward in radial directions by the pressure of the compression chambers 14 during the operation of the compressor, is reduced. With the screw compressor 1 having the protruding portions 25, because the amount of movement of the slide valves 10 outward in radial directions can be reduced, the gap between the outer circumferential surface of the screw rotor 3 and the surface of the slide valves 10 facing the outer circumferential surface of the screw rotor 3 can be prevented from widening, and the performance of the compressor can thereby be prevented from being decreased.

[0061] In addition, in each of the protruding portions 25, in radial directions RD of the rotating shaft 5, the end portion on one side is formed integrally with the intermediate inner cylindrical portion 22, and at least a part of the end portion on the other side faces the inner circumferential wall 23a of the outer cylindrical portion 23. With the screw compressor 1 having the protruding portions 25, the cylindrical portion 20 can be prevented from being deformed during the operation of the compressor. Moreover, with the protruding portions 25 in which at least each part of the end portion on the other side faces the inner circumferential wall 23a of the outer cylindrical portion 23, pressure loss generated by the protruding portions 25 serving as resistance to refrigerant gas when the refrigerant gas flows through the discharge flow passage 7 can be prevented from increasing, compared with the protruding portions 25 whose each end portion on the other side is coupled to and formed integrally with the outer cylindrical portion 23 as in Fig. 2.

[0062] In addition, the protruding portions 25 each include, in a radial direction RD of the rotating shaft 5, the end portion on one side formed integrally with the intermediate inner cylindrical portion 22 and the end portion on the other side formed integrally with the outer cylindrical portion 23, and the protruding portions 25 each have a columnar shape connecting the intermediate inner cylindrical portion 22 and the outer cylindrical portion 23 to one another. Thus, the casing 2 can ensure its strength, and strains can further be prevented or reduced compared with the configuration in which, in radial directions RD of the rotating shaft 5, the end portions of the protruding portions 25 on one side are each formed integrally with the intermediate inner cylindrical portion 22, and the end portions on the other side each face the inner circumferential wall 23a of the outer cylindrical portion 23.

[0063] In addition, the protruding portions 25 each have the same length as the semicylindrical portions 24 in the axial direction AD of the rotating shaft 5. Thus, compared with a case where the protruding portions 25 each have a length smaller than the length of the semicylindrical portions 24 in the axial direction AD of the rotating shaft 5, the casing 2 can further ensure its strength, and the cylindrical portion 20 can further be prevented from being strained.

Embodiment 2

[0064] Fig. 10 illustrates schematically a configuration of the screw compressor 1 according to Embodiment 2 and is a sectional view at the position of line A-A of Fig. 1. Note that the configuration elements having the same functions and effects as the configuration elements of the screw compressor 1 according to Embodiment 1 are denoted by the same reference signs, and the description of such configuration elements will be omitted. Differences from Embodiment 1 will be described in Embodiment 2, and the configurations that are not described in Embodiment 2 are similar to the configurations of Embodiment 1. In the screw compressor 1 according to Embodiment 2, the structure of the protruding portions 25 is further specified.

[0065] The protruding portions 25 of the screw compressor 1 according to Embodiment 2 each have a length smaller than the length of the semicylindrical portions 24 in the axial direction AD of the rotating shaft 5. In Fig. 10, a length L1 is the length of the protruding portions 25 in the axial direction AD, and a length L2 is the length of the semicylindrical portions 24 in the axial direction AD.

(Functions and Effects of Screw Compressor 1)

[0066] With the screw compressor 1 according to Embodiment 2, during the operation of the compressor, the cylindrical portion 20, which includes the intermediate inner cylindrical portion 22 and the inner cylindrical portion 21, can be prevented from being deformed, by the protruding portions 25 having a length smaller than the length of the semicylindrical portions 24. In addition, with the screw compressor 1 according to Embodiment 2, during the operation of the compressor, pressure loss generated by the protruding portions 25 serving as resistance to refrigerant gas when the refrigerant gas flows through the discharge flow passage 7 can be prevented or reduced, by the protruding portions 25 having a length smaller than the length of the semicylindrical portions 24. That is, the screw compressor 1 having the protruding portions 25 can achieve, at the same time, prevention or reduction of deformation of the cylindrical portion 20 and prevention or reduction of pressure loss of the refrigerant flowing through the discharge flow passage 7 during the operation of the compressor, and such a high-performance screw compressor can thus be provided.

Embodiment 3

[0067] Fig. 11 is a front view of the screw compressor 1 according to Embodiment 3. Fig. 12 illustrates schematically a configuration of the screw compressor 1 according to Embodiment 3 and is an enlarged sectional view at the position of line D-D of Fig. 11. In Fig. 12, each of the solid-line arrows represents a direction in which the high-pressure refrigerant gas discharged from each of the compression chambers 14 flows. Note that the configuration elements having the same functions and effects as the configuration elements of the screw compressors 1 according to Embodiments 1 and 2 are denoted by the same reference signs, and the description of such configuration elements will be omitted. Differences from Embodiment 1 or Embodiment 2 will be described in Embodiment 3, and the configurations that are not described in Embodiment 3 are similar to the configurations of Embodiment 1 or Embodiment 2. In the screw compressor 1 according to Embodiment 3, the structure of the protruding portions 25 is further specified.

[0068] In the casing 2, in the axial direction AD of the rotating shaft 5, a discharge-side end portion is the end portion 2a on one side (refer to Fig. 2) on which refrigerant is discharged, and a suction-side end portion is the end portion 2b on the other side (refer to Fig. 2) on which refrigerant is sucked. The protruding portions 25 of the screw compressor 1 according to Embodiment 3 each include a tapered portion 25a formed such that a width W1 of the protruding portion 25 decreases from the discharge-side end portion toward the suction-side end portion. The protruding portions 25 may each be formed only by the tapered portion 25a. That is, the protruding portions 25 may each be formed such that the entirety of the protruding portion 25 is tapered toward the upstream side in a direction in which refrigerant flows.

[0069] Although the width of each of the protruding portions 25 decreases gradually from the end on the downstream side of refrigerant gas in Fig. 12, only a part of each of the protruding portions 25 on the upstream side of the flow passage of refrigerant gas may be tapered. For example, the protruding portions 25 may each have a part having the width W1 that is uniform from the discharge-side end portion toward the suction-side end portion and each may have the tapered portion 25a in a distal end part in a direction from the discharge-side end portion toward the suction-side end portion. That is, the protruding portions 25 may each be formed such that only the distal end part of the protruding portion 25 is tapered toward the upstream side in the direction in which refrigerant flows.

(Functions and Effects of Screw Compressor 1)

[0070] With the screw compressor 1 according to Embodiment 3, during the operation of the compressor, the cylindrical portion 20, which includes the intermediate inner cylindrical portion 22 and the inner cylindrical portion 21, can be prevented from being deformed, by the protruding portions 25 having the tapered portions 25a. In addition, with the screw compressor 1 according to Embodiment 2, during the operation of the compressor, pressure loss generated by the protruding portions 25 serving as resistance to refrigerant gas when the refrigerant gas flows through the discharge flow passage 7 can be prevented or reduced, by the protruding portions 25 having the tapered portions 25a. That is, the screw compressor 1 having the protruding portions 25 can achieve, at the same time, prevention or reduction of deformation of the cylindrical portion 20 and prevention or reduction of pressure loss of the refrigerant flowing through the discharge flow passage 7 during the operation of the compressor, and such a high-performance screw compressor can thus be provided.

Embodiment 4

[0071] Fig. 13 is a schematic top view illustrating schematically a top face of the casing 2 of the screw compressor 1 according to Embodiment 4. Fig. 14 is a schematic side view illustrating schematically a side face of the casing 2 of the screw compressor 1 according to Embodiment 4. Note that the configuration elements having the same functions and effects as the configuration elements of the screw compressors 1 according to Embodiments 1 to 3 are denoted by the same reference signs, and the description of such configuration elements will be omitted. Differences from Embodiments 1 to 3 will be described in Embodiment 4, and the configurations that are not described in Embodiment 4 are similar to the configurations of Embodiments 1 to 3. In the screw compressor 1 according to Embodiment 4, the structure of the casing 2 is further specified.

[0072] The casing 2 of the screw compressor 1 according to Embodiment 4 further includes outside protruding portions 26, which are each a wall extending in a radial direction RD of the rotating shaft 5 and in the axial direction AD of the rotating shaft 5 and protrude from the outer circumferential wall 22b of the intermediate inner cylindrical portion 22. The outside protruding portions 26 each include, in a radial direction RD of the rotating shaft 5, an end portion on one side formed integrally with the intermediate inner cylindrical portion 22 and an end portion on the other side protruding toward the outside of the casing 2, and the outside protruding portions 26 each have a height larger than the width of the outside protruding portion 26 in the circumferential direction CD.

[0073] The screw compressor 1 includes the motor 4 (refer to Fig. 2) coupled to the rotating shaft 5. As Fig. 5 illustrates, the casing 2 includes the motor accommodation portion 27 housing the motor 4. The motor accommodation portion 27 is formed at a position apart from the outer cylindrical portion 23 in the axial direction AD. The motor accommodation portion 27 is formed at the end portion other than the end portion at which the outer cylindrical portion 23 is disposed in the axial direction AD of the rotating shaft 5.

[0074] The motor accommodation portion 27 has a hollow cylindrical shape and has an outside diameter OD2 larger than an outside diameter OD1 of the intermediate inner cylindrical portion 22. In the axial direction AD of the rotating shaft 5, the outside protruding portions 26 are each formed integrally with the outer cylindrical portion 23 and the motor accommodation portion 27 such that the outside protruding portion 26 connects the outer cylindrical portion 23 and the motor accommodation portion 27 to one another. More specifically, the outside protruding portions 26 are each formed between the bottom wall portion 23c of the outer cylindrical portion 23 and the motor accommodation portion 27 in the axial direction AD of the rotating shaft 5.

[0075] The casing 2 has an upper part and a lower part and the outside protruding portion 26 is provided in each of the upper part and the lower part of the casing 2. One of the outside protruding portions 26 provided in the upper part of the casing 2 protrudes at the upper portion of the casing 2. The one of the outside protruding portions 26 provided in the upper part of the casing 2 is preferably formed on an upper apex portion of the intermediate inner cylindrical portion 22.

[0076] Another one of the outside protruding portions 26 provided in the lower part of the casing 2 protrudes at the lower portion of the casing 2. The other one of the outside protruding portions 26 provided in the lower part of the casing 2 is preferably formed on a lower apex portion of the intermediate inner cylindrical portion 22. Although the casing 2 preferably includes the one outside protruding portion 26 protruding upward and the other outside protruding portion 26 protruding downward, the casing 2 may have only one of the outside protruding portions 26.

[0077] The outside protruding portions 26 are each a wall extending in a radial direction RD of the rotating shaft 5 and in the axial direction AD of the rotating shaft 5. As Fig. 13 illustrates, each of the outside protruding portions 26 is a part of the casing 2 and has a width W3, in the circumferential direction CD of the rotating shaft 5, smaller than a length L3 of the outside protruding portion 26 in the axial direction AD of the rotating shaft 5. That is, as Fig. 13 illustrates, the length L3 of each outside protruding portion 26 in the axial direction AD of the rotating shaft 5 is larger than the width W3 of each outside protruding portion 26 in the circumferential direction CD of the rotating shaft 5.

[0078] The outside protruding portions 26 are each provided in a direction G orthogonal to a straight line F connecting centers E of the pair of gate rotors 6 (not illustrated). The length L3, which is a length of each of the outside protruding portions 26 in the axial direction, is larger than a diameter D1 of each of the gate rotors 6 (refer to Fig. 6). In the axial direction AD of the rotating shaft 5, the screw compressor 1 includes the gate rotors 6 and the screw rotor 3 within a range in which the outside protruding portions 26 are formed.

(Functions and Effects of Screw Compressor 1)

[0079] In most instances, a casing of a screw compressor is required to have, in the axial direction of a rotating shaft, a length enough to house components such as a screw rotor, a motor, and the rotating shaft. During a pressure resistance test or the operation of the compressor, when pressure acts on an inner side of the casing, local stress concentration occurs on the casing serving as the contour due to the structure of the casing required to have a certain length in the axial direction, and the casing may thereby be bent in radial directions including the vertical direction. More specifically, when viewed in a vertical section of the casing taken in the axial direction of the rotating shaft, the casing may be bent into a U shape such that a center part of the casing bulges. As a result, a cylindrical portion formed in an inner part of the casing is also displaced in the vertical direction or in a radial direction, and the roundness of the cylindrical portion increases. In addition, the casing is required to have a space for housing a gate rotor and its circumferential components (not illustrated), and a wall face of the casing defining the space is thereby likely to have a low rigidity and is thus likely to be deformed.

[0080] The casing 2 of the screw compressor 1 according to Embodiment 4 includes the outside protruding portions 26. Each of the outside protruding portions 26 includes, in a radial direction RD of the rotating shaft 5, the end portion on one side formed integrally with the intermediate inner cylindrical portion 22 and the end portion on the other side protruding toward the outside of the casing 2. The casing 2 of the screw compressor 1 having the outside protruding portions 26 can be increased in rigidity compared with a case where no outside protruding portions 26 are provided. In the screw compressor 1, when internal pressure is applied to the casing 2, the rigidity is ensured by the presence of the outside protruding portions 26, and local stress concentration on the casing 2 is thereby reduced.

[0081] In the screw compressor 1, because such local stress concentration on the casing 2 is reduced by the outside protruding portions 26 when internal pressure is applied to the casing 2, the intermediate inner cylindrical portion 22, which is a part of the casing 2, is prevented from being displaced, that is, the roundness is prevented from increasing. Thus, with the screw compressor 1, when internal pressure is applied to the casing 2, plastic deformation caused by a pressure resistance test or elastic deformation caused during the operation of the compressor can be prevented or reduced, and permanent strain that remains in the casing 2 after the load is removed can be reduced.

[0082] In addition, in the axial direction AD of the rotating shaft 5, the outside protruding portions 26 are each formed integrally with the outer cylindrical portion 23 and the motor accommodation portion 27 such that the outside protruding portions 26 each connect the outer cylindrical portion 23 and the motor accommodation portion 27 to one another. With the outside protruding portions 26 formed integrally with the outer cylindrical portion 23 and the motor accommodation portion 27, the rigidity of the casing 2 can further be increased compared with a casing not having the above-described configuration. Thus, the casing 2 of the screw compressor 1 including the outside protruding portions 26 can be prevented from being bent in the vertical direction or in radial directions compared with a case where no outside protruding portions 26 are provided.

[0083] In addition, as Fig. 13 illustrates, the outside protruding portions 26 are each a part of the casing 2 and each have the width W3, in the circumferential direction CD of the rotating shaft 5, smaller than the length L3 of each of the outside protruding portions 26 in the axial direction AD of the rotating shaft 5. That is, the length L3 of each outside protruding portion 26 in the axial direction AD of the rotating shaft 5 is larger than the width W3 of each outside protruding portion 26 in the circumferential direction CD of the rotating shaft 5. Accordingly, the wall of each outside protruding portion 26 has a thickness, in the axial direction AD of the rotating shaft 5, larger than the thickness of the outside protruding portion 26 in the circumferential direction CD of the rotating shaft 5. Thus, the casing 2 of the screw compressor 1 having the outside protruding portions 26 can be increased in rigidity compared with a case where no outside protruding portions 26 are provided, and the casing 2 can thereby be prevented from being bent in the vertical direction or radial directions.

Embodiment 5

[0084] Fig. 15 is a schematic top view illustrating schematically a top face of the casing 2 of the screw compressor 1 according to Embodiment 5. Note that the configuration elements having the same functions and effects as the configuration elements of the screw compressors 1 according to Embodiments 1 to 4 are denoted by the same reference signs, and the description of such configuration elements will be omitted. Differences from Embodiments 1 to 4 will be described in Embodiment 5, and the configurations that are not described in Embodiment 5 are similar to the configurations of Embodiments 1 to 4. In the screw compressor 1 according to Embodiment 5, the structure of the outside protruding portions 26 is further specified.

[0085] In the casing 2, in the axial direction AD of the rotating shaft 5, a discharge-side end portion is the end portion 2a on one side on which refrigerant is discharged, and a suction-side end portion is the end portion 2b on the other side on which refrigerant is sucked. The outside protruding portions 26 are each formed such that a width W3 of the outside protruding portion 26 decreases gradually from the discharge-side end portion toward the suction-side end portion.

(Functions and Effects of Screw Compressor 1)

[0086] The outside protruding portions 26 are each formed such that the width W3 of the outside protruding portion 26 decreases gradually from the discharge-side end portion toward the suction-side end portion. With the screw compressor 1 having the above-described configuration, deformation of a discharge-side part of the cylindrical portion 20 (refer to Fig. 1) of the casing 2 due to internal pressure can be prevented or reduced in particular, and refrigerant gas can thereby be prevented from leaking from the high-pressure side of the compression chambers 14 whose difference in pressure from the low-pressure side is large.

Embodiment 6

[0087] Fig. 16 is a schematic top view illustrating schematically a top face of the casing 2 of the screw compressor 1 according to Embodiment 6. Fig. 17 is a schematic side view illustrating schematically a side face of the casing 2 of the screw compressor 1 according to Embodiment 6. Note that the configuration elements having the same functions and effects as the configuration elements of the screw compressors 1 according to Embodiments 1 to 5 are denoted by the same reference signs, and the description of such configuration elements will be omitted. Differences from Embodiments 1 to 5 will be described in Embodiment 6, and the configurations that are not described in Embodiment 6 are similar to the configurations of Embodiments 1 to 5. In the screw compressor 1 according to Embodiment 6, the structure of the outside protruding portions 26 is further specified.

[0088] The outside protruding portions 26 each include a lower protruding portion 26a protruding from the intermediate inner cylindrical portion 22 and an upper protruding portion 26b protruding from the lower protruding portion 26a. Of one of the outside protruding portions 26 that protrudes upward from the intermediate inner cylindrical portion 22, the lower protruding portion 26a protrudes upward from the intermediate inner cylindrical portion 22, and the upper protruding portion 26b protrudes upward from the lower protruding portion 26a. Of the other one of the outside protruding portions 26 that protrudes downward from the intermediate inner cylindrical portion 22, the lower protruding portion 26a protrudes downward from the intermediate inner cylindrical portion 22, and the upper protruding portion 26b protrudes downward from the lower protruding portion 26a.

[0089] As Fig. 16 illustrates, in each of the outside protruding portions 26, the lower protruding portion 26a has a width W4, in the circumferential direction CD of the rotating shaft 5 (refer to Fig. 1), larger than a width W5 of the upper protruding portion 26b in the circumferential direction CD of the rotating shaft 5. In addition, as Fig. 17 illustrates, in each of the outside protruding portions 26, the lower protruding portion 26a has a height H1, in a radial direction RD of the rotating shaft 5, smaller than a height H2 of the upper protruding portion 26b in the radial direction RD of the rotating shaft 5. Note that such a height is a length of each of the outside protruding portions 26 in a radial direction RD. One of the outside protruding portions 26, with its lower protruding portion 26a and its upper protruding portions 26b, is formed such that a section perpendicular to the axial direction AD of the rotating shaft 5 has an inverse T shape.

(Functions and Effects of Screw Compressor 1)

[0090] The outside protruding portions 26 each include the lower protruding portion 26a protruding from the intermediate inner cylindrical portion 22 and the upper protruding portion 26b protruding from the lower protruding portion 26a. The screw compressor 1 having the above-described configuration enables increase in the major axis-side rigidity of the casing 2, which may be deformed into an oval shape by internal pressure, thereby enabling prevention or reduction of deformation of the casing 2 caused by internal pressure.

[0091] In addition, in each of the outside protruding portions 26, the width W4 of the lower protruding portion 26a in the circumferential direction CD of the rotating shaft 5 (refer to Fig. 1) is larger than the width W5 of the upper protruding portion 26b in the circumferential direction CD of the rotating shaft 5. Moreover, in each of the outside protruding portions 26, the height H1 of the lower protruding portion 26a in a radial direction RD of the rotating shaft 5 is smaller than the height H2 of the upper protruding portion 26b in the radial direction RD of the rotating shaft 5. The outside protruding portions 26 each including the lower protruding portion 26a and the upper protruding portion 26b, which have the above-described configurations, enables reduction of a material to be used compared with a case where the entire outside protruding portions 26 each have the width W4 of the lower protruding portion 26a. Thus, with the outside protruding portions 26 each including the lower protruding portion 26a and the upper protruding portion 26b, the material costs can be reduced while the rigidity is ensured.

Embodiment 7

[0092] Fig. 18 is a schematic side view illustrating schematically a side face of the casing 2 of the screw compressor 1 according to Embodiment 7. Note that a schematic top view of the casing 2 of the screw compressor 1 according to Embodiment 7 is similar to the schematic top view illustrated in Fig. 13 or Fig. 15. In addition, the configuration elements having the same functions and effects as the configuration elements of the screw compressors 1 according to Embodiments 1 to 6 are denoted by the same reference signs, and the description of such configuration elements will be omitted. Differences from Embodiments 1 to 6 will be described in Embodiment 7, and the configurations that are not described in Embodiment 7 are similar to the configurations of Embodiments 1 to 6. In the screw compressor 1 according to Embodiment 7, the structure of the outside protruding portions 26 according to Embodiment 5 is further specified.

[0093] As described above, in the casing 2, in the axial direction AD of the rotating shaft 5, a discharge-side end portion is the end portion 2a on one side on which refrigerant is discharged, and a suction-side end portion is the end portion 2b on the other side on which refrigerant is sucked. The outside protruding portions 26 are each formed such that a height H of the outside protruding portion 26 decreases gradually from the discharge-side end portion toward the suction-side end portion. In other words, the outside protruding portions 26 are each formed such that the height H of the outside protruding portion 26 increases gradually from the motor accommodation portion 27 side toward the discharge-side end portion.

(Functions and Effects of Screw Compressor 1)

[0094] The outside protruding portions 26 are each formed such that the height H of the outside protruding portion 26 increases gradually from the motor accommodation portion 27 side toward the discharge-side end portion. With the screw compressor 1 having the above-described configuration, deformation of the discharge-side part of the cylindrical portion 20 (refer to Fig. 1) of the casing 2 due to internal pressure can be prevented or reduced in particular, and refrigerant gas can thereby be prevented from leaking from the high-pressure side of the compression chambers 14 whose difference in pressure from the low-pressure side is large.

[0095] Embodiments 1 to 7 described above may be implemented in combination with one another. In addition, the configurations represented by the above-described embodiments are examples and may be combined with another known technique, and a part of the configurations may be omitted or changed without departing from the spirit.

Reference Signs List

[0096] 1: screw compressor, 1L: screw compressor, 2: casing, 2a: end portion, 2b: end portion, 3: screw rotor, 3a: screw groove, 4: motor, 4a: stator, 4b: motor rotor, 5: rotating shaft, 6: gate rotor, 6a: gate-rotor tooth, 6b: gate-rotor support, 7: discharge flow passage, 7a: inlet portion, 7b: outlet portion, 8: discharge port, 10: slide valve, 10a: guide portion, 10b: coupling portion, 10c: valve body portion, 10d: coupling rod, 11: slide-valve driving mechanism, 12: main bearing, 13: bearing housing, 14: compression chamber, 15: low-pressure chamber, 16: high-pressure chamber, 20: cylindrical portion, 21: inner cylindrical portion, 21a: inner circumferential wall, 21b: outer circumferential wall, 21c: inside through hole, 22: intermediate inner cylindrical portion, 22a: inner circumferential wall, 22b: outer circumferential wall, 23: outer cylindrical portion, 23a: inner circumferential wall, 23b: outer circumferential wall, 23c: bottom wall portion, 24: semicylindrical portion, 24a: apex portion, 24b: slide-valve accommodation groove, 25: protruding portion, 25a: tapered portion, 26: outside protruding portion, 26a: lower protruding portion, 26b: upper protruding portion, 27: motor accommodation portion

Claims

1. A screw compressor comprising:

a casing forming a contour;
a screw rotor accommodated inside the casing such that the screw rotor is movable and having an outer circumferential wall having a helical groove;
a gate rotor accommodated inside the casing and having a tooth that meshes with the helical groove of the screw rotor; and
a slide valve accommodated inside the casing and disposed such that the slide valve is slidable in an axial direction of a rotating shaft of the screw rotor,
the casing including
an inner cylindrical portion having a hollow cylindrical shape and housing the screw rotor,
an intermediate inner cylindrical portion having a hollow cylindrical shape such that an inner circumferential wall of the intermediate inner cylindrical portion faces an outer circumferential wall of the inner cylindrical portion at an end portion of the casing on one side in the axial direction of the rotating shaft,
an outer cylindrical portion having a hollow cylindrical shape such that an inner circumferential wall of the outer cylindrical portion faces an outer circumferential wall of the intermediate inner cylindrical portion at the end portion of the casing on the one side in the axial direction of the rotating shaft and formed in the axial direction of the rotating shaft,
a semicylindrical portion serving as a wall portion forming a semicylindrical groove inside the intermediate inner cylindrical portion, the semicylindrical portion being formed integrally with the inner cylindrical portion and the intermediate inner cylindrical portion and housing the slide valve inside the semicylindrical portion, and
a protruding portion serving as a wall extending in a radial direction of the rotating shaft and in the axial direction of the rotating shaft, the protruding portion protruding from the outer circumferential wall of the intermediate inner cylindrical portion at a position where the semicylindrical portion and the intermediate inner cylindrical portion are integrated to each other.

2. The screw compressor of claim 1, wherein

the protruding portion includes,
in a radial direction of the rotating shaft, an end portion on one side formed integrally with the intermediate inner cylindrical portion and an end portion on an other side formed integrally with the outer cylindrical portion, and the protruding portion has a columnar shape connecting the intermediate inner cylindrical portion and the outer cylindrical portion to one another.

3. The screw compressor of claim 1 or 2, wherein

the protruding portion has
a length equal to or a length smaller than a length of the semicylindrical portion in the axial direction of the rotating shaft.

4. The screw compressor of any one of claims 1 to 3, wherein

the casing includes,
in the axial direction of the rotating shaft, a discharge-side end portion that is an end portion on one side on which refrigerant is discharged and a suction-side end portion that is an end portion on an other side on which refrigerant is sucked, and
the protruding portion includes
a tapered portion formed such that a width of the protruding portion decreases from the discharge-side end portion toward the suction-side end portion.

5. The screw compressor of any one of claims 1 to 4, wherein

the casing further includes
an outside protruding portion that is a wall extending in a radial direction of the rotating shaft and in the axial direction of the rotating shaft and protruding from the outer circumferential wall of the intermediate inner cylindrical portion, and
the outside protruding portion includes,
in a radial direction of the rotating shaft, an end portion on one side formed integrally with the intermediate inner cylindrical portion and an end portion on an other side protruding toward an outside of the casing.

6. The screw compressor of claim 5, further comprising

a motor coupled to the rotating shaft, wherein
the casing includes
a motor accommodation portion housing the motor at an end portion of the casing on an other side in the axial direction of the rotating shaft,
the motor accommodation portion has
a hollow cylindrical shape and has an outside diameter larger than an outside diameter of the intermediate inner cylindrical portion, and
the outside protruding portion is formed,
in the axial direction of the rotating shaft, integrally with the outer cylindrical portion and the motor accommodation portion such that the outside protruding portion connects the outer cylindrical portion and the motor accommodation portion to one another.

7. The screw compressor of claim 6, wherein

the casing includes,
in the axial direction of the rotating shaft, a discharge-side end portion that is an end portion on one side on which refrigerant is discharged and a suction-side end portion that is an end portion on an other side on which refrigerant is sucked, and
the outside protruding portion is formed such that a height of the outside protruding portion increases gradually from a region of the motor accommodation portion toward the discharge-side end portion.

8. The screw compressor of any one of claims 5 to 7, wherein

the outside protruding portion is formed such that a width of the outside protruding portion in a circumferential direction of the rotating shaft is smaller than a length of the outside protruding portion in the axial direction of the rotating shaft.

9. The screw compressor of any one of claims 5 to 8, wherein

the casing includes,
in the axial direction of the rotating shaft, a discharge-side end portion that is an end portion on one side on which refrigerant is discharged and a suction-side end portion that is an end portion on an other side on which refrigerant is sucked, and
the outside protruding portion is formed such that a width of the outside protruding portion decreases from the discharge-side end portion toward the suction-side end portion.

10. The screw compressor of any one of claims 5 to 9, wherein

the outside protruding portion includes
a lower protruding portion protruding from the intermediate inner cylindrical portion, and
an upper protruding portion protruding from the lower protruding portion,
a width of the lower protruding portion in a circumferential direction of the rotating shaft is larger than a width of the upper protruding portion in the circumferential direction of the rotating shaft, and
a height of the lower protruding portion in a radial direction of the rotating shaft is smaller than a height of the upper protruding portion in a radial direction of the rotating shaft.

FIG. 1

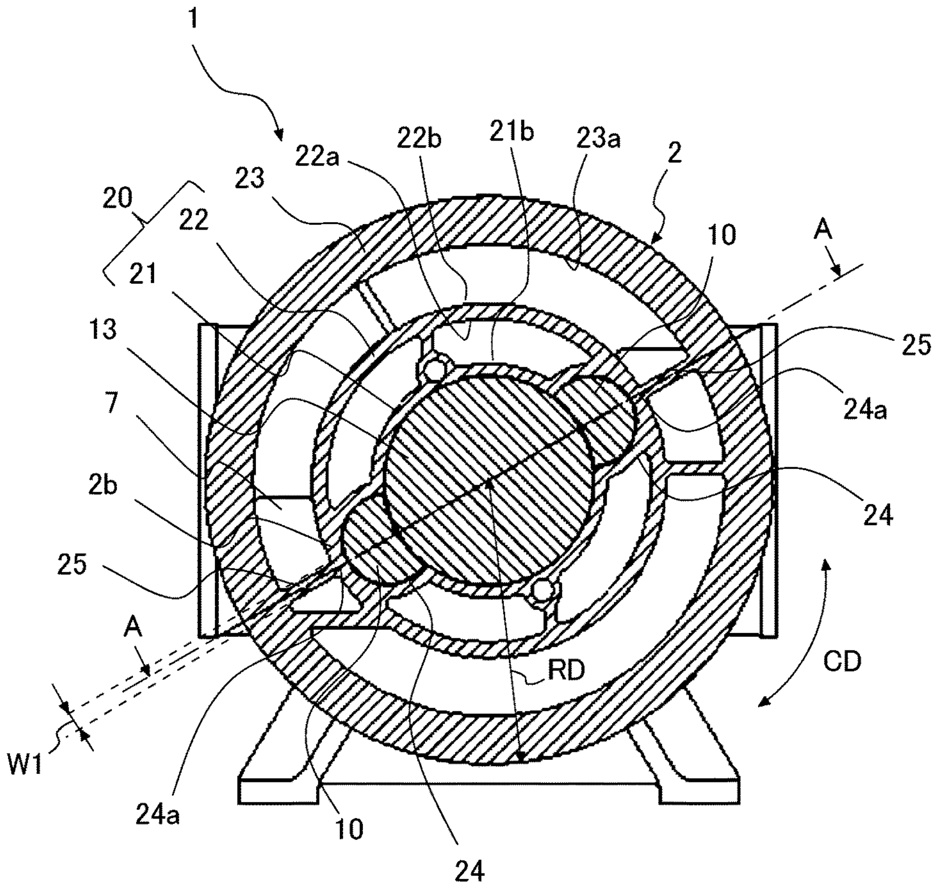

1
22a
22b
21b
23a
2
23
20
22
21
10
A
25
24a
13
7
24
2b
25
A
RD
CD
W1
24a
10
24

FIG. 2

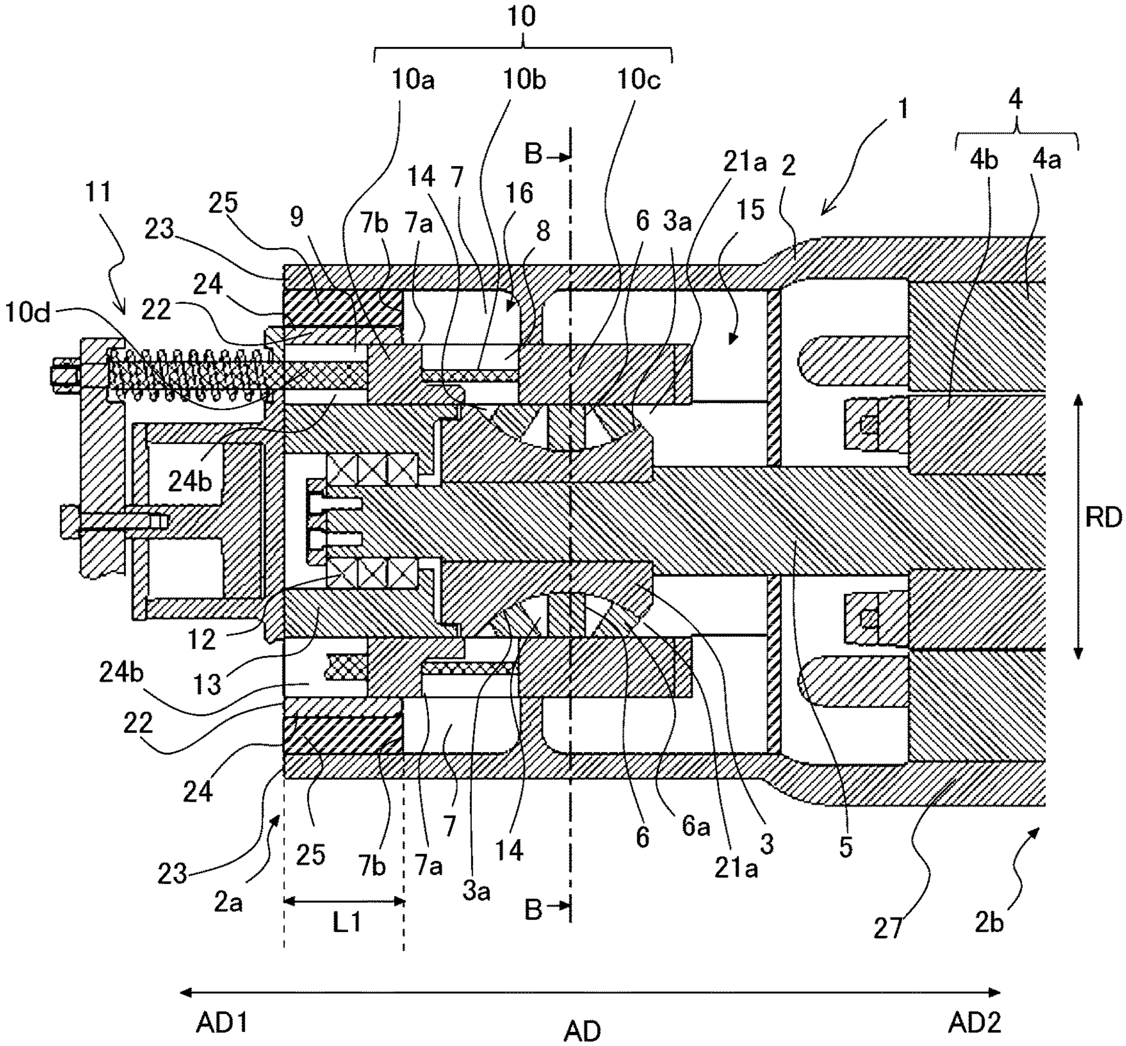
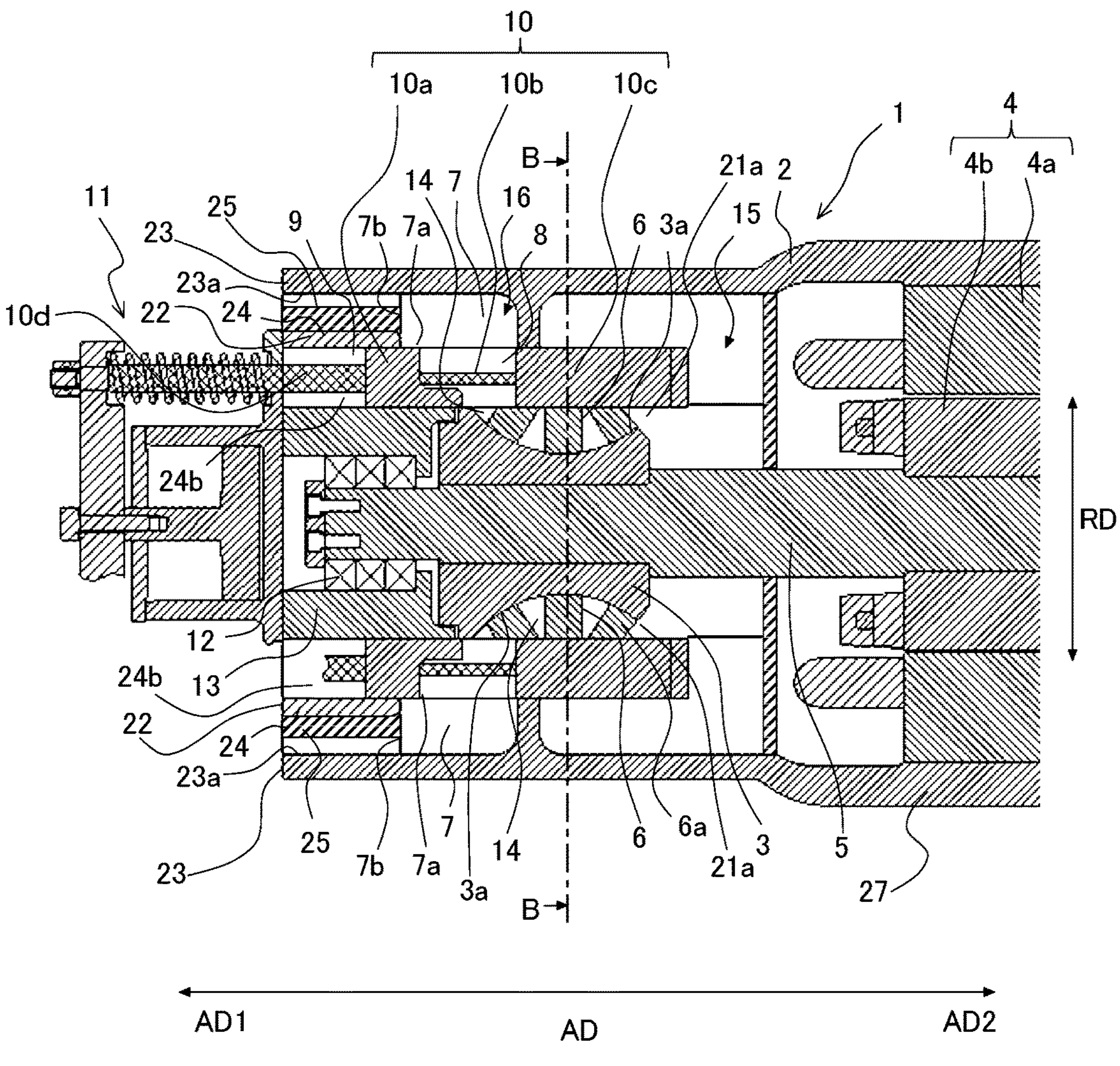

10
10a
10b
10c
1
4
4b
4a
11
25
9
14
7
B
16
21a
2
23
7b
7a
8
6
3a
15
24
10d
22
24b
RD
12
13
24b
22
24
23
2a
25
7b
7a
7
3a
14
B
6
6a
21a
3
5
27
2b
L1
AD1
AD
AD2

FIG. 3



10
10a
10b
10c
1
4
4b
4a
11
10d
25
23
23a
22
24
9
7b
7a
14
7
16
8
B
6
3a
21a
2
15
24b
12
13
22
24
23a
23
25
7b
7a
7
3a
14
6
6a
21a
3
5
27
RD
AD1
AD
AD2

FIG. 4

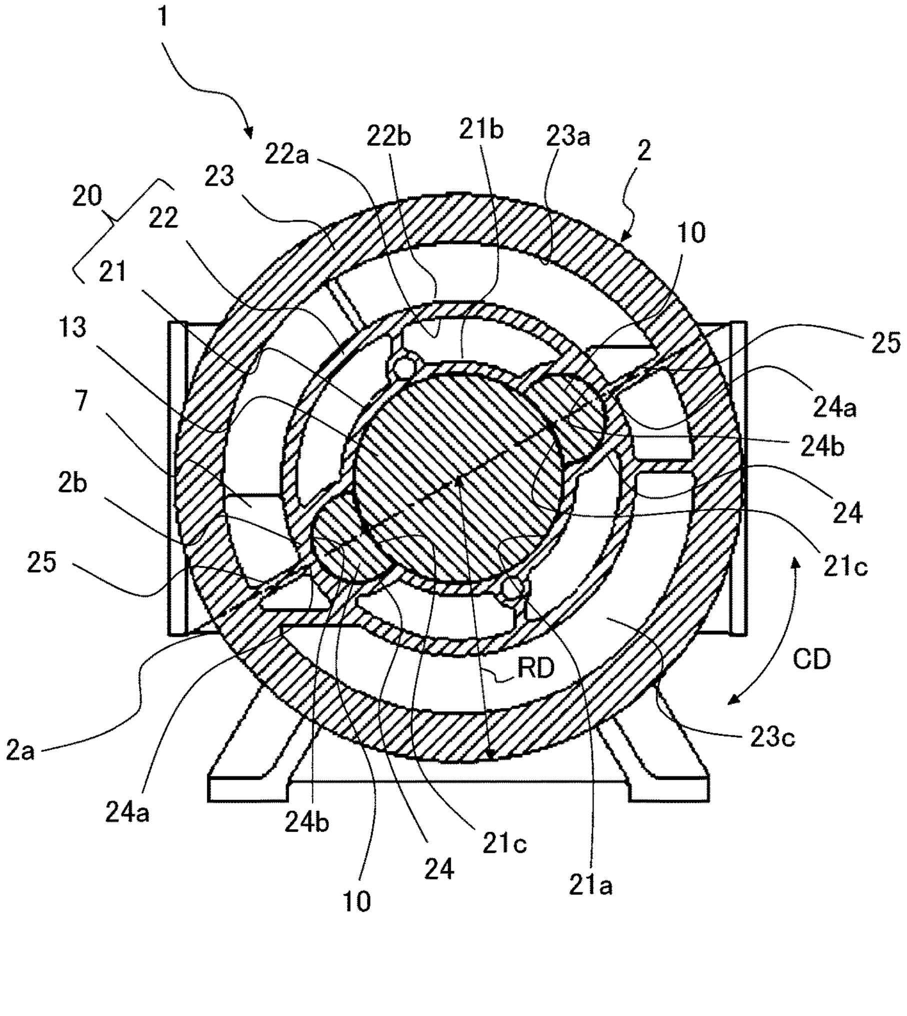

1
22a
22b
21b
23a
2
20
23
22
10
21
25
13
24a
7
24b
24
2b
21c
25
CD
RD
2a
23c
24a
24b
24
21c
21a
10

FIG. 5

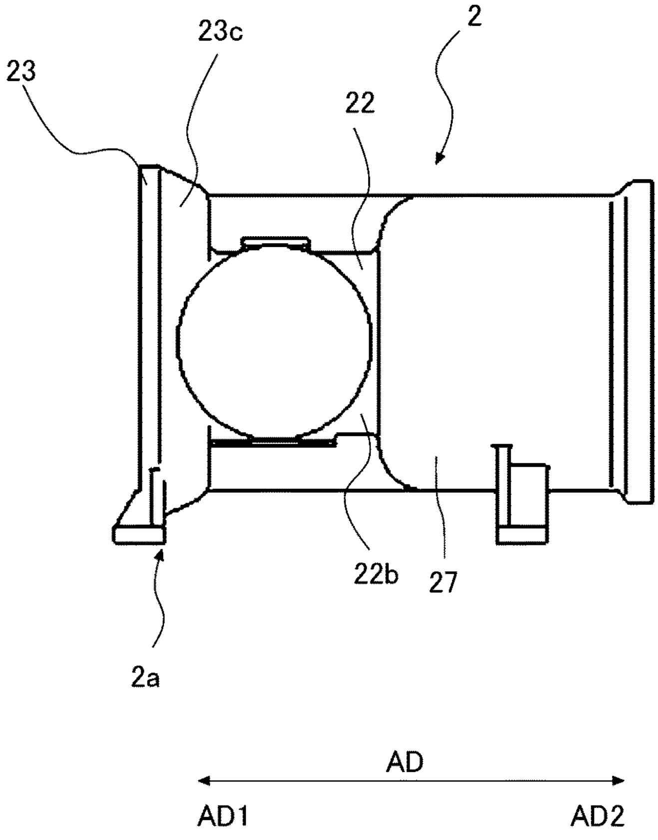


FIG. 6

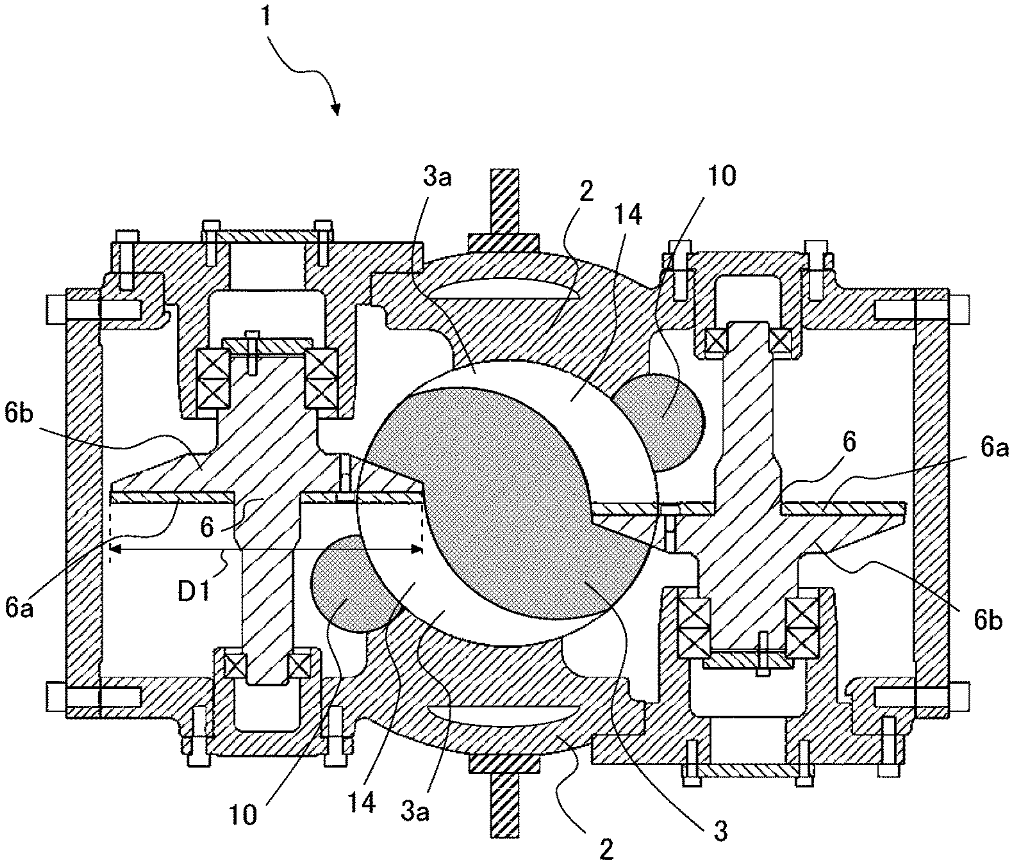
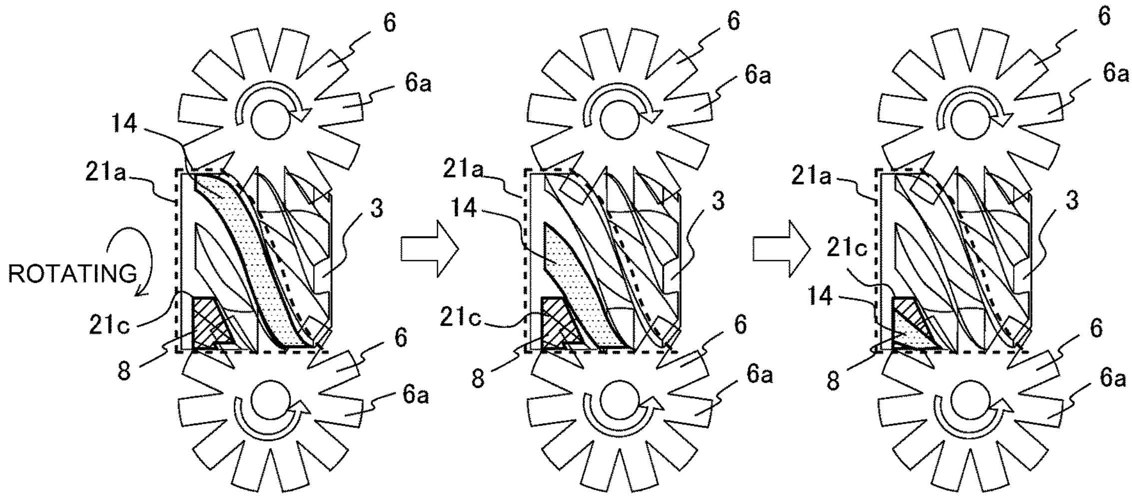


FIG. 7



(a) SUCTION (b) COMPRESSION (c) DISCHARGE

FIG. 8

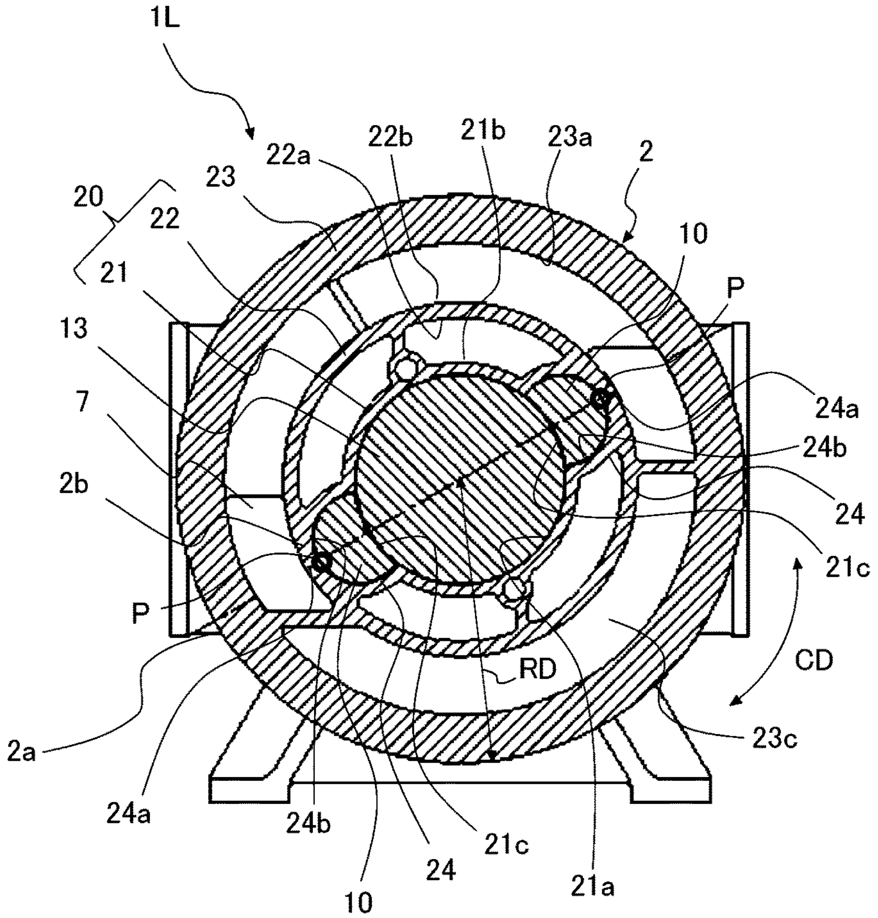

1L
22a
22b
21b
23a
2
23
20
22
10
P
21
13
24a
7
24b
24
2b
21c
P
CD
RD
2a
23c
24a
24b
21c
24
21a
10

FIG. 9

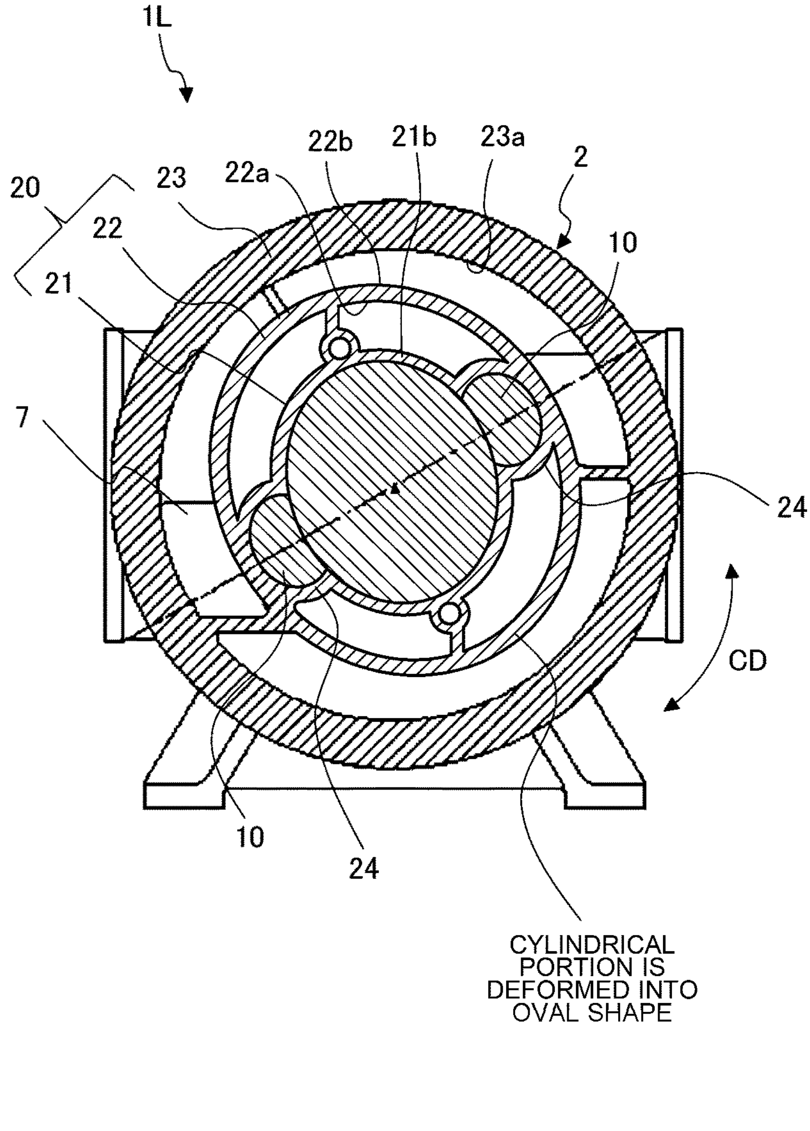

1L
20
23
22a
22b
21b
23a
2
22
21
10
7
24
CD
10
24
CYLINDRICAL PORTION IS DEFORMED INTO OVAL SHAPE

FIG. 10

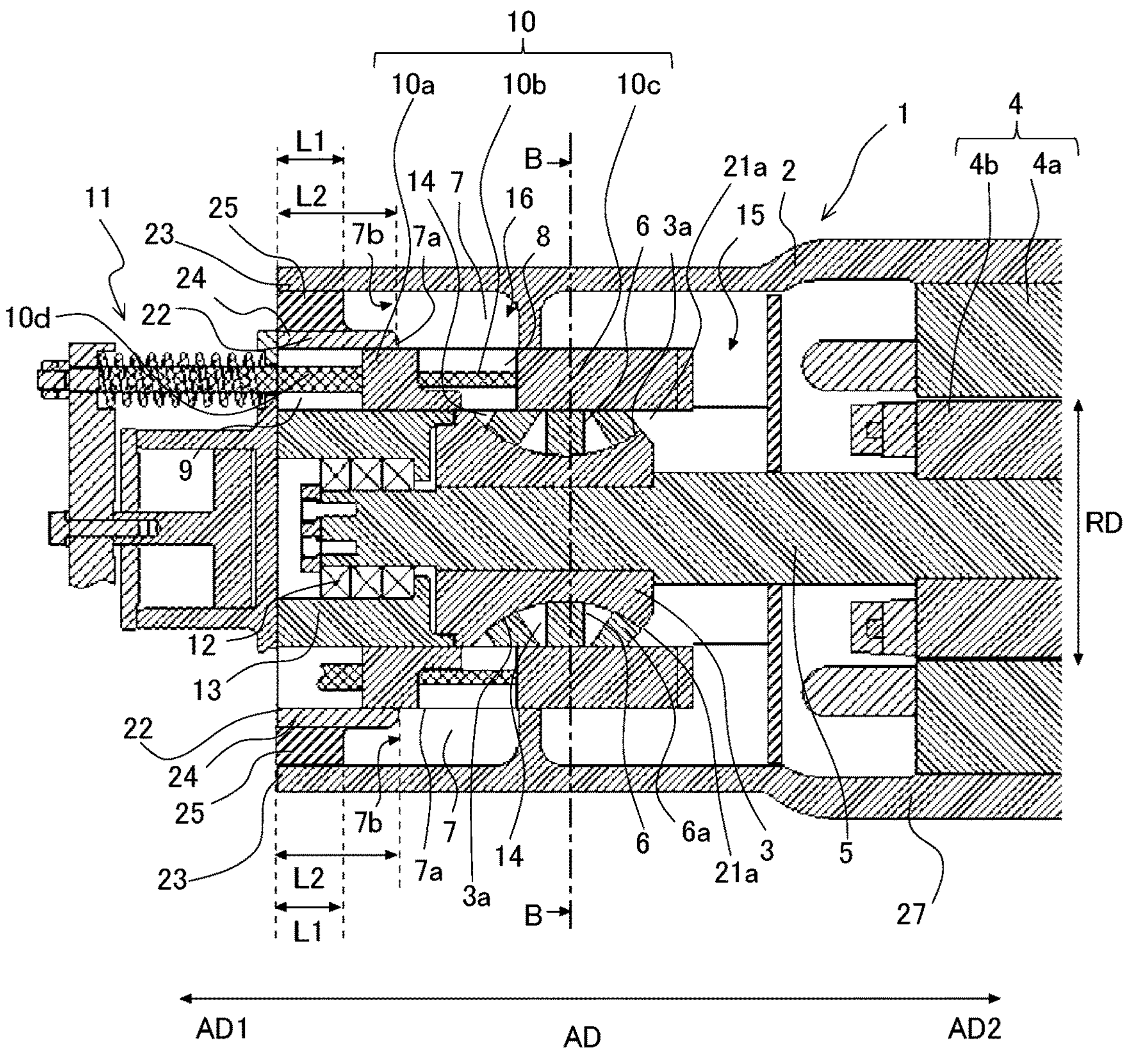

10
10a
10b
10c
1
4
4b
4a
L1
L2
B
14
7
16
8
6
3a
21a
2
15
11
25
23
7b
7a
24
22
10d
9
RD
12
13
5
6a
3
27
AD1
AD
AD2

FIG. 11

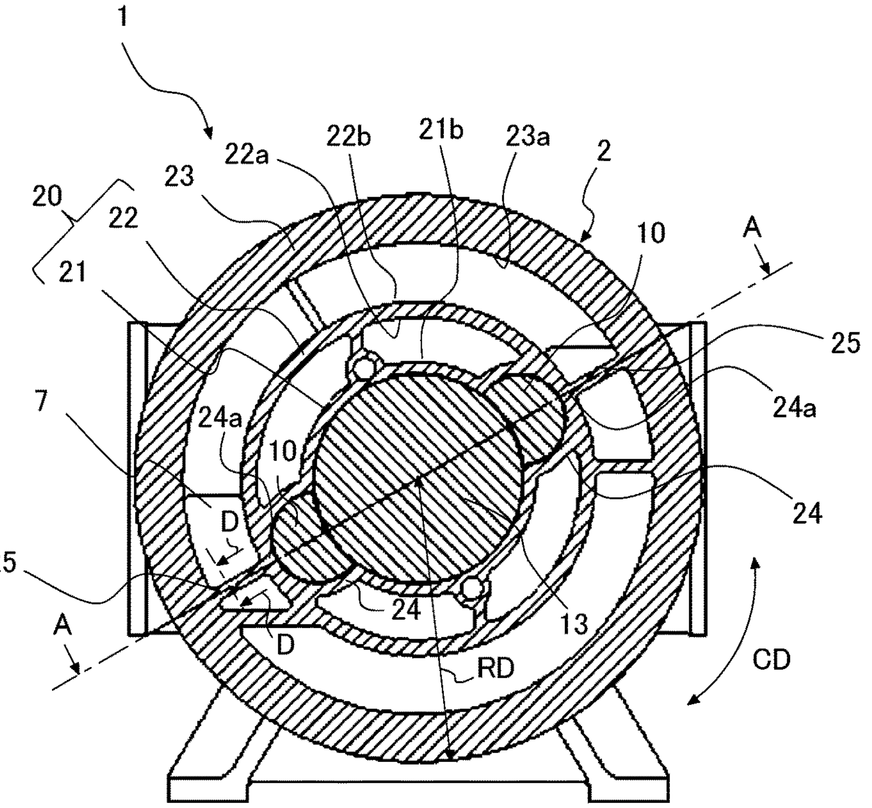

1
22a
22b
21b
23a
2
20
23
22
10
A
21
25
24a
7
24a
10
24
D
25
D
24
13
A
D
RD
CD

FIG. 12

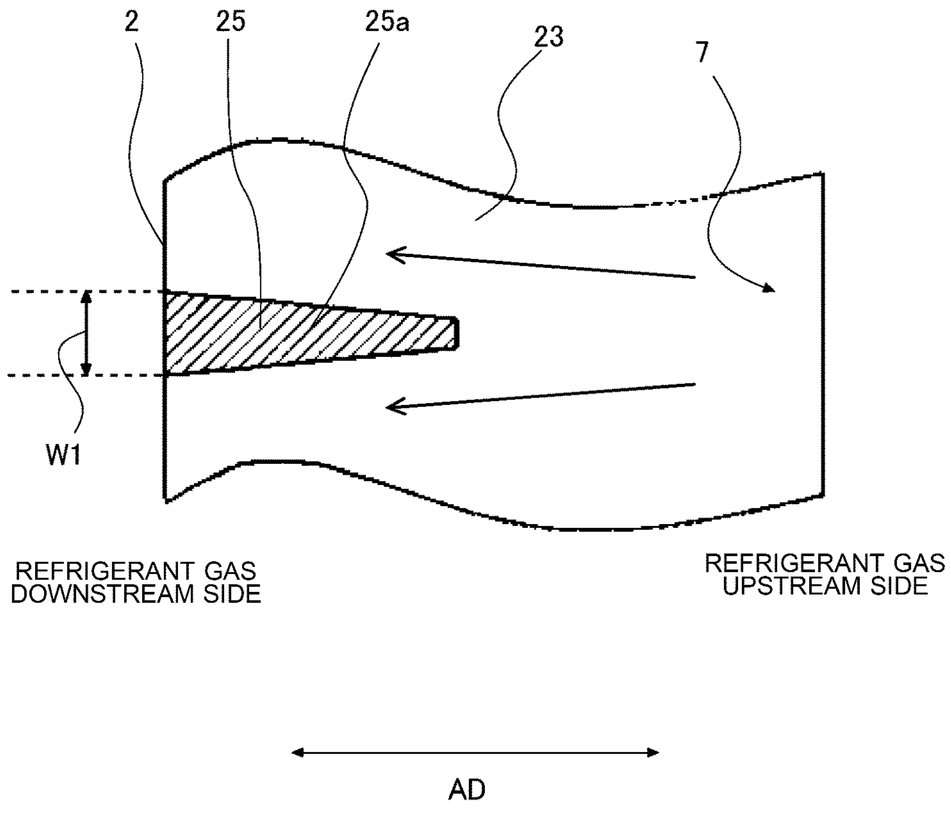

2
25
25a
23
7
W1
REFRIGERANT GAS
DOWNSTREAM SIDE
REFRIGERANT GAS
UPSTREAM SIDE
AD

FIG. 13

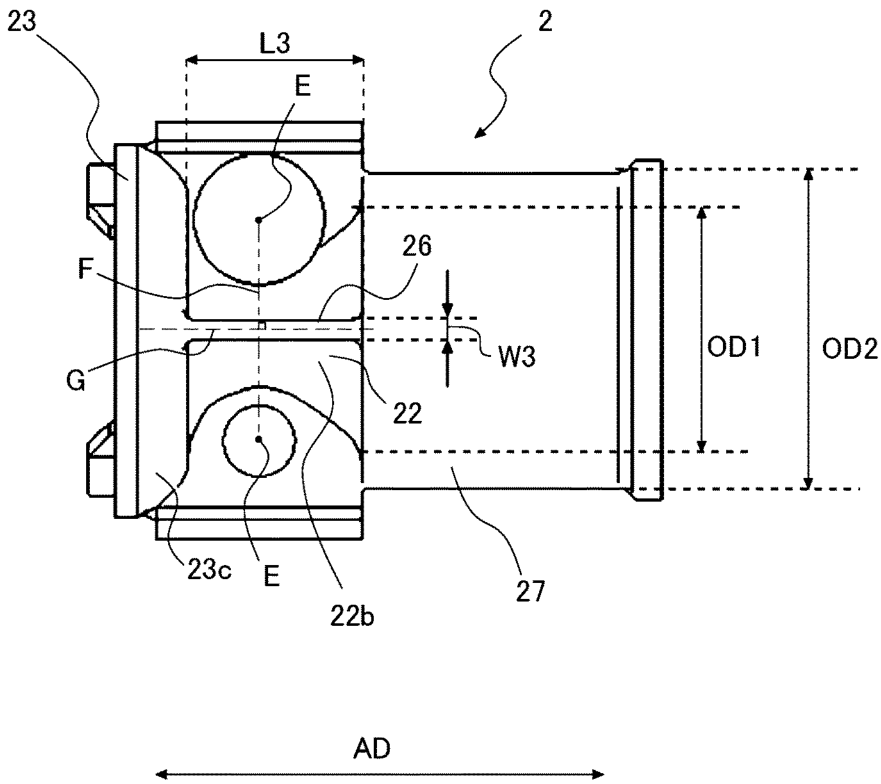


FIG. 14

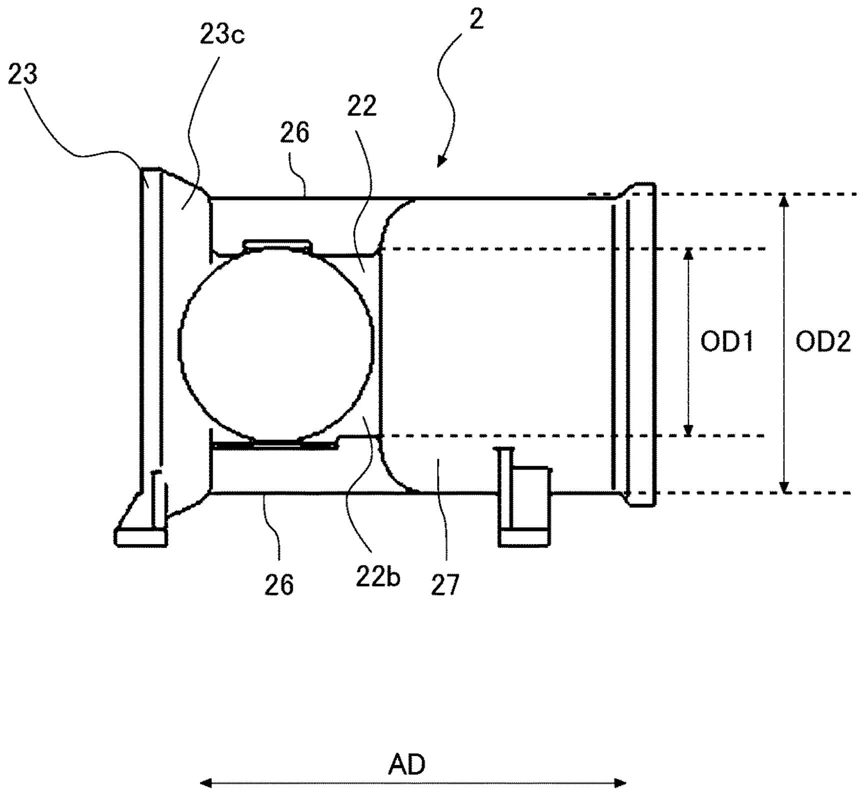


FIG. 15

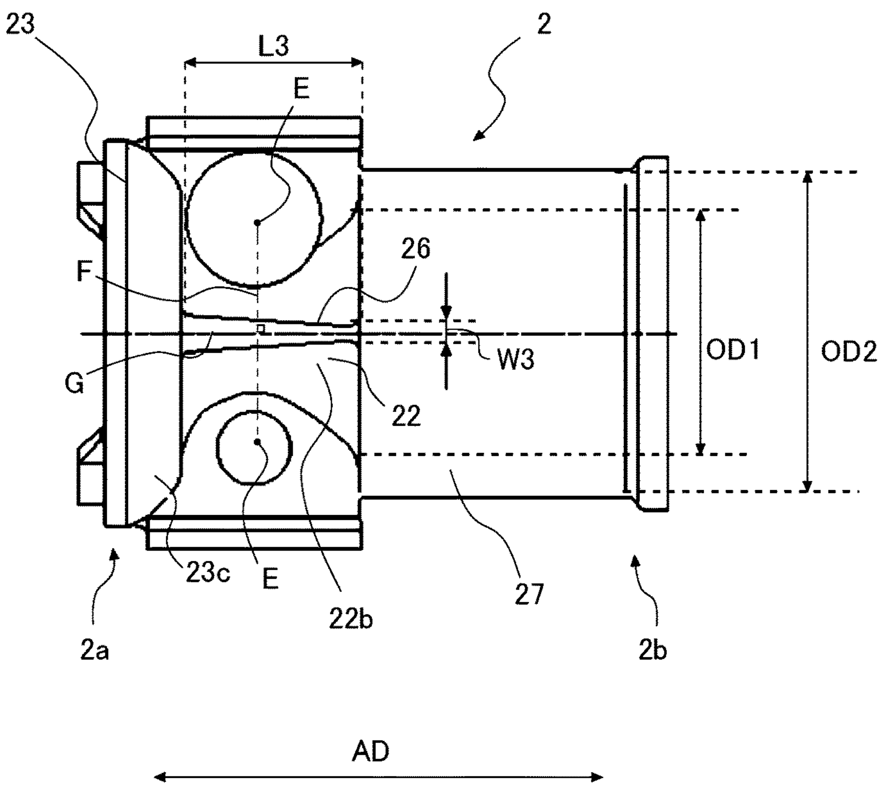


FIG. 16

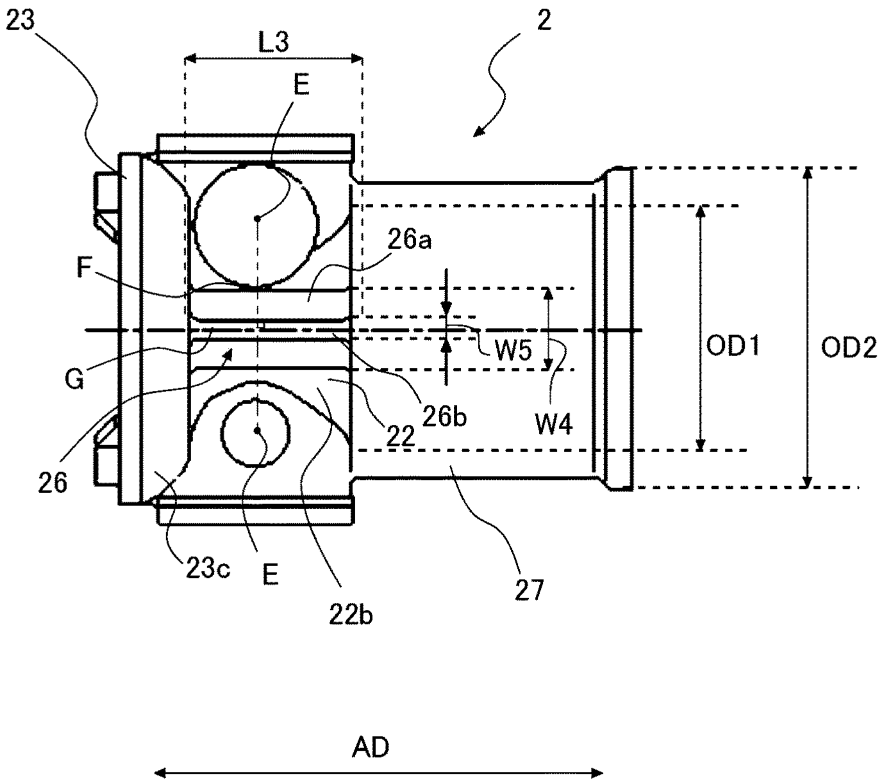


FIG. 17

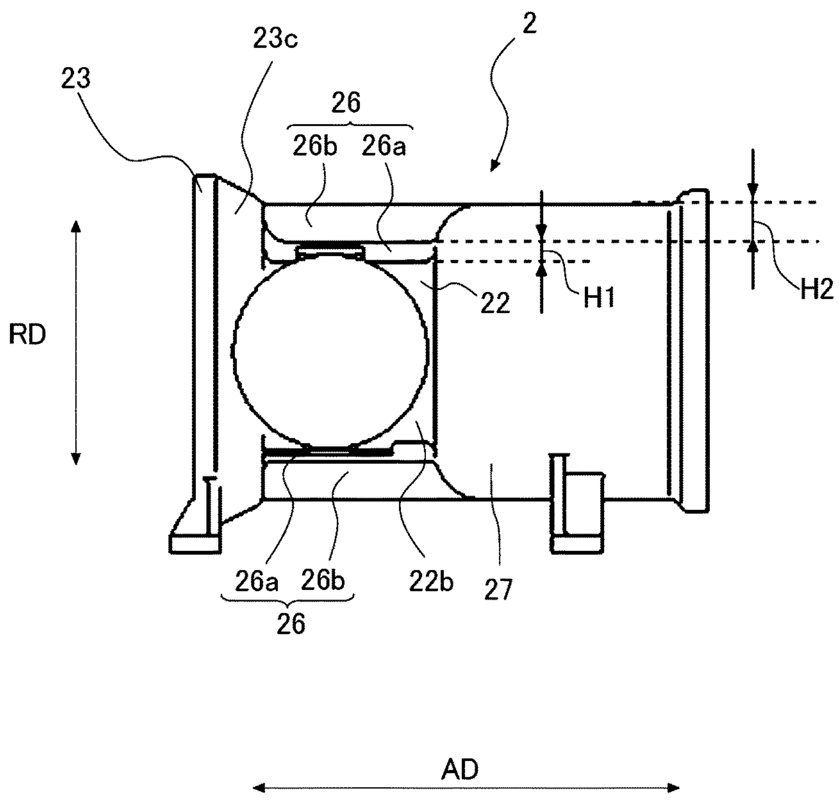
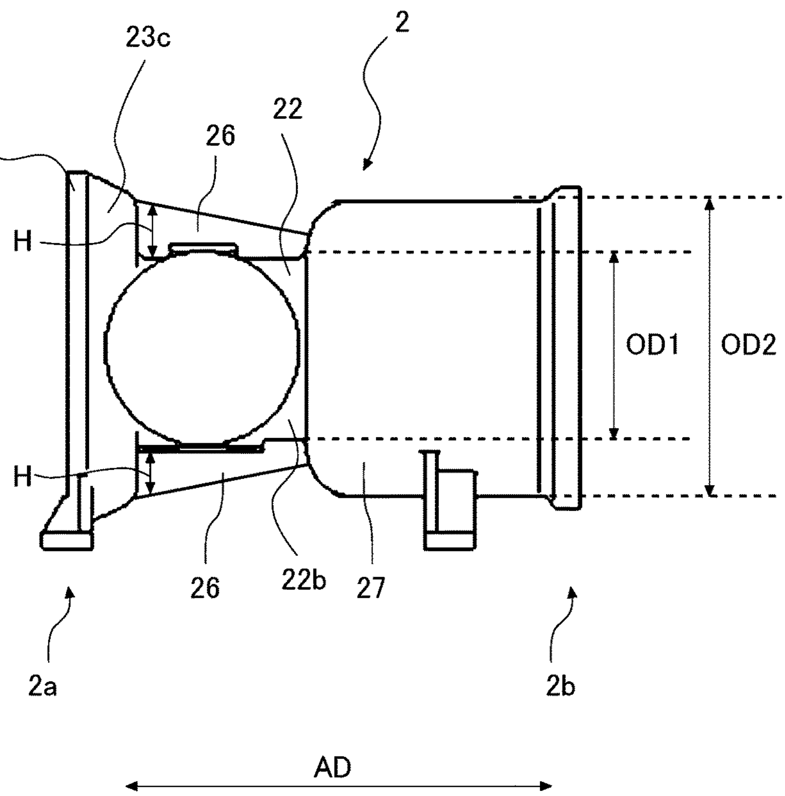


FIG. 18



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/023329

A. CLASSIFICATION OF SUBJECT MATTER
F04C 18/52(2006.01)i; F04C 29/00(2006.01)i
FI: F04C18/52; F04C29/00 B

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04C18/52; F04C29/00

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2017-145732 A (DAIKIN IND LTD) 24 August 2017 (2017-08-24) paragraphs [0023]-[0077], fig. 1-2, 6	1-10
A	JP 2019-7399 A (DAIKIN IND LTD) 17 January 2019 (2019-01-17) fig. 3	1-10

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 July 2021 (19.07.2021)	27 July 2021 (27.07.2021)

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

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/023329

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2017-145732 A	24 Aug. 2017	WO 2017/141768 A1 EP 3385539 A1 paragraphs [0023]-[0077], fig. 1-2, 6 CN 108431421 A	
JP 2019-7399 A	17 Jan. 2019	(Family: none)	

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

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Patent documents cited in the description

- JP 2009243412 A **[0005]**