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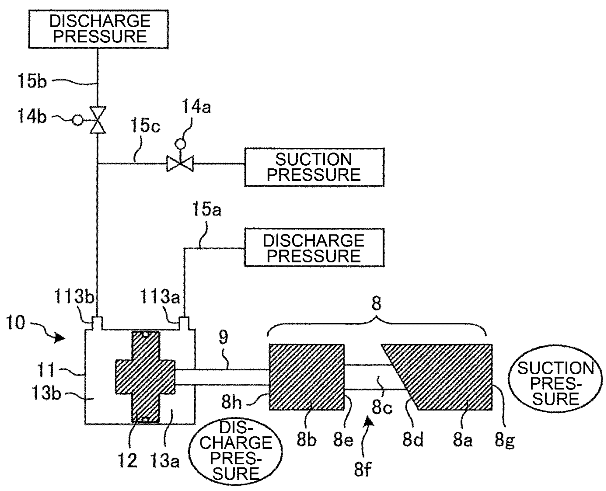
(54) **SCREW COMPRESSOR**

(57) A screw compressor includes an internal-volume-ratio variable mechanism including a variable Vi valve configured to make a Vi value being an internal volume ratio variable. The screw compressor controls a position of the variable Vi valve in two stages. The position of the variable Vi valve when the Vi value is set to be large is set to attain a Vi value with which a compressor efficiency during operation under a predetermined high-load condition or a predetermined high-compression-ratio condition is equal to or higher than a set efficiency set in advance.

FIG. 2



EP 3 933 204 A1

Description

Technical Field

[0001] The present disclosure relates to a screw compressor used for refrigerant compression in, for example, a refrigerator or an air-conditioning apparatus.

Background Art

[0002] Some screw compressors include a variable internal-volume-ratio valve (hereinafter, referred to as a variable Vi valve) that is a slide valve that adjusts the timing of discharge start to make an internal volume ratio Vi variable, and adjusts the opening degree of the variable Vi valve by a driving force from a driving device depending on an operation compression ratio (for example, see Patent Literature 1). The internal volume ratio in the screw compressor is a ratio between a tooth groove space volume at the time of suction and a tooth groove space volume immediately before discharge, and represents a ratio between a volume when the suction is completed and a volume when a discharge port is opened.

[0003] As illustrated in Figs. 1 and 2 of Patent Literature 1, the variable Vi valve of Patent Literature 1 is controlled such that the difference between an optimum Vi value calculated from a discharge pressure HP and a suction pressure LP and a current Vi value obtained from a position detecting unit decreases. To bring the Vi value close to the optimum Vi value in actual operation, the opening degree of the variable Vi valve is adjusted to minimize motor driving power.

[0004] The screw compressor has an appropriate compression ratio corresponding to the internal volume ratio, and an inappropriate compression loss is not generated under an operating condition where the compression ratio at the time of actual operation is the appropriate compression ratio. However, when the operation is performed at a low compression ratio lower than the appropriate compression ratio, gas is excessively compressed to a pressure equal to or higher than a discharge pressure before the discharge port opens, and excessive compression work is performed. In contrast, when the operation is performed at a high compression ratio higher than the appropriate compression ratio, the discharge port opens before the pressure reaches the discharge pressure, causing a state of insufficient compression in which backflow of gas is generated. Both of the operation at the low compression ratio and the operation at the high compression ratio cause a loss of power and cause a decrease in efficiency.

[0005] Thus, as in Patent Literature 1, a technique has been proposed in which the internal volume ratio is made variable by steplessly adjusting the position of the variable Vi valve to attain the internal volume ratio at which a high compressor efficiency is obtained for a compression ratio (discharge pressure/suction pressure) depending on an operation load.

Citation List

Patent Literature

[0006] Patent Literature 1: Japanese Patent No. 4147891

Summary of Invention

Technical Problem

[0007] In Patent Literature 1, position control of the variable Vi valve is steplessly performed, and a control amount of the variable Vi valve is calculated from detection results of a discharge pressure, a suction pressure, and a rotation frequency. That is, in Patent Literature 1, the position control of the variable Vi valve is stepless control, and hence the configuration and control are complicated.

[0008] The present disclosure has been made to address the above-described problems, and an object of the present disclosure is to obtain a screw compressor whose configuration and control can be simplified while an internal volume ratio is made variable.

Solution to Problem

[0009] A screw compressor of an embodiment of the present disclosure includes an internal-volume-ratio variable mechanism including a variable Vi valve configured to make a Vi value being an internal volume ratio variable. The screw compressor controls a position of the variable Vi valve in two stages. The position of the variable Vi valve when the Vi value is set to be large is set to attain a Vi value with which a compressor efficiency during operation under a predetermined high-load condition or a predetermined high-compression-ratio condition is equal to or higher than a set efficiency set in advance.

Advantageous Effects of Invention

[0010] With the embodiment of the present disclosure, since the position control of the variable Vi valve is performed in the two stages, the configuration and control can be simplified while the internal volume ratio is made variable.

Brief Description of Drawings

[0011]

[Fig. 1] Fig. 1 is a general configuration diagram of a screw compressor according to Embodiment 1 of the present disclosure.
[Fig. 2] Fig. 2 is a schematic diagram of an internal-volume-ratio variable mechanism including a driving device for the screw compressor according to Embodiment 1 of the present disclosure.
[Fig. 3] Fig. 3 is an operation schematic diagram when a Vi value is large in the screw compressor according to Embodiment 1 of the present disclosure.
[Fig. 4] Fig. 4 is an operation schematic diagram when a Vi value is small in the screw compressor according to Embodiment 1 of the present disclosure.
[Fig. 5] Fig. 5 is an operation schematic diagram when a Vi value is large in the screw compressor according to Embodiment 2 of the present disclosure.
[Fig. 6] Fig. 6 is an operation schematic diagram when a Vi value is small in the screw compressor according to Embodiment 2 of the present disclosure.
[Fig. 7] Fig. 7 illustrates a modification of the screw compressor according to any one of Embodiment 1 and Embodiment 2 of the present disclosure.

Description of Embodiments

Embodiment 1

[0012] Fig. 1 is a general configuration diagram of a screw compressor according to Embodiment 1 of the present disclosure.
[0013] The screw compressor according to Embodiment 1 is a single screw compressor, and as schematically illustrated in Fig. 1, the screw compressor includes a cylindrical casing main body 1, a screw rotor 3 housed in the casing main body 1, and a motor 2 that rotatably drives the screw rotor 3. The motor 2 includes a stator 2a that is secured in contact with the inside of the casing main body 1 and a motor rotor 2b that is disposed inside the stator 2a. The rotation speed of the motor 2 is controlled by an inverter method. The capacity control for operating the screw compressor at a desired operation compression ratio may be implemented through rotation speed control by driving the motor 2 with an inverter.
[0014] The screw rotor 3 and the motor rotor 2b are disposed on the same axis, and both are secured to a screw shaft 4. A plurality of helical grooves (hereinafter referred to as screw grooves) 3a are formed in the outer peripheral surface of the screw rotor 3. The screw rotor 3 is coupled to and rotatably driven by the motor rotor 2b secured to the screw shaft 4. The space in the screw grooves 3a formed in the screw rotor 3 is surrounded by the inner cylindrical surface of the casing main body 1 and a pair of gate rotors (not illustrated) that mesh with and are engaged with the grooves to define a compression chamber 5.
[0015] In the casing main body 1, a discharge pressure side and a suction pressure side are separated from each other by a separation wall (not illustrated). A discharge chamber 6 and a discharge port 7 that opens to the discharge chamber 6 are formed on the discharge pressure side. In the casing main body 1, a suction chamber 16 is formed on the suction pressure side. The casing main body 1 is further provided with a pair of variable Vi valves 8 that are coupled to a pair of rods 9 and a pair of driving devices 10 and are movable in the axial direction. The variable Vi valves 8 define part of the discharge port 7. Illustration of the driving device 10 coupled to the other variable Vi valve 8 is omitted.
[0016] Fig. 2 is a schematic diagram of an internal-volume-ratio variable mechanism including a driving device for the screw compressor according to Embodiment 1 of the present disclosure.
[0017] The driving device 10 forms part of an internal-volume-ratio variable mechanism (hereinafter, referred to as a variable Vi mechanism), and is configured to couple a piston 12 provided in a cylinder 11 and the variable Vi valve 8 to each other by the rod 9.
[0018] The variable Vi valve 8 includes a valve main body 8a, a guide portion 8b, and a coupling portion 8c. The coupling portion 8c is provided at a discharge-port-side end portion 8e of the guide portion 8b. The rod 9 is coupled to

an end surface of the guide portion 8b on the side near the driving device 10. The discharge-port-side end portion 8d of the valve main body 8a and a discharge-port-side end portion 8e of the guide portion 8b are coupled to each other by the coupling portion 8c, and the gap therebetween serves as a discharge gap 8f communicating with the discharge port 7.

[0019] The inside of the cylinder 11 is partitioned into two spatial chambers by the piston 12. A cylinder chamber 13a is formed on the front side (on the side of the variable Vi valve) of the piston 12, and a cylinder chamber 13b is formed on the rear side (on the side opposite to the variable Vi valve) of the piston 12. The cylinder 11 has a pressure introduction hole 113a provided on the cylinder chamber 13a side close to the variable Vi valve 8. The cylinder 11 also has a pressure introduction hole 113b provided on the cylinder chamber 13b side far from the variable Vi valve 8.

[0020] The cylinder chamber 13a communicates with the discharge chamber 6 illustrated in Fig. 1 via the pressure introduction hole 113a and a flow path 15a, and a discharge pressure is normally introduced into the cylinder chamber 13a. The cylinder chamber 13b communicates with the discharge chamber 6 illustrated in Fig. 1 through the pressure introduction hole 113b and a flow path 15b and communicates with the suction chamber 16 illustrated in Fig. 1 through a flow path 15c branched from the middle of the flow path 15b. The flow path 15b is provided with a solenoid valve 14b that opens and closes the flow path 15b, and the flow path 15c is provided with a solenoid valve 14a that opens and closes the flow path 15c. A discharge pressure or a suction pressure is selectively introduced into the cylinder chamber 13b by opening and closing of the solenoid valve 14a and the solenoid valve 14b.

[0021] The solenoid valve 14a and the solenoid valve 14b described above are examples, and each may be any valve unit that is capable of opening and closing a flow path or switching flow paths. For example, the solenoid valve 14a and the solenoid valve 14b each may be a stop valve or a three-way valve. In the case of a three-way valve capable of switching flow paths, it is sufficient that one three-way valve is provided at a branch portion of the flow paths, and thus the solenoid valve 14a and the solenoid valve 14b may be omitted. The flow path 15a, the flow path 15b, and the flow path 15c may be formed inside the wall of the casing main body 1 and the wall of the cylinder 11, or may be connected by using a pipe.

[0022] Next, the operation of the variable Vi valve 8 will be described. With this variable Vi mechanism, the Vi value can be set to two values of a large value and a small value.

(i) Operation when Vi Value Is Large

[0023] Fig. 3 is an operation schematic diagram when a Vi value is large in the screw compressor according to Embodiment 1 of the present disclosure.

[0024] When the Vi value is large, the driving device 10 positions the variable Vi valve 8 in the left direction represented by the arrow in the drawing, thereby delaying the timing at which the discharge port 7 opens.

[0025] That is, when the Vi value is large, the solenoid valve 14a is opened and the solenoid valve 14b is closed so that the pressure in the cylinder chamber 13b is a suction pressure. In contrast, the cylinder chamber 13a is coupled to the discharge chamber 6, and a discharge pressure is normally introduced into the cylinder chamber 13a. Hence, the piston 12 is to move in the left direction in the drawing due to the pressure difference in the cylinder 11.

[0026] In the variable Vi valve 8 coupled to the piston 12, a suction pressure acts on a suction-side end portion 8g of the valve main body 8a, and a discharge pressure immediately after discharge acts on the discharge-port-side end portion 8d. The same pressure as the pressure acting on the discharge-port-side end portion 8d acts on the discharge-port-side end portion 8e of the guide portion 8b in directions opposite to each other. A discharge pressure acts on a driving-device-side end portion 8h of the guide portion 8b. Thus, the loads acting on the discharge-port-side end portion 8d and the discharge-port-side end portion 8e in the variable Vi valve 8 cancel out each other. Hence, the variable Vi valve 8 is to move in the right direction in the drawing due to the pressure difference between the pressure acting on the driving-device-side end portion 8h and the pressure acting on the suction-side end portion 8g.

[0027] In this case, the area of each of both end surfaces in the movement direction of the piston 12 is set to be larger than the area of the driving-device-side end portion 8h of the variable Vi valve 8. Thus, the piston 12 and the variable Vi valve 8 move in the left direction in the drawing due to the pressure difference received in both the areas. Since the variable Vi valve 8 stops at a position at which the piston 12 abuts against the wall surface of the cylinder chamber 13, the variable Vi valve 8 is accurately positioned at a position at which the Vi value is large.

(ii) Operation when Vi Value Is Small

[0028] Fig. 4 is an operation schematic diagram when the Vi value is small in the screw compressor according to Embodiment 1 of the present disclosure.

[0029] When the Vi value is small, the driving device 10 positions the variable Vi valve 8 in the right direction represented by the arrow in the drawing, thereby advancing the timing at which the discharge port 7 opens.

[0030] That is, when the Vi value is small, the solenoid valve 14a is closed and the solenoid valve 14b is opened so that the pressure in the cylinder chamber 13b is a discharge pressure. In contrast, since the cylinder chamber 13a is coupled to the discharge chamber 6 and a discharge pressure is normally introduced into the cylinder chamber 13a, there is no pressure difference in the cylinder chamber 13.

[0031] In the variable Vi valve 8 coupled to the piston 12, a suction pressure acts on the suction-side end portion 8g of the valve main body 8a, and a discharge pressure immediately after discharge acts on the discharge-port-side end portion 8d. The same pressure as the pressure acting on the discharge-port-side end portion 8d acts on the discharge-port-side end portion 8e of the guide portion 8b in directions opposite to each other. A discharge pressure acts on the driving-device-side end portion 8h of the guide portion 8b.

[0032] Thus, the variable Vi valve 8 moves in the right direction in the drawing due to the pressure difference between the discharge pressure acting on the driving-device-side end portion 8h and the suction pressure acting on the suction-side end portion 8g. Since the variable Vi valve 8 stops at a position at which the piston 12 abuts against the wall surface of the cylinder chamber 13, the variable Vi valve 8 is accurately positioned at a position at which the Vi value is small. Alternatively, as illustrated in Fig. 1, the variable Vi valve 8 may be positioned at a position where the suction-side end portion 8g of the variable Vi valve 8 abuts against the wall surface of the casing main body 1.

[0033] Setting of the Vi value will be described. For setting of the Vi value, there are a policy for setting to secure a wide operation range and a policy for setting to improve "rated performance" or "primary annual performance factor" which is one of indexes of energy saving. Setting methods based on the respective policies will be described below.

(Securing Wide Operation Range)

[0034] To secure a wide operation range, the large-side Vi value may be set as follows. To protect the compressor, the operation range is set, for example, by setting an upper limit temperature for the temperature of discharged refrigerant gas, the temperature of windings of the motor stator, or another temperature. When the evaporating temperature is constant, increasing the condensing temperature as high as possible in a range lower than the upper limit temperature leads to securing a wide operation range. In contrast, when the condensing temperature is constant, making the evaporating temperature as low or as high as possible leads to securing a wide operation range.

[0035] The temperature of the discharged refrigerant gas is likely to increase during operation under a high-compression-ratio condition, and the winding temperature is likely to increase under a high-load condition or a high-compression-ratio condition. The high-compression-ratio condition involves conditions including a high condensing temperature and a low evaporating temperature. The high-load condition involves conditions including a high condensing temperature and a high evaporating temperature. Thus, when the temperature of the discharged refrigerant gas and the winding temperature are about to reach the upper limit temperatures during operation under the high-load condition or the high-compression-ratio condition, the operation has to be changed such that the temperature of the discharged refrigerant gas and the winding temperature do not reach the upper limit temperatures. To change the operation, for example, a measure such as reducing the rotation speed of the compressor to decrease the condensing temperature has to be taken so that the operating temperature condition falls within the operation range. That is, when it is desired to continue the operation while keeping the condensing temperature high, the temperature of the discharged refrigerant gas and the winding temperature increase during operation under the high-load condition or the high-compression-ratio condition. Thus, a measure such as decreasing the condensing temperature is required, and the operation range is narrowed.

[0036] The temperature of the discharged refrigerant gas and the winding temperature under a certain operating condition tend to decrease as the compressor efficiency under the operating condition increases. Thus, by increasing the compressor efficiency during operation under the high-load condition or the high-compression-ratio condition, it is possible to suppress increases in the temperature of the discharged refrigerant gas and the winding temperature without taking a measure such as decreasing the condensing temperature. Consequently, this leads to securing of a wide operation range. The compressor efficiency is determined by the internal structure of the compressor and structural elements such as the number of winding turns of the motor.

[0037] The large-side Vi value is set to a Vi value with which the compressor efficiency is equal to or higher than a set efficiency set in advance during operation under a predetermined high-load condition or a predetermined high-compression-ratio condition. The compressor efficiency is a value that changes depending on the Vi value, and is expressed by a graph that projects upward when the horizontal axis represents Vi and the vertical axis represents the compressor efficiency. That is, there is a Vi value with which the compressor efficiency is the maximum. Based on this, the large-side Vi value may be the Vi value when the compressor efficiency is the maximum, or in other words, only has to be set to a value with which the compressor efficiency is equal to or higher than the set efficiency. The set efficiency only has to be appropriately set depending on performance or another factor required for the screw compressor. For example, when the maximum efficiency is 100%, the set efficiency may be 95% or more.

[0038] In a case where a screw compressor that secures a wide operation range is configured, the Vi value is set as described above. Thus, the position when the variable Vi valve 8 is moved to the side where the Vi value is large is set to attain the set Vi value.

(Improvement in Rated Performance or Primary Annual Performance Factor)

[Improvement in Rated Performance: Large-side Vi Value]

[0039] The large-side Vi value is set so that the rated performance is improved. The rated performance is performance under conditions defined by industrial standards or other standards, and represents the performance of the compressor. The rated performance is a value that changes depending on the Vi value, and is represented by a graph that projects upward when the horizontal axis represents Vi and the vertical axis represents the rated performance. That is, there is a Vi value with which the rated performance is the maximum. Based on this, the large-side Vi value may be the Vi value when the rated performance is the maximum, or in other words, only has to be set to a Vi value with which the rated performance is equal to or higher than a set performance set in advance. The set performance only has to be appropriately set depending on performance or another factor required for the screw compressor. For example, when the maximum performance is 100%, the set performance may be 95% or more.

[0040] In a case where a screw compressor aiming at improvement in the rated performance is configured, the Vi value is set as described above. Thus, the position when the variable Vi valve 8 is moved to the side where the Vi value is large is set to attain the set Vi value.

[Improvement in Primary Annual Performance Factor: Small-side Vi Value]

[0041] The small-side Vi value is set as follows. In the refrigerating and air-conditioning apparatus, in addition to a coefficient of performance called COP representing energy consumption efficiency, there is a coefficient of performance for a refrigerator throughout a year such as an integrated part load value (IPLV) or an European seasonal energy efficiency ratio (ESEER).

[0042] In the Air-Conditioning and Refrigeration Institute (ARI), an IPLV that is a primary annual performance factor is calculated by the following formula.

$$\mathrm{IPLV} = 0.01\times A + 0.42\times B + 0.45\times C + 0.12\times D$$

A = COP at 100% load, B = COP at 75% load,
C = COP at 50% load, D = COP at 25% load

[0043] With this formula, the weight to be multiplied differs depending on the load during operation. Of the annual operation period of the refrigerating and air-conditioning apparatus, operation at 75% load accounts for 42%, and operation at 50% load accounts for 45%. Thus, the weights for the two conditions are large in the formula of the IPLV.

[0044] Indexes are defined similary in the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) and EUROVENT/CECOMAF.

[0045] In the case of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA), an IPLV is defined as the following formula.

$$\mathrm{IPLV} = 0.01\times A + 0.47\times B + 0.37\times C + 0.15\times D$$

A = COP at 100% load, B = COP at 75% load,
C = COP at 50% load, D = COP at 25% load

[0046] In the case of EUROVENT/CECOMAF, an ESEER is defined as an European seasonal energy efficiency ratio. Like the IPLV, the ESEER is a value obtained by multiplying an energy efficiency ratio of four operation load conditions by a weighting factor, and is calculated by the following formula. For the calculation of the ESEER, an energy efficiency ratio (EER) that is a value representing an energy consumption efficiency is used as in the case of the COP.

$$\mathrm{ESEER} = 0.03\times A + 0.33\times B + 0.41\times C + 0.23\times D$$

A = EER at 100% load, B = EER at 75% load,
C = EER at 50% load, D = EER at 25% load

[0047] As described above, the weight at 75% load and the weight at 50% load are large for various indexes representing the coefficients of performance throughout a year of the refrigerating and air-conditioning apparatus.

[0048] Here, describing with an example of the formula of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA), "0.01×A" may be a coefficient of performance in 100% load operation, and "0.47×B + 0.37×C + 0.15×D" may be a coefficient of performance in partial load operation.

[0049] The small-side Vi value is set to perform efficient operation in partial load operation, and is set to a Vi value with which the value of "0.47×B + 0.37×C + 0.15×D" is equal to or greater than a set value set in advance. In other words, the small-side Vi value is set based on the top three operation loads having large weights in the primary annual performance factor.

[0050] The value of "0.47×B + 0.37×C + 0.15×D" is a value that changes depending on the Vi value, and is represented by a graph that projects upward when the horizontal axis represents Vi and the vertical axis represents "0.47×B + 0.37×C + 0.15×D". That is, there is a Vi value with which the value of "0.47×B + 0.37×C + 0.15×D" is the maximum. Based on this, the small-side Vi value may be the Vi value when "0.47×B + 0.37×C + 0.15×D" is the maximum, or in other words, only has to be a value that is equal to or greater than the set value. The set value only has to be appropriately set depending on performance or another factor required for the screw compressor. For example, when the maximum set value is 100%, the set value may be 95% or more.

[0051] When a screw compressor that performs efficient operation in partial load operation is configured, the Vi value is set as described above. Thus, the position when the variable Vi valve 8 is moved to attain the small-side Vi value is set to attain the set Vi value.

[0052] When the small-side Vi value is set as described above and the large-side Vi value is set to a Vi value with which the compressor efficiency is equal to or higher than the set efficiency during operation under the high-load condition or the high-compression-ratio condition, a wide operation range can be secured and the IPLV can be improved.

[0053] When the small-side Vi value is set as described above and the larger-side Vi value is set to a Vi value with which the rated performance is equal to or higher than the set performance during operation under the rated condition, both the rated performance and the IPLV can be improved.

[0054] It is determined that the small-side Vi value is set based on the top three operation loads having large weights in the primary annual performance factor. However, as described above, operation at 75% load and operation at 50% load account for the majority of operation period per year. Thus, the small-side Vi value may be set based on the top one or top two operation loads having large weights in the primary annual performance factor.

[0055] As described above, in Embodiment 1, the variable Vi valve is controlled under the simple two-stage control based on only the discharge pressure and the suction pressure. Thus, the configuration and control can be simplified without necessity of a special device while the internal volume ratio is made variable.

[0056] The position of the variable Vi valve when the Vi value is set to be large is set to attain the Vi value with which the compressor efficiency is equal to or higher than the set efficiency during operation under the high-load condition or the high-compression-ratio condition. Thus, a wide operation range can be secured.

[0057] The position of the variable Vi valve when the Vi value is set to be large is set to attain the Vi value with which the rated performance is equal to or higher than the set performance. Thus, the rated performance can be improved.

[0058] The position of the variable Vi valve when the Vi value is set to be small is set to attain the Vi value with which a value obtained by multiplying each of the coefficients of performance at the top one to top three operation loads by the weight corresponding to the operation load is equal to or greater than the set value. This can improve the partial load performance and improve the compressor efficiency.

Embodiment 2

[0059] Embodiment 1 provides the configuration in which the pressure introduction hole 113a of the cylinder chamber 13a is coupled to the discharge chamber 6. Embodiment 1 also provides the configuration in which the pressure introduction hole 113b of the cylinder chamber 13b is coupled to the discharge chamber 6 in the casing main body 1 through the flow path 15b via the solenoid valve 14b, and is coupled to the suction chamber 16 in the casing main body 1 through the flow path 15c via the solenoid valve 14a. Embodiment 2 has a configuration in which the pressure introduction hole 113a is coupled to the discharge chamber 6 in the casing main body 1 through the flow path 15b via the solenoid valve 14b, and is coupled to the suction chamber 16 in the casing main body 1 through the flow path 15c via the solenoid valve 14a. The pressure introduction hole 113b is coupled to the suction chamber 16 in the casing main body 1.

[0060] Next, the operation of the variable Vi valve 8 according to Embodiment 2 will be described. As in Embodiment 1, the Vi value can be set to two values of a large value and a small value.

(i) Operation when Vi Value Is Large

[0061] Fig. 5 is an operation schematic diagram when a Vi value is large in the screw compressor according to Embodiment 2 of the present disclosure.

[0062] When the Vi value is large, the driving device 10 positions the variable Vi valve 8 in the left direction represented by the arrow in the drawing, thereby delaying the timing at which the discharge port 7 opens.

[0063] That is, when the Vi value is large, the solenoid valve 14a is closed and the solenoid valve 14b is opened so that the pressure in the cylinder chamber 13a is a discharge pressure. In contrast, the cylinder chamber 13b is coupled to the suction chamber 16, and a suction pressure is normally introduced into the cylinder chamber 13b. Hence, the piston 12 is to move in the left direction in the drawing due to the pressure difference in the cylinder chamber 13.

[0064] In the variable Vi valve 8 coupled to the piston 12, a suction pressure acts on the suction-side end portion 8g of the valve main body 8a, and a discharge pressure immediately after discharge acts on the discharge-port-side end portion 8d. The same pressure as the pressure acting on the discharge-port-side end portion 8d acts on the discharge-port-side end portion 8e of the guide portion 8b in directions opposite to each other. A discharge pressure acts on the driving-device-side end portion 8h of the guide portion 8b.

[0065] Thus, the loads acting on the discharge-port-side end portions 8d and 8e in the variable Vi valve 8 cancel out each other. Hence, the variable Vi valve 8 is to move in the right direction in the drawing due to the pressure difference between the pressure acting on the driving-device-side end portion 8h and the pressure acting on the suction-side end portion 8g. However, since the area of each of both end surfaces of the piston 12 in the movement direction is set to be larger than the area of the driving-device-side end portion 8h of the variable Vi valve 8, the piston 12 and the variable Vi valve 8 move in the left direction in the drawing due to the pressure difference received in both the areas. Since the variable Vi valve 8 stops at a position at which the piston 12 abuts against the wall surface of the cylinder chamber 13, the variable Vi valve 8 is accurately positioned at a position at which the Vi value is large.

(ii) Operation when Vi Value Is Small

[0066] Fig. 6 is an operation schematic diagram when the Vi value is small in the screw compressor according to Embodiment 2 of the present disclosure.

[0067] When the Vi value is small, the driving device 10 positions the variable Vi valve 8 in the right direction represented by the arrow in the drawing, thereby advancing the timing at which the discharge port 7 opens.

[0068] That is, when the Vi value is small, the solenoid valve 14a is opened and the solenoid valve 14b is closed so that the pressure in the cylinder chamber 13a is a suction pressure. In contrast, since the cylinder chamber 13b is coupled to the suction chamber 16 and a suction pressure is normally introduced into the cylinder chamber 13b, there is no pressure difference in the cylinder chamber 13.

[0069] In the variable Vi valve 8 coupled to the piston 12, a suction pressure acts on the suction-side end portion 8g of the valve main body 8a, and a discharge pressure immediately after discharge acts on the discharge-port-side end portion 8d. The same pressure as the pressure acting on the discharge-port-side end portion 8d acts on the discharge-port-side end portion 8e of the guide portion 8b in directions opposite to each other. A discharge pressure acts on the driving-device-side end portion 8h of the guide portion 8b.

[0070] Thus, the variable Vi valve 8 moves in the right direction in the drawing due to the pressure difference between the discharge pressure acting on the driving-device-side end portion 8h and the suction pressure acting on the suction-side end portion 8g. Since the variable Vi valve 8 stops at a position at which the piston 12 abuts against the wall surface of the cylinder chamber 13, the variable Vi valve 8 is accurately positioned at a position at which the Vi value is small. Alternatively, as illustrated in Fig. 1, the variable Vi valve 8 may be positioned at a position where the suction-side end portion 8g of the variable Vi valve 8 abuts against the wall surface of the casing main body 1.

[0071] According to Embodiment 2, effects similar to those of Embodiment 1 can be obtained.

[0072] The screw compressor according to the present disclosure is not limited to those illustrated in Figs. 1 to 6, and may be modified and implemented, for example, as described below within the scope not departing from the gist of the present disclosure.

[0073] Fig. 7 illustrates a modification of the screw compressor according to any one of Embodiment 1 and Embodiment 2 of the present disclosure.

[0074] In this modification, the piston 12 illustrated in Fig. 1 is omitted, and a piston rod 17 is provided. In Fig. 1, there is one piston for one variable Vi valve. In contrast, in this modification, the piston rod 17 is coupled to rods 9 of two variable Vi valves 8 via a common attachment plate 18, and the one piston rod 17 is provided for the two variable Vi valves 8. As described above, the number of pistons 12 for the variable Vi valves 8 is not limited.

Reference Signs List

[0075] 1: casing main body, 2: motor, 2a: stator, 2b: motor rotor, 3: screw rotor, 3a: screw groove, 4: screw shaft, 5: compression chamber, 6: discharge chamber, 7: discharge port, 8: variable Vi valve, 8a: valve main body, 8b: guide portion, 8c: coupling portion, 8d: discharge-port-side end portion, 8e: discharge-port-side end portion, 8f: discharge gap, 8g: suction-side end portion, 8h: driving-device-side end portion, 9: rod, 10: driving device, 11: cylinder, 12: piston, 13:

cylinder chamber, 13a cylinder chamber, 13b: cylinder chamber, 14a: solenoid valve, 14b: solenoid valve, 15a: flow path, 15b: flow path, 15c: flow path, 16: suction chamber, 17: piston rod, 18: attachment plate, 113a: pressure introduction hole, 113b: pressure introduction hole

Claims

1. A screw compressor comprising an internal-volume-ratio variable mechanism including a variable Vi valve configured to make a Vi value being an internal volume ratio variable,

wherein the screw compressor controls a position of the variable Vi valve in two stages, and
wherein the position of the variable Vi valve when the Vi value is set to be large is set to attain a Vi value with which a compressor efficiency during operation under a predetermined high-load condition or a predetermined high-compression-ratio condition is equal to or higher than a set efficiency set in advance.

2. A screw compressor comprising an internal-volume-ratio variable mechanism including a variable Vi valve configured to make a Vi value being an internal volume ratio variable,

wherein the screw compressor controls a position of the variable Vi valve in two stages, and
wherein the position of the variable Vi valve when the Vi value is set to be large is set to attain a Vi value with which a rated performance is equal to or higher than a set performance set in advance.

3. The screw compressor of claim 1 or 2,
wherein the position of the variable Vi valve when the Vi value is set to be small is set to attain a Vi value with which a value obtained by multiplying each of coefficients of performance at top one to top three operation loads having large weights in a primary annual performance factor calculated by applying weights for four operation loads, by the weight corresponding to the operation load is equal to or greater than a set value set in advance.

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

wherein the internal-volume-ratio variable mechanism includes
a piston coupled to the variable Vi valve; and
a cylinder configured to house the piston,
wherein inside of the cylinder is divided into two spatial chambers by the piston, and
wherein the two spatial chambers are disposed as a cylinder chamber into which a discharge pressure is normally introduced and a cylinder chamber into which a suction pressure or a discharge pressure is introduced via a valve unit, in order of closeness to the variable Vi valve.

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

wherein the internal-volume-ratio variable mechanism includes
a piston coupled to the variable Vi valve; and
a cylinder configured to house the piston,
wherein inside of the cylinder is divided into two spatial chambers by the piston, and
wherein the two spatial chambers are disposed as a cylinder chamber into which a suction pressure or a discharge pressure is introduced via a valve unit and a cylinder chamber into which a suction pressure is normally introduced, in order of closeness to the variable Vi valve.

6. The screw compressor of any one of claims 1 to 5, wherein capacity control is performed by inverter rotation speed control.

FIG. 1

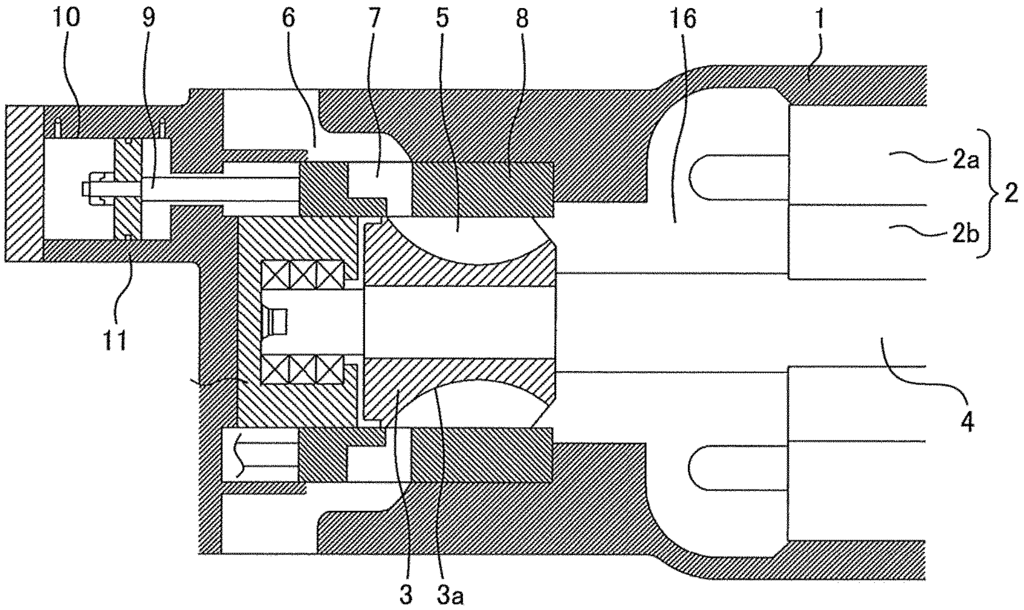

10
9
6
7
5
8
16
1
2a
2
2b
11
4
3
3a

FIG. 2

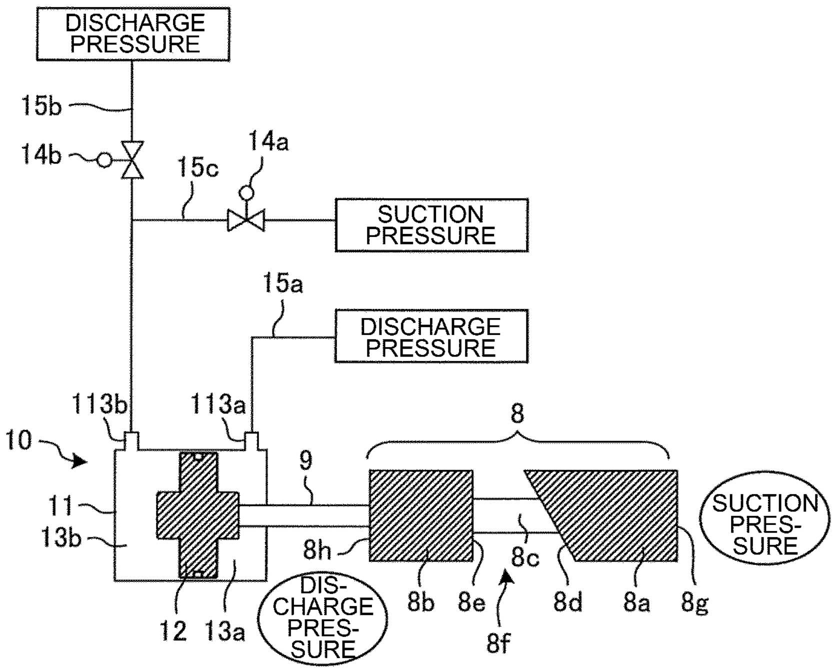

DISCHARGE PRESSURE
15b
14b
15c
14a
SUCTION PRESSURE
15a
DISCHARGE PRESSURE
113b
113a
8
10
9
11
13b
8h
SUCTION PRES-SURE
8c
12
13a
DIS-CHARGE PRES-SURE
8b
8e
8f
8d
8a
8g

FIG. 3

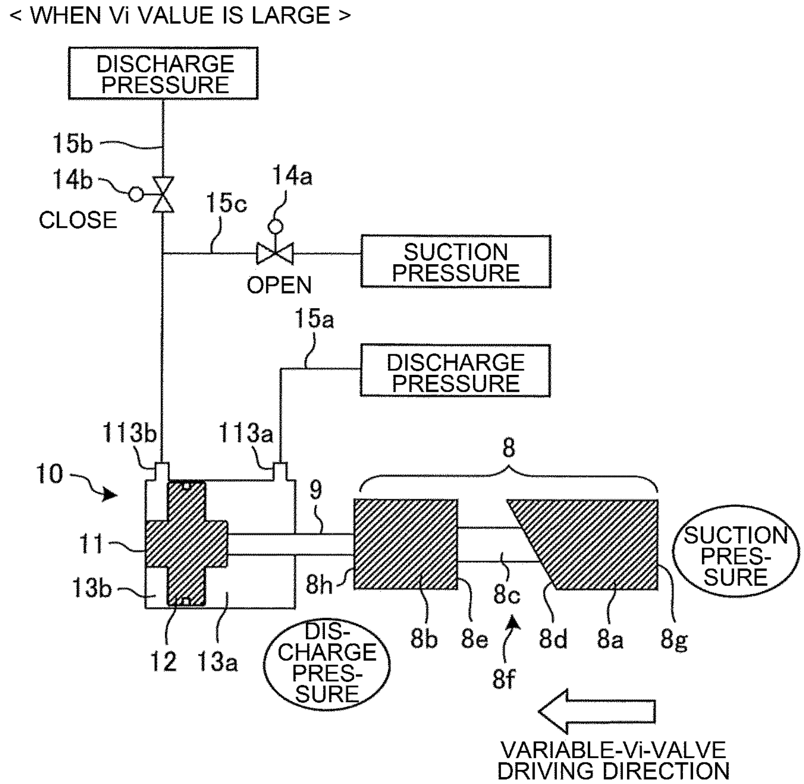

< WHEN Vi VALUE IS LARGE >
DISCHARGE PRESSURE
15b
14b
CLOSE
15c
14a
OPEN
SUCTION PRESSURE
15a
DISCHARGE PRESSURE
113b
113a
10
11
13b
12
13a
9
8h
8
DIS-CHARGE PRES-SURE
8b
8e
8c
8f
8d
8a
8g
SUCTION PRES-SURE
VARIABLE-Vi-VALVE DRIVING DIRECTION

FIG. 4

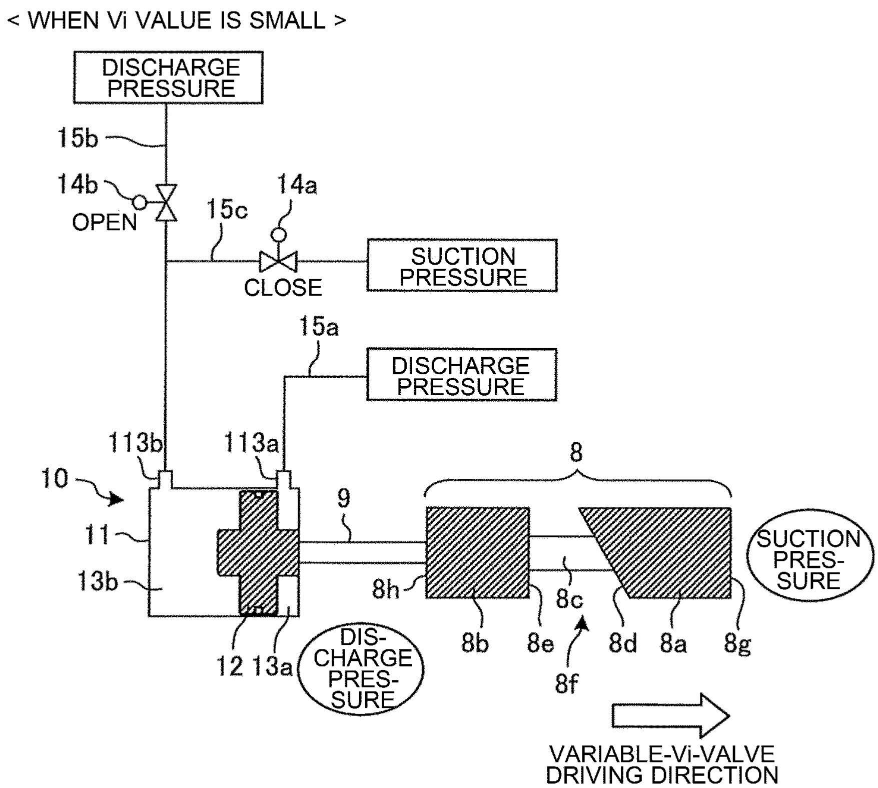

< WHEN Vi VALUE IS SMALL >
DISCHARGE PRESSURE
15b
14b
OPEN
15c
14a
CLOSE
SUCTION PRESSURE
15a
DISCHARGE PRESSURE
113b
113a
10
11
13b
12
13a
9
8h
8
DIS-CHARGE PRES-SURE
8b
8e
8c
8f
8d
8a
8g
SUCTION PRES-SURE
VARIABLE-Vi-VALVE DRIVING DIRECTION

FIG. 5

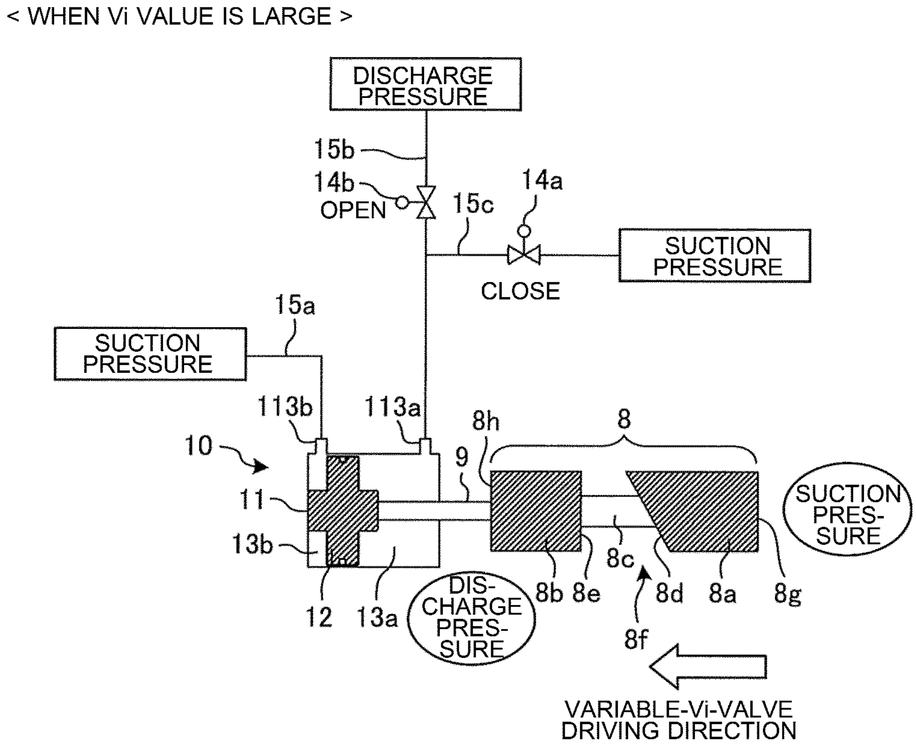

< WHEN Vi VALUE IS LARGE >
DISCHARGE PRESSURE
15b
14b
OPEN
15c
14a
CLOSE
SUCTION PRESSURE
15a
SUCTION PRESSURE
113b
113a
10
11
13b
12
13a
9
8h
8
SUCTION PRES-SURE
8c
8b 8e
8d
8a
8g
DIS-CHARGE PRES-SURE
8f
VARIABLE-Vi-VALVE DRIVING DIRECTION

FIG. 6

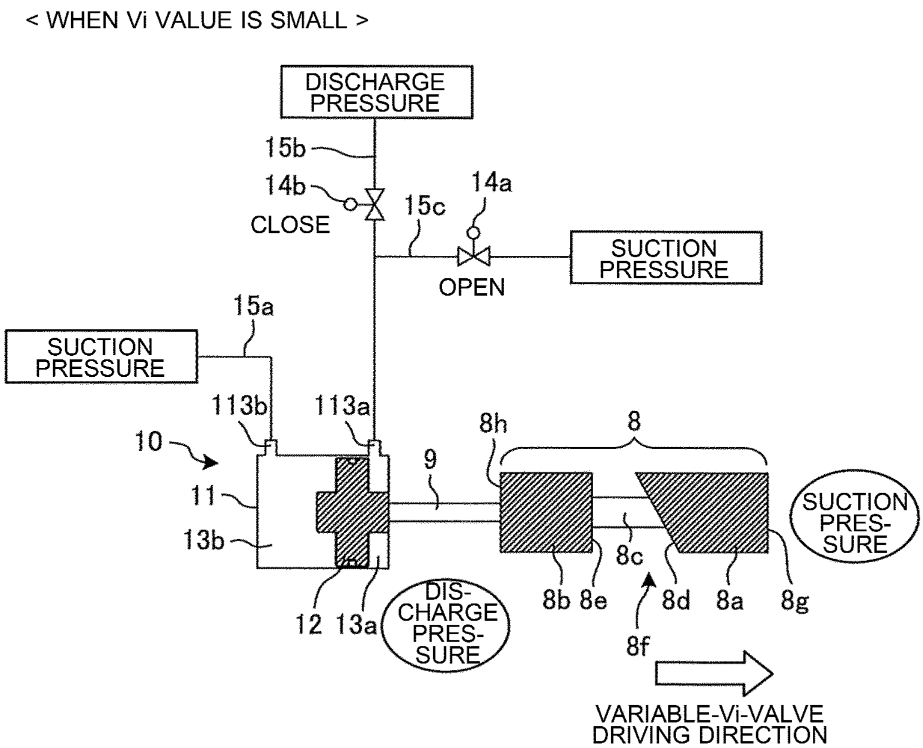
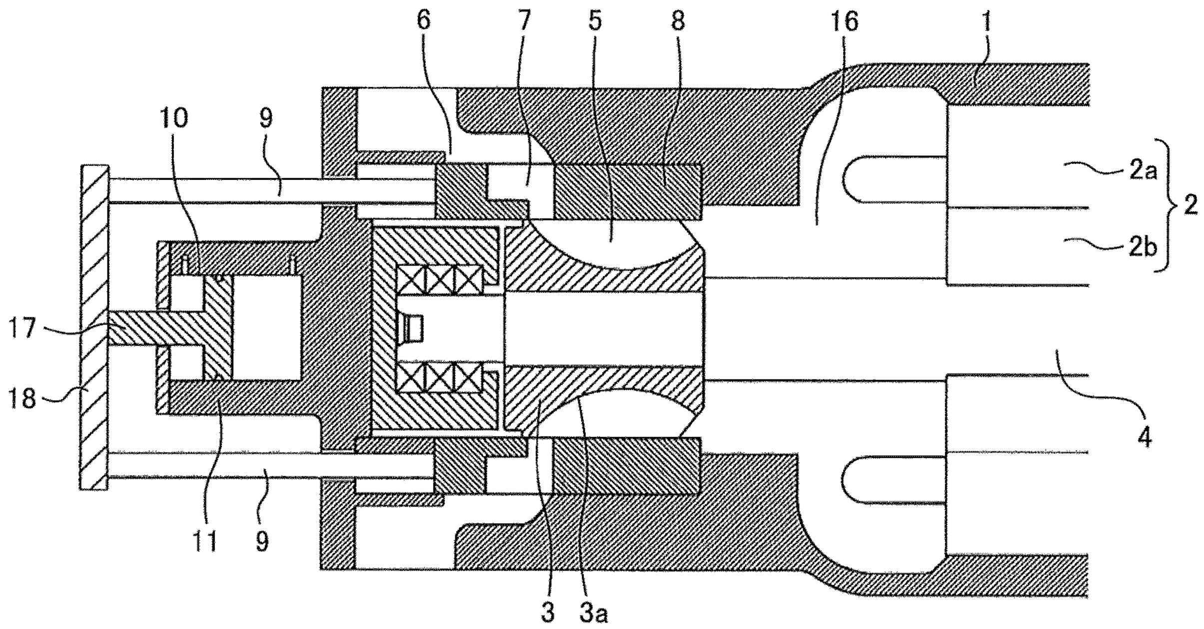

< WHEN Vi VALUE IS SMALL >
DISCHARGE PRESSURE
15b
14b
CLOSE
15c
14a
OPEN
SUCTION PRESSURE
15a
SUCTION PRESSURE
113b
113a
10
11
13b
12
13a
9
8h
8
SUCTION PRES-SURE
8c
8b 8e
8d
8a
8g
DIS-CHARGE PRES-SURE
8f
VARIABLE-Vi-VALVE DRIVING DIRECTION

FIG. 7



INTERNATIONAL SEARCH REPORT	International application No. PCT/JP2019/008079

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F04C18/52(2006.01)i, F04C18/16(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, F04C18/16, 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	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2013-124600 A (MITSUBISHI ELECTRIC CORP.) 24 June 2013, paragraphs [0011]-[0027], fig. 1-7 (Family: none)	1-6
Y	JP 2014-206098 A (MITSUBISHI ELECTRIC CORP.) 30 October 2014, paragraphs [0011]-[0058], fig. 1-5 (Family: none)	1-6

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13.05.2019	28.05.2019

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

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 4147891 B **[0006]**