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(54) **ROTARY COMPRESSOR**

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(57) **ABSTRACT**

There is provided a two-stage compression rotary compressor in which the balancer mass of a rotor can be made as small as possible, and the moments that tilt the whole of a shaft can be balanced. The axial length L**2** of a high-stage side crankshaft **72** corresponding to a high-stage compressing section **32** is longer than the axial length L**1** of a low-stage side crankshaft **73** corresponding to a low-stage compressing section **31** (L**2**>L**1**).

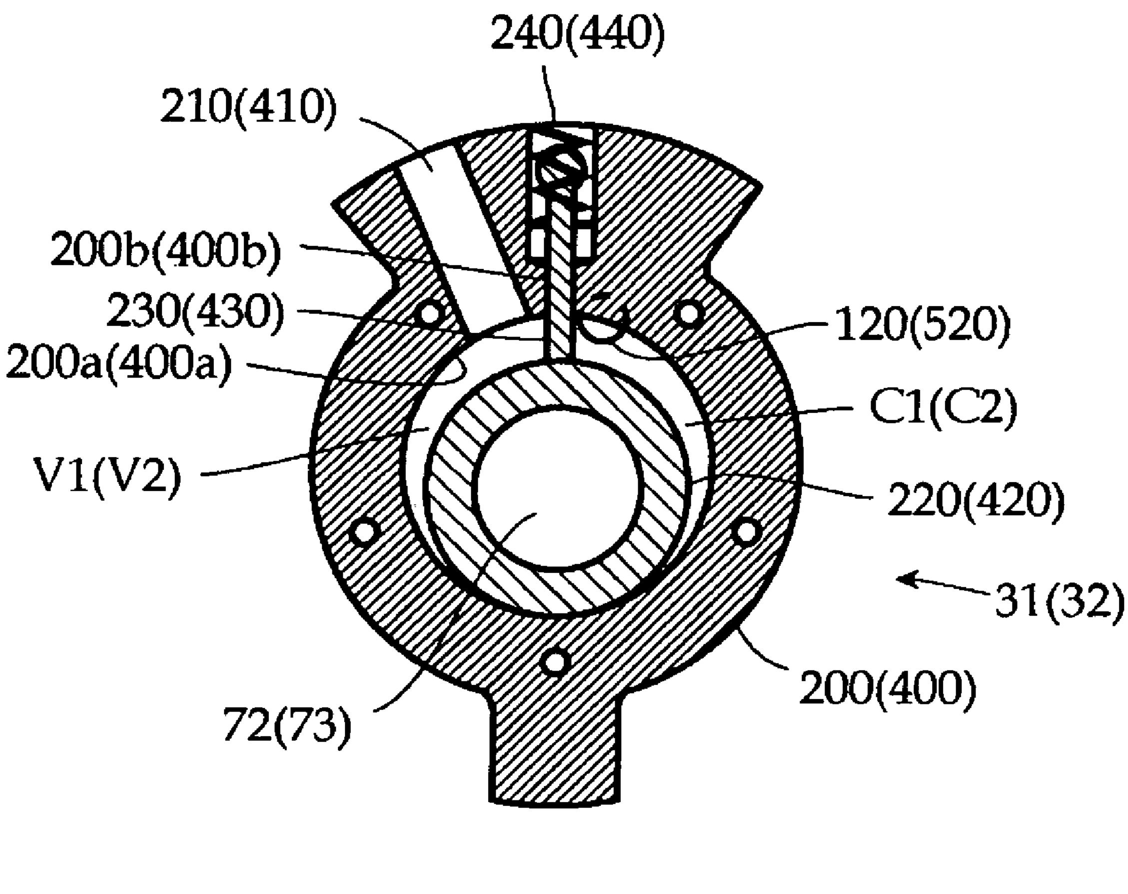


FIG. 1

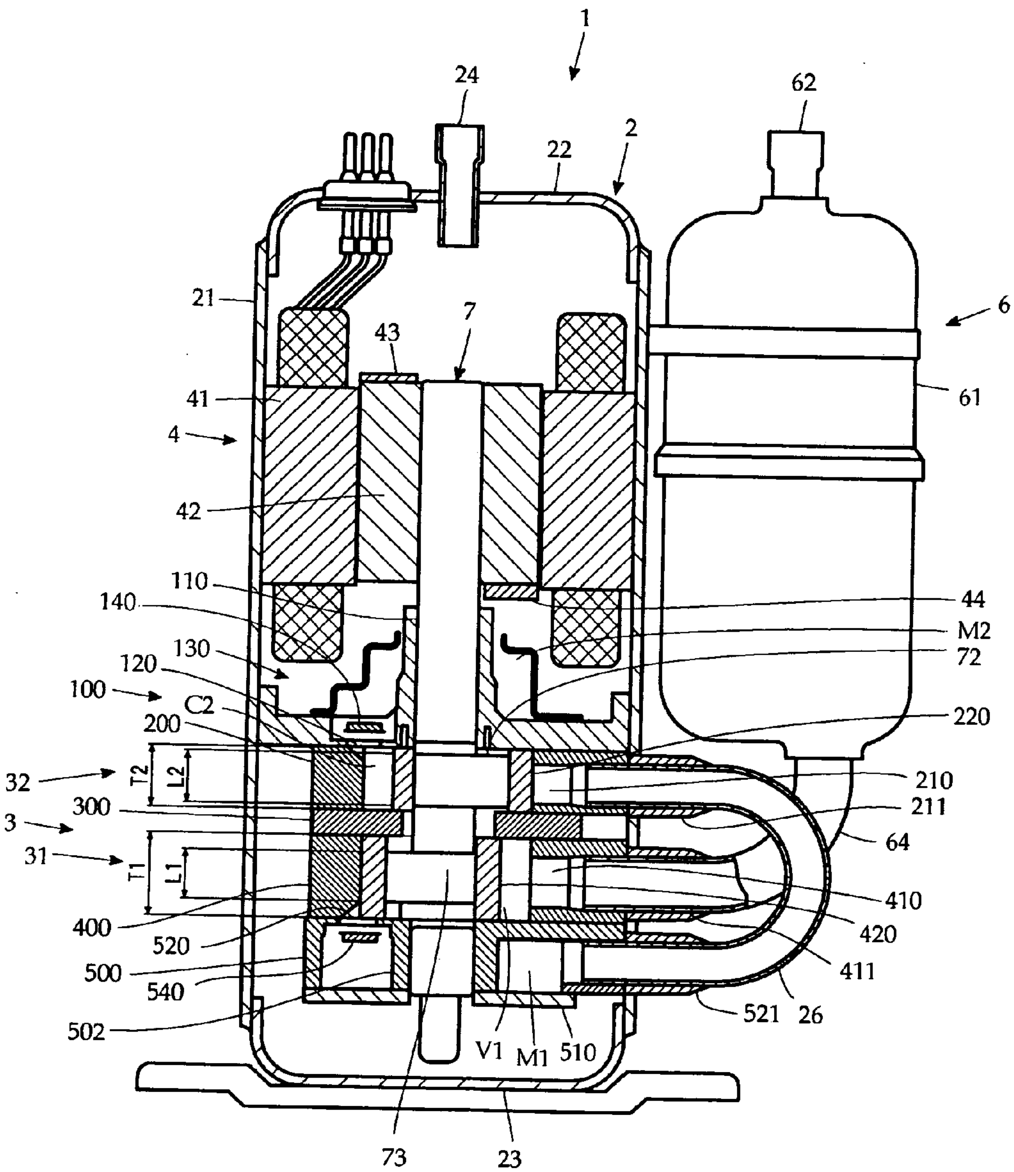

1
24
62
2
22
6
21
7
43
61
41
4
42
110
44
140
M2
130
72
120
100
C2
220
200
T2
L2
32
210
300
211
3
64
31
T1
L1
410
400
420
520
411
500
540
502
521
26
V1
M1
510
73
23

FIG. 2

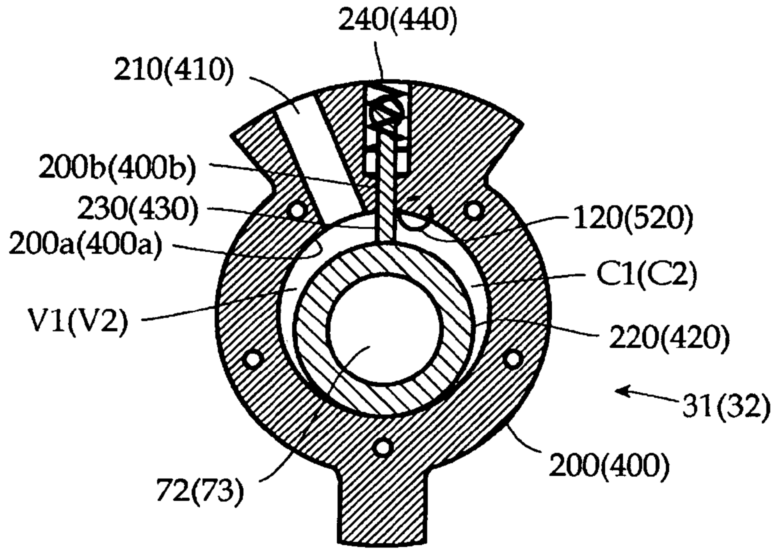

240(440)
210(410)
200b(400b)
230(430)
200a(400a)
V1(V2)
72(73)
120(520)
C1(C2)
220(420)
31(32)
200(400)

FIG. 3

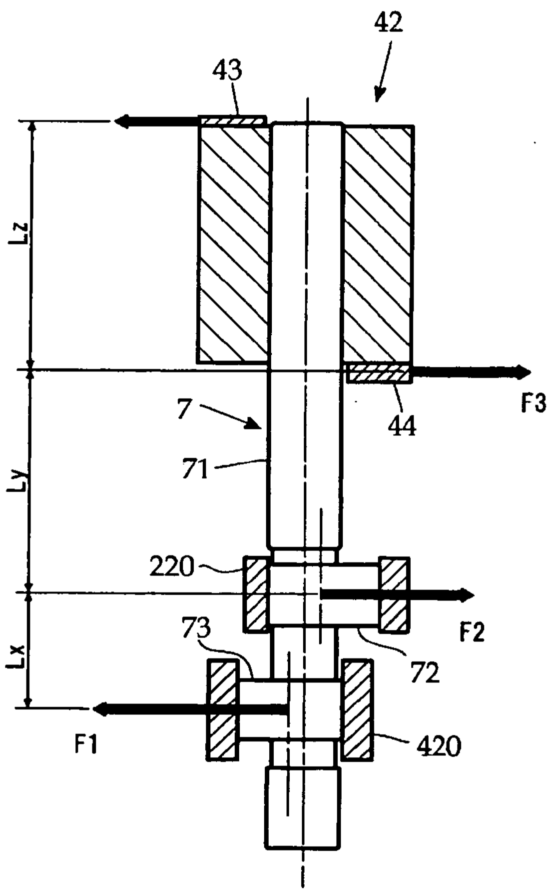
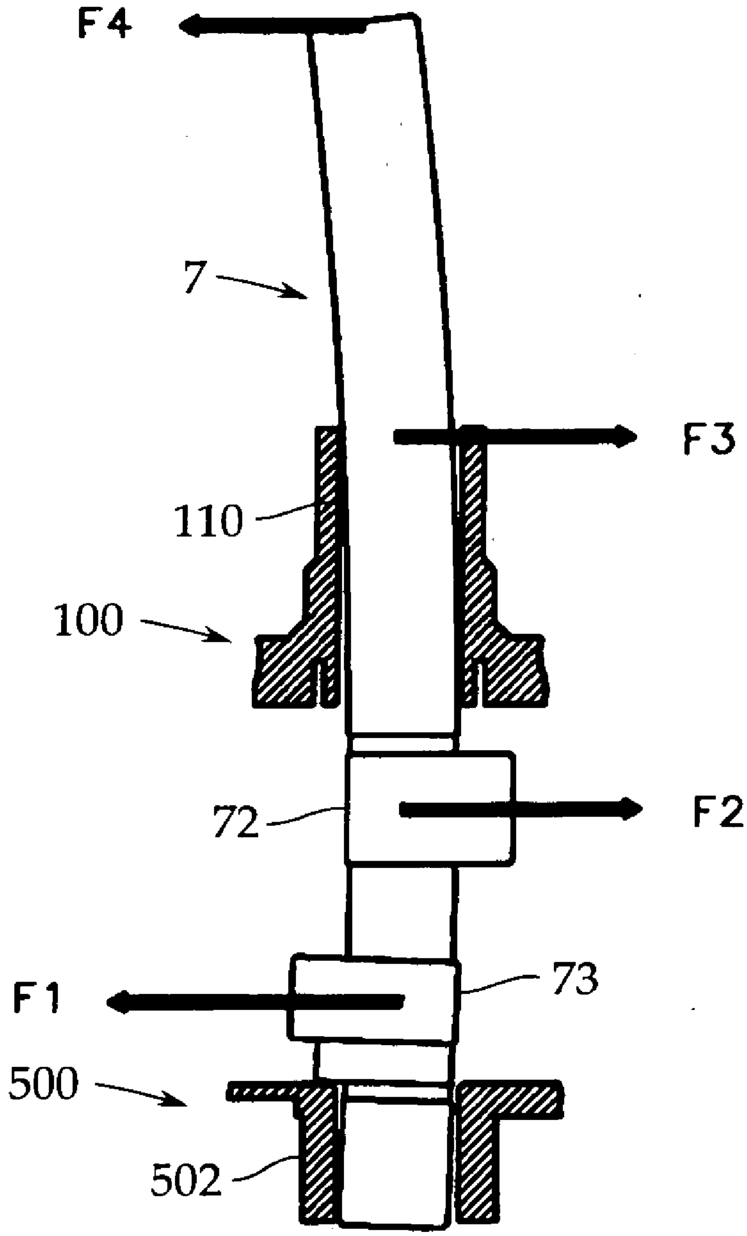

42
43
Lz
Ly
Lx
7
71
44
F3
220
73
72
F2
F1
420

FIG. 4



ROTARY COMPRESSOR

TECHNICAL FIELD

[0001] The present invention relates to a rotary compressor having two-stage compressing sections including a low-stage compressing section and a high-stage compressing section. More particularly, it relates to a technique for preventing a deflection occurring on a shaft connecting a motor and the compressing section to each other to enhance the reliability.

BACKGROUND ART

[0002] Generally, in a rotary compressor, in order to reduce a loss of refrigerant caused by the leakage by sealing the gap of a compression chamber and to lubricate sliding portions such as bearings, a compressing section is arranged in the lower part of a closed vessel in which lubricating oil accumulates.

[0003] Also, in a two-stage compression rotary compressor, in order to make better the balance of compressive load torques produced in two compressing sections and the balance of centrifugal forces acting on the off-center parts corresponding to the two compressing sections, that is, turning pistons and the off-center parts of a shaft engaging with the pistons, the compression phases of a low-stage compressing section and a high-stage compressing section are shifted through 180 degrees.

[0004] By the centrifugal forces acting on the two off-center parts of the shaft and the two turning pistons, a moment that tends to tilt the whole of the shaft is produced. Therefore, a balancer is attached to above and below a rotor of a motor to cancel the moment that tends to tilt the whole of the shaft.

[0005] In the two-stage compression rotary compressor, in terms of the compression characteristics thereof, the volume of the high-stage compressing section must be smaller than the volume of the low-stage compressing section. As means for decreasing the volume of compression chamber, there are available a method in which the thickness of compression chamber, that is, the thickness of a cylinder is decreased and a method in which the turning radius of the piston is decreased. In both of these methods, the centrifugal forces acting on the off-center parts of the shaft and the pistons are smaller in the high-stage compressing section having a smaller volume than in the low-stage compressing section having a larger volume.

[0006] Therefore, as described in Japanese Patent Application Publication No. H11-230073, there is known means for decreasing the mass of the balancer by arranging the low-stage compressing section, on which a larger centrifugal force acts, on the side close to the rotor to which the balancer is attached, that is, by arranging the low-stage compressing section above the high-stage compressing section.

[0007] However, in the case where the low-stage compressing section is arranged above the high-stage compressing section, there arises a problem described below. Depending on the operation pressure condition and the rotational speed condition of the compressor, the oil level of lubricating oil lowers from the compressing section arranged on the upper side in the closed vessel, and the compressing section on the upper side is exposed to refrigerant gas. Therefore, the refrigerant leaks into a suction chamber and the compression chamber passing through a gap between a vane and a vane groove, whereby a leakage loss is created.

[0008] If the low-stage compressing section is arranged on the upper side, since the interior of closed vessel has the discharge pressure of the high-stage compressing section, the difference in pressure between the suction chamber and the compression chamber is large as compared with the case where the high-stage compressing section is arranged on the upper side, so that the quantity of refrigerant leaking into the suction chamber and the compression chamber through the gap increases, which presents a problem of further decreased efficiency of compressor.

[0009] Accordingly, an object of the present invention is to provide a rotary compressor in which the mass of a balancer can be decreased, and thereby the deflection of a shaft is reduced, so that the seizure in bearing parts and the contact of a rotor with a stator can be prevented.

SUMMARY OF THE INVENTION

[0010] To achieve the above object, the present invention has some features described below. A rotary compressor having a two-stage compressing section including a low-stage compressing section and a high-stage compressing section provided in a closed shell, and a motor for driving the two-stage compressing section, the high-stage compressing section being arranged on the motor side, is characterized in that when the axial length of the off-center part of shaft corresponding to the low-stage compressing section, that is, a low-stage side crankshaft, is taken as L**1**, and the axial length of the off-center part of shaft corresponding to the high-stage compressing section, that is, a high-stage side crankshaft, is taken as L**2**, L**2** is longer than L**1**.

[0011] According to this configuration, the mass of a balancer attached to a rotor can be made small by making the axial length of the high-stage side crankshaft longer than that of the low-stage side crankshaft. Thereby, the deflection of the whole of the shaft is reduced, so that seizure caused by a local excessive load of a bearing part and the contact of the rotor with a stator can be prevented.

[0012] As a preferable mode, the rotary compressor is characterized in that the rotational speed of the compressing section is variable. According to this configuration, in the rotary compressor in which the rotational speed is variable, when the rotational speed is high, the centrifugal forces acting on an upper balancer and a lower balancer increase, by which the deflection of the shaft is increased, and therefore the effect of the present invention is further increased.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a longitudinal sectional view of a rotary compressor in accordance with one embodiment of the present invention;

[0014] FIG. **2** is a transverse sectional view of a compressing section of the rotary compressor shown in FIG. **1**;

[0015] FIG. **3** is a schematic view showing rotating parts of the rotary compressor shown in FIG. **1** and centrifugal forces acting thereon; and

[0016] FIG. **4** is a schematic view showing a deflected state of a shaft formed by centrifugal forces of the rotary compressor shown in FIG. **1**.

DETAILED DESCRIPTION

[0017] An embodiment of the present invention is explained with reference to FIG. **1**. The present invention is not limited to this embodiment. A rotary compressor **1**

includes a cylindrical closed vessel **2** arranged in the vertical direction, a motor **4** provided in an upper part in the closed vessel **2**, and a compressing section **3** in a lower part therein.

[0018] The closed vessel **2** consists of a cylindrical main shell **21**, a dome-shaped top shell **22** that closes the upper end part of the main shell **21**, and a dome-shaped bottom shell **23** that closes the lower end part of the main shell **21**. The top shell **22** and the bottom shell **23** are fixed to the main shell **21** by welding.

[0019] The top shell **22** is provided with a refrigerant discharge pipe **24** for discharging the refrigerant having been discharged into the closed vessel **2** from the compressing section **3** to the outside of the closed vessel **2**.

[0020] A stator **41** of the motor **4** is shrinkage fitted to the main shell **21**. A rotor **42** of the motor **4** is shrinkage fitted onto a shaft **7** mechanically connecting the motor **4** to the compressing section **3**. Above and below the rotor **42**, an upper balancer **43** and a lower balancer **44** are attached, respectively, to balance the centrifugal forces of the whole of rotating parts.

[0021] The compressing section **3** is provided with a high-stage compressing section **32** in the upper part thereof and a low-stage compressing section **31** in the lower part thereof. The discharge side of the low-stage compressing section **31** and the suction side of the high-stage compressing, section **32** are connected to each other by an intermediate connection pipe **26** on the outside of the closed vessel **2**, by which a two-stage compressing section is formed.

[0022] Next, the configuration of each section of the compressing section **3** is explained with reference to FIG. **2**. FIG. **2** shows the transverse cross section of the low-stage compressing section **31** shown in FIG. **1**. The configuration of the high-stage compressing section **32** is the same as that of the low-stage compressing section **31** except that the pistons are 180° out-of-phase.

[0023] Each of the compressing sections **31** and **32** has a cylinder **200**, **400** and a cylindrical piston **220**, **420** accommodated in a cylindrical cylinder bore **200***a*, **400***a* formed on the inside of the cylinder **200**, **400**. Between the internal wall of the cylinder bore **200***a*, **400***a* and the outer peripheral surface of the piston **220**, **420**, a working space for refrigerant is formed.

[0024] The cylinder **200**, **400** is provided with a cylinder groove **200***b*, **400***b* directed from the cylinder bore **200***a*, **400***a* toward the outer periphery direction, and has a flat plate shaped vane **230**, **430** in the cylinder groove **200***b*, **400***b*.

[0025] Between the vane **230**, **430** and the internal wall of the closed vessel **2**, a spring **240**, **440** is provided. By the urging force of the spring **240**, **440**, the tip end of the vane **230**, **430** is brought into sliding contact with the outer wall of the piston **220**, **420**, by which the working space is divided into a suction chamber V**1**, V**2** and a compression chamber C**1**, C**2**.

[0026] In order to make the working space volume of the high-stage compressing section **32** smaller than that of low-stage compressing section **31**, each of the cylinder **200**, the piston **220**, and the vane **230** on the high-stage side has a smaller thickness in the axial direction than each of the cylinder **400**, the piston **420**, and the vane **430** on the low-stage side.

[0027] Next, referring again to FIG. **1**, the whole of the compressor **1** is explained. The compressor **1** has a main frame **100** above the high-stage side cylinder **200**, an intermediate partition plate **300** between the high-stage side cylinder **200** and the low-stage side cylinder **400**, and a sub-frame **500** below the low-stage side cylinder **400**, and the upside and the downside of each of the two working spaces are closed by the main frame **100**, the intermediate partition plate **300**, and the sub-frame **500**, whereby each of the two working spaces is formed into a closed space.

[0028] Above the main frame **100**, a high-stage side discharge muffler cover **130** is provided, and a high-stage side discharge muffler chamber M**2** for reducing the pressure pulsation of discharged refrigerant is formed. Below the sub-frame **500**, a low-stage side discharge muffler cover **510** is provided, and a low-stage side discharge muffler chamber M**1** for reducing the pressure pulsation of discharged refrigerant is formed.

[0029] The high-stage side discharge muffler cover **130**, the main frame **100**, the high-stage side cylinder **200**, the intermediate partition plate **300**, the low-stage side cylinder **400**, the sub-frame **500**, and the low-stage side discharge muffler cover **510** are fixed integrally with bolts (not shown), and further the outer peripheral part of the main frame **100** is fixed to the main shell **21** by spot welding.

[0030] The main frame **100** and the sub-frame **500** have bearing parts **110** and **502**, respectively, so that the shaft **7** is fitted in the bearing parts **110** and **502** so as to be rotatably supported.

[0031] The shaft **7** has two crankshafts **72** and **73** that are off-centered in the 180° different direction. One crankshaft **72** engages with the piston **220** of the high-stage compressing section **32**, and the other crankshaft **73** engages with the piston **420** of the low-stage compressing section **31**.

[0032] Along with the rotation of the shaft **7**, the pistons **220** and **420** turn while slidingly contacting with the inside walls of the respective cylinder bores **200***a* and **400***a*, and following this turning motion of the pistons **220** and **420**, the vanes **230** and **430** reciprocate, by which the volumes of the suction chambers V**1** and V**2** and the compression chambers C**1** and C**2** are changed continuously. Thus, the compressing section **3** repeats the suction and compression of refrigerant.

[0033] The suction chamber V**1** of the low-stage compressing section **31** is connected to a refrigerant suction pipe **64** via a low-stage side suction hole **410** provided in the cylinder **400**. The compression chamber C**1** of the low-stage compressing section **31** is connected to the intermediate connection pipe **26** via a low-stage side discharge hole **520** provided in the sub-frame **500** and the low-stage side discharge muffler chamber M**1**.

[0034] More specifically, the low-stage side discharge hole **520** is provided with a check valve **540**. Also, the refrigerant suction pipe **64** is connected to the low-stage side suction hole **410** via a low-stage side suction connection pipe **411**, and the intermediate connection pipe **26** is connected to the low-stage side discharge muffler chamber M**1** via an intermediate discharge connection pipe **521**.

[0035] The suction chamber V**2** of the high-stage compressing section **32** is connected to the intermediate connection pipe **26** via a high-stage side suction hole **210** provided in the cylinder **200**. The compression chamber C**2** of the high-stage compressing section **32** is open to the interior of the closed vessel **2** via a high-stage side discharge hole **120** provided in the main frame **100** and the high-stage side discharge muffler chamber M**2**.

[0036] More specifically, the high-stage side discharge hole **120** is provided with a check valve **140**. Also, the intermediate connection pipe **26** is connected to the high-stage side suction hole **210** via an intermediate suction connection pipe **211**.

[0037] At the side of the body of the compressor **1**, an accumulator **6** consisting of an independent closed vessel **61** is provided. Above the accumulator **6**, a refrigerant return pipe **62** is provided, the refrigerant return pipe **62** being connected to a heat pump system, not shown. Below the accumulator **6**, there is provided the refrigerant suction pipe **64** one end having an L shape of which is extended to the upper part in the accumulator **6** and the other end of which is connected to the suction chamber V**1** of the low-stage compressing section **31** from the side surface of the compressor **1**.

[0038] Next, the flow of refrigerant in the above-described configuration is explained with reference to FIGS. **1** and **2**. The refrigerant flowing from the heat pump system side into the accumulator **6** passing through the refrigerant return pipe **62** is separated so that a liquid refrigerant lies in the lower part of the accumulator **6** and a gas refrigerant lies in the upper part thereof.

[0039] When the low-stage side piston **420** is turned to increase the volume of the low-stage side suction chamber V**1**, the gas refrigerant in the accumulator **6** is sucked into the low-stage side suction chamber V**1** of the compressor body **1** through the refrigerant suction pipe **64**.

[0040] After one turn of the piston **420**, the low-stage side suction chamber V**1** comes to a position isolated from the low-stage side suction hole **410**, and is turned to the low-stage side compression chamber C**1** as it is, by which the refrigerant is compressed.

[0041] When the pressure of the compressed refrigerant reaches the pressure in the low-stage side discharge muffler chamber M**1** on the outside of the check valve **540** provided in the low-stage side discharge hole **520**, that is, an intermediate pressure, the check valve **540** is opened, by which the compressed refrigerant is discharged into the low-stage side discharge muffler chamber M**1**.

[0042] After the pressure pulsation of refrigerant, which may cause noise, has been reduced in the low-stage side discharge muffler chamber M**1**, the refrigerant is guided into the suction chamber V**2** of the high-stage compressing section **32** through the intermediate connection pipe **26**.

[0043] The refrigerant guided into the suction chamber V**2** of the high-stage compressing section **32** is sucked, compressed, and discharged in the high-stage compressing section **32** on the same principle as that of the low-stage compressing section **31**. After the pressure pulsation of refrigerant has been reduced in the high-stage side discharge muffler chamber M**2**, the refrigerant is discharged into the closed vessel **2**.

[0044] The refrigerant is further guided to a portion above the motor **4** after passing through a core notch (not shown) in the stator **41** of the motor **4** and a gap between a core and a coil, and is discharged to the system side through the discharge pipe **24**.

[0045] Next, the centrifugal forces acting on the rotating parts in the compressor configured as described above are explained with reference to FIG. **3**.

[0046] FIG. **3** is a schematic view extractingly showing the rotating parts in the compressor.

[0047] As the centrifugal forces acting on the rotating parts, there are generated a centrifugal force (F**1**) acting on the low-stage side crankshaft **73** and the low-stage side piston **420** engaging therewith, a centrifugal force (F**2**) acting on the high-stage side crankshaft **72** and the high-stage side piston **220** engaging therewith, a centrifugal force (F**4**) acting on the upper balancer **43** attached to above the rotor **42**, and a centrifugal force (F**3**) acting on the lower balancer **44** attached to below the rotor **42**. To balance these centrifugal forces in the horizontal direction, the following equation holds.

$$F1+F4=F2+F3 \quad (1)$$

[0048] To balance moments that tend to tilt the whole of shaft, Equation (2) is obtained from the moment around the application point of F**3**.

$$F1\times(Lx+Ly)=F2\times Ly+F4\times Lz \quad (2)$$

F**3** and F**4**, that is, the mass of the upper balancer **43** of the rotor **42** and the mass of the lower balancer **44** thereof are determined so as to satisfy Equation (2).

[0049] Rearranging Equation (2) gives

$$F4=(F1\times(Lx+Ly)-F2\times Ly)/Lz \quad (3)$$

[0050] From Equation (3), it can be seen that F**4** can be decreased as F**1** is decreased or F**2** is increased.

[0051] That is to say, the upper balancer **43** of the rotor **42** can be made smaller as the mass of the low-stage side crankshaft **73** is decreased or the mass of the high-stage side crankshaft **72** is increased.

[0052] Hereunder, the state in which the shaft **7** is deflected by the centrifugal forces acting on the shaft **7** is explained with reference to FIG. **4**.

[0053] FIG. **4** is a schematic view extractingly showing the shaft **7** and the bearing part **110** supporting the shaft **7**.

[0054] If the deflection of the whole of the shaft **7** increases, especially in the bearing part **110** of the main frame **100**, the shaft **7** deforms exceeding the gap between the shaft **7** and the bearing part **110**, and comes locally into contact with the bearing part **110** at the upper or lower part of the bearing part **110**, which may cause seizure.

[0055] To solve this problem, the axial length of the high-stage side crankshaft **72** is made longer than the axial length of the low-stage side crankshaft **73**. Thereby, the upper balancer **43** of the rotor **42** can be made small, so that the deflection of the whole of the shaft **7** is reduced, whereby seizure caused by a local excessive load of the bearing part **110** and the contact of the rotor **42** with the stator **41** can be prevented.

[0056] On the other hand, the effect described below can be achieved. In the compressor used for a heat pump for an air conditioner, a water heater, and the like, the suction pressure Ps and the discharge pressure Pd of the compressor change mainly depending on the outside air temperature condition. This fact means that the compression ratio ϕ (=Pd/Ps) as the whole of compressor is not constant, so that it is necessary to respond to a wide range.

[0057] Taking the suction volume of the low-stage compressing section **31** as V**1**, the suction volume of the high-stage compressing section **32** as V**2**, and the specific heat of compressed gas as κ, in the case where losses in the compressing sections **31** and **32** are neglected, the compression ratio $\phi 1$ of the low-stage compressing section **31** is expressed as $\phi 1=(V1/V2)^{\kappa}$. That is to say, the compression ratio $\phi 1$ of the low-stage compressing section **31** is determined by the suction volumes of the two cylinders without depending on the outside air temperature condition.

[0058] Therefore, under the condition in which the total compression ratio ϕ is high, for example, in a cooling operation under a condition in which the outside air temperature is especially high or in a heating operation under a condition in which the outside air temperature is especially low, the compression ratio ϕ2 of the high-stage compressing section **32** is high necessarily.

[0059] That is to say, under such a condition, the load torque of the high-stage compressing section **32** is higher than that of the low-stage compressing section **31**. To support this load, the length of crankshaft not shorter than a predetermined length is necessary. However, the increase in length of crankshaft achieved than necessary is unfavorable because it may cause an increase in slide loss in a crank part.

[0060] Therefore, as described above, the axial length L**2** of the high-stage side crankshaft is made longer than the axial length L**1** of the low-stage side crankshaft (L**2**>L**1**). Thereby, both of the improvement in reliability in the crankshaft bearing parts and the improvement in efficiency due to the reduction in slide loss can be achieved.

[0061] In this embodiment, the rotary compressor **1** configured so that in the compressor provided with the two-stage compression type compressing section having the low-stage compressing section **31** and the high-stage compressing section **32**, the working space volume of the high-stage compressing section **32** is made smaller than that of the low-stage compressing section **31** by making the axial length of the high-stage compressing section **32** shorter than that of the low-stage compressing section **31** has been shown typically as a preferred mode. However the configuration of the rotary compressor **1** may be such that the working space volume of the high-stage compressing section **32** is made smaller by making the axial lengths of the low-stage compressing section **31** and the high-stage compressing section **32** equal to each other and by making the turning radius of the high-stage side piston **220** smaller than that of the low-stage side piston **420**.

[0062] Also, the rotary compressor **1** may be a two-stage compression rotary compressor configured so that a gas injection cycle is used as the refrigerating cycle, and an injection refrigerant is allowed to flow into an intermediate compressing section between the low-stage compressing section **31** and the high-stage compressing section **32**.

[0063] Also, the compressing mechanism of the compressing section **3** is not limited to the compressing mechanism shown in this embodiment if the compressor is configured so that the change in volumes of the suction chamber V**1**, V**2** and the compression chamber C**1**, C**2** caused by the turning motion of the piston **220**, **420** imparted by the crankshaft **72**, **73** is utilized.

[0064] The present application is based on, and claims priority from, Japanese Applications Serial Number JP2007-083399, filed Mar. 28, 2007 the disclosure of which is hereby incorporated by reference herein in its entirety.

1. A rotary compressor comprising:

a closed vessel;

a low-stage compressing section and a high-stage compressing section provided in the closed vessel;

a shaft provided with a low-stage side off-center part and a high-stage side off-center part corresponding to the low-stage compressing section and the high-stage compressing section, respectively;

a motor connected mechanically to the shaft to drive the low-stage compressing section and the high-stage compressing section,

each of the low-stage compressing section and the high-stage compressing section having a cylinder; a piston turning in the cylinder while engaging with the off-center part of the shaft; and a vane the tip end of which comes into sliding contact with the piston while the vane reciprocates in a vane groove in the cylinder to form a suction chamber and a compression chamber for refrigerant together with the cylinder and the piston, and

further comprising:

an intermediate partition plate held between the low-stage compressing section and the high-stage compressing section to close one end surface of the suction chamber and the compression chamber; and

a main frame and a sub-frame each of which is provided with a bearing part for rotatably supporting the shaft and closes one end surface of the suction chamber and the compression chamber, in which

means for allowing the discharge side of the low-stage compressing section and the suction side of the high-stage compressing section to communicate with each other is provided, whereby a two-stage compressing section is formed, wherein

when the axial length of the off-center part of shaft corresponding to the low-stage compressing section is taken as L**1**, and the axial length of the off-center part of shaft corresponding to the high-stage compressing section is taken as L**2**, L**2** is longer than L**1**.

2. The rotary compressor according to claim **1**, wherein the rotational speed of the compressing section is variable.

* * * * *