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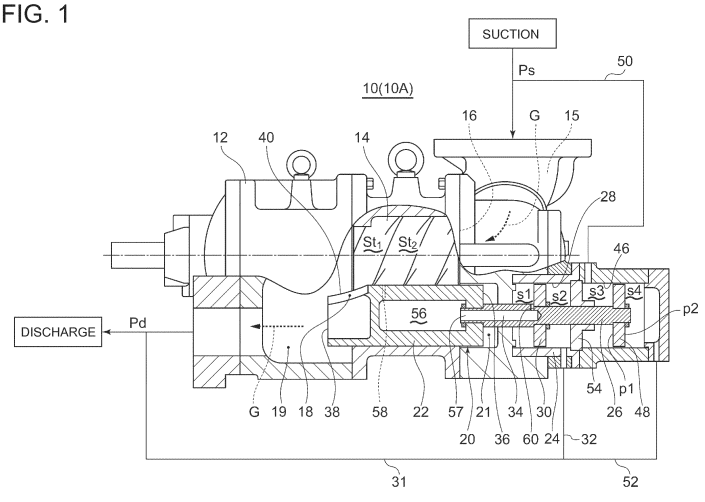
(54) SCREW COMPRESSOR

(57) A screw compressor according to some embodiments includes a screw rotor, a rotor casing accommodating the screw rotor, and an internal-volume-ratio-adjusting valve capable of changing internal volume ratio. The internal-volume-ratio-adjusting valve includes a valve body movable along an axial direction of the screw rotor and defining a gas-discharge position, and a cylinder containing at least one pressurizing chamber with a cylinder rod and a piston. The cylinder rod is coupled to the valve body and disposed along the axial direction. The piston is fixed inside the pressurizing chamber to the cylinder rod and divides the pressurizing chamber into two pressurizing spaces along the axial direction. The screw compressor further includes a first communication passage connecting one of the two pressurizing spaces with the discharge gas passage, and a second communication passage connecting the other with a just-before-discharge tooth space immediately before a tooth space that communicates with the discharge port.

FIG. 1



EP 3 524 818 A1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a screw compressor including an internal-volume-ratio adjusting valve.

BACKGROUND ART

[0002] A screw compressor includes a screw rotor including a pair of a male rotor and a female rotor, and a rotor casing accommodating the screw rotor. The rotor casing has a suction gas passage and a suction port through which a gas to be compressed is sucked, and a discharge port and a discharge gas passage through which the compressed gas is discharged.

[0003] A tooth space is formed between the screw rotor and the rotor casing, and when the male rotor and the female rotor rotate in opposite directions, a gas is sucked into the tooth space from the suction port. The gas sealed in the tooth space is compressed as the tooth space gradually contracts with the rotation of the screw rotor, and the compressed gas is discharged from the discharge port.

[0004] The screw compressor is the most effective when the pressure of the gas sealed in the tooth space just before communication with the discharge port is equal to the pressure of the gas in the discharge gas passage (which is substantially equal to the discharge pressure of the compressor).

[0005] (The discharge pressure of the compressor, the pressure of the gas in the discharge gas passage, and the pressure of the gas discharged from the discharge port are treated as equal, regardless of pressure loss.)

[0006] The tooth space is shifted toward the discharge side with the rotation of the screw rotor, and when the volume of the tooth space is maximized, the tooth space is isolated from the suction port. A ratio of this maximum volume to the tooth space volume just before communication with the discharge port is an internal volume ratio (maximum volume / tooth space volume just before discharge), and an internal-volume-ratio adjusting valve is used for adjusting the internal volume ratio to obtain the maximum efficiency.

[0007] Examples of the internal-volume-ratio adjusting valve include a slide valve which moves a valve body in the axial direction of the screw rotor within the rotor casing and defines the discharge position of the gas. As a method of operating the slide valve, there may be mentioned a method of manually operating the valve body, and a method of hydraulically driving the valve body using a hydraulic circuit in accordance with command from an external controller.

[0008] Patent Document 1 discloses a configuration with a hydraulic cylinder, in which a valve body is coupled to a piston slidably disposed within the cylinder via a piston rod, and the piston is moved in the axial direction of the screw rotor by hydraulic driving.

[0009] Patent Document 2 discloses a configuration which eliminates a driving mechanism using hydraulic driving or the like. In this configuration, an internal space of a cylinder which contains a piston coupled to a valve body is divided into three pressurizing chambers, and discharge gas or suction gas is selectively introduced into the pressurizing chambers, so that three-stage different differential pressures are imparted to the piston by differential pressure between discharge gas and suction gas or total pressure of discharge gas and suction gas. This allows the piston to be moved into three positions.

Citation List

Patent Literature

[0010]

Patent Document 1: JPH10-2288A
Patent Document 2: JP2014-206098A

SUMMARY

Problems to be Solved

[0011] It is difficult to frequently operate a valve body with the method of manually controlling the position of a valve body of an internal-volume-ratio adjusting valve. Accordingly, it is difficult to keep the screw compressor at high efficiency by this method.

[0012] The method of operating a valve body by hydraulic driving requires a hydraulic instrument and accessories such as an electromagnetic valve for moving the valve body, and a control instrument including sensors, resulting in costly.

[0013] The means disclosed in Patent Document 2 is advantageous in that it does not require a hydraulic instrument for driving the valve body. However, in this means, the position of the valve body of the slide valve is limited to three positions, and thus continuous positional control is difficult. Further, this means fails to adjust the position of the valve body so that the pressure of the gas sealed in the tooth space just before communication with the discharge port is equal to the pressure of the gas in the discharge gas passage.

[0014] An object of some embodiments is to improve the efficiency of a screw compressor by equalizing the pressure of a gas in a tooth space just before discharge with the discharge pressure of the compressor, without expensive driving and control instruments.

Solution to the Problems

[0015]

(1) According to some embodiments, a screw compressor includes: a screw rotor including a pair of a male rotor and a female rotor; a rotor casing accommodating the screw rotor, the rotor casing having a suction gas passage and a suction port through which a gas is sucked and a discharge port and a discharge gas passage through which the gas is discharged; and an internal-volume-ratio adjusting valve capable of changing an internal volume ratio. The internal-volume-ratio adjusting valve includes: a valve body disposed inside the rotor casing, the valve body being movable along an axial direction of the screw rotor and defining a discharge position at which the gas is discharged from tooth spaces formed between the screw rotor and the rotor casing to the discharge port; and a cylinder containing at least one pressurizing chamber and having a cylinder rod and a piston, the cylinder rod being coupled to the valve body and being disposed along the axial direction of the screw rotor, the piston being fixed inside the or each pressurizing chamber to the cylinder rod and dividing the or each pressurizing chamber into two pressurizing spaces along the axial direction of the screw rotor. The screw compressor further includes: a first communication passage connecting a first one of the two pressurizing spaces with the discharge gas passage; and a second communication passage connecting a second one of the two pressurizing spaces with a just-before-discharge tooth space immediately before a tooth space that communicates with the discharge port.

To the piston of the internal-volume-ratio adjusting valve, the pressure of gas supplied to the two pressurizing spaces is applied, and thus, opposite forces are applied to the piston along the axial direction of the screw rotor (hereinafter, also referred to as "rotor axial direction").

Into one of the two pressurizing spaces, the gas in the discharge gas passage is introduced via the first communication passage, and thus the pressure of the discharge gas is applied to the piston. Into the other of the two pressurizing spaces, the gas is introduced from the just-before-discharge tooth space via the second communication passage, and the pressure of this gas is applied to the piston.

The valve body is moved in the rotor axial direction by the difference between the pressures applied to the piston from both sides. When the pressures applied from both sides are equal to each other, the movement of the valve body of the internal-volume-ratio adjusting valve in the screw rotor axial direction is stopped.

In this way, since the valve body is automatically moved into a position where the discharge pressure in the discharge gas passage is equal to the pressure in the just-before-discharge tooth space, the pressure of the gas in the discharge gas passage is always made equal to the pressure of the gas in the just-before-discharge tooth space. Thus, it is possible to automatically and continuously move the valve body into the optimum position always, and thus it is possible to constantly operate the screw compressor most efficiently. On the other hand, since the valve body is operated by the difference between pressures applied to the piston from both sides, it is unnecessary to provide driving and control instruments for driving and controlling the valve body

(2) In an embodiment, in the above configuration (1), the first one of the two pressurizing spaces is located on a suction port side with respect to the piston, and the second one of the two pressurizing spaces is located on a discharge port side with respect to the piston.

With the above configuration (2), the discharge pressure of the compressor is transmitted to one of the two pressurizing spaces, and the pressure of the just-before-discharge tooth space is transmitted to the other of the pressurizing spaces.

Thus, for instance, if the discharge pressure of the compressor is higher, the valve body of the internal-volume-ratio adjusting valve is pushed toward the discharge port; whereas if the pressure of the just-before-discharge tooth space is higher, the valve body of the internal-volume-ratio adjusting valve is pushed toward the suction port. Consequently, the pressure of the gas in the just-before-discharge tooth space is automatically adjusted so as to be equal to the pressure of the discharge gas passage.

(3) In an embodiment, in the above configuration (1) or (2), the valve body has a first end surface facing a space filled with a gas of suction pressure (hereinafter, also referred to as "suction gas space") communicating with the suction gas passage and a second end surface facing the discharge gas passage, and the cylinder contains a first

pressurizing chamber and a second pressurizing chamber which are arranged along the axial direction of the screw rotor. In the first pressurizing chamber, the first one of the two pressurizing spaces separated by the piston communicates with the first communication passage, and the second one of the two pressurizing spaces communicates with the second communication passage. Further, the screw compressor includes: a third communication passage connecting the suction gas passage with a forward pressurizing space, where the piston is pressurized in a forward direction from the discharge port toward the suction port, of the two pressurizing spaces separated by the piston in the second pressurizing chamber; and a fourth communication passage connecting the discharge gas passage with a backward pressurizing space, where the piston is pressurized in a backward direction from the suction port toward the discharge port, of the two pressurizing spaces formed in the second pressurizing chamber. An area of a pressure-receiving surface of the first end surface pressurized by the gas in the suction gas space is equal to an area of a pressure-receiving surface of the piston in the forward pressurizing space, and an area of a pressure-receiving surface of the second end surface pressurized by the gas in the discharge gas passage is equal to an area of a pressure-receiving surface of the piston in the backward pressurizing space.

In the above embodiment, the valve body of the internal-volume-ratio adjusting valve has a first end surface facing the suction gas space and a second end surface facing the discharge gas passage. In this embodiment, the pressure of the gas sucked from the suction port to the screw rotor is applied to the first end surface, and the pressure of the gas discharged from the discharge port to the discharge gas passage is applied to the second end surface.

In this embodiment, the gas in the suction gas passage is introduced into the forward pressurizing space in the second pressurizing chamber, and thus the piston receives a pressure equal and opposite to the pressure applied to the first end surface from the gas in the suction gas space. Further, the gas in the suction gas passage is introduced into the backward pressurizing space in the second pressurizing chamber, and thus the piston receives a pressure equal and opposite to the pressure applied to the second end surface from the gas in the discharge gas space.

As a result, the pressures applied to the valve body of the internal-volume-ratio adjusting valve from the discharge gas passage and the suction gas passage are canceled, and thus the valve body is operated only by the pressure applied to the piston in the first pressurizing chamber.

The first pressurizing chamber may be located at a position closer to the discharge port than the second chamber is, or the second pressurizing chamber may be located at a position closer to the discharge port than the first chamber is.

(4) In an embodiment, in any one of the above configurations (1) to (3), the second communication passage includes: a hollow portion formed in the valve body and in the cylinder rod; a first communication hole formed in the valve body and connecting the just-before-discharge tooth space and the hollow space; and a second communication hole formed in the cylinder rod and connecting the hollow portion and the second one of the two pressurizing spaces.

With the above configuration (4), since the second communication passage is formed within the valve body and the cylinder rod, a space outside the valve body and the cylinder for forming the second communication passage is unnecessary. Thus, it is possible to downsize the screw compressor.

(5) In an embodiment, in any one of the above configurations (1) to (3), the second communication passage includes a channel formed in the rotor casing facing a discharge-side end of the screw rotor, and the channel has an opening open to the just-before-discharge tooth space from a wall surface of the rotor casing.

With the above configuration (5), the just-before-discharge tooth space communicates with the second communication passage, via the opening and the channel, at a position where the just-before-discharge tooth space is closest to the discharge port. Accordingly, it is possible to improve the precision for making the pressure of the gas in the just-before-discharge tooth space equal to the pressure of the gas discharged from the discharge port.

(6) In an embodiment, in any one of the above configurations (1) to (5), the cylinder contains a first pressurizing chamber and a second pressurizing chamber which are arranged along the axial direction of the screw rotor, the first pressurizing chamber is located on a discharge port side of the screw rotor with respect to the second pressurizing chamber, among the two pressurizing spaces formed in the first pressurizing chamber, the second one, communicating with the second communication passage, of the two pressurizing spaces is located on the discharge port side with respect to the first one of the two pressurizing spaces.

[0016] With the above configuration (6), the second one of the two pressurizing spaces, which communicates with the second communication passage, is located closest, of the pressurizing spaces formed by the first pressurizing chamber and the second pressurizing chamber, to the discharge port. Thus, it is possible to reduce the volume of the hollow portion formed in the valve body and the rod, and it is possible to easily form the second communication passage.

Advantageous Effects

[0017] According to some embodiments, during operating of the screw compressor, it is possible to constantly equalize the pressure of the gas in a tooth space just before discharge with the pressure of the gas discharged from the discharge

port. Thereby, it is possible to constantly operate the screw compressor at high efficiency. Further, since driving and control instruments are unnecessary for operating the valve body of the internal-volume-ratio adjusting valve, it is possible to reduce the cost.

BRIEF DESCRIPTION OF DRAWINGS

[0018]

FIG. 1 is a vertical front view of a screw compressor according to an embodiment.
FIG. 2 is a vertical front view of a screw compressor according to an embodiment.
FIG. 3 is a top view of an internal-volume-ratio adjusting valve according to an embodiment, where the internal-volume-ratio adjusting valve is partially shown by a cross-section.
FIG. 4 is a vertical front view of an internal-volume-ratio adjusting valve according to an embodiment.
FIG. 5 is a front view of a valve body, showing an end surface of the valve body, as seen in the direction of arrow A in FIG. 4.
FIG. 6 is a perspective view of an internal-volume-ratio adjusting valve and a rotor casing according to an embodiment.
FIG. 7 is a graph showing a case where the pressure of a just-before-discharge tooth space is optimum.
FIG. 8 is a graph showing a case where the pressure of a just-before-discharge tooth space is in excessive compression.
FIG. 9 is a graph showing a case where the pressure of a just-before-discharge tooth space is in insufficient compression.

DETAILED DESCRIPTION

[0019] Embodiments of the present invention will now be described in detail with reference to the accompanying drawings. It is intended, however, that unless particularly specified, dimensions, materials, shapes, relative positions and the like of components described in the embodiments shall be interpreted as illustrative only and not intended to limit the scope of the present invention.

[0020] For instance, an expression of relative or absolute arrangement such as "in a direction", "along a direction", "parallel", "orthogonal", "centered", "concentric" and "coaxial" shall not be construed as indicating only the arrangement in a strict literal sense, but also includes a state where the arrangement is relatively displaced by a tolerance, or by an angle or a distance whereby it is possible to achieve the same function.

[0021] For instance, an expression of an equal state such as "same" "equal" and "uniform" shall not be construed as indicating only the state in which the feature is strictly equal, but also includes a state in which there is a tolerance or a difference that can still achieve the same function.

[0022] Further, for instance, an expression of a shape such as a rectangular shape or a cylindrical shape shall not be construed as only the geometrically strict shape, but also includes a shape with unevenness or chamfered corners within the range in which the same effect can be achieved.

[0023] On the other hand, an expression such as "comprise", "include", "have", "contain" and "constitute" are not intended to be exclusive of other components.

[0024] A screw compressor 10 (10A, 10B) according to some embodiments includes a screw rotor 14 composed of a pair of male rotor and a female rotor and accommodated in a rotor casing 12, as shown in FIGs. 1 and 2. The rotor casing 12 has a suction gas passage 15 and a suction port 16 through which a gas G is sucked, and a discharge port 18 and a discharge gas passage 19 through which the gas G after compression is discharged. Additionally, an internal-volume-ratio adjusting valve 20 capable of changing the internal volume ratio is provided.

[0025] Between the screw rotor 14 and the rotor casing 12, multiple tooth spaces St_1, St_2 are formed along the rotor axial direction.

[0026] The internal-volume-ratio adjusting valve 20 includes a valve body 22 and a cylinder 24 having a cylinder rod 26 coupled to the valve body 22. The valve body 22 is disposed within the rotor casing 12, is movable along the rotor axial direction, and defines a discharge position at which the gas G is discharged through the discharge port 18. The cylinder 24 is disposed, for instance, so as to protrude to the outside of the rotor casing 12. The cylinder 24 contains at least one pressurizing chamber 28. The cylinder rod 26 is disposed along the rotor axial direction and has a first end connected to the valve body 22 and a second end introduced into the pressurizing chamber 28. A piston 30 is disposed in the pressurizing chamber 28 and fixed to the cylinder rod 26. The pressurizing chamber 28 is divided into two pressurizing spaces s1 and s2 along the rotor axial direction by the piston 30.

[0027] Further, a first communication passage 32 communicating with the pressurizing space s2 of the two pressurizing spaces s1, s2 and with the discharge gas passage 19 is provided. A second communication passage 34 connecting the pressurizing space s1 of the two pressurizing spaces s1, s2 with the tooth space St_2 immediately adjacent to the tooth

space St_1 that communicates with the discharge port 18 at the axial end of the screw rotor 14 on the discharge side is provided.

[0028] In the above configuration, the gas G sucked through the suction port 16 to the tooth space with the rotation of the screw rotor 14 and sealed in the tooth space is compressed as the tooth space gradually contracts toward the discharge port 18. The compressed gas is then discharged with a predetermined discharge pressure Pd from the discharge port 18.

[0029] The gas G discharged from the discharge port 18 and having the discharge pressure Pd is introduced into the pressurizing space s2 via the first communication passage 32. The gas G having an intermediate pressure Pm in the just-before-discharge tooth space St_2 is introduced into the pressurizing space s1 via the second communication passage 34.

[0030] As shown in FIGs. 3 and 4, opposite forces f_1 and f_2 along the rotor axial direction are applied to the piston 30, which divides the pressurizing chamber 28 into the two pressurizing spaces s1 and s2, due to the gas supplied to each of the pressurizing spaces s1 and s2.

[0031] As shown in FIG. 7, when the pressure Pm of the just-before-discharge tooth space St_2 is equal to the discharge pressure Pd of the tooth space St_1, the operating efficiency of the screw compressor 10 is maximized.

[0032] In an operating example shown in FIG. 8, the pressure Pm of the just-before-discharge tooth space St_2 is higher than the discharge pressure Pd, so that the operating efficiency is reduced due to power loss Lp.

[0033] In an operating example shown in FIG. 9, the pressure of the gas G in the just-before-discharge tooth space St_2 is lower than the predetermined discharge pressure. In this case, the gas G will flow back from the discharge port 18 into the tooth space during discharge, and the pressure of the tooth space increases to the discharge pressure Pd. Thus, extra work is caused for ejecting the backflow of the gas G from the discharge port 18 to the discharge gas passage 19, which reduces the compression efficiency.

[0034] In FIGs. 1 and 2, the valve body 22 of the internal-volume-ratio adjusting valve 20 moves in the rotor axial direction by the differential pressure between the pressures (forces) f_1 and f_2 applied to the piston 30 from both sides. When the pressures (forces) f_1 and f_2 are equal to each other, i.e., when the discharge pressure Pd of the gas G discharged from the discharge port 18 is equal to the pressure (intermediate pressure Pm) of the gas G in the just-before-discharge tooth space St_2, the movement of the valve body 22 in the axial direction is stopped.

[0035] In this way, since the valve body 22 is automatically stopped at a rotor-axial-directional position where the discharge pressure Pd is equal to the intermediate pressure Pm, the discharge pressure Pd can be always made equal to the intermediate pressure Pm. Thus, it is possible to adjust the discharge position of the discharge port 18 to be the optimum position automatically and continuously, and thus it is possible to constantly operate the screw compressor 10 most efficiently.

[0036] On the other hand, since the valve body 22 is operated by the difference between pressures applied to the piston 30 from both sides, it is unnecessary to provide driving and control instruments for driving and controlling the internal-volume-ratio adjusting valve 20, and it is possible to reduce the cost.

[0037] In an embodiment, as shown in FIGs. 1 and 2, the pressurizing space s2 communicating with the discharge gas passage 19 via the first communication passage 32 is located on the suction port side with respect to the piston 30. The pressurizing space s1 communicating with the just-before-discharge tooth space St_2 is located on the discharge port side with respect to the piston 30. Accordingly, the discharge pressure is transmitted to the pressurizing space s2, and the pressure of the just-before-discharge tooth space St_2 is transmitted to the pressurizing space s1.

[0038] Thus, for instance, if the discharge pressure of the gas G is higher, the valve body 22 of the internal-volume-ratio adjusting valve 20 is pushed toward the discharge port; whereas if the pressure of the just-before-discharge tooth space St_2 is higher, the valve body 22 of the internal-volume-ratio adjusting valve 20 is pushed toward the suction port. Consequently, the pressure of the gas G in the just-before-discharge tooth space St_2 is automatically adjusted so as to be equal to the discharge pressure of the compressor.

[0039] In an embodiment, as shown in FIGs. 3 to 5, a part of the discharge port 18 (a notch 40 for defining the discharge position) is formed on a second end surface 38 of the valve body 22 facing the discharge gas passage 19.

[0040] Additionally, as shown in FIGs. 3 and 4, the rotor casing 12 has a suction-side end surface 42 and a discharge-side end surface 44.

[0041] When the tooth space St_1 communicates with the discharge port 18, the gas G sealed in the tooth space St_1 is discharged to the discharge port 18.

[0042] The dashed dotted line 45 represents a rotational center axis of the male rotor or the female rotor of the screw rotor 14.

[0043] In some embodiments, as shown in FIGs. 1 and 2, the valve body 22 has a first end surface 36 facing the suction gas space 21 communicating with the suction gas passage 15 and a second end surface facing the discharge gas passage 19. The cylinder 24 has a first pressurizing chamber 28 and a second pressurizing chamber 46 arranged along the rotor axial direction.

[0044] The cylinder rod 26 is introduced into the first pressurizing chamber 28 and the second pressurizing chamber

46. A piston 30 is disposed in the first pressurizing chamber 28, and a piston 48 is disposed in the second pressurizing chamber 46. The pistons 30 and 48 are fixed to the cylinder rod 26. The first pressurizing chamber 28 is divided into two pressurizing spaces s1 and s2 in the rotor axial direction by the piston 30, and the second pressurizing chamber 46 is divided into two pressurizing spaces s3 and s4 in the rotor axial direction.

[0045] As shown in FIGs. 3 and 4, the piston 48 receives a force f3 from the discharge side toward the suction side of the screw rotor 14 by a gas supplied to the forward pressurizing space s3, and receives a force f4 from the suction side toward the discharge side of the rotor casing 12 by a gas supplied to the backward pressurizing space s4. The forces f3 and f4 are applied to the piston 48 in opposite directions to each other.

[0046] Further, as shown in FIGs. 1 and 2, a third communication passage 50 connecting the suction gas passage 15 with the forward pressurizing space s3 is provided, and a fourth communication passage 52 connecting the discharge gas passage 19 with the backward pressurizing space s4 is provided. Additionally, the compressor is configured so that the area of a pressure-receiving surface of the first end surface 36 receiving the pressure Ps of suction gas is equal to the area of a pressure-receiving surface p1 of the piston 48 in the forward pressurizing space s3, and the area of a pressure-receiving surface of the second end surface 38 receiving the pressure Pd of discharge gas is equal to the area of a pressure-receiving surface p2 of the piston 48 in the backward pressurizing space s4. The pressure-receiving surface p2 also includes an end surface 26a of the cylinder rod 26 so as to have the same area as the pressure-receiving surface of the discharge gas passage 19.

[0047] In the above configuration, the gas G in the suction gas passage 15 is introduced into the forward pressurizing space s3 via the third communication passage 50, and the gas G from the discharge gas passage 19 is introduced into the backward pressurizing space s4 via the fourth communication passage 52.

[0048] Let Asv1 be the area of the pressure-receiving surface of the first end surface 36 of the valve body 22, Asv2 be the area of the pressure-receiving surface of the second end surface 38, Ap1 be the area of the pressure-receiving surface p1 of the piston 48, and Ap2 be the area of the pressure-receiving surface p2. Further, the areas of the pressure-receiving surfaces at which the piston 30 receives the forces f1 and f2 from the pressurizing spaces s1 and s2 are assumed equal and defined as Ap3.

[0049] In this case, assuming that the direction from the discharge port toward the suction port is positive (forward), force F applied to the valve body 22 is calculated by the following expression (1):

$$F=Pd\times Asv2-Ps\times Asv1+Pm\times Ap3-Pd\times Ap3+Ps\times Ap1-Pd\times Ap2 \quad (1)$$

[0050] In expression (1), since Asv1=Ap1 and Asv2=Ap2, expression (1) is rewritten as expression (2):

$$F=Pm\times Ap3-Pd\times Ap3 \quad (2)$$

[0051] Accordingly, when Pm is equal to Pd, F is 0, i.e., the valve body 22 is stopped. That is, when the valve body 22 is stopped, the operating efficiency of the screw compressor 10 is maximized.

[0052] Thus, since the area of the pressure-receiving surface of the first end surface 36 is equal to the area of the pressure-receiving surface p1 of the piston 48 to which the force f3 is applied, the pressure of the gas G applied to the first end surface 36 and the force f3 are canceled. Further, since the area of the pressure-receiving surface of the second end surface 38 is equal to the area of the pressure-receiving surface p2 of the piston 48 to which the force f4 is applied, the pressure of the gas G applied to the second end surface 38 and the force f4 are canceled. Consequently, only the forces f1 and f2 are applied to the valve body 22, and the valve body 22 is moved in the rotor axial direction by the difference between the forces f1 and f2.

[0053] According to the present embodiment, it is possible to automatically and continuously adjust the position of the valve body 22 in the rotor axial direction into the optimum position so that the forces f1 and f2 are equal to each other by canceling the pressures of the gas G applied to the first end surface 36 and the second end surface 38 of the valve body 22. Thus, it is possible to constantly operate the screw compressor 10 most efficiently.

[0054] In the embodiments shown in FIGs. 1 and 2, a part of the first communication passage 32 and a part of the fourth communication passage 52 are formed by a single main communication passage 31 communicating with the discharge gas passage 19.

[0055] Additionally, a partition wall 54 is disposed in the single cylinder 24 to form the first pressurizing chamber 28 and the second pressurizing chamber 46. Alternatively, two cylinders may be disposed, and the first pressurizing chamber 28 may be contained in one of the cylinders while the second pressurizing chamber 46 may be contained in the other of the cylinders. In this case, the two cylinders are arranged in series with a single cylinder rod 26 so that the cylinder rod 26 is introduced into the two cylinder rods.

[0056] In an embodiment, as shown in FIGs. 1 and 4, the second communication passage 34 includes a hollow portion 56 formed in the valve body 22, a hollow portion 57 formed in the cylinder rod 26, a first communication hole 58 formed in the valve body 22 and connecting the just-before-discharge tooth space St_2 and the hollow portion 56, and a second communication hole 60 formed in the cylinder rod 26 and connecting the hollow portion 57 and the pressurizing space s1 of the first pressurizing chamber 28.

[0057] With the above configuration, since the second communication passage 34 is formed within the valve body 22 and the cylinder rod 26, a space outside the valve body 22 and the cylinder rod 26 for forming the second communication passage 34 is unnecessary. Thus, it is possible to downsize the screw compressor 10 (10A, 10B).

[0058] In an embodiment, as shown in FIGs. 2 and 6, the second communication passage 34 includes a channel 62 formed in the rotor casing 12 facing a discharge side end of the screw rotor 14. The channel 62 includes an opening 64 opening to the just-before-discharge tooth space St_2.

[0059] With the above configuration, the just-before-discharge tooth space St_2 communicates with the second communication passage 34 at a position where the just-before-discharge tooth space St_2 is closest to the discharge port 18. Accordingly, it is possible to improve the precision for controlling the pressure of the gas G in the just-before-discharge tooth space St_2 so as to be equal to the pressure of the discharge gas in the discharge gas passage 19.

[0060] FIG. 6 shows the male rotor 14a and the female rotor 14b inside the rotor casing 12. In the embodiment shown in FIG. 6, the channel 62 is formed in the rotor casing 12 facing a discharge-side end of the male rotor 14a, and the opening 64 opens to the rotor casing 12 on the male rotor side. Additionally, the channel 62 is connected to a communication pipe 66 disposed outside the rotor casing 12. The communication pipe 66 communicates with the pressurizing space s1 via the communication hole 68 formed in the partition wall of the cylinder 24 and the rotor casing 12, as shown in FIG. 2. In an exemplary embodiment, the channel 62 is formed in the rotor casing 12 facing a discharge-side end of the female rotor 14b, and the opening 64 opens to the rotor casing 12 on the female rotor side.

[0061] In an embodiment, as shown in FIG. 1, the first pressurizing chamber 28 is located on the discharge port side of the screw rotor 14 with respect to the second pressurizing chamber 46, and the pressurizing space s1 communicating with the second communication passage 34, of the two pressurizing spaces s1 and s2 formed in the first pressurizing chamber 28, is located on the discharge port side of the screw rotor 14 with respect to the pressurizing space s2.

[0062] With the above configuration, the pressurizing space s1 is located closest of the four pressurizing spaces s1 to s4 to the discharge port 18. Thus, it is possible to reduce the hollow portions 56 and 57 formed inside the valve body 22 and the cylinder rod 26, and it is possible to easily form the hollow portions.

Industrial Applicability

[0063] According to some embodiments, it is possible to improve the efficiency of a screw compressor at low cost by equalizing the pressure of a gas in a tooth space just before discharge with the discharge pressure of the compressor, without expensive driving and control instruments.

Reference Signs List

[0064]

10 (10A, 10B)	Screw compressor
12	Rotor casing
14	Screw rotor
14a	Male rotor
14b	Female rotor
15	Suction gas passage
16	Suction port
18	Discharge port
19	Discharge gas passage
20	Internal-volume-ratio adjusting valve
21	Suction gas space
22	Valve body
24	Cylinder
26	Cylinder rod
28	First pressurizing chamber
30, 48	Piston
31	Main communication passage
32	First communication passage

34	Second communication passage
36	First end surface
38	Second end surface
40	Notch
42	Suction-side end surface
44	Discharge-side end surface
46	Second pressurizing chamber
50	Third communication passage
52	Fourth communication passage
54	Partition wall
56, 57	Hollow portion
58	First communication hole
60	Second communication hole
62	Channel
64	Opening
66	Communication pipe
68	Communication hole
G	Gas
Pd	Discharge pressure
Pm	Intermediate pressure
Ps	Suction pressure
St_1	Tooth space
St_2	Just-before-discharge tooth space
p1, p2	Pressure receiving surface

Claims

1. A screw compressor comprising:

a screw rotor including a pair of a male rotor and a female rotor;
a rotor casing accommodating the screw rotor, the rotor casing having a suction gas passage and a suction port through which a gas is sucked and a discharge port and a discharge gas passage through which the gas is discharged; and
an internal-volume-ratio adjusting valve capable of changing an internal volume ratio,
wherein the internal-volume-ratio adjusting valve includes:

a valve body disposed inside the rotor casing, the valve body being movable along an axial direction of the screw rotor and defining a discharge position at which the gas is discharged from tooth spaces formed between the screw rotor and the rotor casing to the discharge port; and
a cylinder containing at least one pressurizing chamber and having a cylinder rod and a piston, the cylinder rod being coupled to the valve body and being disposed along the axial direction of the screw rotor, the piston being fixed inside the or each pressurizing chamber to the cylinder rod and dividing the or each pressurizing chamber into two pressurizing spaces along the axial direction of the screw rotor,

wherein the screw compressor further comprises:

a first communication passage connecting a first one of the two pressurizing spaces with the discharge gas passage; and
a second communication passage connecting a second one of the two pressurizing spaces with a just-before-discharge tooth space immediately before a tooth space that communicates with the discharge port.

2. The screw compressor according to claim 1,
wherein the first one of the two pressurizing spaces is located on a suction port side with respect to the piston, and
wherein the second one of the two pressurizing spaces is located on a discharge port side with respect to the piston.

3. The screw compressor according to claim 1 or 2,
wherein the valve body has a first end surface facing a suction gas space communicating with the suction gas

passage and a second end surface facing the discharge gas passage,
wherein the cylinder contains a first pressurizing chamber and a second pressurizing chamber which are arranged along the axial direction of the screw rotor,
wherein, in the first pressurizing chamber, the first one of the two pressurizing spaces separated by the piston communicates with the first communication passage, and the second one of the two pressurizing spaces communicates with the second communication passage,
wherein the screw compressor further comprises:

a third communication passage connecting the suction gas passage with a forward pressurizing space of the two pressurizing spaces separated by the piston in the second pressurizing chamber, wherein, in the forward pressurizing space, the piston is pressurized in a forward direction from the discharge port toward the suction port; and
a fourth communication passage connecting the discharge gas passage with a backward pressurizing space of the two pressurizing spaces formed in the second pressurizing chamber, wherein, in the backward pressurizing space, the piston is pressurized in a backward direction from the suction port toward the discharge port,

wherein an area of a pressure-receiving surface of the first end surface pressurized by the gas in the suction gas space is equal to an area of a pressure-receiving surface of the piston in the forward pressurizing space, and an area of a pressure-receiving surface of the second end surface pressurized by the gas in the discharge gas passage is equal to an area of a pressure-receiving surface of the piston in the backward pressurizing space.

4. The screw compressor according to any one of claims 1 to 3,
wherein the second communication passage includes:

a hollow portion formed in the valve body and in the cylinder rod;
a first communication hole formed in the valve body and connecting the just-before-discharge tooth space and the hollow space; and
a second communication hole formed in the cylinder rod and connecting the hollow portion and the second one of the two pressurizing spaces.

5. The screw compressor according to any one of claims 1 to 3,
wherein the second communication passage includes a channel formed in the rotor casing facing a discharge-side end of the screw rotor, and the channel has an opening open to the just-before-discharge tooth space from a wall surface of the rotor casing.

6. The screw compressor according to any one of claims 1 to 5,
wherein the cylinder contains a first pressurizing chamber and a second pressurizing chamber which are arranged along the axial direction of the screw rotor,
wherein the first pressurizing chamber is located on a discharge port side of the screw rotor with respect to the second pressurizing chamber, and
wherein, among the two pressurizing spaces formed in the first pressurizing chamber, the second one, communicating with the second communication passage, of the two pressurizing spaces is located on the discharge port side with respect to the first one of the two pressurizing spaces.

FIG. 1

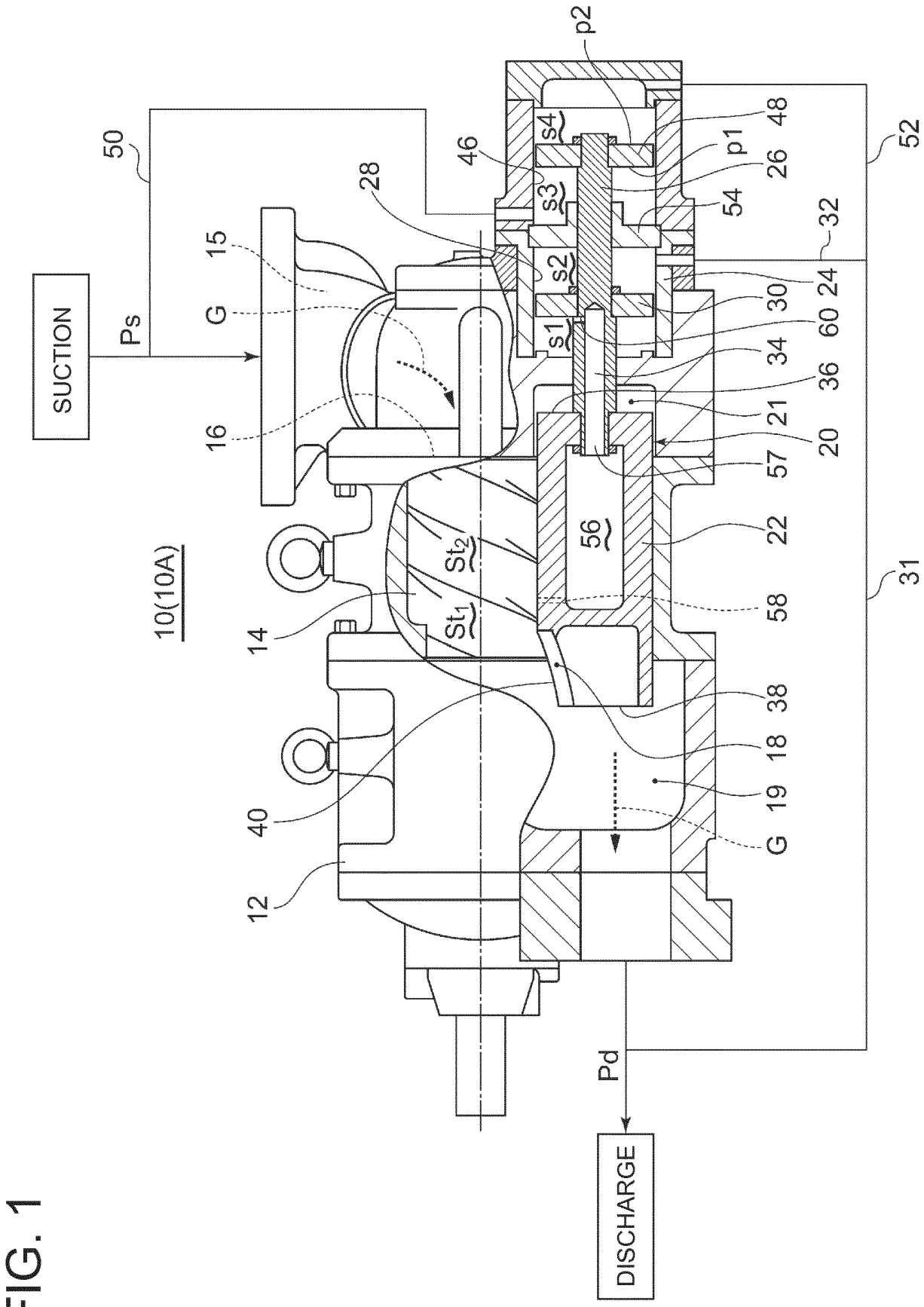

SUCTION
Ps
50
15
G
16
10(10A)
28
46
p2
s4
s3
s2
s1
48
p1
26
54
32
52
24
30
60
34
36
21
20
57
56
22
31
58
14
St2
St1
38
18
19
G
40
12
Pd
DISCHARGE

FIG. 2

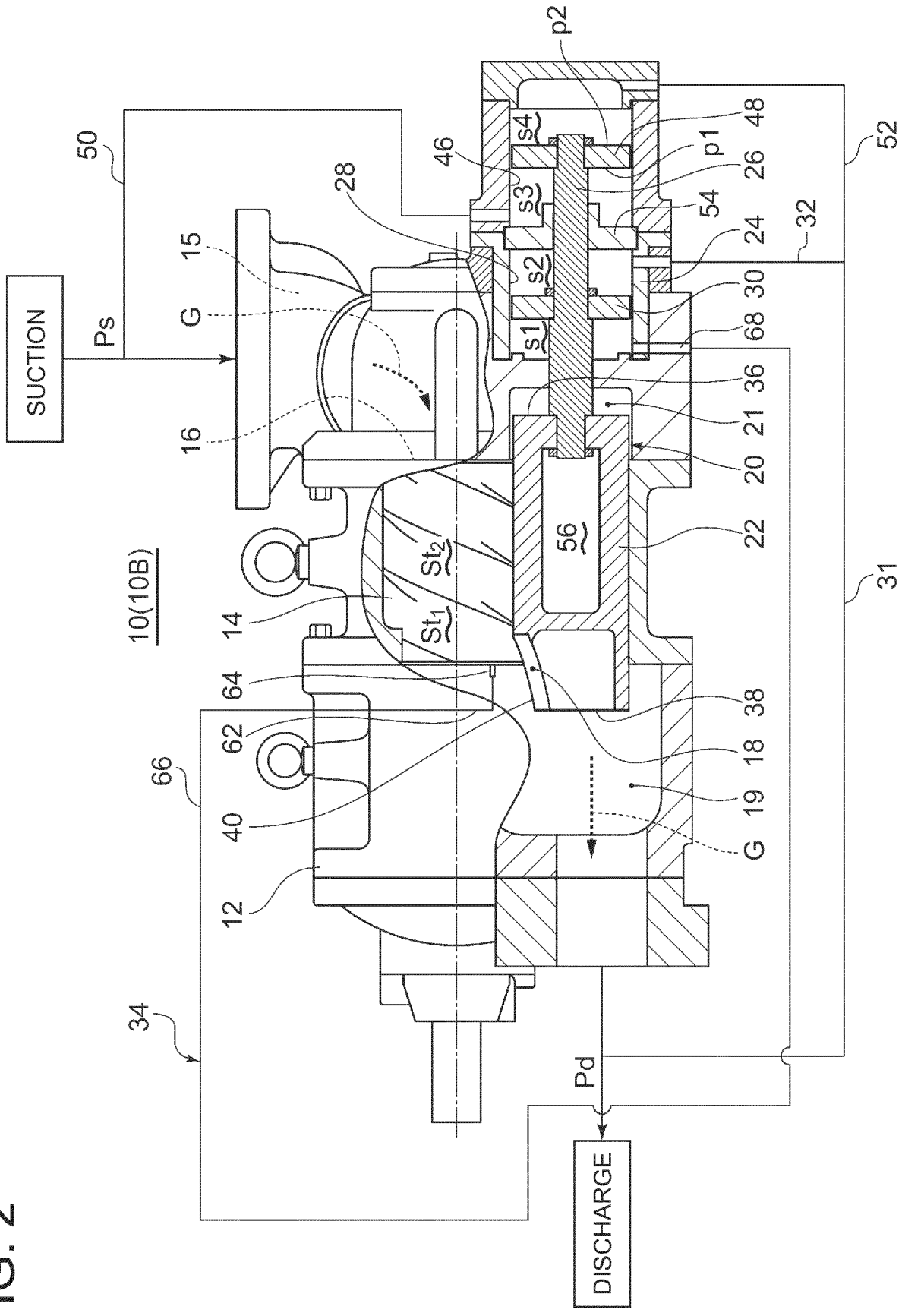

SUCTION
Ps
50
15
G
16
28
46
p2
48
52
s4
p1
26
s3
54
32
24
s2
30
s1
68
36
21
20
56
22
31
10(10B)
14
St2
St1
64
62
38
18
66
40
19
G
12
34
Pd
DISCHARGE

FIG. 3

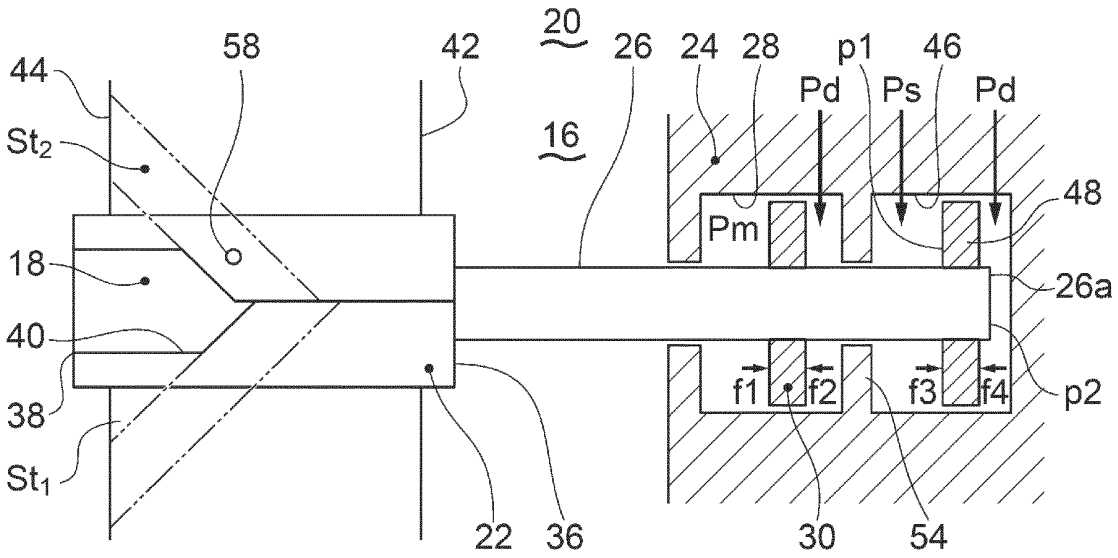

44
St2
18
40
38
St1
58
42
20
16
26
24
28
p1
46
Pd
Ps
Pd
48
Pm
26a
p2
f1
f2
f3
f4
22
36
30
54

FIG. 4

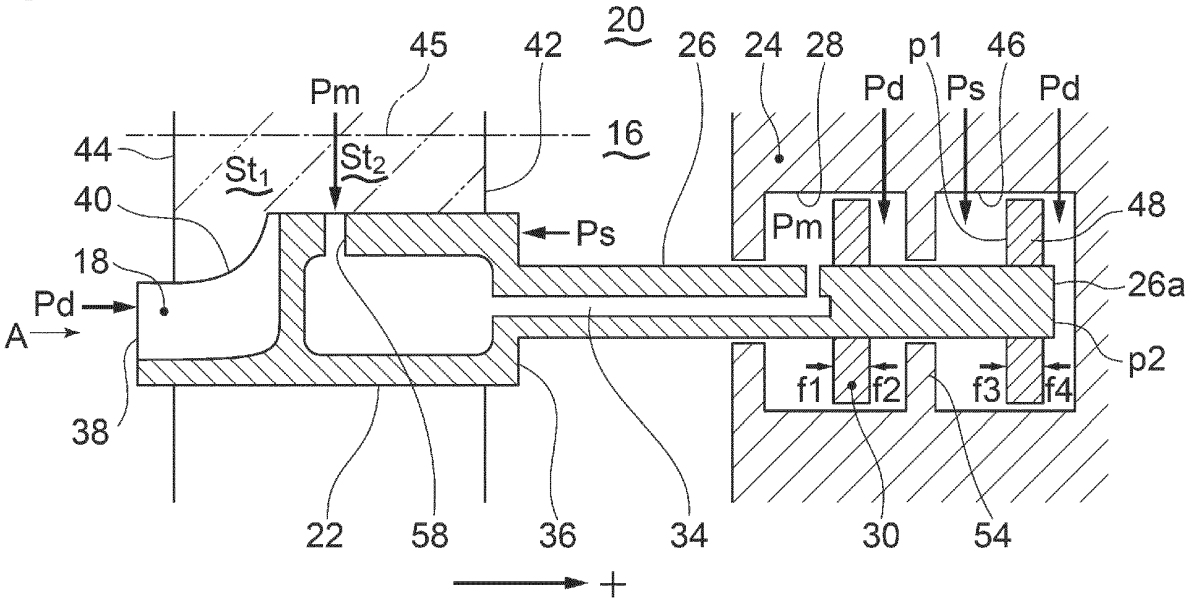
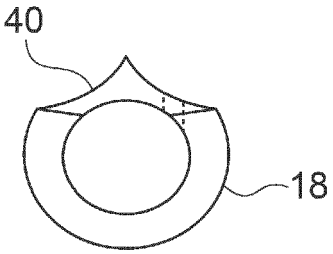

45
42
20
26
24
28
p1
46
Pm
Pd
Ps
Pd
44
St1
St2
16
40
Ps
48
Pm
18
26a
Pd
A
p2
f1
f2
f3
f4
38
22
58
36
34
30
54
+

FIG. 5



VIEW A

FIG. 6

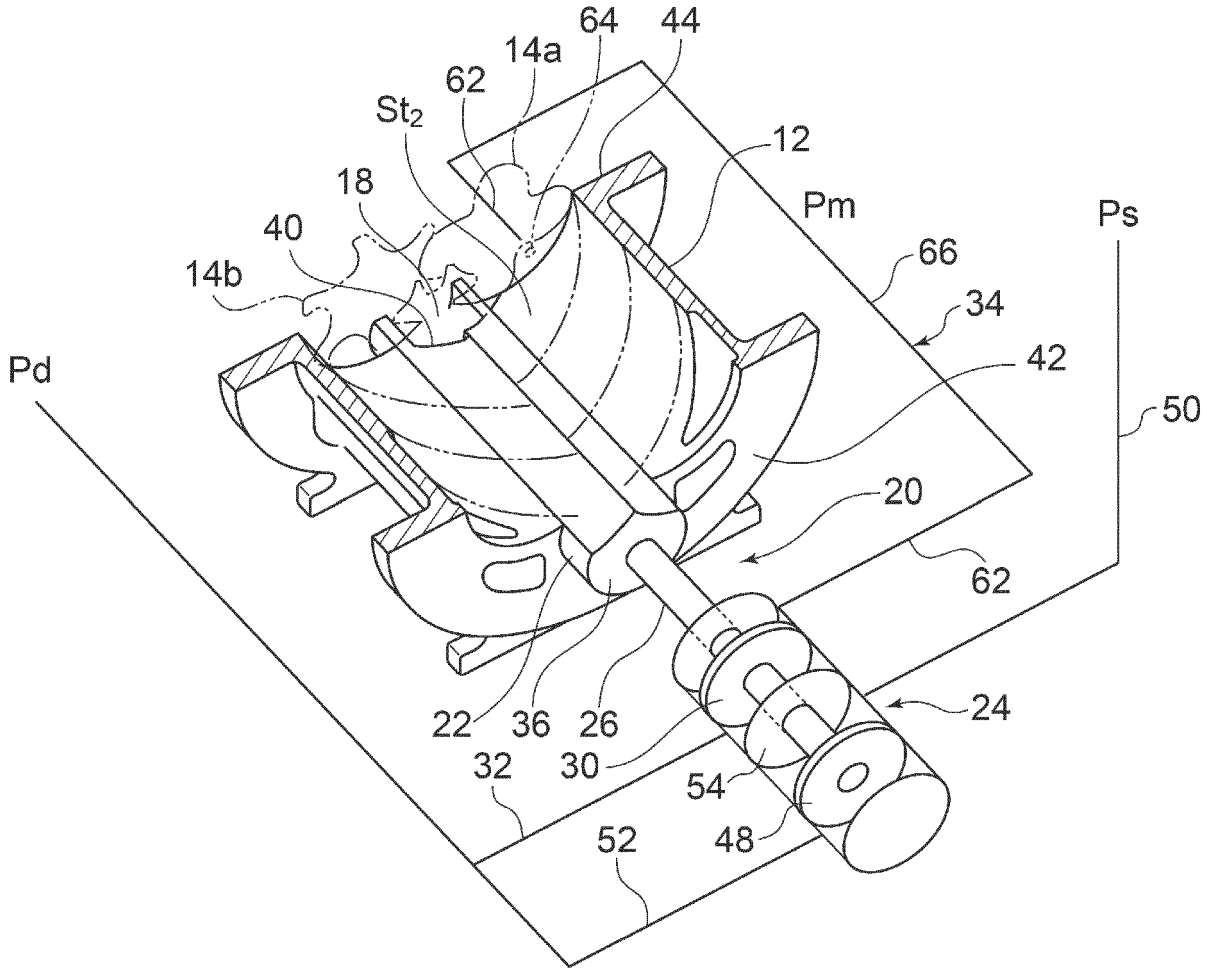


FIG. 7

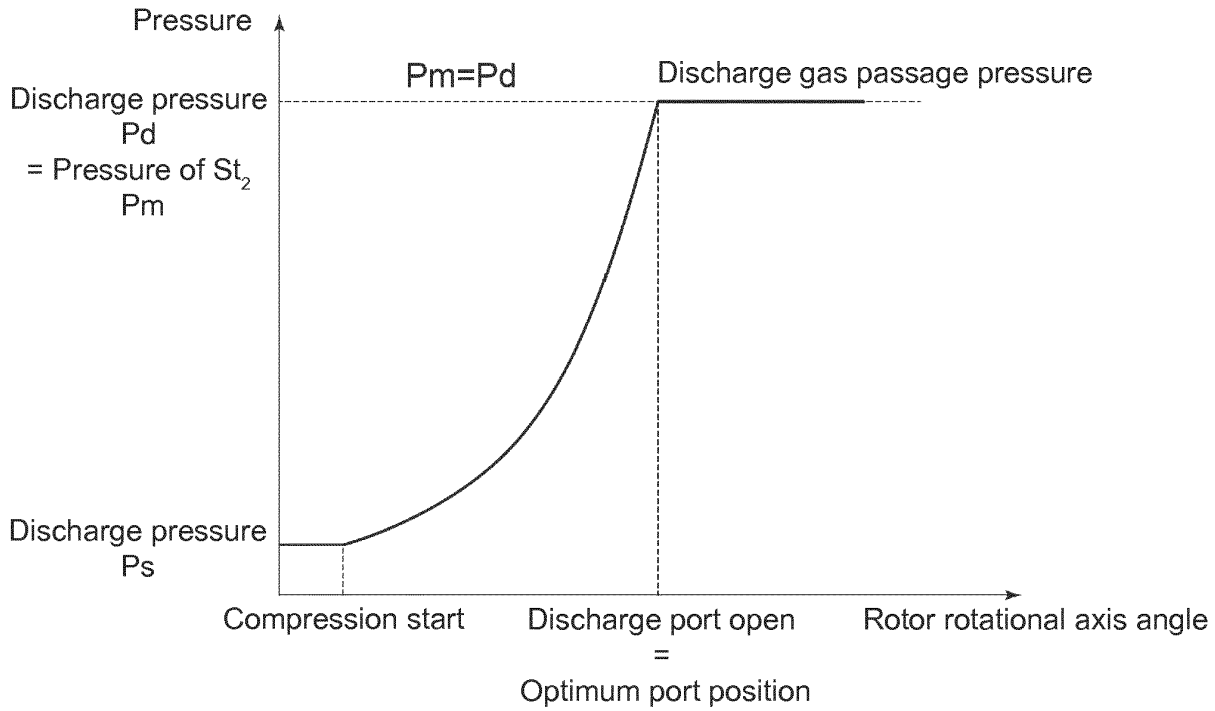

Pressure
Pm=Pd
Discharge gas passage pressure
Discharge pressure
Pd
= Pressure of St2
Pm
Discharge pressure
Ps
Compression start
Discharge port open
=
Optimum port position
Rotor rotational axis angle

FIG. 8

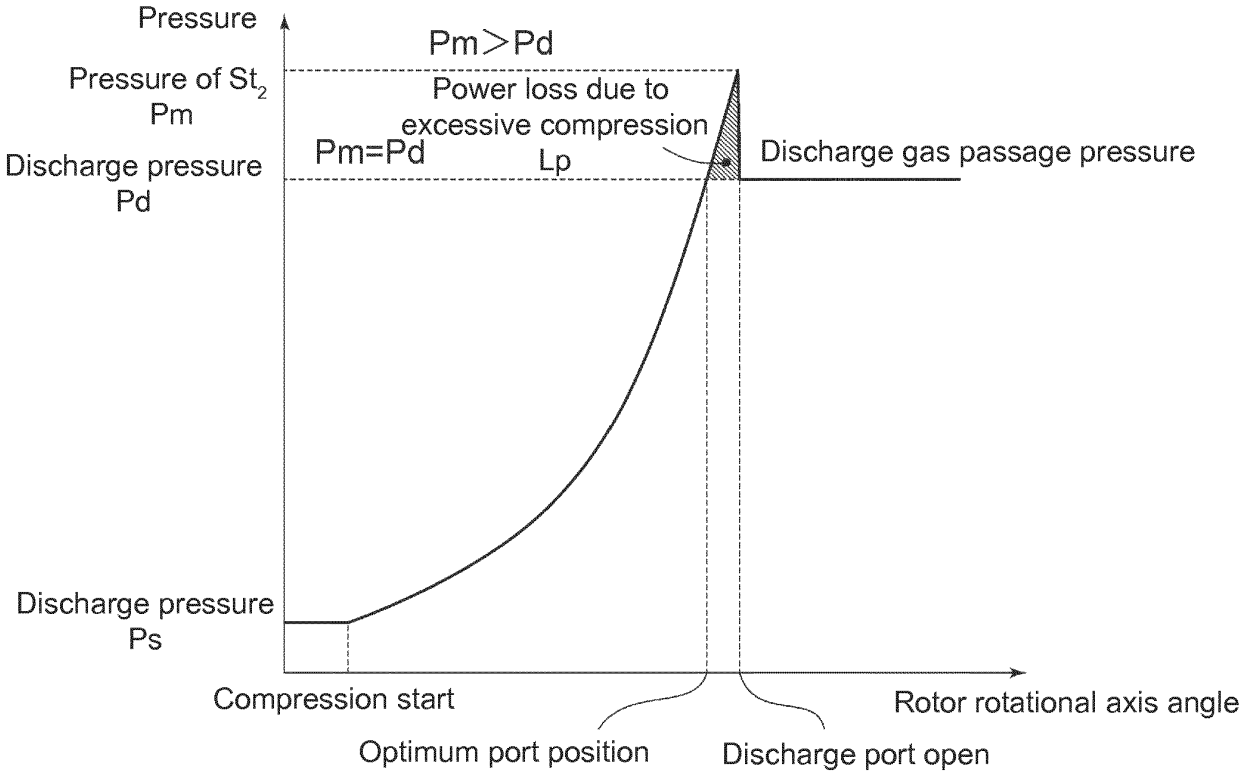
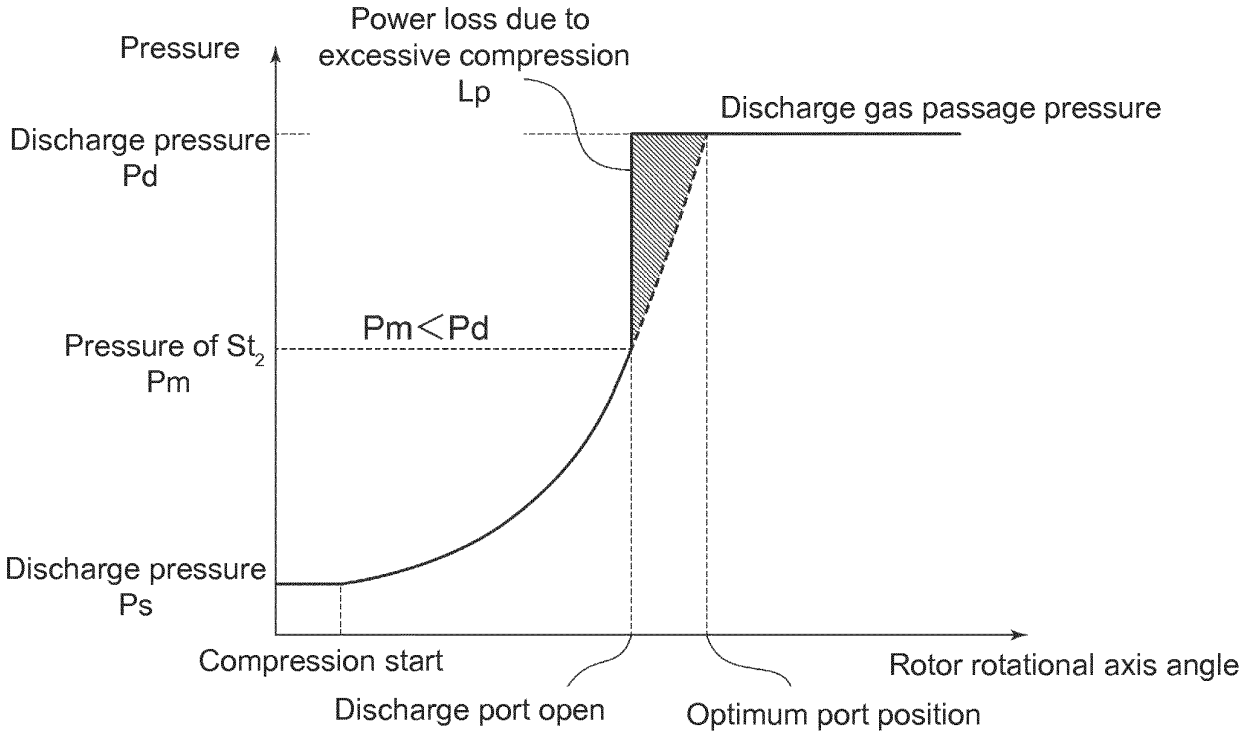

Pressure
Pm>Pd
Pressure of St2
Pm
Power loss due to
excessive compression
Lp
Pm=Pd
Discharge gas passage pressure
Discharge pressure
Pd
Discharge pressure
Ps
Compression start
Optimum port position
Discharge port open
Rotor rotational axis angle

FIG. 9


Pressure
Power loss due to excessive compression
Lp
Discharge gas passage pressure
Discharge pressure
Pd
Pm<Pd
Pressure of St2
Pm
Discharge pressure
Ps
Compression start
Discharge port open
Optimum port position
Rotor rotational axis angle

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/037793

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F04C18/16(2006.01)i, F04C28/12(2006.01)i, F04C28/26(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. F04C18/16, F04C28/12, F04C28/26

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	1971-2017
Registered utility model specifications of Japan	1996-2017
Published registered utility model applications of Japan	1994-2017

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	JP 2013-2289 A (MITSUBISHI ELECTRIC CORP.) 07 January 2013, paragraphs [0012]-[0020], fig. 1-5 (Family: none)	1-3 4-6
Y	JP 2011-80385 A (EBARA REFRIGERATION EQUIPMENT & SYSTEMS CO., LTD.) 21 April 2011, paragraphs [0023]-[0024], fig. 1-2 (Family: none)	4-6
Y	US 2012/0282129 A1 (NEMIT, JR. Paul) 08 November 2011, paragraph [0026], fig. 6-7 & CN 102777383 A	4-6
Y	JP 2011-21535 A (HITACHI APPLIANCES, INC.) 03 February 2011, paragraph [0030], fig. 5-6 (Family: none)	5-6
A	JP 2013-92091 A (MITSUBISHI ELECTRIC CORP.) 16 May 2013, paragraphs [0023]-[0027], fig. 1-5 (Family: none)	1-6
A	JP 58-192990 A (SULLAIR TECHNOLOGY AB) 10 November 1983, publication gazette, page 3, upper right column, line 9 to lower right column, line 1, fig. 3 & US 4842501 A, column 4, lines 8-42, fig. 3 & GB 2119445 A & DE 3314582 A1	1-6

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Date of the actual completion of the international search	Date of mailing of the international search report
20 December 2017 (20.12.2017)	09 January 2018 (09.01.2018)

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

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

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Patent documents cited in the description

- JP H102288 A **[0010]**
- JP 2014206098 A **[0010]**