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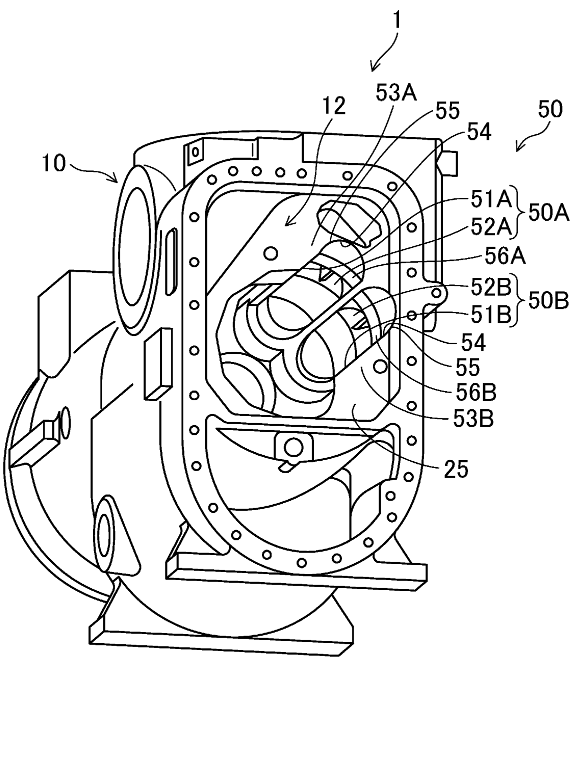
(54) SCREW COMPRESSOR

(57) Disclosed is a screw compressor (1) including a slide valve mechanism (50) configured to adjust an opening area of a cylinder opening (51A, 51B) of a cylinder (25) of a casing (10). A plurality of valve members (52A, 52B) are arranged for a single compression chamber, and move in an axial direction of a screw rotor to adjust the opening area of the cylinder opening (51A, 51B). The casing (10) has a plurality of valve housing portions (53A, 53B) housing the valve members (52A, 52B), respectively.

FIG.3



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a screw compressor including a screw rotor, a gate rotor, and a slide valve mechanism.

BACKGROUND ART

[0002] Screw compressors have been used as compressors for compressing refrigerant and air. For example, Patent Document 1 discloses a screw compressor (a single-screw compressor) having one screw rotor and one gate rotor.

[0003] In this screw compressor, the screw rotor and the gate rotor are housed in a casing. The screw rotor is rotatably inserted into a cylinder formed in a central portion of the casing. The screw rotor has helical screw grooves. Gates of the gate rotor respectively mesh with the screw grooves, thereby defining a compression chamber. The casing has therein a low-pressure chamber and a high-pressure chamber. When the screw rotor rotates, a fluid in the low-pressure chamber is sucked into the compression chamber. After compressed in the compression chamber, the fluid is discharged into the high-pressure chamber.

[0004] The screw compressor of Patent Document 1 is provided with a slide valve mechanism. The slide valve mechanism has a valve member having an inner surface (the surface positioned inward in the radial direction of the casing) substantially bordering the outer periphery of the screw rotor with an oil film interposed therebetween. The cylinder has a valve housing portion slidably housing the valve member. The valve housing portion has a slide groove (a cylinder opening). The valve member has a cross section formed into an arc shape so as to be fitted into the valve housing portion, and partially has a curved surface recessed along the outer periphery of the screw rotor.

[0005] The slide valve mechanism is used to control the internal volume ratio of a compression mechanism and to control the operating capacity of the compressor. To control the internal volume ratio, a discharge-side end face of the valve member is shifted in the axial direction of the screw rotor to adjust the size of the discharge-side cylinder opening, and the timing when the fluid is discharged is adjusted. Further, to control the operating capacity, the size of a bypass cylinder opening that communicates with a bypass passage to return the refrigerant being compressed toward an inlet of the compression chamber is adjusted.

[0006] If the internal volume ratio is controlled, moving the valve member in the axial direction allows the timing when the refrigerant is discharged from the compression chamber to the high-pressure chamber of the casing through the discharge-side cylinder opening of the cylinder to be adjusted. As a result, the ratio of the discharge volume to the suction volume is adjusted. If the operating capacity is controlled, moving the valve member in the axial direction allows adjustment of the return amount (unloading amount) by which the refrigerant being compressed returns to the low-pressure chamber of the casing through the bypass cylinder opening of the cylinder.

CITATION LIST

PATENT DOCUMENT

[0007] Patent Document 1: Japanese Unexamined Patent Publication No. H06-042475

SUMMARY

TECHNICAL PROBLEM

[0008] The cylinder opening formed on the discharge side of the valve member constitutes a discharge port as can be seen from the foregoing description. As the flow rate of a working fluid to be discharged through the opening increases, the pressure loss therethrough increases. Thus, it is recommended that, to reduce the pressure loss, the flow rate be reduced through increasing the opening area of the discharge port. However, increasing the size of a valve member (101) as shown in, for example, FIG. 13 to increase the opening area increases the diameter of the valve member (101). As a result, the projecting amount (P) by which the valve member (101) projects radially outward from a screw rotor (100) increases, and the size of a valve housing portion housing the valve member (101) also increases. This increases the size of the casing of the screw compressor as well.

[0009] It is an object of the present disclosure to substantially prevent the size of a casing of a screw compressor including a slide valve from increasing.

SOLUTION TO THE PROBLEMS

[0010] A first aspect of the disclosure is directed to a screw compressor including: a screw rotor (30) having helical screw grooves (31); a gate rotor (40) having gates (41) meshing with the screw groove (31); a casing (10) internally having a cylinder (25) into which the screw rotor (30) is rotatably inserted; a compression chamber (23) defined inside the cylinder (25) by the screw rotor (30) and the gate rotor (40) meshing with each other; and a slide valve mechanism (50) configured to adjust an opening area of a cylinder opening (51A, 51B) of the cylinder (25), the cylinder opening (51A, 51B) communicating with the compression chamber (23). The slide valve mechanism (50) includes: a plurality of valve members (52A, 52B) arranged for the single compression chamber (23), the valve members (52A, 52B) moving in an axial direction of the screw rotor (30) to adjust the opening area; and a plurality of valve housing portions (53A, 53B) of the casing (10) housing the valve members (52A, 52B), respectively.

[0011] According to the first aspect, the plurality of separate valve members (52A, 52B) of the slide valve mechanism (50) are arranged for one compressor. This can reduce the size of these valve members (52A, 52B) even if the opening area of a discharge port is increased. This can substantially prevent the size of the casing (10) of the screw compressor from increasing.

[0012] A second aspect of the disclosure is an embodiment of the first aspect. In the second aspect, each valve housing portion (53A, 53B) has a curved wall (54) projecting radially outward of the screw rotor (30) from the cylinder (25) to have an arc-shaped cross section, the curved wall (54) extending in the axial direction of the screw rotor (30), and an outer peripheral surface of each valve member (52A, 52B) is configured as a curved surface having an arc-shaped cross section, the curved surface being fitted to the curved wall (54) of an associated one of the valve housing portions (53A, 53B). The "arc-shaped cross section" as used herein means an arc-shaped cross section perpendicular to the axis of the valve member.

[0013] According to the second aspect, portions of each valve member (52A, 52B) and the associated valve housing portion (53A, 53B) fitted to each other have an arc-shaped cross section. This can simplify the configurations of the valve members (52A, 52B) and the valve housing portions (53A, 53A). In addition, the portions of each valve member (52A, 52B) and the associated valve housing portion (53A, 53B) fitted to each other have an arc-shaped cross section without a flat portion or a similar portion. This can also substantially prevent the strength of the casing (10) from decreasing.

[0014] A third aspect of the disclosure is an embodiment of the first or second aspect. In the third aspect, the screw rotor (30) and the gate rotor (40) are provided as a pair of rotors within the casing (10).

[0015] According to the third aspect, the size of the casing (10) of a so-called one gate rotor screw compressor can be effectively reduced.

[0016] A fourth aspect of the disclosure is an embodiment of any one of the first to third aspects. In the fourth aspect, axial displacements of the valve members (52A, 52B) during operation of the slide valve mechanism (50) are different from each other. The axial displacement of each valve member (52A, 52B) is determined, for example, based on the axial displacement of the screw groove (31) at the spot where the valve member (52A, 52B) is provided.

[0017] According to the fourth aspect, the axial displacements of the valve members (52A, 52B) are different from each other. Thus, the valve members (52A, 52B) are set to respectively have optimum opening areas, thereby efficiently increasing the area of a discharge port and reducing pressure loss.

[0018] A fifth aspect of the disclosure is an embodiment of any one of the first to fourth aspects. In the fifth aspect, each valve member (52A, 52B) has a high pressure end face (57a, 57b) facing a channel through which a high-pressure fluid compressed in the compression chamber (23) flows into a discharge passage in the casing (10), and the high pressure end faces (57a, 57b) of the valve members (52A, 52B) have different angles of inclination ($\theta 1$, $\theta 2$). The inclination (the angle of inclination ($\theta 1$, $\theta 2$)) of the high pressure end face (57a, 57b) of each valve member (52A, 52B) is determined, for example, based on the inclination of the associated screw groove (31) at the spot where the valve member (52A, 52B) is provided.

[0019] According to the fifth aspect, the inclinations (the angles of inclination ($\theta 1$, $\theta 2$)) of the high pressure end faces (57a, 57b) of the valve members (52A, 52B) are different from each other. Thus, the valve members (52A, 52B) are set to respectively have optimum angles of inclination ($\theta 1$, $\theta 2$), thereby efficiently increasing the area of the discharge port and reducing pressure loss.

[0020] A sixth aspect of the disclosure is an embodiment of any one of the first to fifth aspects. In the sixth aspect, the slide valve mechanism (50) further includes: a driving mechanism (60) configured to move at least one of the valve members (52A, 52B) as a target member to be driven; and an interlocking mechanism (70) configured to move another one of the valve members (52A, 52B) as a following target member following the target member to be driven.

[0021] According to the sixth aspect, one of the valve members (52A, 52B) to be interlocked is designed to follow the another one thereof to be driven. This facilitates optimizing the displacements of the valve members (52A, 52B) on a member-by-member basis. This can efficiently reduce pressure loss.

[0022] A seventh aspect of the disclosure is an embodiment of any one of the first to sixth aspects. In the seventh aspect, the slide valve mechanism (50) is an operating capacity adjusting mechanism configured to return a portion of an intermediate-pressure fluid being compressed through a plurality of bypass passages (59a, 59b) of the casing (10) to an inlet of the compression chamber (23), each valve member (52A, 52B) has a low pressure end face (58a, 58b) facing a channel through which the intermediate-pressure fluid flows out of the compression chamber (23) into an associated one of the bypass passages (59a, 59b), and axial positions of the low pressure end faces (58a, 58b) of the valve members (52A, 52B) are different from each other.

[0023] An eighth aspect of the disclosure is an embodiment of the seventh aspect. In the eighth aspect, opening areas of the bypass passages (59a, 59b) respectively corresponding to the valve members (52A, 52B) are determined to be substantially equal to each other. The axial position of the low pressure end face (58a, 58b) of each valve members (52A, 52B) is determined, for example, based on the axial position of the associated screw groove (31) at the spot where the valve member (52A, 52B) is provided.

[0024] According to the seventh and eighth aspects, the axial positions of the low pressure end faces (58a, 58b) of the valve members (52A, 52B) are different from each other. In particular, in the eighth aspect, the opening areas of the bypass passages (59a, 59b) respectively corresponding to the valve members (52A, 52B) are substantially equal to each other. Since an appropriate amount of refrigerant being compressed is accordingly returned through each of the valve members (52A, 52B) to the low pressure side of the compression mechanism, capacity control can be efficiently performed by unloading.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

[FIG. 1] FIG. 1 is a vertical cross-sectional view of a screw compressor according to an embodiment (a cross-sectional view taken along line I-I shown in FIG. 2).

[FIG. 2] FIG. 2 is a cross-sectional view taken along line II-II shown in FIG. 1.

[FIG. 3] FIG. 3 is a perspective view of a casing of the screw compressor shown in FIG. 1 as viewed from a discharge-side end face of the casing.

[FIG. 4] FIG. 4 shows the external appearances of a screw rotor and a gate rotor meshing with each other.

[FIG. 5] FIG. 5 is a cross-sectional view of the screw rotor and the gate rotor meshing with each other.

[FIG. 6] FIG. 6 is a perspective view of the screw rotor and the gate rotor meshing with each other.

[FIG. 7] FIG. 7 is a developed view of a screw rotor showing the shape and arrangement of valve members of a slide valve mechanism of the screw compressor shown in FIGS. 1 to 3.

[FIG. 8] FIG. 8 is a plan view of the slide valve mechanism.

[FIG. 9] FIG. 9 is a developed view of a screw rotor showing the fully loaded state of a slide valve mechanism according to a first variation.

[FIG. 10] FIG. 10 is a developed view of a screw rotor showing the unloaded state of the slide valve mechanism according to the first variation.

[FIG. 11] FIG. 11 is a side view of a slide valve mechanism according to another variation.

[FIG. 12] FIG. 12 is a plan view of the slide valve mechanism shown in FIG. 11.

[FIG. 13] FIG. 13 is a perspective view showing an exemplary combination of a screw rotor and a slide valve of a known screw compressor.

DESCRIPTION OF EMBODIMENTS

[0026] Embodiments will now be described in detail with reference to the drawings.

[0027] A screw compressor (1) of this embodiment, shown in FIGS. 1 and 2, is used for refrigerating and air conditioning. The screw compressor (1) is provided to a refrigerant circuit performing a refrigeration cycle, and compresses a refrigerant. The screw compressor (1) includes a hollow casing (10) and a compression mechanism (20).

[0028] A substantially central portion of the interior of the casing (10) houses the compression mechanism (20) configured to compress a low-pressure refrigerant. The interior of the casing (10) is partitioned into a low-pressure chamber (11) into which a low-pressure gas refrigerant is introduced from an evaporator (not shown) of a refrigerant circuit and which guides the low-pressure gas to the compression mechanism (20), and a high-pressure chamber (12) into which a high-pressure gas refrigerant that has been discharged from the compression mechanism (20) flows. The compression mechanism (20) is interposed between the low-pressure chamber (11) and the high-pressure chamber (12).

[0029] An electric motor (15) is fixed inside the casing (10). The electric motor (15) includes a stator (15a), and a rotor (15b) rotating in the stator (15a). The electric motor (15) and the compression mechanism (20) are connected together through a drive shaft (21) serving as a shaft. A bearing holder (27) is provided in the casing (10). The drive shaft (21) has a discharge-side end portion supported by bearings (26) fitted to the bearing holder (27), and an intermediate portion supported by a bearing (28).

[0030] The compression mechanism (20) includes a cylinder (25) formed in the casing (10), one screw rotor (30) disposed inside the cylinder (25), and one gate rotor (40) meshing with the screw rotor (30). The screw rotor (30) is fitted to the drive shaft (21), and is prevented from rotating around the drive shaft (21) by a key (not shown). The screw compressor (1) of this embodiment is a so-called one gate rotor single-screw compressor including the screw rotor (30) and the gate rotor (40), which are provided as a pair of rotors within the casing (10) as described above.

[0031] The cylinder (25) with a predetermined thickness is formed in a central portion of the casing (10). The screw rotor (30) is rotatably inserted into the cylinder (25). The cylinder (25) has two surfaces (right and left ends in FIG. 1) respectively facing the low-pressure chamber (11) and the high-pressure chamber (12). The cylinder (25) has an end face inclined along the direction in which a plurality of screw grooves (31) described below are twisted, without being formed over the entire periphery of the screw rotor (30).

[0032] As shown in FIGS. 4 to 6, the (three in this embodiment) helical screw grooves (31) are formed on the outer peripheral surface of the screw rotor (30). The screw rotor (30) is rotatably fitted into the cylinder (25), and has teeth each having an outer peripheral surface surrounded by the cylinder (25).

[0033] On the other hand, the gate rotor (40) is formed into the shape of a disk including a plurality of gates (41) (ten gates in this first embodiment) arranged radially. The gate rotor (40) has an axis that lies on a plane perpendicular to the axis of the screw rotor (30). The gate rotor

(40) is configured such that some of its gates (41) pass through a portion of the cylinder (25) to respectively mesh with the screw grooves (31) of the screw rotor (30). The screw rotor (30) is made of metal, and the gate rotor (40) is made of a synthetic resin.

[0034] The gate rotor (40) is disposed in a gate rotor chamber (14) defined in the casing (10). The gate rotor (40) has a central portion connected to a driven shaft (45) serving as a shaft. The driven shaft (45) is rotatably supported by a bearing (46) provided in the gate rotor chamber (14). The bearing (46) is held in the casing (10) via a bearing housing.

[0035] A suction cover (16) is fitted to an end face of the casing (10) near the low-pressure chamber (11), and a discharge cover (17) is fitted to an end face of the casing (10) near the high-pressure chamber (12). The gate rotor chamber (14) of the casing (10) is covered with a gate rotor cover (18). A discharge-side portion of the casing (10) is provided with a driving mechanism (60) configured to drive a slide valve mechanism (50) to be described below. The driving mechanism (60) is mounted on a stationary plate (19) of the bearing holder (27).

[0036] In the compression mechanism (20), the inner peripheral surface of the cylinder (25), the screw grooves (31) of the screw rotor (30), and the gates (41) of the gate rotor (40) surround a compression chamber (23). A right end portion of the screw rotor (30) shown in FIGS. 1, 4, and 5 is close to the suction side thereof, and a left end portion thereof is close to the discharge side thereof. An outer peripheral portion of a suction-side end portion (32) of the screw rotor (30) is tapered. Each screw groove (31) of the screw rotor (30) opens, at its suction-side end portion (32), to the low-pressure chamber (11), and this open portion functions as a suction port of the compression mechanism (20).

[0037] In the compression mechanism (20), the rotation of the screw rotor (30) causes the gates (41) of the gate rotor (40) to move with respect to the associated screw grooves (31) of the screw rotor (30). Thus, the compression chamber (23) is repeatedly expanded and contracted. Thus, a suction stroke, a compression stroke, and a discharge stroke for a refrigerant are sequentially performed.

[0038] As shown in FIG. 3, the screw compressor (1) includes a slide valve mechanism (50) configured to adjust the timing when the compression chamber (23) communicates with a discharge port (24) (see FIG. 7) to control the internal volume ratio (the ratio of the discharge volume to the suction volume of the compression mechanism (20)).

[0039] In this embodiment, the slide valve mechanism (50) includes a plurality of slide valve sub-mechanisms (in this embodiment, two slide valve sub-mechanisms (first and second slide valve sub-mechanisms (50A) and (50B)) provided for the single compression chamber (23). The slide valve mechanism (50) adjusts the opening area of each of cylinder openings (51) of the cylinder (25) to communicate with the compression chamber (23) defined by the gates (41) meshing with the screw grooves (31). As shown in FIG. 3, the first slide valve sub-mechanism (50A) adjusts the opening area of a first cylinder opening (51A), and the second slide valve sub-mechanism (50B) adjusts the opening area of a second cylinder opening (51B).

[0040] The slide valve mechanism (50) includes two valve members (52) (first and second valve members (52A) and (52B)), and the same number of valve housing portions (53) (first and second valve housing portions (53A) and (53B)) as that of the valve members (52A, 52B). In this embodiment, as shown in FIG. 7, the valve members (52A, 52B) are each movable with respect to the single compression chamber (23) in the axial direction of the screw rotor (30). The valve housing portions (53A, 53B) are formed in the cylinder (25) of the casing (10) to extend along the axial direction. The valve housing portions (53A, 53B) house the valve members (52A, 52B), respectively. An opening of each valve housing portion (53A, 53B) near the screw rotor (30) constitutes an associated one of the cylinder openings (51A, 51B).

[0041] Each valve housing portion (53A, 53B) has a curved wall (54) protruding radially outward of the screw rotor (30) from the cylinder (25) to have an arc-shaped cross section and extending in the axial direction of the screw rotor (30). The outer peripheral surface of each valve member (52A, 52B) is configured as a curved surface (55) having an arc-shaped cross section and fitted to the curved wall (54) of the associated valve housing portion (53A, 53B). The "arc-shaped cross section" means an arc-shaped cross section perpendicular to its axial direction.

[0042] The axial displacement of each valve member (52A, 52B) during operation of the slide valve mechanism (50) is determined based on the axial displacement of the associated screw groove (31) at a spot where the valve member (52A, 52B) is provided (an associated one of the points A and B in FIG. 7). The axial displacement of the screw groove (31) varies between the spot where the valve member (52A) is provided and the spot where the valve member (52B) is provided. Thus, as shown in FIG. 8, the axial displacements (S1, S2) of the valve members (52A, 52B) are also determined to be different from each other.

[0043] As shown in FIG. 7, each valve member (52A, 52B) has a high pressure end face (57a, 57b) facing a channel through which a high-pressure fluid compressed in the compression chamber (23) flows into a discharge passage in the casing (10). The inclination (the angle of inclination $\theta 1$, $\theta 2$ in FIG. 8) of the high pressure end face (57a, 57b) of the valve member (52A, 52B) is determined based on the inclination of the associated screw groove (31) at the spot where the valve member (52A, 52B) is provided (an associated one of the points A and B in FIG. 7). The inclination of the screw groove (31) continuously changes, and varies between the spot where the valve member (52A) is provided and the spot where the valve member (52B) is provided. Thus, the angles ($\theta 1$, $\theta 2$) of inclination of the high pressure end faces (57a, 57b) of the valve members (52A, 52B) are different from each other.

[0044] As shown in FIG. 1, the slide valve mechanism (50) includes a driving mechanism (60) configured to move one (52A) of the valve members (52A, 52B) as a target member to be driven. The driving mechanism (60) is connected to driven portions (56A, 56B) of the valve members (52A, 52B) shown in FIG. 3 to drive the valve members (52A, 52B). The driving mechanism (60) includes a cylinder disposed on the discharge side of the valve members (52A, 52B), and a piston moving forward and backward through the cylinder in the axial direction of the screw rotor (30), although its specific structure is not shown. The cylinder is disposed in the casing (10).

[0045] The slide valve mechanism (50) includes an interlocking mechanism (70) configured to move the other one (52B) of the valve members (52A, 52B) except the target member to be driven, as a following target member following the target member to be driven (FIG. 8).

[0046] In this embodiment, the interlocking mechanism (70) is configured as a link mechanism. The link mechanism (70) includes link rods (71a, 71b) respectively provided on end faces of the valve members (52B, 52A) on the suction side thereof, and a link arm (73) swingable around a fulcrum pin (72). The link rods (71a, 71b) and the link arm (73) are connected together. The distances (swing radii) from the fulcrum pin (72) to the link rods (71a, 71b) are different from each other. Thus, the displacements (strokes (S1, S2)) of the valve members (52A, 52B) during operation of the slide valve mechanism (50) are different from each other. The displacement of each valve member (52A, 52B) is determined based on the axial displacement of the screw groove (31) at the spot where the valve member (52A, 52B) is provided (an associated one of the points A and B in FIG. 7) as described above.

[0047] A coupling portion between each link rod (71a, 71b) and the link arm (73) includes a pin (74a) provided for the link rod (71a, 71b), and a slit which is formed on the link arm (73) and in which the pin (74a) is to be engaged.

[0048] Although not shown, if three or more valve members (52) are provided, the driving mechanism (60) merely needs to be configured to move at least one of the valve members (52) as a target member to be driven, and the interlocking mechanism (70) merely needs to be configured to move remaining ones of the valve members (52) as following target members following the target member to be driven.

[0049] Adjusting the positions of the valve members (52A, 52B) of the slide valve mechanism (50) allows the positions of the high pressure end faces (57a, 57b) facing the channel through which the high-pressure refrigerant compressed in the compression chamber (23) flows into the discharge passage in the casing (10) to change. This causes the opening area of the cylinder opening formed on the discharge side of the cylinder (25) of the casing (10) to change. Thus, the timing when the screw groove (31) communicates with the discharge port (not shown) during the rotation of the screw rotor (30) changes. This allows the internal volume ratio of the compression mechanism (20) to be adjusted.

-Operation-

[0050] Next, it will be described how the screw compressor (1) operates.

[0051] In the screw compressor (1), upon actuation of the electric motor, the screw rotor (30) is rotated in conjunction with the rotation of the drive shaft (21). The gate rotor (40) is also rotated in conjunction with the rotation of the screw rotor (30), thereby causing the compression mechanism (20) to repeatedly perform a suction stroke, a compression stroke, and a discharge stroke.

[0052] In the compression mechanism (20), the rotation of the screw rotor (30) causes the screw grooves (31) and the gates (41) to move relative to each other. This causes the volume of the compression chamber (23) of the screw compressor (1) to increase and then decrease.

[0053] While the volume of the compression chamber (23) is increasing, the low-pressure gas refrigerant in the low-pressure chamber (11) is sucked into the compression chamber (23) through the suction port (the suction stroke). If the rotation of the screw rotor (30) is advanced, the gates (41) of the gate rotor (40) define the compression chamber (23) such that the compression chamber (23) is separated from the low-pressure chamber. At that time, an action for increasing the volume of the compression chamber (23) ends, and an action for decreasing the volume is started. While the volume of the compression chamber (23) is decreasing, the sucked refrigerant is compressed (the compression stroke). Further rotation of the screw rotor (30) allows the compression chamber (23) to move. As a result, a discharge-side end of the compression chamber (23) communicates with the discharge port. If the discharge-side end of the compression chamber (23) opens to communicate with the discharge port, a high-pressure gas refrigerant is discharged from the compression chamber (23) to the high-pressure chamber (12) (the discharge stroke).

-Operation of Slide Valve Mechanism-

[0054] Adjusting the positions of the valve members (52A, 52B) of the slide valve mechanism (50) allows the opening areas of the associated cylinder openings (the openings communicating with the discharge port) (51A, 51B) formed on the discharge side of the cylinder (25) of the casing (10) to change. This change in area triggers a change in the ratio of the discharge volume to the suction volume to adjust the internal volume ratio of the compression mechanism (20), and causes the timing when the screw groove (31) communicates with the discharge port during the rotation of the screw rotor (30) to change.

[0055] In this embodiment, each valve member (52A, 52B) is displaced by an amount corresponding to the axial displacement (S1, S2) of the associated screw groove (31) at the spot where the valve member (52A, 52B) is provided (an associated one of the points A and B in FIG. 7), and the displacements of the valve members (52A, 52B) are different from each other. Accordingly, the screw groove (31) (the compression chamber (23)) passing through the high pressure end faces (57a, 57b) to communicate with the discharge port through the valve members (52A, 52B) at substantially the same timing. This allows the area of the discharge opening to be larger than if only one valve member is provided. This reduces the flow rate of discharge gas.

[0056] In this embodiment, the inclination (the angle of inclination (θ1, θ2)) of the high pressure end face (57a, 57b) of each valve member (52A, 52B) is determined based on the inclination of the associated screw groove (31) at the spot where the valve member (52A, 52B) is provided (an associated one of the points A and B in FIG. 7). Thus, the area of the discharge opening is adjusted while the positions of the high pressure end faces (52a, 52b) of the valve members (57A, 57B) and the angles of inclination (θ1, θ2) are optimized. This more effectively reduces pressure loss.

-Advantages of Embodiment-

[0057] According to this embodiment, in the so-called one gate rotor screw compressor, the plurality of (two) separate valve members (52A, 52B) are provided for the slide valve mechanism (50). Thus, one compressor includes the plurality of (two) valve members (52A, 52B). This can reduce the size of these valve members (52A, 52B) even if the opening area of the discharge port is increased. Thus, the size of the casing (10) of the screw compressor can be substantially prevented from increasing. In this embodiment, the valve housing portions (53A, 53B) do not have to be increased in size. This can substantially prevent the rigidity of the casing (10) from decreasing, and makes it less likely to deform the casing (10) that is resisting pressure. Thus, the dimensional accuracy of the casing (10) can be substantially prevented from decreasing due to such a deformation.

[0058] In this embodiment, portions of each valve member (52A, 52B) and the associated valve housing portion (53A, 53B) fitted to each other have an arc-shaped cross section. This can simplify the configurations of the valve members (52A, 52B) and the valve housing portions (53A, 53A), and can facilitate machining these members to shorten the machining period. Further, since the valve members (52A, 52B) and the valve housing portions (53A, 53B) have an arc-shaped cross section, the dimensional accuracy of these members is also substantially prevented from decreasing, thereby substantially preventing leakage of refrigerant from causing a reduction in efficiency. In addition, the portions of each valve member (52A, 52B) and the associated valve housing portion (53A, 53B) fitted to each other have an arc shape without a flat portion. This helps substantially prevent the strength of the casing (10) from decreasing.

[0059] In this embodiment, the axial displacement of each valve member (52A, 52B) is determined in accordance with the axial displacement of the associated screw groove (31) at the spot corresponding to the valve member (52A, 52B), and the inclination of the high pressure end face (57a, 57b) of the valve member (52A, 52B) is determined in accordance with the inclination of the associated screw groove (31) at the spot corresponding to the valve member (52A, 52B). This can efficiently increase the area of the discharge port, and efficiently reduce pressure loss.

[0060] Further, in this embodiment, one of the valve members (52A, 52B) to be interlocked is designed to follow the other one thereof to be driven. This allows the displacement of each valve member (52A, 52B) to be suitable and efficient for the axial displacement of the associated screw groove (31) at the spot where the valve member (52A, 52B) is provided. This also more effectively reduces pressure loss.

-Variations of Embodiment-

<First Variation)

[0061] FIGS. 9 and 10 show a slide valve mechanism (50) according to a first variation.

[0062] This slide valve mechanism (50) is used in an operating capacity adjusting mechanism performing an unload operation for returning a portion of an intermediate-pressure gas refrigerant being compressed through bypass passages (59a, 59b) of the casing (10) to an inlet of the compression chamber (23). FIG. 9 shows the states of valve members (52A, 52B) fully loaded without being unloaded. FIG. 10 shows the unloaded states of the valve members (52A, 52B).

[0063] In the slide valve mechanism (50) of the first variation, each valve member (52A, 52B) has a low pressure end face (58a, 58b) facing a channel through which an intermediate-pressure gas refrigerant flows out of the compression chamber (23) into the associated bypass passage (59a, 59b).

[0064] As shown in FIGS. 9 and 10, the low pressure end faces (58a, 58b) of the valve members (52A, 52B) are set not to be axially coplanar but to be axially misaligned. The axial position of the low pressure end face (58a, 58b) of each valve members (52A, 52B) is determined based on the axial position of the associated screw groove (23) at the spot where the valve member (52A, 52B) is provided (an associated one of the points C and D in FIG. 9). The positions of the low pressure end faces (58a, 58b) of the valve members (52A, 52B) are determined so that the bypass passages (59a, 59b) of the valve members (52A, 52B) communicating with the screw groove (23) has substantially the same area.

[0065] The other configuration of this variation is the same as, or similar to, that of the foregoing embodiment.

[0066] If the operating capacity of the screw compressor (1) is controlled, the valve members (52A, 52B) sliding toward the high pressure side (in the direction in which the valve members (52A, 52B) shift from the position shown in FIGS. 9 to the position shown in FIG. 10) respectively increase the opening areas of cylinder openings (51A, 51B) of the low pressure end faces (58a, 58b) of the valve members (52A, 52B) (the opening areas of the bypass passages (59a, 59b)). Then, the refrigerant returns from the cylinder openings (51A, 51B) at a position during a compression stroke of the compression chamber (23) through the bypass passages (59a, 59B) to the low-pressure chamber (11) of the casing (10).

[0067] In this case, as the opening areas increase, the amount of the intermediate-pressure refrigerant returned in the compression mechanism (20) increases. As a result, the operating capacity decreases. In contrast, the valve members (52A, 52B) sliding toward the low pressure side (in the direction in which the valve members (52A, 52B) shift from the position shown in FIG. 10 to the position shown in FIG. 9) increase the associated opening areas. This reduces the amount of the refrigerant returned to the low-pressure chamber (11). This increases the operating capacity. When the valve members (52A, 52B) are slid to respectively vary the opening areas of the cylinder openings (51A, 51B), a flow rate at which the refrigerant returns from the compression chamber (23) during the compression stroke to the low pressure side varies. As a result, the capacity of the compression mechanism (20) varies.

[0068] In this variation, the positions of the low pressure end faces (58a, 58b) of the valve members (52A, 52B) are determined so that the openings of the bypass passages (59a, 59b) for the respective valve members (52A, 52B) communicating with the screw groove (23) has substantially the same area. Thus, the refrigerant is returned through the cylinder openings (51A, 51B) on the low-pressure sides of the valve members (52A, 52B) to the low pressure side by substantially the same amount. As a result, the refrigerant being compressed returns uniformly through the valve members (52A, 52B) to the low pressure chamber.

[0069] In contrast, for example, if the low pressure end faces (58a, 58b) of the valve members (52A, 52B) are not formed to have the same positional relationship with the screw groove (23), the amount of the refrigerant returned through one of the valve members to the low pressure side is reduced. Accordingly, in this case, if the valve members (52A, 52B) are displaced by the same amount, the amount of the refrigerant returned (the unloaded amount of the refrigerant) is smaller than that in the slide valve mechanism (50) of the first variation. Thus, according to the slide valve mechanism (50) of the first variation, the refrigerant is returned through the valve members (52A, 52B) by substantially the same amount. This can reduce the displacements of the valve members (52A, 52B). Since an appropriate amount of refrigerant being compressed is returned through each of the valve members (52A, 52B) to the low pressure side of the compression mechanism, capacity control can be efficiently performed by unloading.

[0070] Just like the foregoing embodiment, the screw compressor (1) including the slide valve mechanism (50) of the first variation also includes the plurality of valve members (52A, 52B) respectively inserted into the plurality of valve housing portions (53A, 53B). This first variation is similar to the first embodiment in that the valve members (52A, 52B) and the valve housing portions (53A, 53B) have an arc-shaped cross section. This substantially prevents the size of the casing from increasing, and substantially prevents the strength of the casing from decreasing.

<Second Variation>

[0071] A configuration of an interlocking mechanism (70) according to a second variation shown in FIGS. 11 and 12 is different from that according to the first embodiment shown in FIG. 8.

[0072] The interlocking mechanism (70) according to the second variation includes a rack and pinion. Specifically, a combination of a first rack (75a) fixed to a first valve member (52A) and a first pinion (76a) meshing with the first rack (75a), and a combination of a second rack (75b) fixed to a second valve member (52B) and a second pinion (76b) meshing with the second rack (75b) form the interlocking mechanism (70). Each pinion (76a, 76b) is fixed to a pinion shaft (76c).

[0073] Just like the first embodiment, high pressure end faces (57a, 57b) of the valve members (52A, 52B) have different inclinations (angles of inclination ($\theta 1$, $\theta 2$)). Further, just like the first embodiment, the strokes of the valve members (52A, 52B) are set to be different from each other. For this purpose, the pinions (76a, 76b) used have different pitch diameters.

[0074] The other configuration of this variation is the same as, or similar to, that of the foregoing first embodiment.

[0075] Just like the embodiment, the screw compressor (1) including the slide valve mechanism (50) of the second variation also includes the plurality of valve members (52A, 52B) respectively inserted into the plurality of valve housing portions (53A, 53B). This second variation is similar to the first embodiment in that the valve members (52A, 52B) and the valve housing portions (53A, 53B) have an arc-shaped cross section. This substantially prevents the size of the casing from increasing, and substantially prevents the strength of the casing from decreasing.

«Other Embodiments»

[0076] The foregoing embodiment may be modified as follows.

[0077] For example, in the foregoing embodiment, the surfaces of each valve member (52A, 52B) and the associated valve housing portion (53A, 53B) fitted to each other are curved to have an arc-shaped cross section. However, these surfaces do not have to be curved to have an arc-shaped cross section. If a plurality of (not always two) valve members (52A, 52B) are provided for one compression chamber, and are respectively housed in valve housing portions (53A, 53B), the size of a casing (10) is more likely to be prevented from increasing, and the strength of the casing (10) is more likely to be substantially prevented from decreasing, than if one large slide valve is used, irrespective of a change in the shape of the surfaces.

[0078] Further, the foregoing embodiment illustrates a screw compressor (1) including only one gate rotor (40) provided for one screw rotor (30) as an example. However, such a screw compressor may include a plurality of gate rotors.

[0079] In the foregoing embodiment, the axial displacements of the valve members (52A, 52B) are different from each other, and the angles of inclination (θ1, θ2) of the high pressure end faces (57a, 57b) of the valve members (52A, 52B) are different from each other. However, either the axial displacements or the angles of inclinations may be different from each other. Even if the axial displacements of the valve members (52A, 52B) are equal to each other, and the angles of inclination thereof are also equal to each other, the casing (10) can be reduced in size.

[0080] In the foregoing embodiment, if two valve members (52A, 52B) are provided, one of them is driven by a driving mechanism (60), and the other one is allowed to follow the one of them through an interlocking mechanism (70). However, both of them may be driven by the driving mechanism (60), and may be configured such that their displacements are adjusted through the interlocking mechanism (70).

[0081] Note that the foregoing description of the embodiment is a merely preferred example in nature, and is not intended to limit the scope, application, or uses of the present disclosure.

INDUSTRIAL APPLICABILITY

[0082] As can be seen from the foregoing description, the present disclosure is useful as a screw compressor including a slide valve mechanism.

DESCRIPTION OF REFERENCE CHARACTERS

[0083]

1	Screw Compressor
10	Casing
20	Compression Mechanism
23	Compression Chamber
25	Cylinder
30	Screw Rotor
31	Screw Groove
40	Gate Rotor
41	Gate
50	Slide Valve Mechanism
51	Cylinder Opening
51A	First Cylinder Opening
51B	Second Cylinder Opening
52	Valve Member
52A	First Valve Member
52B	Second Valve Member
53	Valve Housing Portion
53A	First Valve Housing Portion
53B	Second Valve Housing Portion
54	Curved Wall
55	Curved Surface
57a	High Pressure End Face
57b	High Pressure End Face
58a	Low Pressure End Face
58b	Low Pressure End Face
60	Driving Mechanism
70	Interlocking Mechanism

Claims

1. A screw compressor comprising:

a screw rotor (30) having helical screw grooves (31);
a gate rotor (40) having gates (41) meshing with the screw grooves (31);
a casing (10) internally having a cylinder (25) into which the screw rotor (30) is rotatably inserted;
a compression chamber (23) defined inside the cylinder (25) by the screw rotor (30) and the gate rotor (40) meshing with each other; and
a slide valve mechanism (50) configured to adjust an opening area of a cylinder opening (51A, 51B) of the cylinder (25), the cylinder opening (51A, 51B) communicating with the compression chamber (23),
the slide valve mechanism (50) including:

a plurality of valve members (52A, 52B) arranged for the single compression chamber (23), the valve members (52A, 52B) moving in an axial direction of the screw rotor (30) to adjust the opening area; and
a plurality of valve housing portions (53A, 53B) of the casing (10) housing the valve members (52A, 52B), respectively.

2. The screw compressor of claim 1, wherein each valve housing portion (53A, 53B) has a curved wall (54) projecting radially outward of the screw rotor (30) from the cylinder (25) to have an arc-shaped cross section, the curved wall (54) extending in the

axial direction of the screw rotor (30), and
an outer peripheral surface of each valve member (52A, 52B) is configured as a curved surface having an arc-shaped cross section, the curved surface being fitted to the curved wall (54) of an associated one of the valve housing portions (53A, 53B).

3. The screw compressor of claim 1 or 2, wherein
the screw rotor (30) and the gate rotor (40) are provided as a pair of rotors within the casing (10).

4. The screw compressor of any one of claims 1 to 3, wherein
axial displacements of the valve members (52A, 52B) during operation of the slide valve mechanism (50) are different from each other.

5. The screw compressor of any one of claims 1 to 4, wherein
each valve member (52A, 52B) has a high pressure end face (57a, 57b) facing a channel through which a high-pressure fluid compressed in the compression chamber (23) flows into a discharge passage in the casing (10), and
the high pressure end faces (57a, 57b) of the valve members (52A, 52B) have different angles of inclination ($\theta 1$, $\theta 2$).

6. The screw compressor of any one of claims 1 to 5, wherein
the slide valve mechanism (50) further includes:

    a driving mechanism (60) configured to move at least one of the valve members (52A, 52B) as a target member to be driven; and
    an interlocking mechanism (70) configured to move another one of the valve members (52A, 52B) as a following target member following the target member to be driven.

7. The screw compressor of any one of claims 1 to 6, wherein
the slide valve mechanism (50) is an operating capacity adjusting mechanism configured to return a portion of an intermediate-pressure fluid being compressed through a plurality of bypass passages (59a, 59b) of the casing (10) to an inlet of the compression chamber (23),
each valve member (52A, 52B) has a low pressure end face (58a, 58b) facing a channel through which the intermediate-pressure fluid flows out of the compression chamber (23) into an associated one of the bypass passages (59a, 59b), and
axial positions of the low pressure end faces (58a, 58b) of the valve members (52A, 52B) are different from each other.

8. The screw compressor of claim 7, wherein
opening areas of the bypass passages (59a, 59b) respectively corresponding to the valve members (52A, 52B) are determined to be substantially equal to each other.

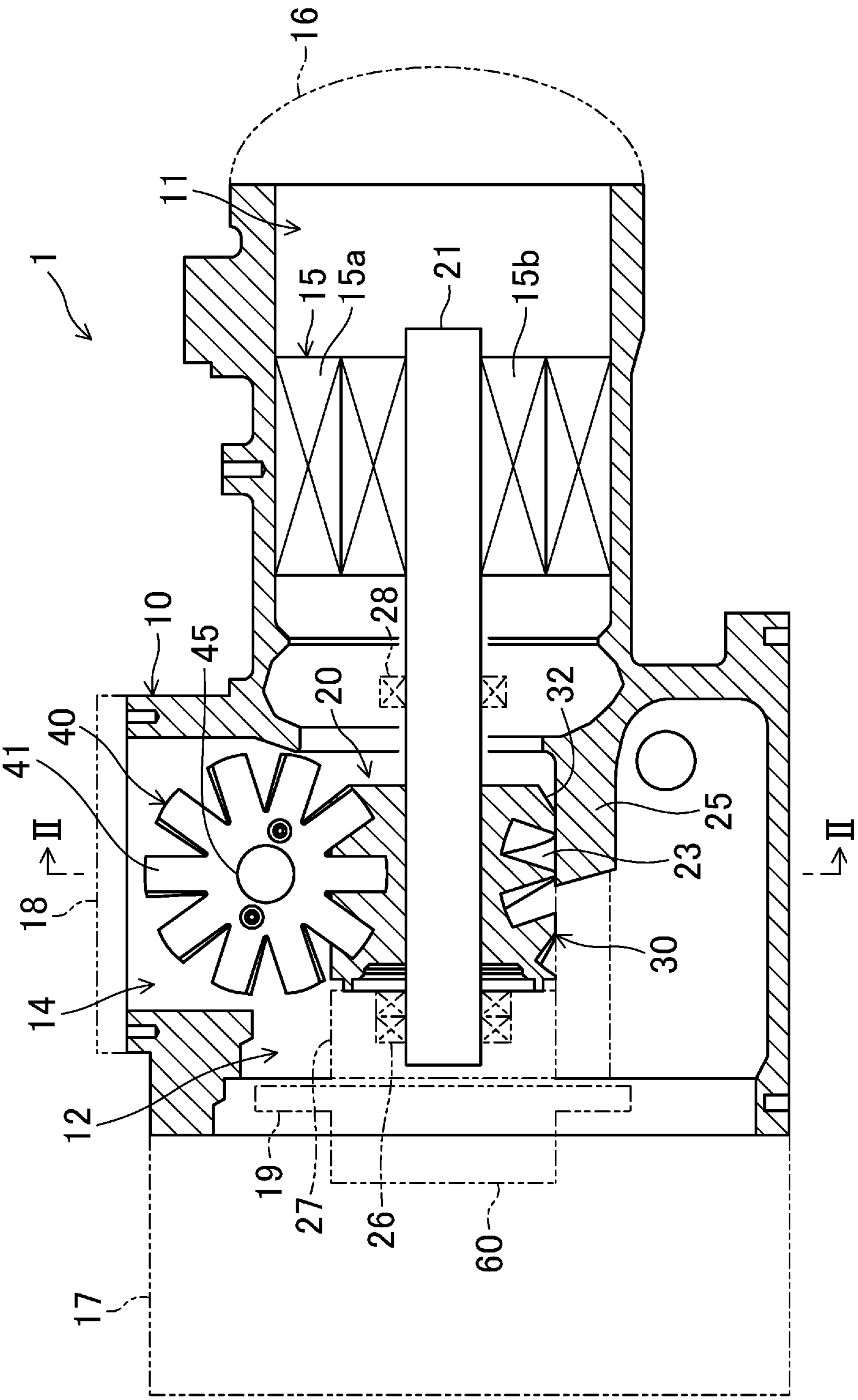

1
10
11
12
14
15
15a
15b
16
17
18
19
20
21
23
25
26
27
28
30
32
40
41
45
60
II
II

FIG.1

FIG.2

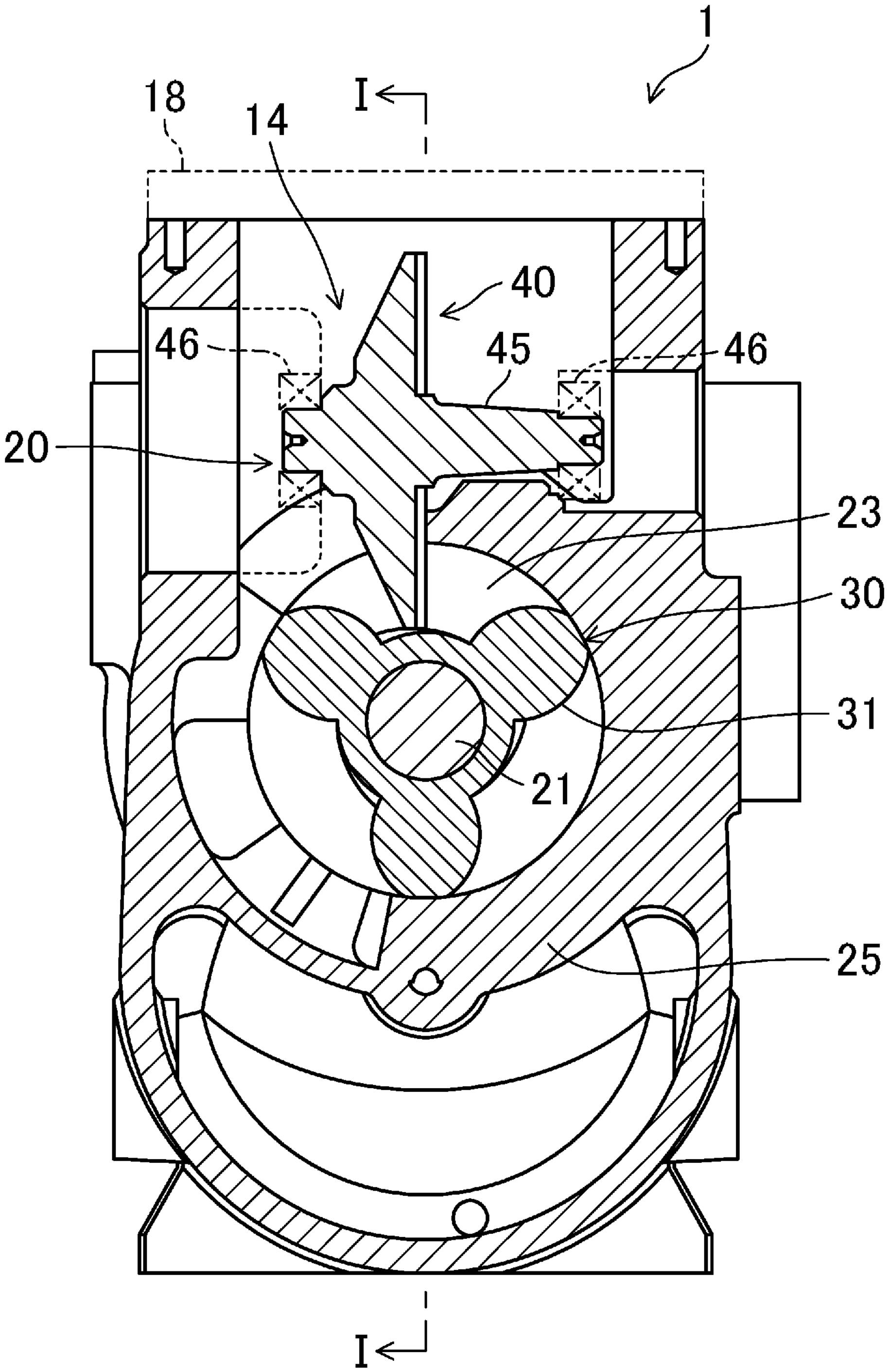


FIG.3

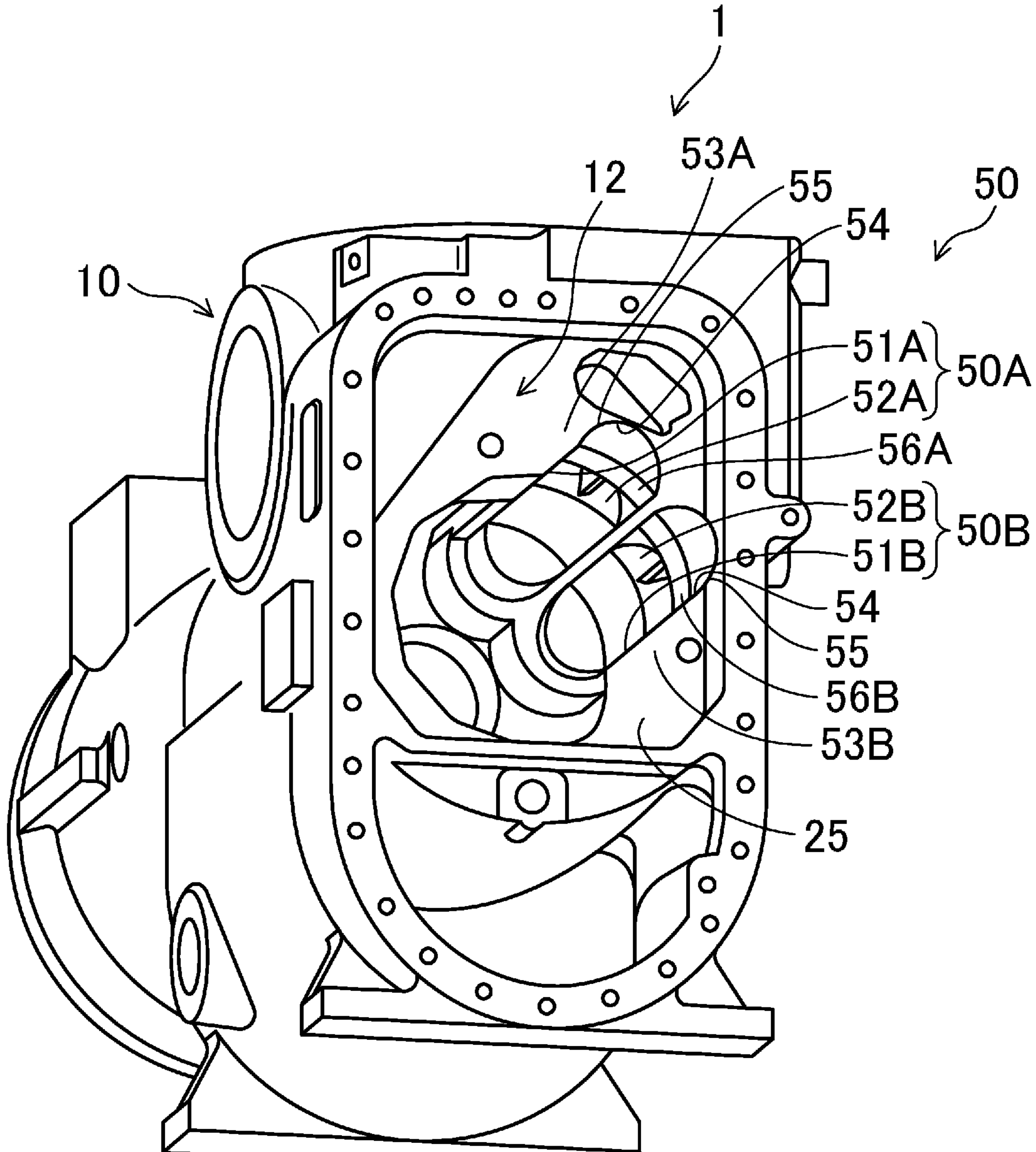


FIG.4

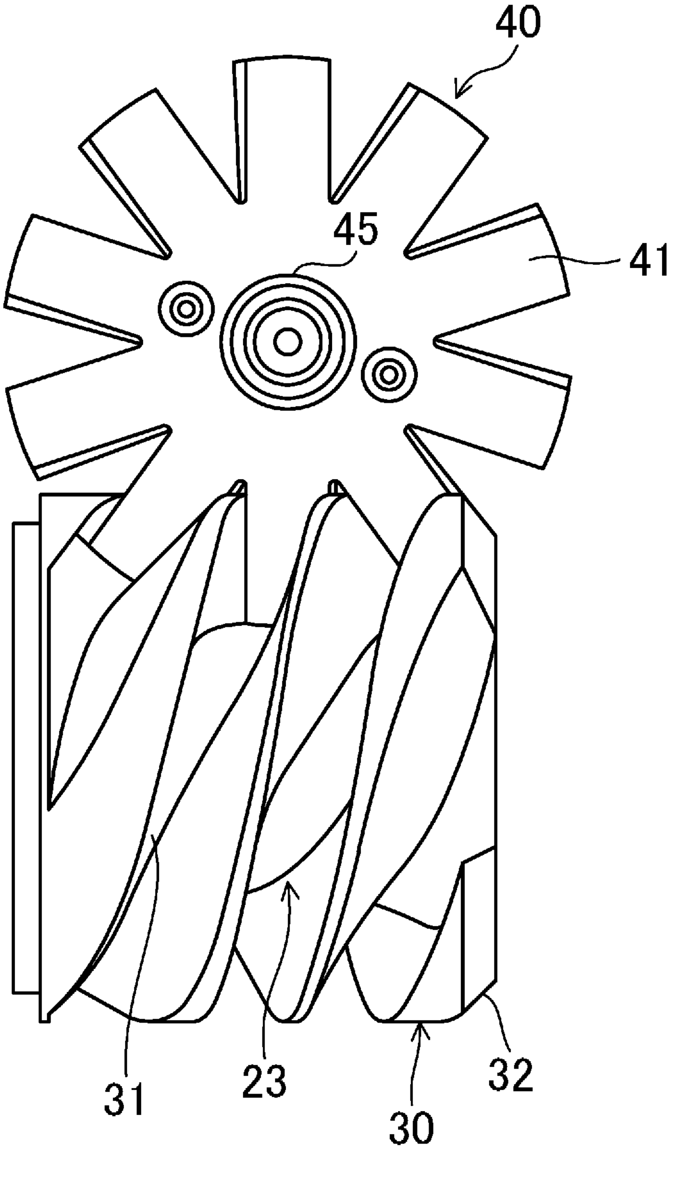


FIG.5

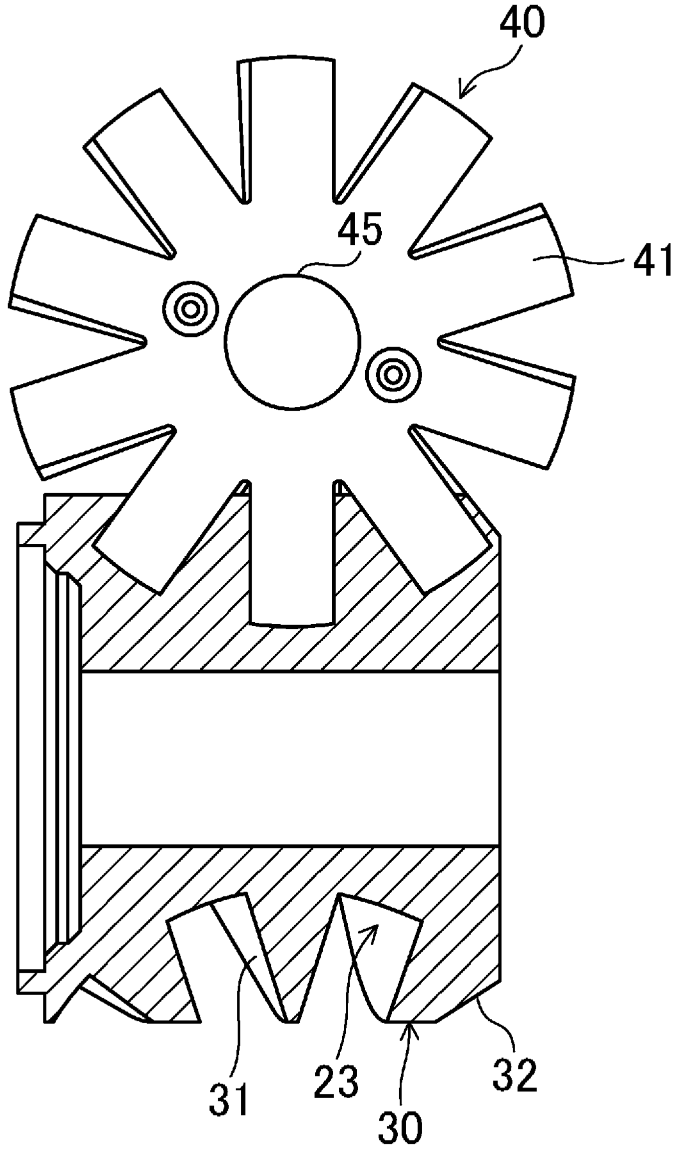


FIG.6

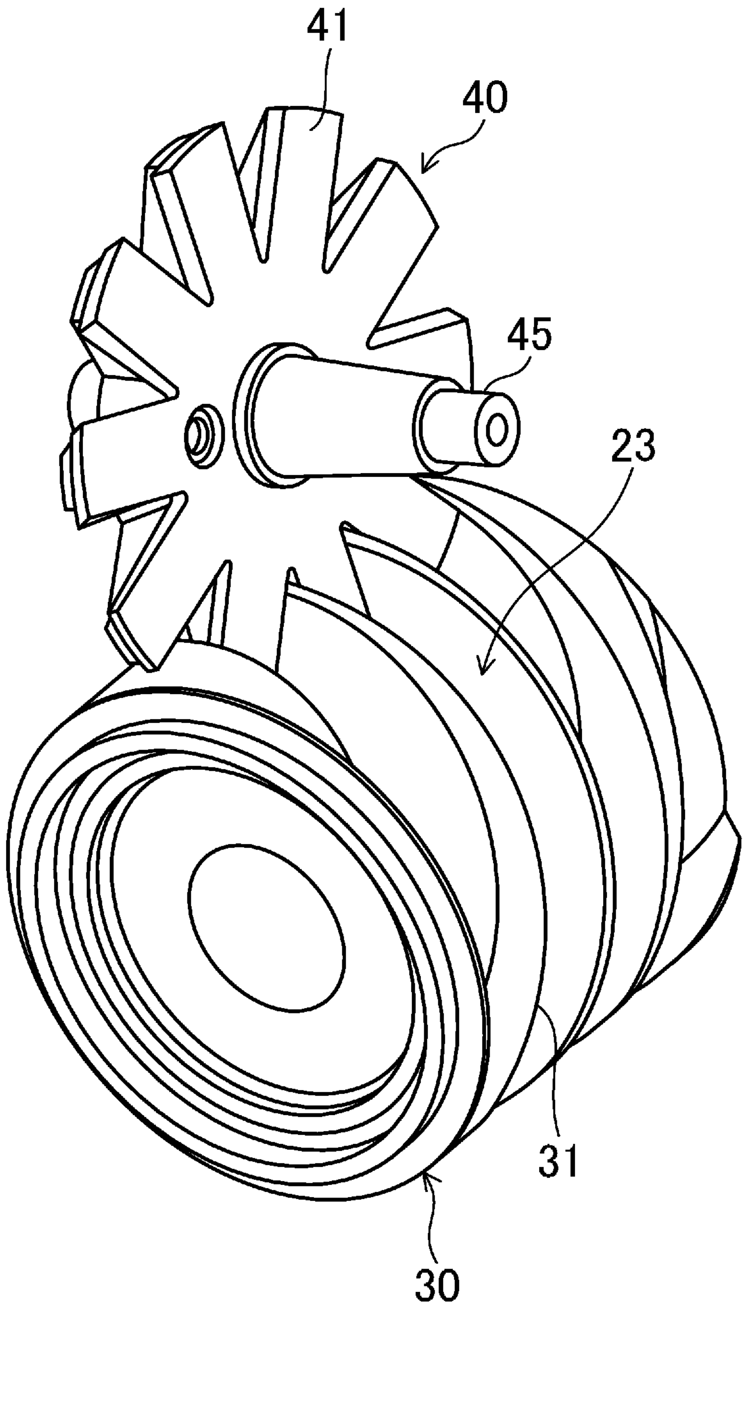


FIG.7

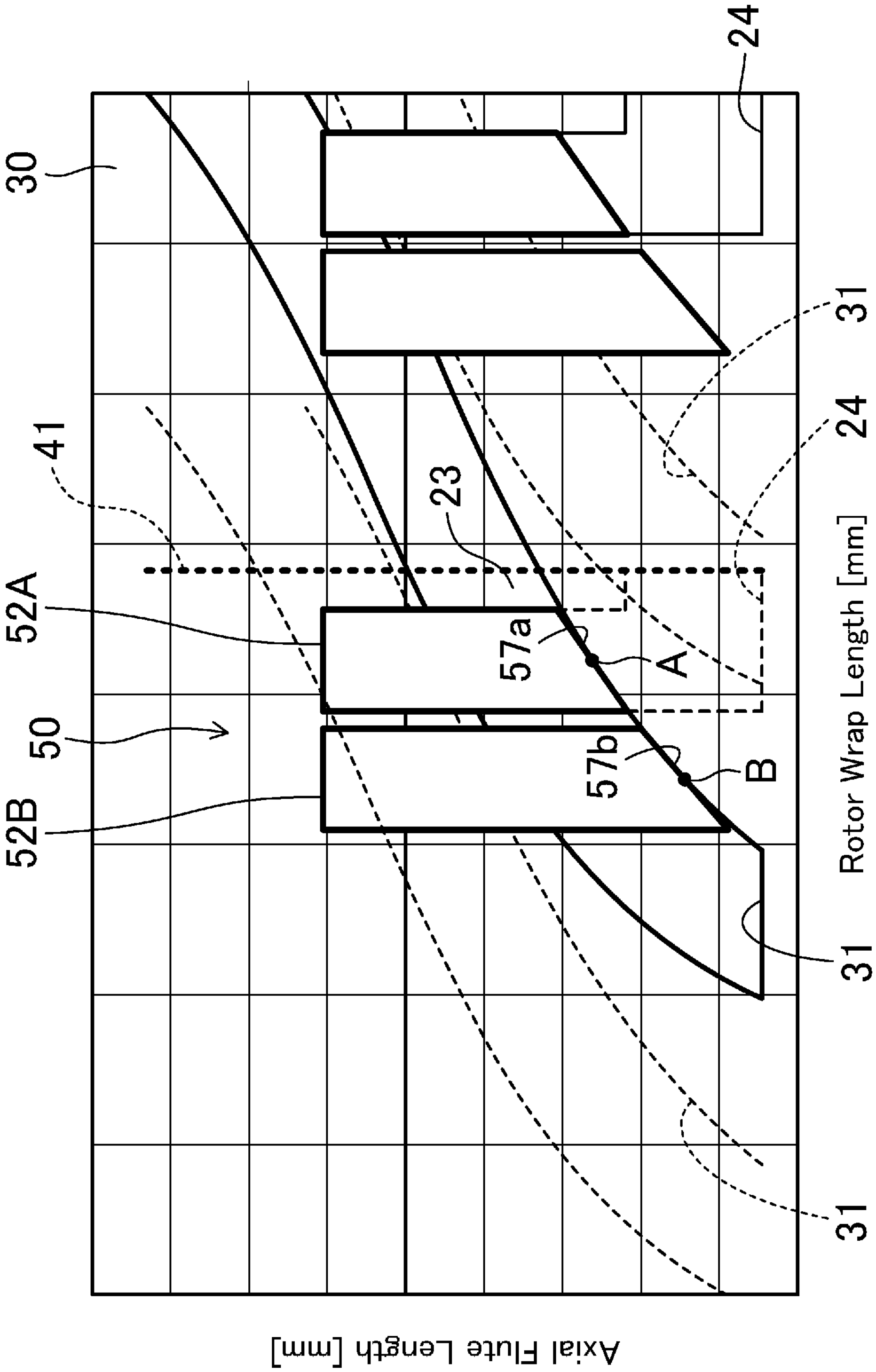

30
24
31
24
41
23
52A
57a
A
50
57b
B
52B
31
31
Rotor Wrap Length [mm]
Axial Flute Length [mm]

FIG.8

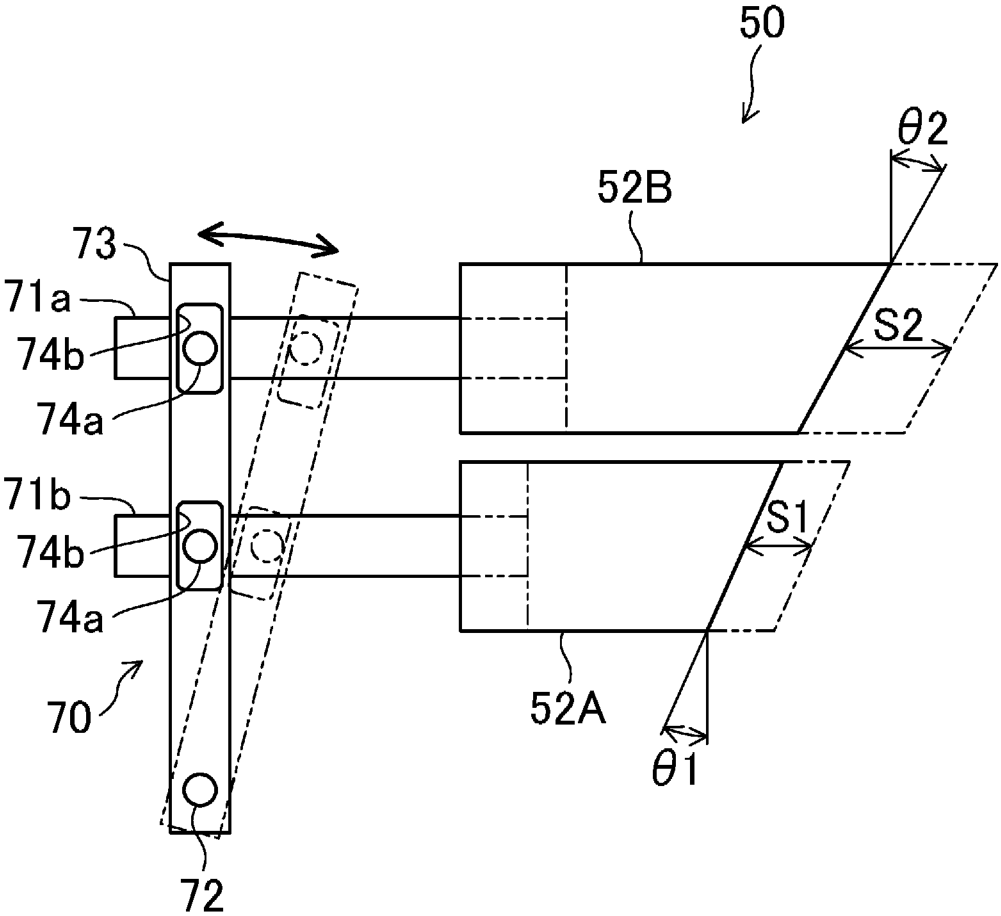


FIG.9

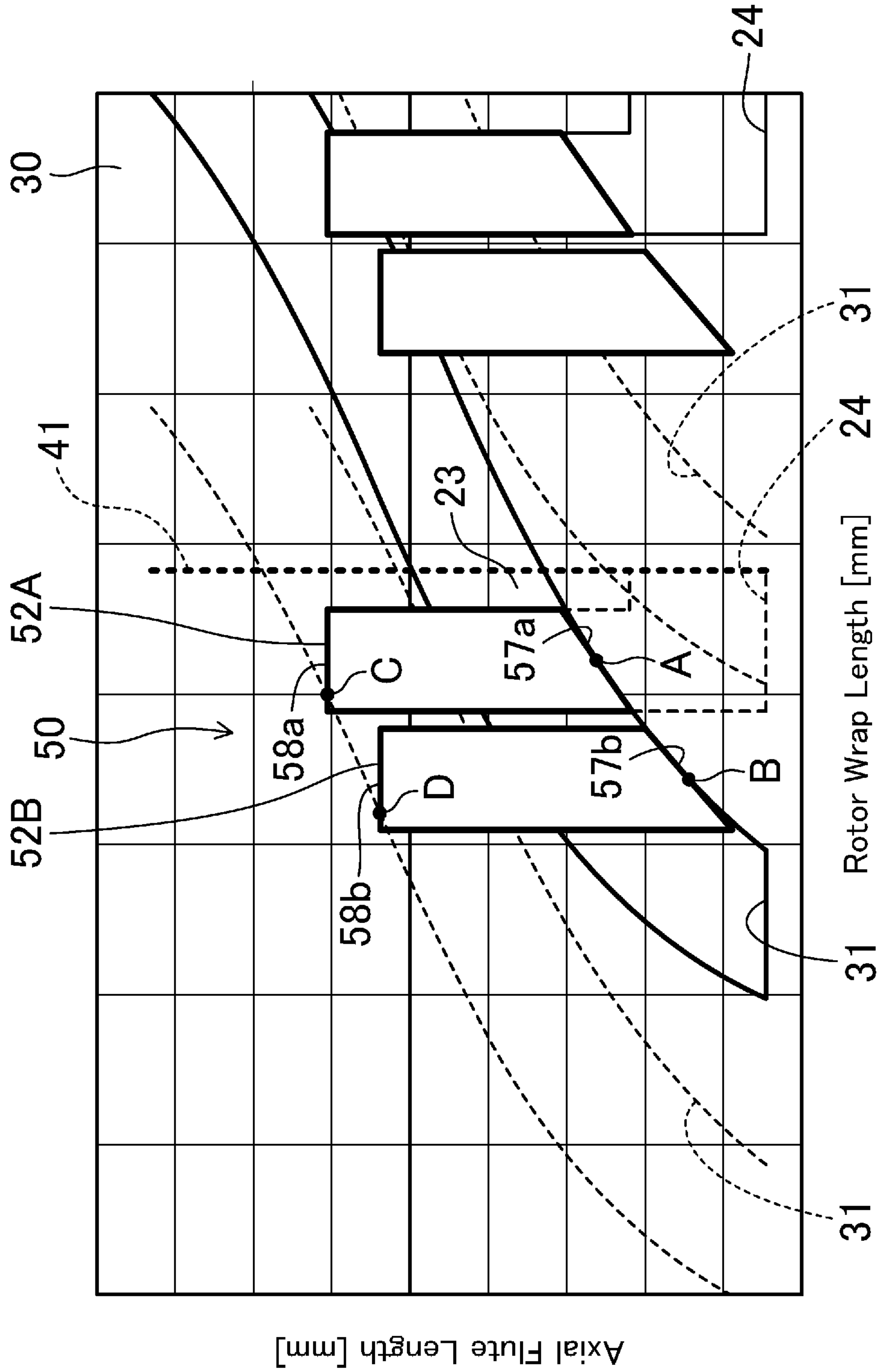

30
24
31
41
52A
50
52B
23
C
58a
D
58b
57a
A
57b
B
Rotor Wrap Length [mm]
Axial Flute Length [mm]

FIG.10

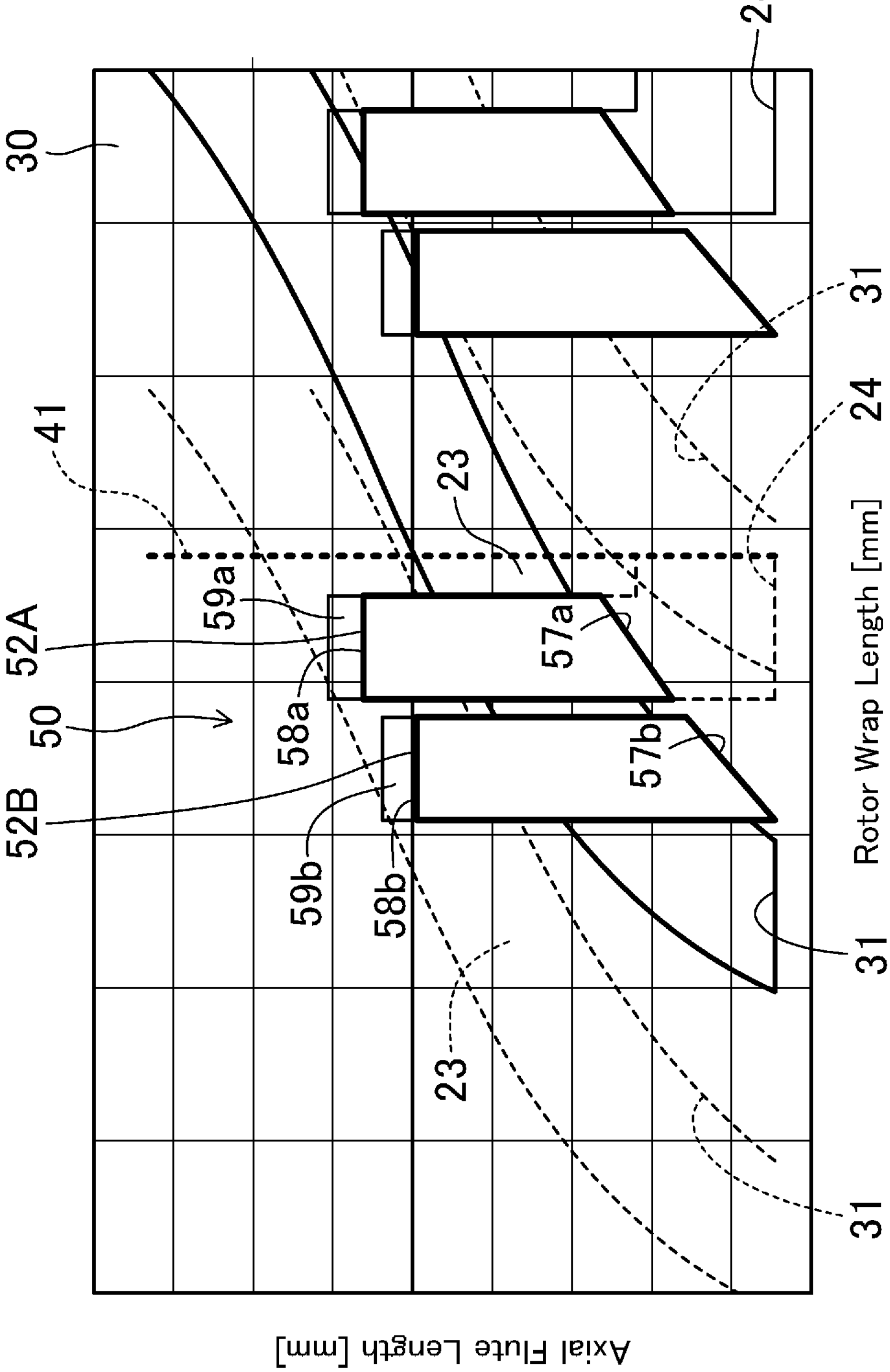

30
24
31
24
41
23
59a
52A
57a
50
58a
57b
52B
59b
58b
31
23
31
Rotor Wrap Length [mm]
Axial Flute Length [mm]

FIG.11

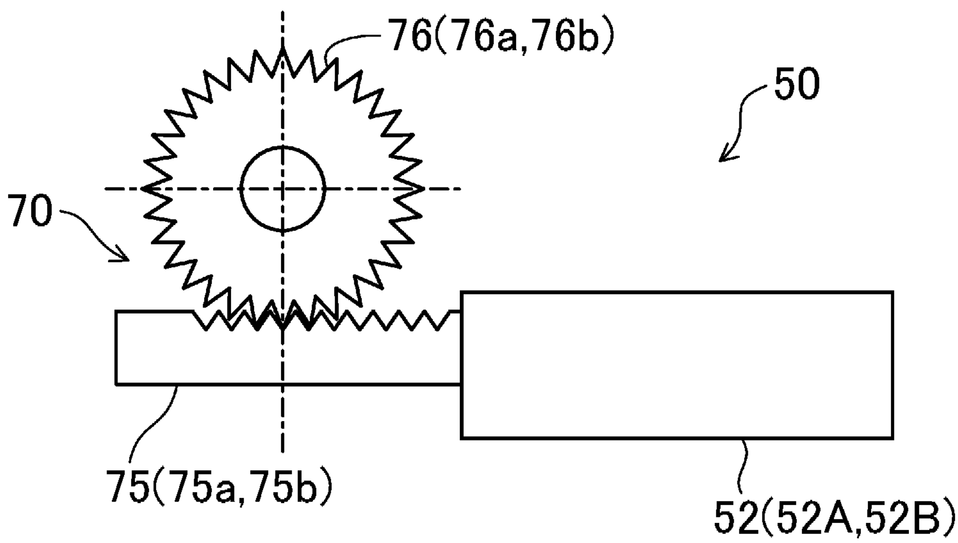

76(76a,76b)
50
70
75(75a,75b)
52(52A,52B)

FIG.12

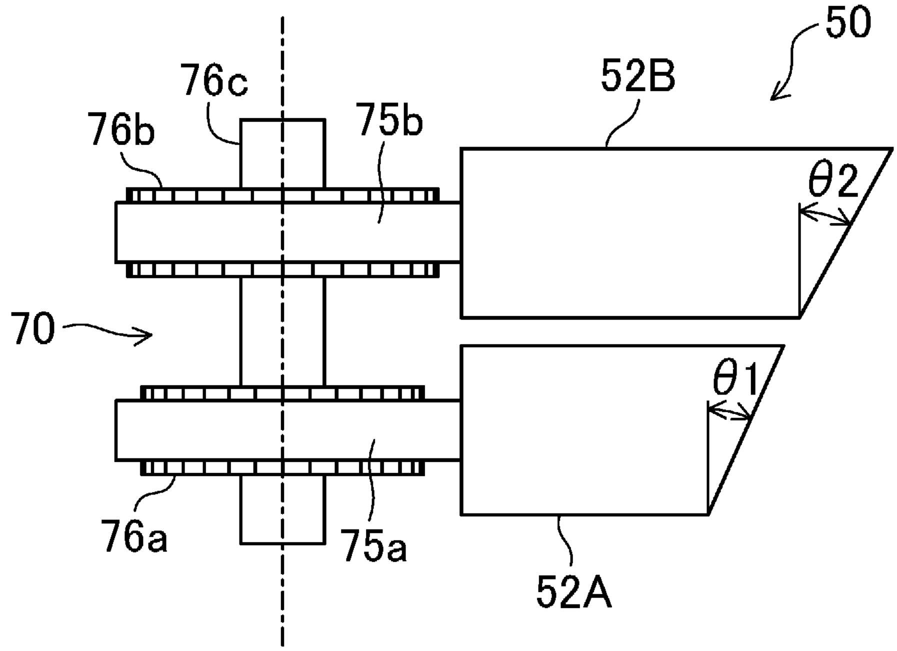
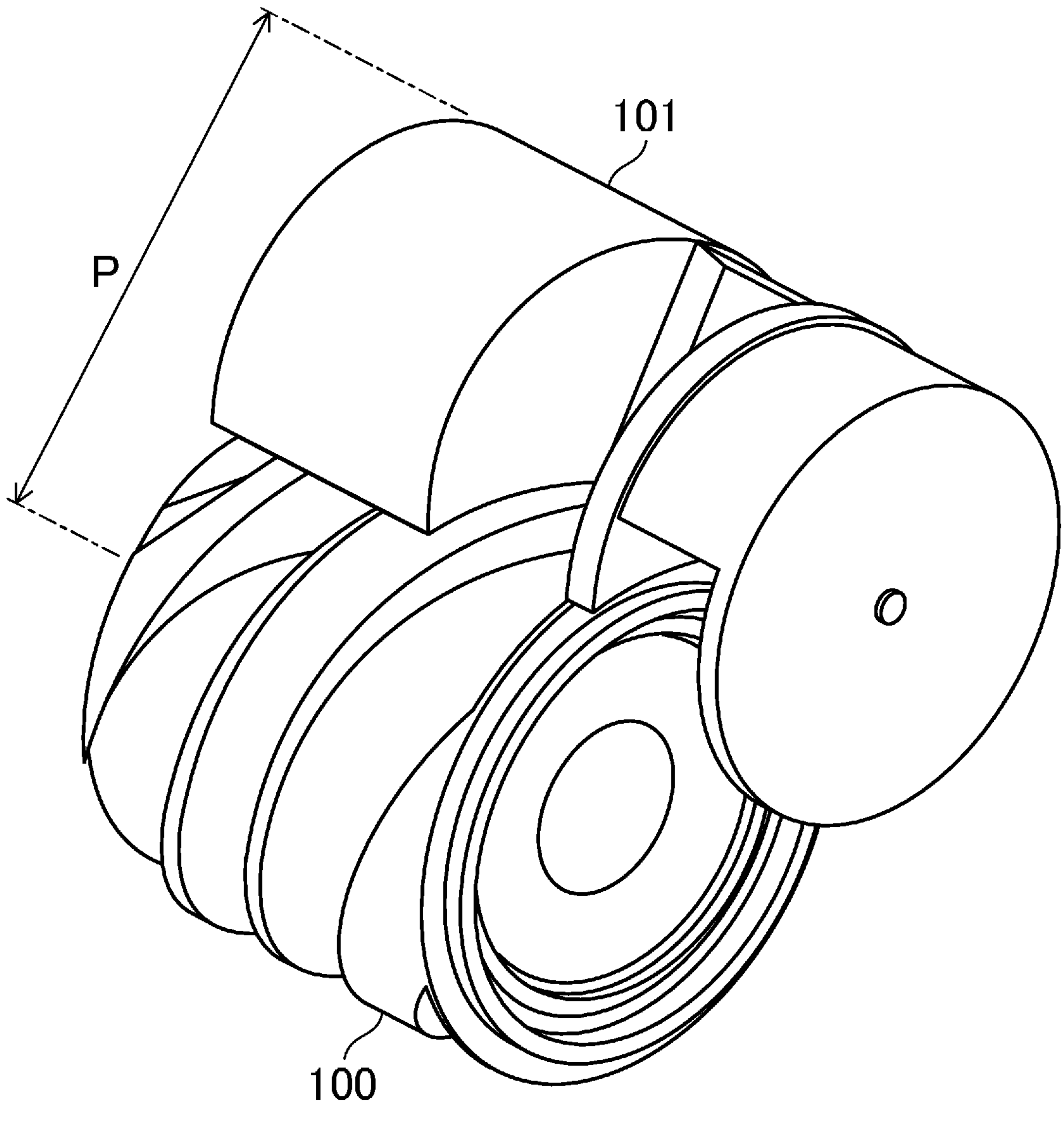

50
76c
52B
76b
75b
θ2
70
θ1
76a
75a
52A

FIG.13



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/038630

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F04C18/52(2006.01)i, F04C28/12(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, F04C28/12

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 1971-2018
Registered utility model specifications of Japan 1996-2018
Published registered utility model applications of Japan 1994-2018

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.
X Y	US 2008/0206075 A1 (PICOUET, Jean Louis) 28 August 2008, paragraphs [0023]-[0044], fig. 2-8B & WO 2008/103147 A1 & CA 2677951 A & CN 101657641 A	1-4 5-8
Y	JP 61-277885 A (VILTER MANUFACTURING CORPORATION) 08 December 1986, fig. 6 & US 4610612 A, fig. 6	5-8
Y	US 4704069 A (VILTER MANUFACTURING CORPORATION) 03 November 1987, fig. 6 (Family: none)	5-8
Y	JP 2013-177868 A (DAIKIN INDUSTRIES, LTD.) 09 September 2013, paragraphs [0053]-[0066], fig. 6 (Family: none)	5-8

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

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Date of the actual completion of the international search	Date of mailing of the international search report
28.11.2018	11.12.2018

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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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/038630

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2014-47708 A (MITSUBISHI ELECTRIC CORP.) 17 March 2014, entire text, all drawings (Family: none)	1-8
A	JP 2014-29133 A (MITSUBISHI ELECTRIC CORP.) 13 February 2014, entire text, all drawings (Family: none)	1-8
A	JP 2009-2257 A (DAIKIN INDUSTRIES, LTD.) 08 January 2009, entire text, all drawings & US 2010/0183468 A1, entire text, all drawings & WO 2009/001765 A1 & EP 2175138 A1 & CN 101688534 A	1-8
A	JP 54-026514 A (OMPHAL SA) 28 February 1979, entire text, all drawings & DE 2833292 A1 & FR 2398901 A	1-8
A	WO 2017/094057 A1 (MITSUBISHI ELECTRIC CORP.) 08 June 2017, entire text, all drawings (Family: none)	1-8
A	GB 429878 A (GOOD, Paul Eckert) 07 June 1935, entire text, all drawings (Family: none)	1-8

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Patent documents cited in the description

- JP H06042475 B **[0007]**