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

(11) EP 3 978 759 A1

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

(43) Date of publication:
06.04.2022 Bulletin 2022/14

(21) Application number: **19930726.5**

(22) Date of filing: **28.05.2019**

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

(52) Cooperative Patent Classification (CPC):
F04C 18/52

(86) International application number:
PCT/JP2019/020999

(87) International publication number:
WO 2020/240678 (03.12.2020 Gazette 2020/49)

(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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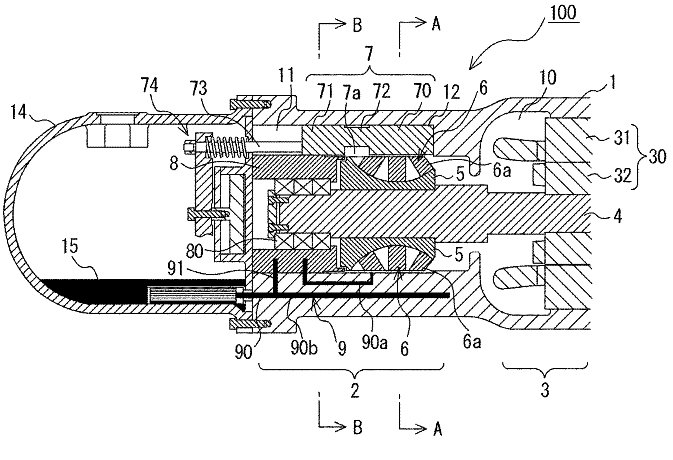
(54) SCREW COMPRESSOR

(57) A screw compressor includes a casing forming an outer shell, a screw shaft configured to be driven to rotate, a screw rotor fixed to the screw shaft, a gate rotor forming, together with the casing and the screw rotor, a compression chamber in which to compress refrigerant, a slide valve configured to slide in a direction parallel to an axis of rotation of the screw rotor, a bearing housing having a bearing inside, the bearing being configured to support one end of the screw shaft so that the screw shaft is able to rotate, an oil separator configured to separate oil mixed into refrigerant compressed in the compression chamber, and a heating mechanism connected to the oil separator and configured to, by utilizing oil separated by the oil separator, thermally expand the bearing housing in a radial direction during operation.

FIG. 1



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Description

Technical Field

[0001] The present disclosure relates to a screw compressor for use in the compression of refrigerant, for example, in a refrigerating machine or other machines.

Background Art

[0002] As disclosed in Patent Literature 1, a screw compressor is known as a type of displacement compressor, and is used as a component of a refrigerant circuit built, for example, in a refrigerating machine or other machines. A known example of a screw compressor is a single-screw compressor including a casing in which one screw rotor having a spiral tooth groove and two gate rotors each having a plurality of gate rotor tooth portions configured to fit into the tooth groove of the screw rotor are housed. The single-screw compressor has a plurality of compression chambers formed by the tooth groove of the screw rotor and the gate rotor tooth portions of the gate rotors meshing and engaging with each other. One end of the screw rotor in a direction parallel to the axis of rotation serves as a suction side through which refrigerant is suctioned, and the other end of the screw rotor in a direction parallel to the axis of rotation serves as a discharge side through which refrigerant is discharged. The casing has its interior partitioned into a low-pressure space provided at a suction side of the compression chambers and a high-pressure space provided at a discharge side of the compression chambers.

[0003] The screw rotor is fixed to a screw shaft configured to be rotated by a drive unit provided in the casing. One axial end portion of the screw shaft is supported by a bearing housing having a bearing inside so that the screw shaft can rotate, and the other axial end portion of the screw shaft is coupled to the drive unit. The screw compressor is configured such that when the screw rotor is driven to rotate by the screw shaft being rotated by the drive unit, refrigerant in the low-pressure space is suctioned into the compression chambers, compressed in the compression chambers, and discharged into the high-pressure space.

[0004] Incidentally, there is a type of screw compressor including a pair of slide valves disposed in a slide groove formed in an inner cylindrical surface of a casing and provided so that the pair of slide valves can slide in a direction parallel to the axis of rotation of a screw rotor. The slide valves slide in a direction parallel to the axis of rotation of the screw rotor, and is provided to effect a change in internal volume ratio by varying discharge opening timing by changing the start position of discharge of high-pressure gas refrigerant compressed in a compression chamber. Each of these slide valves includes a valve body portion facing the screw rotor and a guide portion forming a sliding surface facing an outer circumferential surface of a bearing housing.

[0005] The screw compressor has a risk that a thermal expansion of the screw rotor by a rise in temperature of the refrigerant gas compressed in the compression chamber may cause reduced spacings between an outer circumferential surface of the screw rotor and the inner cylindrical surface of the casing and between the outer circumferential surface of the screw rotor and the slide valve. Further, the screw compressor has a risk that the screw rotor may rotate backward due to a differential pressure in the casing after stoppage of operation. The inverse rotation of the screw rotor undesirably causes the valve body portion of the slide valve to fall toward the screw rotor or rotate in a circumferential direction due to the influence of, for example, a variation in internal pressure of the compression chamber. As a result, the valve body portion of the slide valve may partially protrude from an inner circumferential surface of a casing bore to make contact with the screw rotor, which may invite a seizure or other trouble.

[0006] To address this problem, Patent Literature 1 discloses a structure in which contact between a slide valve and the screw rotor is avoided by providing a guide portion of the slide valve with a protruding portion relatively protruding more in a circumferential direction than a valve body portion of the slide valve and bringing the protruding portion into contact with a bearing holder when the slide valve rotates in a circumferential direction.

Citation List

Patent Literature

[0007] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2013-60877

Summary of Invention

Technical Problem

[0008] In the screw compressor of Patent Literature 1, in a case where there has occurred a torsional deformation between the valve body portion and the guide portion of the slide valve, the spacing between the valve body portion and the screw rotor is reduced more than necessary even when the protruding portion provided on the guide portion comes into contact with the bearing holder, with the result that the slide valve and the screw rotor may make contact with each other.

[0009] The present disclosure has been made to solve such a problem, and has as an object to provide a highly-reliable screw compressor capable of reducing contact between a slide valve and a screw rotor.

Solution to Problem

[0010] A screw compressor according to an embodiment of the present disclosure includes a casing forming an outer shell, a screw shaft disposed in the casing and configured to be driven to rotate, a screw rotor, fixed to the screw shaft, that has a spiral tooth groove in an outer circumferential surface thereof, a gate rotor having a plurality of gate rotor tooth portions configured to fit into the tooth groove of the screw rotor and forming, together with the casing and the screw rotor, a compression chamber in which to compress refrigerant, a slide valve provided in a slide groove formed in an inner cylindrical surface of the casing and configured to slide in a direction parallel to an axis of rotation of the screw rotor, a bearing housing having a bearing inside and having an outer peripheral surface on which the slide valve slides, the bearing being configured to support one end of the screw shaft so that the screw shaft is able to rotate, an oil separator configured to separate oil mixed into refrigerant compressed in the compression chamber, and a heating mechanism connected to the oil separator and configured to, by utilizing oil separated by the oil separator, thermally expand the bearing housing in a radial direction during operation.

Advantageous Effects of Invention

[0011] In the screw compressor according to the embodiment of the present disclosure, before the valve body portion of the slide valve falls toward the screw rotor or rotates in a circumferential direction, the bearing housing, which has thermally expanded, comes into contact with the slide valve to support the slide valve. This makes it possible to reduce contact between the slide valve and the screw rotor and achieve a highly-reliable screw compressor.

Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is a cross-sectional view illustrating an internal structure of a screw compressor according to Embodiment 1.

[Fig. 2] Fig. 2 illustrates the internal structure of the screw compressor according to Embodiment 1 and illustrates a portion different from that shown in Fig. 1.

[Fig. 3] Fig. 3 is an enlarged cross-sectional view of main components as taken along line A-A in Fig. 1.

[Fig. 4] Fig. 4 is an enlarged cross-sectional view of main components as taken along line B-B in Fig. 1.

[Fig. 5] Fig. 5 is a perspective view illustrating a structure of a bearing housing of the screw compressor according to Embodiment 1.

[Fig. 6] Fig. 6 is an explanatory diagram illustrating a suction step of an operation of a compression unit of the screw compressor according to Embodiment 1.

[Fig. 7] Fig. 7 is an explanatory diagram illustrating a compression step of the operation of the compression unit of the screw compressor according to Embodiment 1.

[Fig. 8] Fig. 8 is an explanatory diagram illustrating a discharge step of the operation of the compression unit of the screw compressor according to Embodiment 1.

[Fig. 9] Fig. 9 is a cross-sectional view illustrating an internal structure of a screw compressor according to Embodiment 2.

[Fig. 10] Fig. 10 is a perspective view illustrating a structure of a bearing housing of the screw compressor according to Embodiment 2.

[Fig. 11] Fig. 11 is a cross-sectional view illustrating an internal structure of a screw compressor according to Embodiment 3.

Description of Embodiments

[0013] The following describes embodiments with reference to the drawings. Identical or equivalent components are given identical signs throughout the drawings, and a description of such components is omitted or simplified as appropriate. Further, the shapes, sizes, and locations, or other attributes of components shown in the drawings are subject to change as appropriate.

Embodiment 1

[0014] Fig. 1 is a cross-sectional view illustrating an internal structure of a screw compressor according to Embodiment 1. Fig. 2 illustrates the internal structure of the screw compressor according to Embodiment 1 and illustrates a portion different from that shown in Fig. 1. Fig. 3 is an enlarged cross-sectional view of main components as taken along line A-A in Fig. 1. Fig. 4 is an enlarged cross-sectional view of main components as taken along line B-B in Fig. 1. Fig. 5 is a perspective view illustrating a structure of a bearing housing of the screw compressor according to Embodiment 1.

[0015] The screw compressor 100 according to Embodiment 1 is described by taking a single-stage single-screw compressor as an example. As shown in Figs. 1 and 2, the screw compressor 100 includes a cylindrical casing forming an outer shell, a compression unit 2 provided in the casing 1, a drive unit 3 provided in the casing 1, and an oil separator 14 provided at one end of the exterior of the casing 1. The casing 1 has its interior partitioned into a low-pressure space 10 and a high-pressure space 11.

[0016] As shown in Figs. 1 and 2, the compression unit 2 includes a screw shaft 4, a screw rotor 5 fixed to the screw shaft 4, a pair of gate rotors 6, a gate rotor support (not illustrated), a pair of slide valves 7, and a bearing housing 8 having a bearing 80 inside and having an outer circumferential surface on which the slide valves 7 slide. The bearing 80 supports an end portion of the screw shaft 4 so that the screw shaft 4 can rotate. Further, as shown in Figs. 1 and 2, the compression unit 2 includes a heating mechanism 9 connected to the oil separator 14 and configured to, by utilizing oil separated by the oil separator 14, thermally expand the bearing housing 8 in a radial direction during operation as shown in Fig. 4.

[0017] As shown in Figs. 1 and 2, the screw shaft 4 is disposed in the casing 1 and driven to rotate by the drive unit 3. The screw shaft 4 extends in a direction parallel to the tube axis of the casing 1. One axial end portion of the screw shaft 4 is supported by the bearing 80, which is placed opposite a discharge side of the screw rotor 5, so that the screw shaft 4 can rotate, and the other axial end portion of the screw shaft 4 is coupled to the driver unit 3.

[0018] As shown in Figs. 1 to 3 and 5, the screw rotor 5 has a plurality of spiral tooth grooves 5a in an outer circumferential surface of a cylinder. The screw rotor 5 is fixed to the screw shaft 4, and rotates together with the screw shaft 4 as the screw shaft 4 is rotated by the drive unit 3. A side of the screw rotor 5 facing the low-pressure space 10 in a direction parallel to the axis of rotation serves as a suction side through which refrigerant is suctioned, and an end of the screw rotor 5 facing the high-pressure space 11 serves as a discharge side through which refrigerant is discharged. Further, a predetermined spacing S is formed between the screw rotor 5 and the slide valves 7. This is intended to prevent a seizure or other trouble from occurring, for example, due to contact during assembly of the screw compressor 100 or contact between the slide valves 7 and the screw rotor 5 during operation of the screw compressor 100.

[0019] The gate rotors 6 have outer circumferential portions each provided with a plurality of gate rotor tooth portions 6a configured to fit into the tooth grooves 5a of the screw rotor 5 and, as shown in Figs. 1 and 2, are disposed so that the screw rotor 5 is interposed between the gate rotors 6 in a radial direction. The compression unit 2 has a compression chamber 20 formed by the tooth grooves 5a of the screw rotor 5 and the gate rotor tooth portions 6a of the gate rotors 6 meshing and engaging with each other. The screw compressor 100 is configured such that two gate rotors 6 kept 180 degrees apart face one screw rotor 5. Therefore, the compression chamber 20 includes two compression chambers 20 one of which is formed above the screw shaft 20 and the other of which is formed below the screw shaft 4. The gate rotor support (not illustrated) has a plurality of gate rotor support tooth portions placed opposite the plurality of gate rotor tooth portions 6a, and serve to support the gate rotors 6.

[0020] As shown in Figs. 1 and 5, the slide valves 7 are provided in a slide groove 12 formed in an inner cylindrical surface of the casing 1, and are configured to slide in a direction parallel to the axis of rotation of the screw rotor 5. The slide valves 7 are for example internal volume ratio adjusting valves. Each of the slide valves 7 includes a valve body portion 70 facing the screw rotor 5 and a guide portion 71 having a sliding surface facing an outer circumferential surface of the bearing housing 8. The valve body portion 70 and the guide portion 71 are coupled by a coupling portion 72. Between the valve body portion 70 and the guide portion 71, a discharge port 7a is provided through which refrigerant compressed in the compression chamber 20 is discharged. The refrigerant discharged from the discharge port 7a is discharged into the high-pressure space 11 through a discharge gas passage.

[0021] The slide valve 7 is connected to a slide valve drive device 74 via a rod 73 fixed to an end face of the guide portion 71. That is, the slide valve 7 moves parallel to the screw shaft 4 as the rod 73 is driven by the slide valve drive device 74 to move in an axial direction. The slide valve drive device 74 is for example configured to drive with gas pressure, configured to drive with hydraulic pressure, or configured to drive with a motor.

[0022] In the screw compressor 100, the timing of discharge of refrigerant suctioned into the compression chamber 20 is adjusted by the valve body portion 70 of the slide valve 7 moving parallel to the screw shaft 4. Specifically, the slide valve 7 can advance the timing of discharge by being located at the suction side to advance the opening of the discharge port 7a, and can delay the timing of discharge by being moved to the discharge side to delay the opening of the discharge port 7a. That is, the screw compressor 100 operates at a low internal volume ratio when the timing of discharge is advanced, and operates at a high internal volume ratio when the timing of discharge is delayed.

[0023] As shown in Fig. 1, the bearing housing 8 is provided in proximity to an end portion of the screw rotor 5 situated at the discharge side. The bearing housing 8 is formed so that the outside diameter of the bearing housing 8 is larger than the outside diameter of the screw rotor 5. Meanwhile, since the bearing housing 8 needs to be inserted in a place in the casing 1 in which the screw rotor 5 is housed, the bearing housing 8 is formed to have an outside diameter smaller than the inside diameter of the casing 1 in the place. In some cases, the outside diameter of the bearing housing 8 may be smaller than the outside diameter of the screw rotor 5.

[0024] As shown in Figs. 1 and 2, the oil separator 14 serves to separate oil 15 mixed into gas refrigerant compressed in the compression chamber 20. The oil 15 separated by the oil separator 14 circulates through the interior of the casing 1, for example, to lubricate the bearing 80, which supports one end of the screw shaft 4 or to seal the gap between an inner wall surface of the casing 1 and the screw rotor 5.

[0025] The drive unit 3 is formed by an electric motor 30. The electric motor 30 is formed by a stator 31, fixed in internal contact with the interior of the casing 1, that has a gap in a radial direction and a motor rotor 32 disposed inside the stator 31 so that the motor rotor 32 can rotate. The motor rotor 32 is connected to an axial end portion of the screw shaft 4, and is disposed on the same axis as the screw rotor 5. In the screw compressor 100, the screw rotor 5 is rotated by the electric motor 30 driving the screw shaft 4 to rotate. In a case where the electric motor 30 is of an inverter type, the electric motor 30 is driven at a variable speed of rotation by an inverter (not illustrated) and operated with an increase or decrease in the speed of rotation of the screw shaft 4.

[0026] Next, an operation of the screw compressor 100 according to Embodiment 1 is described with reference to Figs. 6 to 8. Fig. 6 is an explanatory diagram illustrating a suction step of the operation of the screw compressor according to Embodiment 1.
Fig. 7 is an explanatory diagram illustrating a compression step of the operation of the screw compressor according to Embodiment 1. Fig. 8 is an explanatory diagram illustrating a discharge step of the operation of the screw compressor according to Embodiment 1. It should be noted that Figs. 6 to 8 describe the respective steps with attention focused on a compression chamber 20 indicated by dot hatching.

[0027] In the screw compressor 100, as shown in Figs. 6 to 8, the screw rotor 5 is caused by the electric motor 30 to rotate via the screw shaft 4, whereby the gate rotor tooth portions 6a of the gate rotors 6 relatively move within the tooth grooves 5a forming the compression chamber 20. This causes a cycle of the suction step (Fig. 6), the compression step (Fig. 7), and the discharge step (Fig. 8) to be repeated in the compression chamber 20.

[0028] Fig. 6 shows a state of the compression chamber 20 during the suction step. The screw rotor 5 is driven by the electric motor 30 to rotate in the direction of a solid arrow. This causes a reduction in volume of the compression chamber 20 as shown in Fig. 7.

[0029] When the screw rotor 5 keeps on rotating, the compression chamber 20 comes to communicate with the discharge port 7a as shown in Fig. 8. This causes high-pressure refrigerant gas compressed in the compression chamber 20 to be discharged outward through the discharge port 7a. Then, similar compression is performed at the back of the screw rotor 5 again.

[0030] Incidentally, the screw compressor 100 has a risk that a thermal expansion of the screw rotor 5 by a rise in temperature of the refrigerant gas compressed in the compression chamber 20 may cause reduced spacings S between an outer circumferential surface of the screw rotor 5 and the inner cylindrical surface of the casing 1 and between the outer circumferential surface of the screw rotor 5 and the slide valve 7. Further, the screw compressor 100 has a risk that the screw rotor 5 may rotate backward due to a differential pressure in the casing 1 after stoppage of operation, and the inverse rotation of the screw rotor 5 undesirably causes the valve body portion 70 of the slide valve 7 to fall toward the screw rotor 5 or rotate in a circumferential direction due to the influence of, for example, a variation in internal pressure of the compression chamber 20. As a result, the valve body portion 70 of the slide valve 7 may partially make contact with the screw rotor 5, which may invite a seizure or other trouble.

[0031] To address this problem, as shown in Figs. 1, 2, and 5, the screw compressor 100 according to Embodiment 1 includes a heating mechanism 9 connected to the oil separator 14 and configured to, by utilizing oil separated by the oil separator 14, thermally expand the bearing housing 8 in a radial direction during operation. The heating mechanism 9 includes an oil passage 90 formed in a wall of the casing 1 facing the bearing housing 8 and connected to the oil separator 14 and a groove portion 91 formed in the bearing housing 8 and configured to communicate with the oil passage 90. That is, the heating mechanism 9 is configured to circulate high-temperature and high-pressure oil separated by the oil separator 14 to the groove portion 91 through the oil passage 90 to thermally expand the bearing housing 8 in a radial direction during operation.

[0032] The groove portion 91 is formed along a circumferential direction of the bearing housing 8. In Embodiment 1, as shown in Fig. 5, the groove portion 91 is formed by two groove portions, namely a first groove portion 91a and a second groove portion 91b, laid side-by-side at a spacing in a direction parallel to the tube axis of the bearing housing 8. One end of the first groove portion 91a serves as a suction port 91c connected to the oil passage 90, and the other end of the first groove portion 91a is connected to the second groove portion 91b. One end of the second groove portion 91b is connected to the first groove portion 91a, and the other end of the second groove porton 91b serves as a discharge port 91d leading to the compression chamber 20. As shown in Figs. 1 and 2, the discharge port 91d and the compression chamber 20 are connected by an oil connecting passage 90a formed in the wall of the casing 1. High-temperature and high-pressure oil having flowed into the groove portion 91 of the bearing housing 8 circulates under a differential pressure within the casing 1, and is fed to the tooth grooves 5a of the screw rotor 5, the bearing 80, or other components.

[0033] In the screw compressor 100 according to Embodiment 1, as shown in Fig. 4, before the valve body portion 70 of the slide valve 70 falls toward the screw rotor 5 or rotates in a circumferential direction, the bearing housing 8, which has thermally expanded, comes into contact with the guide portion 71 of the slide valve 7 to support the guide portion 71. This makes it possible to reduce contact between the slide valve 7 and the screw rotor 5 and achieve a highly-reliable screw compressor.

[0034] It is difficult to machine the groove portion 91 only in a portion of the outer circumferential surface of the bearing housing 8 with a lathe machine. This problem is addressed by using a casting mold in advance to mold the bearing housing 8 with the groove portion 91 formed in an outer circumferential portion of the bearing housing 8 and performing surface treatment with a lathe machine. Since the surface of the groove portion 91 does not affect the function of the screw compressor 100, there is no problem even if the surface of the groove portion 91 remains a casting surface 92. Therefore, the surface of the groove portion 91 remains a casting surface 92 formed by a casting mold. That is, making the groove portion 91 of the screw compressor 100 according to Embodiment 1 remain the casting surface 92 eliminates the need for additional processing of the groove portion 91 and makes it possible to reduce manufacturing cost and enhance productivity.

[0035] Further, as shown in Fig. 2, the casing 1 has an inner wall surface provided with a spacer 13 in a place facing the bearing housing 8 across the screw rotor 5. Moreover, the heating mechanism 9 has a branch passage 90b, connected to the spacer 13, that branches off from the oil passage 90 and extends in a direction parallel to the tube axis of the casing 1. That is, the heating mechanism 9 can circulate the high-temperature and high-pressure oil separated by the oil separator 14 to the branch passage 90b through the oil passage 90 to increase a heat-transfer area to thermally expand the inner wall surface of the casing 1. Therefore, the screw compressor 100 according to Embodiment 1 can effectively reduce contact between the casing 1 and the screw rotor 5.

[0036] The screw compressor 100 according to Embodiment 1 does not necessarily need to provide the spacer 13 or connect the branch passage 90b branching off from the oil passage 90, and may be configured to omit the spacer 13 and the branch passage.

[0037] As mentioned above, a screw compressor 100 according to Embodiment 1 includes a casing 1 forming an outer shell, a screw shaft 4 disposed in the casing 1 and configured to be driven to rotate, a screw rotor 5, fixed to the screw shaft 4, that has a spiral tooth groove 5a in an outer circumferential surface thereof, a gate rotor 6 having a plurality of gate rotor tooth portions 6a configured to fit into the tooth groove 5a of the screw rotor 5 and forming, together with the casing 1 and the screw rotor 5, a compression chamber 20 in which to compress refrigerant, a slide valve 7 provided in a slide groove 12 formed in an inner cylindrical surface of the casing 1 and configured to slide in a direction parallel to an axis of rotation of the screw rotor 5, a bearing housing 8 having a bearing 80 inside and having an outer peripheral surface on which the slide valve 7 slides, the bearing 80 being configured to support one end of the screw shaft 4 so that the screw shaft 4 is able to rotate, an oil separator 14 configured to separate oil mixed into refrigerant compressed in the compression chamber 20, and a heating mechanism 9 connected to the oil separator 14 and configured to, by utilizing oil separated by the oil separator 14, thermally expand the bearing housing 8 in a radial direction during operation.

[0038] The heating mechanism 9 includes an oil passage 90 formed in a wall of the casing 1 facing the bearing housing 8 and connected to the oil separator 14 and a groove portion 91 formed in the bearing housing 8 and configured to communicate with the oil passage 90. The heating mechanism 9 is configured to circulate high-temperature and high-pressure oil separated by the oil separator 14 to the groove portion 91 through the oil passage 90 to thermally expand the bearing housing 8 in a radial direction during operation.

[0039] Therefore, in the screw compressor 100 according to Embodiment 1, before the valve body portion 70 of the slide valve 70 falls toward the screw rotor 5 or rotates in a circumferential direction, the bearing housing 8, which has thermally expanded, comes into contact with the guide portion 71 of the slide valve 7 to support the guide portion 71. This makes it possible to reduce contact between the slide valve 7 and the screw rotor 5 and achieve a highly-reliable screw compressor.

[0040] Further, the casing 1 has an inner wall surface provided with a spacer 13 in a place facing the bearing housing 8 across the screw rotor 5. The heating mechanism 9 has a branch passage 90b, connected to the spacer 13, that branches off from the oil passage 90 and extends in a direction parallel to a tube axis of the casing 1. That is, the heating mechanism 9 can circulate the high-temperature and high-pressure oil separated by the oil separator 14 to the branch passage 90b through the oil passage 90 to increase a heat-transfer area to thermally expand the inner wall surface of the casing 1. Therefore, the screw compressor 100 according to Embodiment 1 can effectively reduce contact between the casing 1 and the screw rotor 5.

[0041] Further, the groove portion 91 is a casting surface 92 formed by a casting mold. That is, making the surface of the groove portion 91, which does not affect the function of the screw compressor 100 according to Embodiment 1, remain the casting surface 92 eliminates the need for additional processing of the groove portion 91 and makes it possible to reduce manufacturing cost and enhance productivity.

Embodiment 2

[0042] Next, a screw compressor 101 according to Embodiment 2 is described with reference to Figs. 9 and 10. Fig. 9 is a cross-sectional view illustrating an internal structure of the screw compressor according to Embodiment 2. Fig. 10 is a perspective view illustrating a structure of a bearing housing of the screw compressor according to Embodiment 2. Components identical to those of the screw compressor 100 described in Embodiment 1 are given identical reference signs, and a description of such components is omitted as appropriate.

[0043] In the screw compressor 101 according to Embodiment 2, as shown in Figs. 9 and 10, the heating mechanism 9 has its groove portion 91 formed up to a place facing a guide portion 71 of the slide valve 7. That is, the heating mechanism 9 is configured to circulate high-temperature and high-pressure oil separated by the oil separator 14 to the groove portion 91 through the oil passage 90 to thermally expand the bearing housing 8 in a radial direction during operation and thermally expand the guide portion 71 of the slide valve 7 in a radial direction. In the screw compressor 101 according to Embodiment 2, a branch passage 90c branching off from the oil passage 90 is connected to the compression chamber 20. High-temperature and high-pressure oil having flowed into the oil passage 90 circulates under a differential pressure within the casing 1, and is fed to the tooth grooves

5a of the screw rotor 5, the bearing 80, or other components.

[0044] Therefore, in the screw compressor 101 according to Embodiment 2, before the valve body portion 70 of the slide valve 70 falls toward the screw rotor 5 or rotates in a circumferential direction, the bearing housing 8, which has thermally expanded, and the guide portion 71 of the slide valve 7, which has thermally expanded, come into contact with each other. This makes it possible to reduce contact between the slide valve 7 and the screw rotor 5 and achieve a highly-reliable screw compressor.

[0045] Although not illustrated, the screw compressor 101 according to Embodiment 2 may be configured such that a spacer 13 is provided on an inner wall surface of the casing 1 located between the compression unit 2 and the drive unit 3 and a branch passage 90b branching off from the oil passage 90 is connected to the spacer 13.

Embodiment 3

[0046] Next, a screw compressor 102 according to Embodiment 3 is described with reference to Fig. 11. Fig. 11 is a cross-sectional view illustrating an internal structure of the screw compressor according to Embodiment 3. Components identical to those of the screw compressor 100 described in Embodiment 1 are given identical reference signs, and a description of such components is omitted as appropriate.

[0047] As shown in Fig. 11, the screw compressor 102 according to Embodiment 3 is configured such that the groove portion 91 is formed along a direction parallel to a tube axis of the bearing housing 8. That is, the heating mechanism 9 is configured to circulate high-temperature and high-pressure oil from the oil separator 14 to the groove portion 91 through the oil passage 90 to thermally expand the whole surface of the bearing housing 8 in a radial direction during operation. As shown in Fig. 11, the groove portion 91 formed along a direction parallel to the tube axis may be formed by a plurality of the groove portions 91 formed in parallel as shown in Fig. 11 or may be formed by one groove portion 91.

[0048] In the screw compressor 102 according to Embodiment 3, a branch passage 90d branching off from the oil passage 90 is connected to the compression chamber 20. High-temperature and high-pressure oil having flowed into the oil passage 90 circulates under a differential pressure within the casing 1, and is fed to the tooth grooves 5a of the screw rotor 5, the bearing 80, or other components.

[0049] Therefore, in the screw compressor 100 according to Embodiment 3, before the valve body portion 70 of the slide valve 70 falls toward the screw rotor 5 or rotates in a circumferential direction, the bearing housing 8, which has thermally expanded, comes into contact with the slide valve 7 to support the slide valve 7. This makes it possible to reduce contact between the slide valve 7 and the screw rotor 5 and achieve a highly-reliable screw compressor.

[0050] Although not illustrated, the screw compressor 102 according to Embodiment 3 may be configured such that a spacer 13 is provided on an inner wall surface of the casing 1 located between the compression unit 2 and the drive unit 3 and a branch passage 90b branching off from the oil passage 90 is connected to the spacer 13.

[0051] While the screw compressor 100 has been described above with reference to an embodiment, the screw compressor 100 is not limited to the configuration of the aforementioned embodiment. For example, the internal configuration of the screw compressor 100 is not limited to the aforementioned content but may include other components. Further, while the screw compressor 100 has been described by taking a single-stage single-screw compressor as an example, the screw compressor 100 may for example be a two-stage screw compressor. Further, the slide valve 7 is not limited to an internal volume ratio adjusting valve but may be configured, for example, to adjust compression capacity. Further, the gate rotor 6 is not limited to being formed by the two gate rotors 6 illustrated, but may be formed by one gate rotor 6. In other words, the screw compressor 100 encompasses a range of design changes and variations in application that persons skilled in the art normally make without departing from the technical idea of the screw compressor 100.

Reference Signs List

[0052] 1: casing 2: compression unit, 3: drive unit, 4: screw shaft, 5: screw rotor, 5a: tooth groove, 6: gate rotor, 6a: gate rotor tooth portion, 7: slide valve, 7a: discharge port, 8: bearing housing, 9: heating mechanism, 10: low-pressure space, 11: high-pressure space, 12: slide groove, 13: spacer, 14: oil separator, 15: oil, 20: compression chamber, 30: electric motor, 31: stator, 32: motor rotor, 70: valve body portion, 71: guide portion, 72: coupling portion, 73: rod, 74: slide valve drive device, 80: bearing, 90: oil passage, 90a: oil connecting passage, 90b, 90c, 90d: branch passage, 91: groove portion, 91a: first groove portion, 91b: second groove portion, 91c: suction port, 91d: discharge port, 92: casting surface, 100, 101, 102: screw compressor, S: spacing

Claims

1. A screw compressor comprising:

a casing forming an outer shell;
a screw shaft disposed in the casing and configured to be driven to rotate;
a screw rotor, fixed to the screw shaft, that has a spiral tooth groove in an outer circumferential surface thereof;
a gate rotor having a plurality of gate rotor tooth portions configured to fit into the tooth groove of the screw rotor and forming, together with the

casing and the screw rotor, a compression chamber in which to compress refrigerant;
a slide valve provided in a slide groove formed in an inner cylindrical surface of the casing and configured to slide in a direction parallel to an axis of rotation of the screw rotor;
a bearing housing having a bearing inside and having an outer peripheral surface on which the slide valve slides, the bearing being configured to support one end of the screw shaft so that the screw shaft is able to rotate;
an oil separator configured to separate oil mixed into refrigerant compressed in the compression chamber; and
a heating mechanism connected to the oil separator and configured to, by utilizing oil separated by the oil separator, thermally expand the bearing housing in a radial direction during operation.

2. The screw compressor of claim 1, wherein

the heating mechanism includes

an oil passage formed in a wall of the casing facing the bearing housing and connected to the oil separator, and
a groove portion formed in the bearing housing and configured to communicate with the oil passage, and

the heating mechanism is configured to circulate oil separated by the oil separator to the groove portion through the oil passage to thermally expand the bearing housing in a radial direction during operation.

3. The screw compressor of claim 2, wherein

the heating mechanism has its groove portion formed up to a place facing a guide portion of the slide valve configured to slide on the outer circumferential surface of the bearing housing, and
the heating mechanism is configured to circulate oil separated by the oil separator to the groove portion through the oil passage to thermally expand the bearing housing in a radial direction during operation and thermally expand the guide portion of the slide valve in a radial direction.

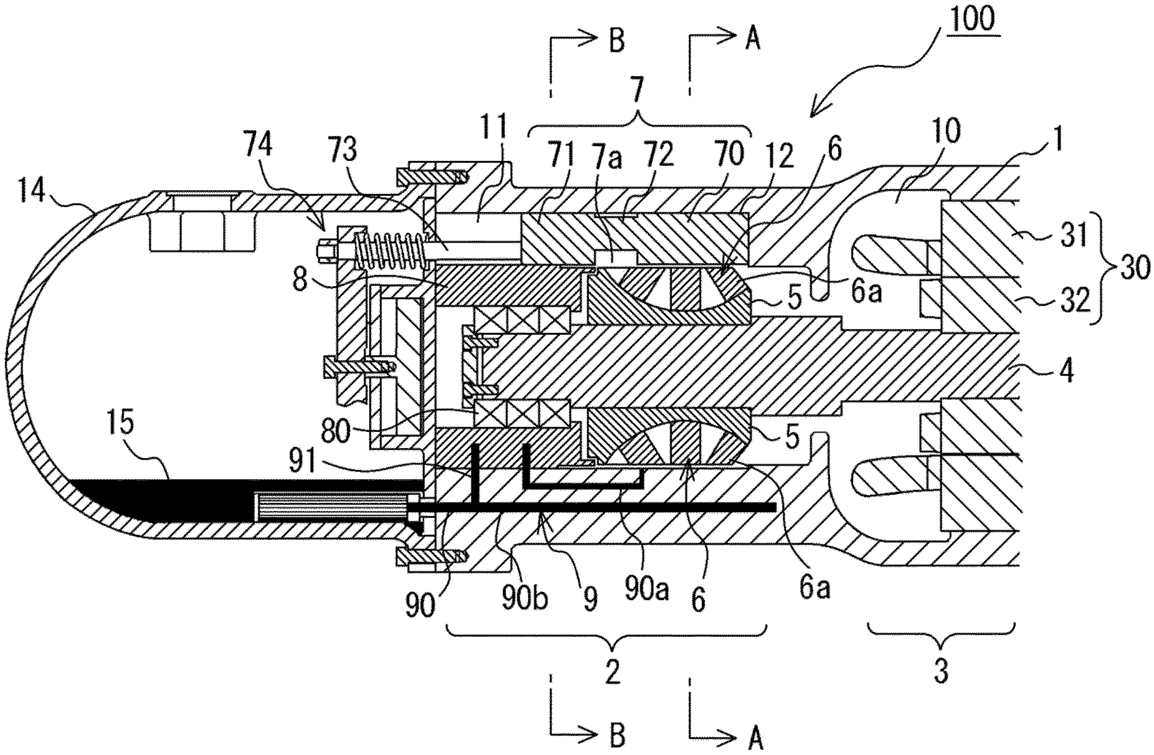
4. The screw compressor of claim 2, wherein the groove portion is formed along a direction parallel to a tube axis of the bearing housing.

5. The screw compressor of any one of claims 2 to 4, wherein

the casing has an inner wall surface provided with a spacer in a place facing the bearing housing across the screw rotor, and
the heating mechanism has a branch passage, connected to the spacer, that branches off from the oil passage and extends in a direction parallel to a tube axis of the casing.

6. The screw compressor of any one of claims 2 to 5, wherein the groove portion is a casting surface formed by a casting mold.

FIG. 1



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7a
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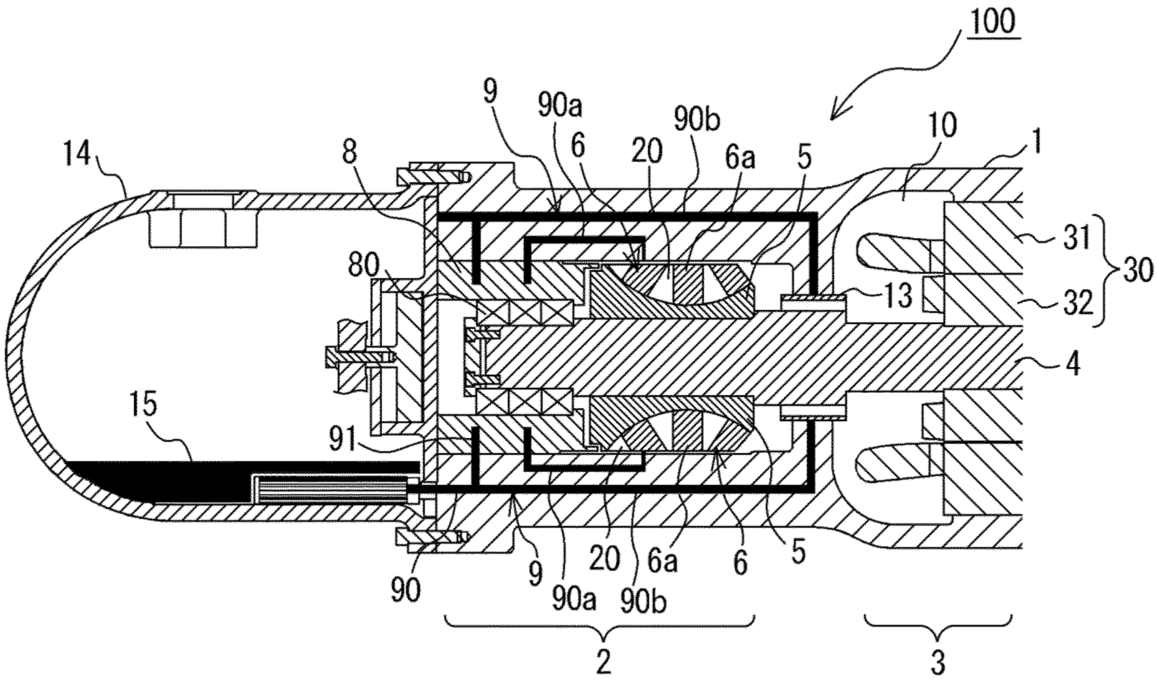
90b
9
90a
6
6a
2
3
B
A

FIG. 2



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2
3

FIG. 3

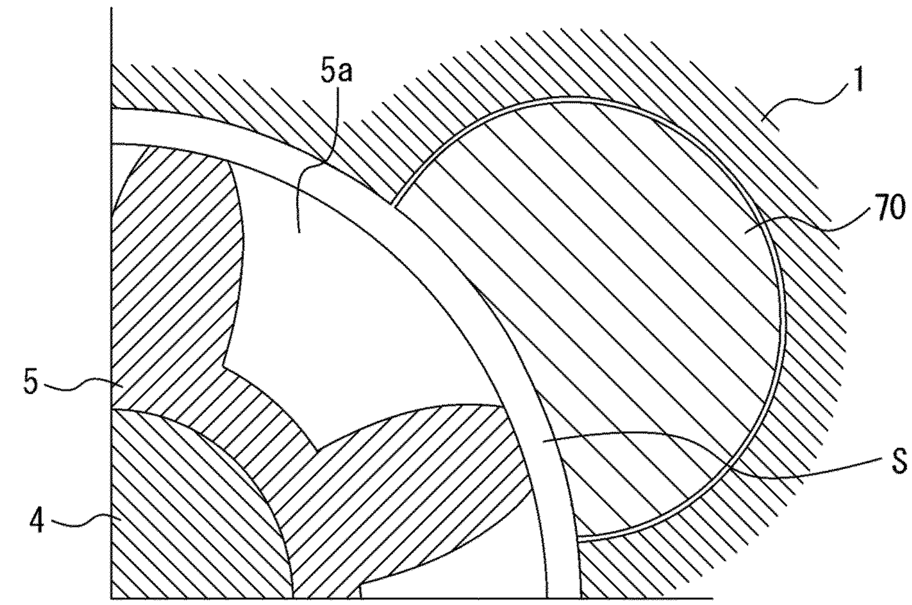


FIG. 4

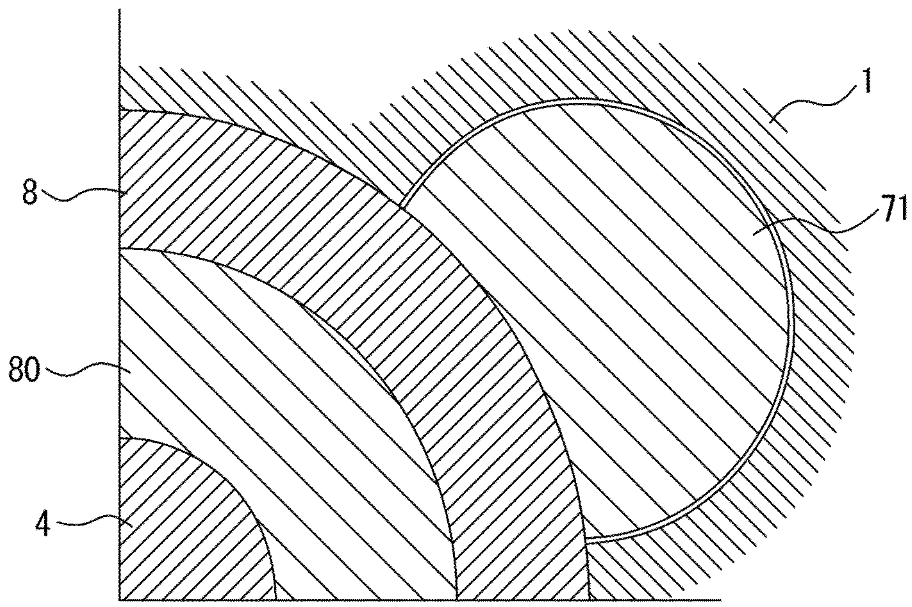
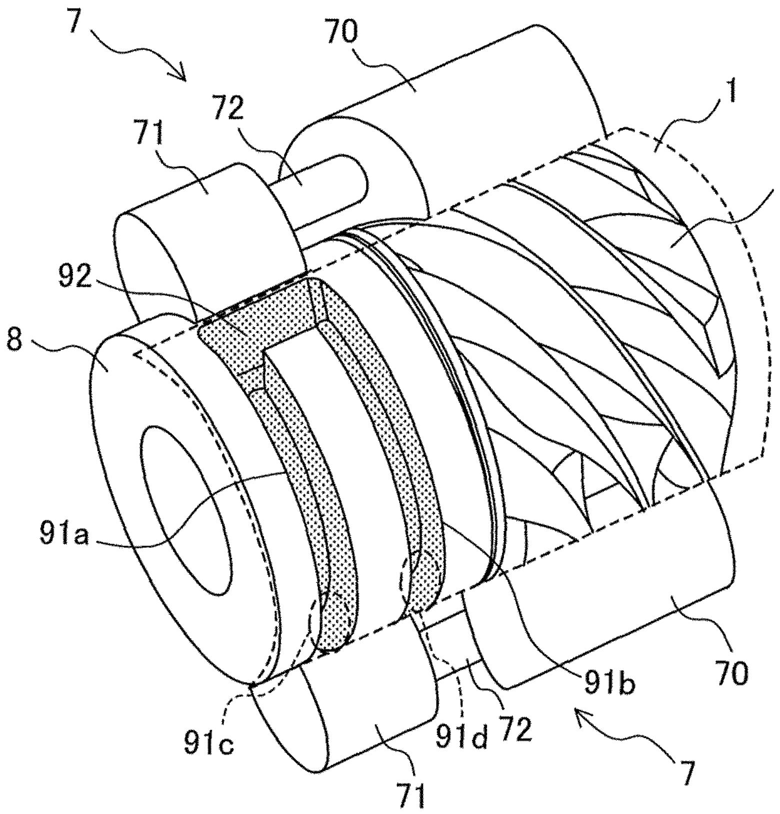


FIG. 5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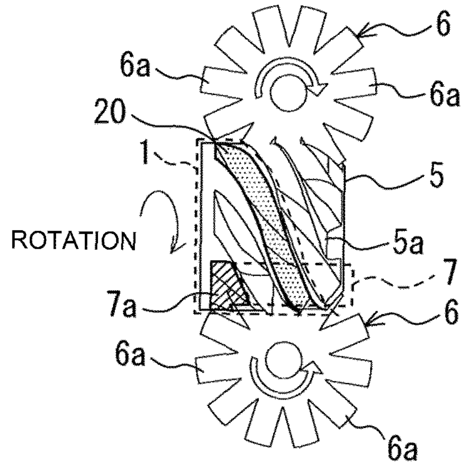
91d
72
7
71

FIG. 6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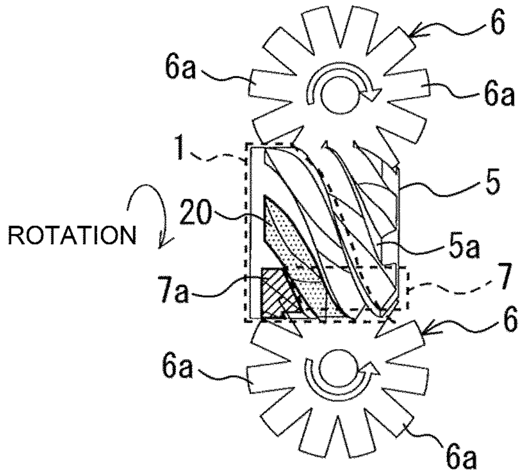
6
6a
6a

FIG. 7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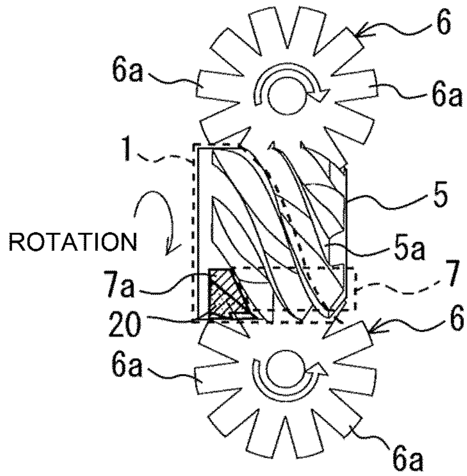
5
20
ROTATION
5a
7a
7
6
6a
6a

FIG. 8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ROTATION
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20
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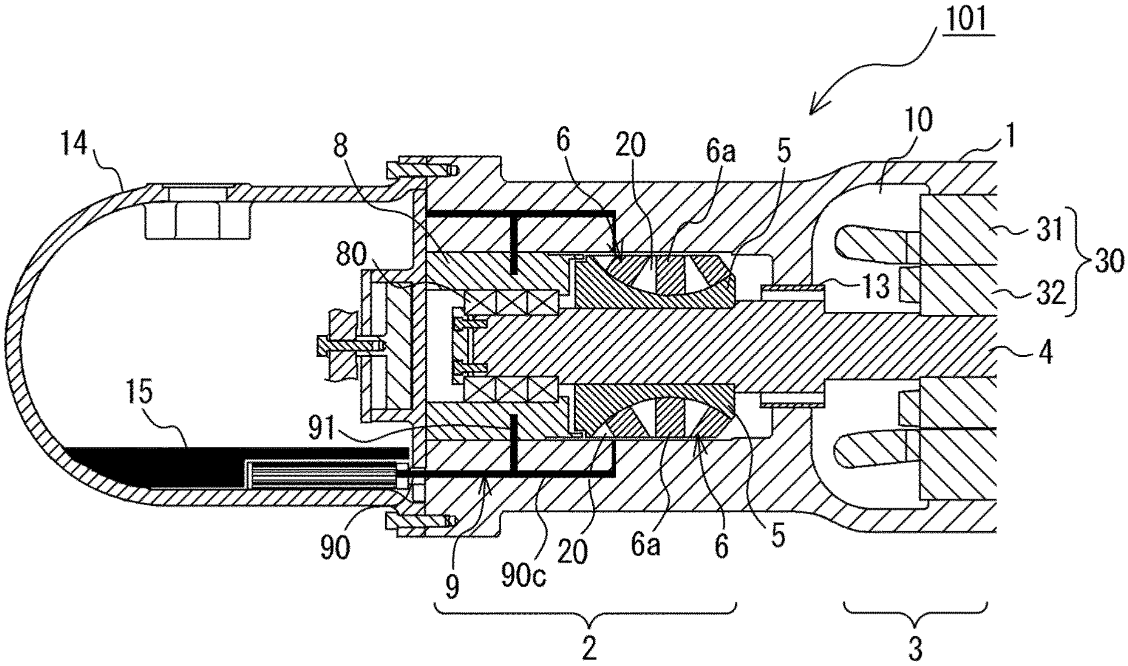
6a
6a

FIG. 9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6a
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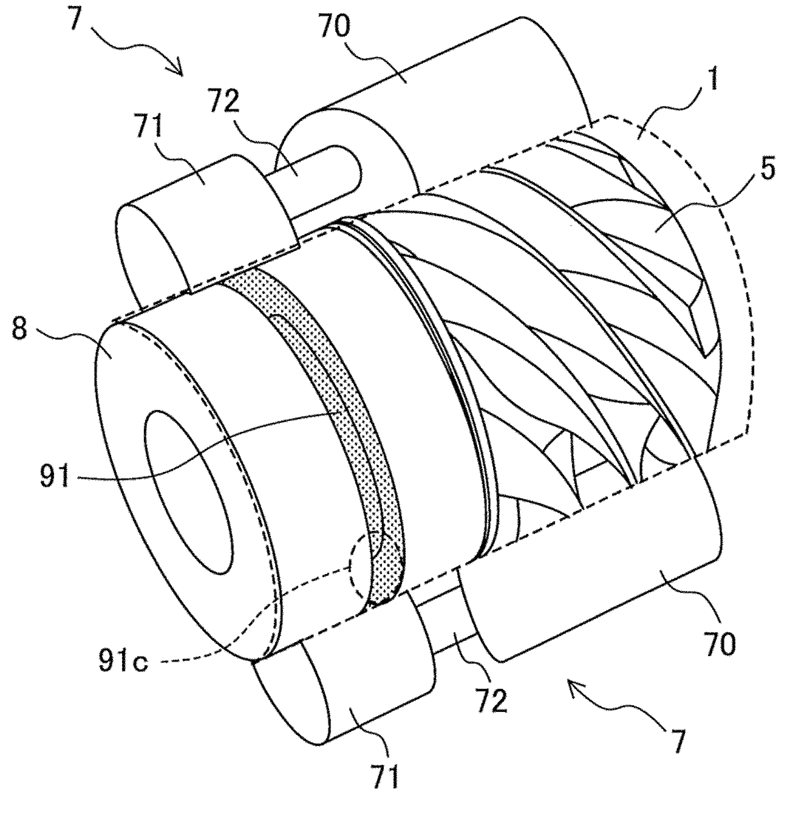
2
3

FIG. 10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91c
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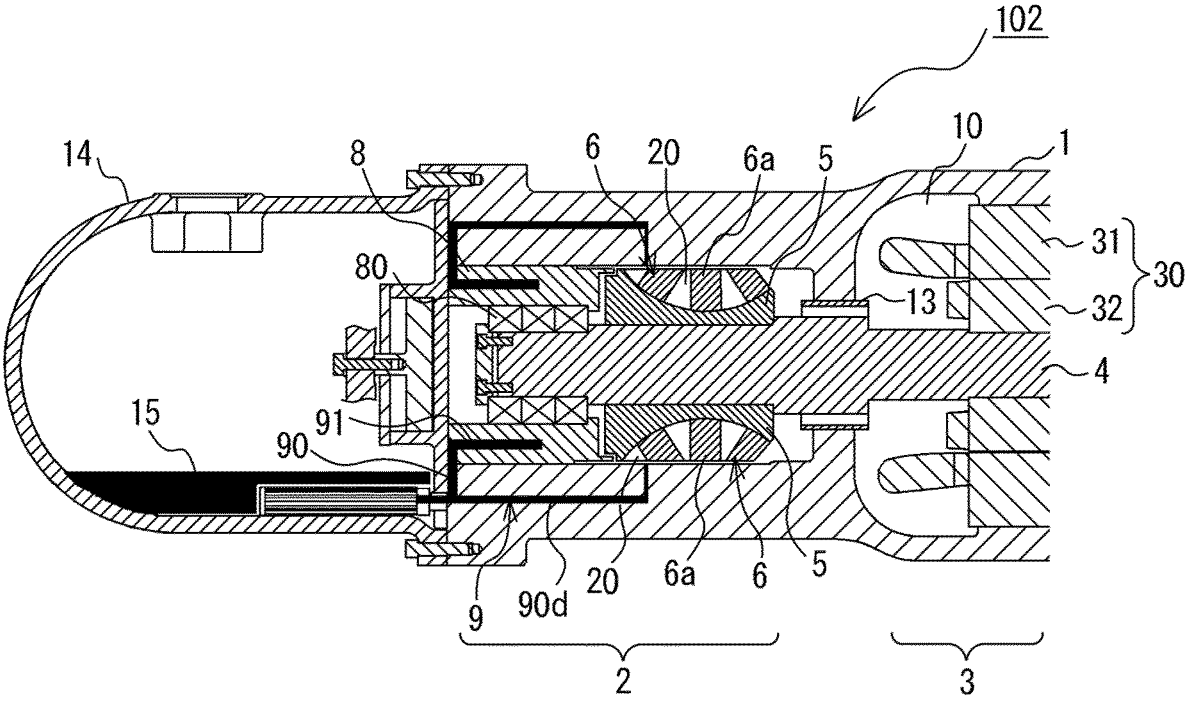
71

FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/020999

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F04C18/52(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. F04C18/52

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	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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.
Y A	JP 2019-19678 A (DAIKIN INDUSTRIES, LTD.) 07 February 2019, paragraphs [0029]-[0097], fig. 1-7 (Family: none)	1-2, 6 3-5
Y	JP 2019-19682 A (DAIKIN INDUSTRIES, LTD.) 07 February 2019, paragraphs [0038]-[0073], fig. 1-10 (Family: none)	1-2, 6
Y	JP 5-106572 A (DAIKIN INDUSTRIES, LTD.) 27 April 1993, paragraphs [0018]-[0026], fig. 1-3 (Family: none)	1-2, 6

☐ 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
21.08.2019	03.09.2019

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

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Patent documents cited in the description

- JP 2013060877 A **[0007]**