TWO-STAGE SCREW COMPRESSOR

ABSTRACT

A two-stage screw compressor of the invention includes a low pressure stage casing provided with a low pressure stage compression mechanism, a discharge casing provided on a discharge side of the low pressure stage casing, a high pressure stage casing provided with a high pressure stage compression mechanism, and intermediate stage casings for connecting the discharge casing and the high pressure stage casing, and accommodating an electric motor. In such a two-stage screw compressor, a cavity is formed on a discharge casing side in the slide valve so as to enlarge the capacity of a discharge space formed in the discharge casing. Thereby, internal resonance occurring in the discharge casing is prevented.
FIG. 3

SOUND PRESSURE LEVEL (dBA)

--- WITHOUT CAVITY OF SLIDE VALVE
--- WITH CAVITY OF SLIDE VALVE

FREQUENCY (Hz)

f   2f   3f   4f   5f
TWO-STAGE SCREW COMPRESSOR
INCORPORATION BY REFERENCE

[0001] The present application claims priority from Japanese application JP 2005-190879 filed on Jun. 30, 2005, the content of which is hereby incorporated by reference into this application.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to a two-stage screw compressor used for a screw refrigerant or the like.

[0003] Regarding a noise spectrum generated by a screw compressor, it is known that a fundamental frequency obtained by multiplying the number of teeth of a male rotor by a rotational frequency, and a higher harmonic component of the fundamental frequency constitute a dominant peak. As means of reducing the noise, various measures such as sticking a noise absorbing material to a casing, enhancing sound insulation performance by forming a casing to have a double structure, or enhancing rigidity of a casing by adding a rib thereto have been taken. As a single-stage single screw compressor, there is the one in which a resonance space is provided inside a slide valve so as to communicate with a compression space to reduce the noise, as shown in JP-A-2005-30362.

[0004] In the above described prior arts, the measures according to the means such as sticking the noise absorbing material to the casing, forming the casing into the double structure, and adding the rib to the casing show a certain degree of noise reduction effect. However, if adopting the above described means, it is necessary to cover the entire cast casing with the noise absorbing material in the case of sticking the noise absorbing material on the casing, and thus it is often difficult in the case of a screw compressor having a complicated cast shape. Further, in the case of the means according to the double structure of the casing and the rib addition, there are the problems of complication of the cast shape and increase in the cast weight.

[0005] In addition, any of the above described prior arts does not take account of increase in noise due to internal resonance in a discharge casing in a two-stage screw compressor, which includes a low pressure stage casing provided with a low pressure stage compression mechanism, the discharge casing provided on a discharge side of the low pressure stage casing, a high pressure stage casing provided with a high pressure stage compression mechanism, and an intermediate stage casing for connecting the discharge casing and the high pressure stage casing and accommodating an electric motor.

BRIEF SUMMARY OF THE INVENTION

[0006] An object of the present invention is to prevent internal resonance occurring in a discharge casing by means of a simple structure, and thereby realize reduction in noise, in a two-stage screw compressor as described above.

[0007] In order to achieve the above-described object, the present invention provides a two-stage screw compressor including: a low pressure stage casing for accommodating a low pressure stage compression mechanism and a bearing member, which low pressure stage casing is provided with a capacity control part constituted by a slide valve, a rod and a piston; a discharge casing provided on a discharge side of the aforesaid low pressure stage casing for accommodating a bearing member supporting the low pressure stage compression mechanism; a high pressure stage casing for accommodating a high pressure stage compression mechanism and a bearing member; and an intermediate stage casing for connecting the aforesaid discharge casing and the aforesaid high pressure stage casing, and accommodating an electric motor, wherein a cavity is formed on a discharge casing side in the slide valve so as to enlarge the capacity of a discharge space formed in the aforesaid discharge casing, so that internal resonance occurring in the discharge casing is prevented.

[0008] In this case, by making the length in an axial direction of the cavity formed in the slide valve half or more of the length in an axial direction of the slide valve, it becomes possible to prevent the internal resonance more reliably.

[0009] Further, it is more effective to provide a porous material in the cavity formed in the slide valve. As the porous material, it is suitable to use a demister constructed by arranging a plurality of metal wires in a net form. Alternatively, the porous material may be constructed by glass wool.

[0010] Another characteristic of the present invention is, in the above described two-stage screw compressor, that the length in an axial direction of a discharge space formed in the aforesaid discharge casing is enlarged by forming the cavity on the discharge casing side in the slide valve so as not to correspond to a wavelength of noise generated by the low pressure stage compression mechanism. In this case, preferably, the wavelength of the noise generated by the low pressure stage compression mechanism is based on a meshing frequency of rotors, which meshing frequency is a frequency including a fundamental frequency obtained by multiplying the number of teeth of a male rotor by a rotational frequency, and a higher harmonic component of the fundamental frequency, and it is desirable to enlarge the length in the axial direction of the discharge space formed in the aforesaid discharge casing by forming the cavity on the discharge casing side in the slide valve so as not to correspond to any of the wavelengths based on the above described frequencies.

[0011] According to the present invention, in a two-stage screw compressor including a low pressure stage casing provided with a low pressure stage compression mechanism, a discharge casing provided on a discharge side of the low pressure stage casing, a high pressure stage casing provided with a high pressure stage compression mechanism, and intermediate stage casings for connecting the discharge casing and the high pressure stage casing, and accommodating an electric motor, a cavity is formed on a discharge casing side in the slide valve to enlarge the capacity of a discharge space formed in the discharge casing, and thereby internal resonance occurring in the discharge casing is prevented. Therefore, the internal resonance occurring in the discharge casing is prevented with a simple structure and significant noise reduction can be realized.

[0012] Hereinafter, an embodiment of the present invention will be described based on the drawings.

[0013] Other objects, features and advantages of the invention will become apparent from the following descrip-
tion of the embodiments of the invention taken in conjunction with the accompanying drawings.

**BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS**

**[0014]** FIG. 1 is a vertical sectional view of a two-stage screw compressor showing one embodiment of the present invention;

**[0015]** FIG. 2 is a vertical sectional view of a main part of a two-stage screw compressor showing another embodiment of the present invention; and

**[0016]** FIG. 3 is a noise spectrum diagram for explaining the effect of the present invention.

**DETAILED DESCRIPTION OF THE INVENTION**

**[0017]** FIG. 1 shows one embodiment of a two-stage screw compressor of the present invention. The screw compressor includes a low pressure stage casing 1 having an inlet opening 26, a discharge casing 2 connected to a discharge side of the low pressure stage casing 1 and having a gas passage 38, a motor cover (intermediate stage casing) 3 which is connected to a downstream side of the discharge casing 2, has a gas passage 39, and accommodates a coil end 8 of an electric motor 7, a motor casing (intermediate stage casing) 4 accommodating the electric motor 7, and a high pressure stage casing 5 having a discharge port 40. These members are connected with bolts or the like to be integrated.

**[0018]** In the low pressure stage casing 1, there are formed a cylindrical bore 31, an inlet port 29 which introduces a refrigerant gas into the cylindrical bore 31, a piston chamber 33 which accommodates a piston 21 for driving a slide valve 23, and the like. In the cylindrical bore 31, a low pressure stage side male rotor 6 which is rotatably supported with roller bearings 11 and 12 and a ball bearing 17, and a low pressure stage side female rotor (not shown) are accommodated so as to mesh with each other. A shaft of the low pressure stage side male rotor 6 is connected to a shaft of the high pressure stage side male rotor 9 by a gear coupling 45. The piston 21 accommodated in the above described piston chamber 33 is connected to the slide valve 23 via a rod 22.

**[0019]** In the discharge casing 2 accommodating the roller bearing 12 and the ball bearing 17 which support the shaft of the low pressure stage side rotor, there is formed a gas passage 38 which allows the cylindrical bore 31 and the above described motor cover 3 to communicate with each other. In the motor cover 3 accommodating a ball bearing 18 which supports a rotary body on the high pressure stage side, there is formed a gas passage 39 which allows the discharge casing 2 and the motor casing 4 to communicate with each other. In the motor casing 4 accommodating the electric motor 7 and a shaft part of the high pressure stage side male rotor 9, there is formed an inlet chamber 28 which introduces the refrigerant gas to the high pressure stage casing 5. In the high pressure stage casing 5, there is formed a cylindrical bore 32, in which the high pressure stage side male rotor 9 which is rotatably supported with roller bearings 13 and 14 and a ball bearing 19, and a high pressure stage side female rotor (not shown) are accommodated so as to mesh with each other. The shaft of the high pressure stage side male rotor 9 is directly connected to the electric motor 7.

**[0020]** Next, flows of the refrigerant gas and oil will be described. The refrigerant gas at low temperature and low pressure which has been sucked from the inlet opening 26 provided in the low pressure stage casing 1 is sucked from the intake port 29 formed in the low pressure stage casing 1 into a compression chamber formed by surfaces of the meshing teeth of the male and female screw rotors on the low pressure stage side and the low pressure stage casing 1. Thereafter, the refrigerant gas is sealed in the compression chamber formed by the meshing tooth surfaces of the male and female screw rotors on the low pressure stage side and the low pressure stage casing 1 as the low pressure stage side male rotor 6 connected to the electric motor 7 is rotated, and is gradually compressed by reduction of the compression chamber to become a gas at high temperature and at high pressure, which is discharged from the discharge port 34 to the gas passage 38 of the discharge casing 2 and further, passes through the gas passage 39 formed in the motor cover 3 to flow into the motor casing 4.

**[0021]** The refrigerant gas having flown into the motor casing 4 passes through an air gap between motor rotors, and is sucked from the intake chamber 28 formed in the motor casing 4 to a compression chamber formed by surfaces of the meshing teeth of the male and female screw rotors on the high pressure stage side, the motor casing 4, and the high pressure stage casing 5. Thereafter, the refrigerant gas is sealed in the compression chamber formed by the meshing tooth surfaces of the male and female screw rotors on the high pressure stage side, the motor casing 4, and the high pressure stage casing 5 as the high pressure stage side male rotor 9 directly connected to the electric motor 7 is rotated, and is gradually compressed by reduction of the compression chamber to become a gas at higher temperature and at higher pressure than before being compressed, which is discharged into the discharge passage 40 of the high pressure side casing 5.

**[0022]** The radial load, derived from compression reaction force acting on the male and female screw rotors on the low pressure stage side during compression, is supported by the roller bearings 11 and 12, and the thrust load derived from the compression reaction force is supported by the ball bearing 17. As for compression reaction force acting on the male and female screw rotors on the high pressure stage side during compression, the radial load is supported by the roller bearings 13 and 14, and the thrust load is supported by the ball bearing 19. Lubricating oil for these bearings is supplied through an oil passage communicating with bearing parts provided in the low pressure stage casing 1, the discharge casing 2, the motor cover 3, the motor casing 4 and the high pressure stage casing 5, respectively.

**[0023]** In a noise spectrum generated by a screw compressor, a fundamental frequency obtained by multiplying the number of teeth of a male rotor by a rotational frequency, and a higher harmonic component (hereinafter, referred to as a meshing frequency) of the fundamental frequency constitute a dominant peak. In the case of the two-stage screw compressor, the discharge casing 2 and the intermediate stage casings (the motor cover 3, the motor casing 4) are required for connecting the low pressure stage casing 1 on the low pressure stage side and the high pressure stage casing 5 on the high pressure stage side. The gas passage 38 and the gas passage 39 are formed in the discharge casing 2 and the intermediate stage casing (motor cover 3), respec-
tively, as spaces. If the length of these spaces 38 and 39 and the wavelength of the meshing frequency correspond to each other, a noise level increases due to internal resonance.

[0024] In the present invention, in order to enlarge the capacity of the spaces formed as the above described gas passages 38 and 39, namely, of a discharge space so as not to correspond to the wavelength of the above described meshing frequency, a cavity 48 is formed on a discharge casing side (gas passage side) in the slide valve 23. By forming the cavity 48, it becomes possible to avoid the internal resonance in the discharge space (gas passages 38 and 39). That is, if the length in an axial direction of the discharge space corresponds to the wavelength of the meshing frequency of the rotors, the internal resonance occurs to increase the noise level, however, by providing the above described cavity 48, the length in the axial direction of the discharge space can be extended so as not to correspond to the wavelength of the meshing frequency of the rotors. As a result, it is possible to avoid the internal resonance by a simple structure, in which the cavity 48 is formed in the slide valve 23, and to achieve reduction in noise. The length in the axial direction of the cavity 48 formed in the slide valve 23 may be extended to half or more of the length in an axial direction of the slide valve, and thereby, the effect of reliably preventing the internal resonance can be obtained.

[0025] FIG. 2 shows another embodiment of the present invention. In this embodiment, a porous material 49 is provided in the cavity 48 formed in the slide valve 23. By providing the porous material 49 like this, it becomes possible, not only to avoid the internal resonance by the cavity 48, but also to convert acoustic wave energy into thermal energy by internal friction of the porous material 49, and thus the noise reduction effect can be further enhanced. The porous material 49 may be anything as long as it has an oil resistance property and a refrigerant resistance property, but extremely high noise reduction effect can be obtained by adopting a demister or glass wool. The demister in this case means the one which is given the function as a porous material by arranging a plurality of metal wires in a meshed form.

[0026] FIG. 3 is a noise spectrum diagram for explaining the effect of the present invention. When there is no cavity in the slide valve 23, the length in the axial direction of the space formed as the gas passages 38 and 39, and the wavelength of a fifth order component (5f) of the meshing frequency correspond to each other, and thus the fifth order component (5f) becomes a dominant peak due to a resonance phenomenon. On the contrary, according to the present invention, since the cavity 48 is provided in the slide valve 23, the space formed as the gas passages 38 and 39 can be enlarged. As a result, by applying the present invention, the length in the axial direction of the entire enlarged space does not correspond to the wavelength of the fifth order component (5f) of the meshing frequency, and therefore, it becomes possible to avoid the resonance phenomenon. Accordingly, it becomes possible to reduce the peak of the fifth order component (5f) significantly, so that significant noise reduction effect can be obtained.

[0027] The noise data shown in FIG. 3 is only one example. The peak which can be decreased by applying the present invention depends on the length in the axial direction of the discharge space and on the wavelength of the meshing frequency, and thus the fifth order component (5f) does not always become the dominant peak. According to the present invention, whatever order component constitutes the dominant peak, it is possible to extend the length in the axial direction of the discharge space by forming the cavity 48 in the slide valve 23, so as not to correspond to the wavelength of the frequency component at which the resonance occurs, which can reduce noise.

[0028] It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

1. A two-stage screw compressor, comprising:
   a low pressure stage casing for accommodating a low pressure stage compression mechanism and a bearing member, the low pressure stage casing being provided with a capacity control part which is constituted by a slide valve, a rod and a piston;
   a discharge casing provided on a discharge side of said low pressure stage casing for accommodating a bearing member supporting the low pressure stage compression mechanism;
   a high pressure stage casing for accommodating a high pressure stage compression mechanism and a bearing member; and
   an intermediate stage casing for connecting said discharge casing and said high pressure stage casing, the intermediate stage casing accommodating an electric motor, wherein
   a cavity is formed on a discharge casing side in the slide valve so as to enlarge the capacity of the discharge space formed in said discharge casing.

2. The two-stage screw compressor according to claim 1, wherein the length in axial direction of the cavity formed in the slide valve is half or more of the length in axial direction of the slide valve.

3. The two-stage screw compressor according to claim 1, wherein a porous material is provided in the cavity formed in the slide valve.

4. The two-stage screw compressor according to claim 1, wherein said porous material is a demister constructed by arranging a plurality of metal wires in a net form.

5. The two-stage screw compressor according to claim 1, wherein said porous material is glass wool.

6. A two-stage screw compressor, comprising:
   a low pressure stage casing for accommodating a low pressure stage compression mechanism and a bearing member, the low pressure stage casing being provided with a capacity control part which is constituted by a slide valve, a rod and a piston;
   a discharge casing provided on a discharge side of said low pressure stage casing for accommodating a bearing member supporting the low pressure stage compression mechanism;
   a high pressure stage casing for accommodating a high pressure stage compression mechanism and a bearing member; and
an intermediate stage casing for connecting said discharge casing and said high pressure stage casing, the intermediate stage casing accommodating an electric motor, wherein

the length in an axial direction of a discharge space formed in said discharge casing is enlarged by forming a cavity on a discharge casing side in the slide valve so as not to correspond to a wavelength of noise generated by the low pressure stage compression mechanism.

7. The two-stage screw compressor according to claim 6, wherein the wavelength of the noise generated by the low pressure stage compression mechanism is based on a meshing frequency of rotors.

8. The two-stage screw compressor according to claim 7, wherein said meshing frequency is a frequency including a fundamental frequency which is obtained by multiplying a number of teeth of a male rotor by a rotational frequency, and a higher harmonic component thereof.

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