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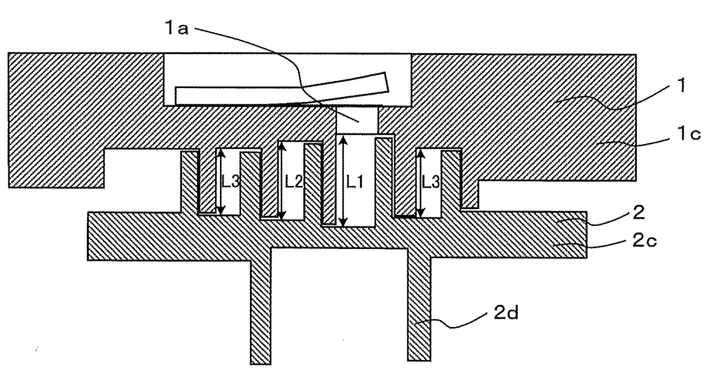
(54) **SCROLL COMPRESSOR**

(57) A scroll compressor includes a stationary scroll including a stationary base plate and a stationary scroll body formed on the stationary base plate, and an orbiting scroll including an orbiting base plate and an orbiting scroll body formed on the orbiting base plate, the orbiting scroll being located with the orbiting base plate being opposite to the stationary base plate, the orbiting scroll body being combined with the stationary scroll body to form a compression chamber. The scroll compressor has a structure in which a base-plate to base-plate distance that is a distance between the stationary base plate and the orbiting base plate increases stepwise from outer circumferential portions of the stationary scroll body and the orbiting scroll body toward central portions thereof.

FIG. 2



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## Description

Technical Field

**[0001]** The present disclosure relates to a scroll compressor to be installed mainly in a refrigerating machine, an air-conditioning apparatus, or a water heater.

Background Art

**[0002]** A scroll compressor includes a stationary scroll including a scroll body, and an orbiting scroll including a scroll body, and forms a compression chamber by combining the scroll bodies with each other. The scroll compressor causes the orbiting scroll to perform rotary motion to compress refrigerant in the compression chamber. There has been a conventional scroll compressor including a stationary scroll including a scroll body with a constant height, and an orbiting scroll including a scroll body with a constant height. The conventional scroll compressor compresses refrigerant two-dimensionally from the outer circumferential portions toward the central portions of the scroll bodies. In contrast to that, a scroll compressor that is available in recent years includes a stationary scroll including a scroll body, and an orbiting scroll including a scroll body, in which stepped portions are provided on the tooth tip side and the tooth bottom side of the scroll bodies and spaced apart from each other in the scroll direction. The scroll bodies have a greater height on the outer circumferential side with reference to each of the stepped portions than on the inner circumferential side (see, for example, Patent Literature 1). This type of stepped scroll compressor makes it possible to compress refrigerant three-dimensionally not only in the circumferential direction, but also in the height direction. The stepped scroll compressor can thus increase the fluid displacement without increasing the outer diameter of the scroll, and accordingly increase the capacity of the compressor.

Citation List

Patent Literature

**[0003]** Patent Literature 1: Japanese Patent Publication No. 6180860

Summary of Invention

Technical Problem

**[0004]** The problem to be solved to a scroll compressor is to reduce refrigerant leakage between compression chambers from the viewpoint of improvement in performance of the scroll compressor. To reduce refrigerant leakage between the compression chambers, it is effective to increase the number of scrolls of the scroll bodies to increase the number of compression chambers, and to reduce the differential pressure between the compression chambers.

**[0005]** For example, carbon dioxide with a larger polytropic exponent exhibits a higher pressure rise rate to a decrease in the compression chamber volume, compared to refrigerant with a smaller polytropic exponent. Thus, when carbon dioxide alone or a refrigerant mixture containing carbon dioxide is used as refrigerant for a scroll compressor that compresses refrigerant two-dimensionally, the compression volume decreases linearly during the two-dimensional compression. Consequently, the pressure in the compression chamber rises to a target high pressure at a relatively small rotational phase. Therefore, the number of scrolls of the scroll bodies cannot be increased.

**[0006]** In Patent Literature 1, since the scroll compressor compresses refrigerant three-dimensionally, the compression rate is higher than that of the two-dimensional compression. Thus, when the scroll compressor uses carbon dioxide alone or a refrigerant mixture containing carbon dioxide, the pressure at the central portion of the scrolls is excessively increased. This leads to a problem similar to the two-dimensional compression in that the number of scrolls of the scroll bodies cannot be increased, which makes it difficult to reduce refrigerant leakage.

**[0007]** The present disclosure has been made to solve the above problems, and an object of the present disclosure is to provide a scroll compressor that can reduce refrigerant leakage between compression chambers to minimize degradation in performance of the scroll compressor even when the scroll compressor uses carbon dioxide alone or a refrigerant mixture containing carbon dioxide as refrigerant.

Solution to Problem

**[0008]** A scroll compressor according to an embodiment of the present disclosure includes: a stationary scroll including a stationary base plate and a stationary scroll body formed on the stationary base plate; and an orbiting scroll including an orbiting base plate and an orbiting scroll body formed on the orbiting base plate, the orbiting scroll being located with the orbiting base plate being opposite to the stationary base plate, the orbiting scroll body being combined with the stationary scroll body to form a compression chamber, wherein the scroll compressor has a structure in which a base-plate to base-plate distance that is a distance between the stationary base plate and the orbiting base plate increases stepwise from outer circumferential portions of the stationary scroll body and the orbiting scroll body toward central portions thereof. Advantageous Effects of Invention

**[0009]** A scroll compressor according to an embodiment of the present disclosure has a structure in which the base-plate to base-plate distance that is a distance between the stationary base plate and the orbiting base plate increases stepwise from the outer circumferential portions of the stationary scroll body and the orbiting scroll body toward the central portions thereof. Therefore, the volume decrease rate in the compression chamber can be reduced, so that even when the scroll compressor uses carbon dioxide alone or a refrigerant mixture containing carbon dioxide as refrigerant, the compression chamber pressure can rise at a reduced rate. With this structure, the number of scrolls of the scroll body can be increased to increase the number of compression chambers. As a result of this, a differential pressure between the compression chambers can be reduced, and performance degradation due to refrigerant leakage can be minimized.

Brief Description of Drawings

**[0010]**

[Fig. 1] Fig. 1 is a schematic cross-sectional view of a scroll compressor according to Embodiment 1.
[Fig. 2] Fig. 2 is a schematic cross-sectional view of a compression mechanism portion of the scroll compressor according to Embodiment 1.
[Fig. 3] Fig. 3 shows a stationary scroll and an orbiting scroll of the scroll compressor according to Embodiment 1 when viewed from the orbiting-scroll side.
[Fig. 4] Fig. 4 is an explanatory diagram showing a tooth height of a scroll body of the scroll compressor according to Embodiment 1.
[Fig. 5] Fig. 5 is an explanatory diagram showing a thickness of a base plate of the scroll compressor according to Embodiment 1.
[Fig. 6] Fig. 6 is a graph showing variations in the compression chamber volume relative to the rotational phase of an orbiting scroll body in the scroll compressor according to Embodiment 1.
[Fig. 7] Fig. 7 is a graph showing variations in the compression chamber pressure relative to the rotational phase of the orbiting scroll body in the scroll compressor according to Embodiment 1.
[Fig. 8] Fig. 8 is an enlarged view of the compression chamber of a scroll compressor according to Embodiment 2.
[Fig. 9] Fig. 9 is a graph showing variations in the compression chamber volume relative to the rotational phase of the orbiting scroll body in the scroll compressor according to Embodiment 2.
[Fig. 10] Fig. 10 is a graph showing variations in the compression chamber pressure relative to the rotational phase of the orbiting scroll body in the scroll compressor according to Embodiment 2.

Description of Embodiments

**[0011]** A scroll compressor according to embodiments of the present disclosure will be described hereinafter with reference to the drawings. In the drawings below including Fig. 1, like reference signs denote the like or corresponding components, and are common throughout the entire descriptions of the embodiments which will be described below. The forms of the constituent elements represented throughout the entire specification are merely examples, and do not intend to limit the constituent elements to the forms described in the specification. Further, the level of the pressure is not particularly determined in relation to an absolute value, but is determined relative to the conditions, operation, or other factors of a system, a device, or the like.

Embodiment 1

**[0012]** Embodiment 1 of the present disclosure is described below with reference to Figs. 1 to 7.

**[0013]** Fig. 1 is a schematic cross-sectional view of a scroll compressor according to Embodiment 1.

**[0014]** This scroll compressor has a function of suctioning refrigerant, compressing the refrigerant into a high-temperature and high-pressure state, and discharging the compressed refrigerant. The scroll compressor includes a compression mechanism portion 36, a drive mechanism portion 37, and other constituent components, all of which are accommodated in a shell 11. The shell 11 serves as a hermetically-sealed container that forms the outer casing. As shown in Fig. 1, in the shell 11, the drive mechanism portion 37 is located on the lower side, while the compression mechanism portion 36 is located on the upper side. An oil reservoir 21 is provided at the bottom of the shell 11.

**[0015]** A suction pipe 8 is connected to the shell 11, through which refrigerant is suctioned. A discharge pipe 9 is connected to the shell 11, through which refrigerant is discharged. In the shell 11, a low-pressure space 23 is formed and filled with refrigerant suctioned through the suction pipe 8.

**[0016]** The compression mechanism portion 36 has a function of compressing refrigerant suctioned through the suction pipe 8, and discharging the compressed refrigerant to a high-pressure space 24 formed in the top portion of the shell 11. This high-pressure refrigerant is discharged from the discharge pipe 9 to the outside of the scroll compressor. The drive mechanism portion 37 has a function of driving the orbiting scroll 2 that makes up the compression mechanism portion 36. That is, the drive mechanism portion 37 drives the orbiting scroll 2 through a rotational shaft 7, so that refrigerant is compressed in the compression mechanism portion 36. Carbon dioxide alone or a refrigerant mixture containing carbon dioxide is used as refrigerant to be compressed in the compression mechanism portion 36.

**[0017]** Further, in the shell 11, a frame 3 and a subframe 4 are located opposite to each other with the drive mechanism portion 37 interposed between the frame 3 and the subframe 4. The frame 3 is located above the drive mechanism portion 37, and is positioned between the drive mechanism portion 37 and the compression mechanism portion 36. The subframe 4 is positioned below the drive mechanism portion 37. The frame 3 and the subframe 4 are fixedly attached to the inner circumferential side of the shell 11 by shrink-fit, welding, or other methods.

**[0018]** A through hole is formed at the central portion of the frame 3. In this through hole, a bearing portion 3a is provided. The frame 3 supports the orbiting scroll 2, while supporting the rotational shaft 7 rotatably by the bearing portion 3a. The bearing portion 3a is made up of, for example, a sliding bearing. At the central portion of the subframe 4, a through hole is formed for the rotational shaft 7 to be supported. A bearing portion 4a is provided in this through hole. The subframe 4 supports the rotational shaft 7 rotatably by the bearing portion 4a. The bearing portion 4a is made up of, for example, a ball bearing.

**[0019]** The compression mechanism portion 36 includes a stationary scroll 1 and an orbiting scroll 2. As shown in Fig. 1, the orbiting scroll 2 is located on the lower side, while the stationary scroll 1 is located on the upper side. The stationary scroll 1 includes a stationary base plate 1c, and a stationary scroll body 1b that is a scroll lap formed on one side of the stationary base plate 1c. The orbiting scroll 2 includes an orbiting base plate 2c, and an orbiting scroll body 2b that is a scroll lap formed on one side of the orbiting base plate 2c. The stationary scroll 1 and the orbiting scroll 2 are fitted to the inside of the shell 11 with the stationary scroll body 1b and the orbiting scroll body 2b engaged with each other. Compression chambers 12 are formed between the stationary scroll body 1b and the orbiting scroll body 2b. The volume of the compression chambers 12 decreases gradually as the compression chambers 12 move from the radially outward side toward the radially inward side.

**[0020]** The stationary scroll 1 is fixed to the inside of the shell 11 through the frame 3. At the central portion of the stationary scroll 1, a discharge port 1a is formed, through which refrigerant compressed into a high pressure is discharged. At the outlet opening of the discharge port 1a, a valve 15 made of a plate spring is located to cover this outlet opening and prevent backflow of refrigerant. At one end side of the valve 15, a valve guard 14 is provided to limit the amount of lift of the valve 15. That is, when refrigerant in the compression chamber 12 is compressed to a high-level pressure, this causes the valve 15 to be lifted against its elastic force, and then the compressed refrigerant is discharged from the discharge port 1a into the high-pressure space 24.

**[0021]** The orbiting scroll body 2b is formed on one side of the orbiting scroll 2, and a hollow cylindrical boss portion 2d is formed at the central portion on the other side of the orbiting scroll 2. In the boss portion 2d, an orbiting bearing portion 2e is provided to receive a driving force from the rotational shaft 7. An eccentric portion 7a of the rotational shaft 7 is inserted into the orbiting bearing portion 2e with a slight gap. As the rotational shaft 7 rotates, the orbiting scroll 2 performs eccentric rotary motion relative to the stationary scroll 1. The orbiting scroll 2 is supported on the other side, opposite to the side on which the orbiting scroll body 2b is formed, by a thrust bearing portion 3b provided in the frame 3 in the axial direction.

**[0022]** Hereinafter, the stationary scroll body 1b and the orbiting scroll body 2b, when they are not distinguished from each other, are collectively referred to as a "scroll body." In addition, the stationary base plate 1c and the orbiting base plate 2c, when they are not distinguished from each other, are collectively referred to as a "base plate."

**[0023]** The drive mechanism portion 37 is made up of at least a stator 19, a rotor 20, and the rotational shaft 7. The rotational shaft 7 is accommodated in the shell 11 in the vertical direction. The stator 19 is held in the shell 11 with the outer circumferential side of the stator 19 fixedly attached to the inside of the shell 11 by shrink fit or other methods. The stator 19 has a function of rotationally driving the rotor 20 when the stator 19 is energized. The rotor 20 is rotatably located on the inner circumferential side of the stator 19, while being fixed to the outer circumference of the rotational shaft 7. The rotor 20 includes permanent magnets therein, and is held with a slight gap between the rotor 20 and the stator 19. The rotor 20 is rotationally driven when the stator 19 is energized, and has a function of rotating the rotational shaft 7.

**[0024]** As the rotor 20 rotates, the rotational shaft 7 rotates to rotationally drive the orbiting scroll 2. The rotational shaft 7 is rotatably supported on its upper side by the bearing portion 3a, while being rotatably supported on its lower side by the bearing portion 4a. The bearing portion 3a is positioned at the central portion of the frame 3. The bearing portion 4a is positioned at the central portion of the subframe 4 fixed to and located in the lower portion of the shell 11. At the upper end portion of the rotational shaft 7, the eccentric portion 7a is provided. The eccentric portion 7a is fitted with the orbiting bearing portion 2e to allow the orbiting scroll 2 to eccentrically rotate.

**[0025]** An oil pump 22 is fixedly attached to the bottom side of the rotational shaft 7. The oil pump 22 is a displacement pump. The oil pump 22 has a function of supplying refrigerating machine oil stored in the oil reservoir 21 to the orbiting bearing portion 2e, the bearing portion 3a, the thrust bearing portion 3b, and the bearing portion 4a through an oil circuit (not shown) provided inside the rotational shaft 7, according to rotation of the rotational shaft 7.

**[0026]** In the shell 11, an Oldham ring 25 is located to prevent the orbiting scroll 2 from rotating about its own axis during the eccentric rotary motion. The Oldham ring 25 is located, for example, between the orbiting scroll 2 and the frame 3. The Oldham ring 25 has a function of preventing the orbiting scroll 2 from rotating about its own axis, and allowing the orbiting scroll 2 to perform orbital motion. The Oldham ring 25 may be located between the orbiting scroll 2 and the stationary scroll 1.

**[0027]** Operation of a compressor is now briefly described.

[0028] When power is supplied through a power terminal (not shown) provided on the shell 11, torque is generated in the stator 19 and the rotor 20, so that the rotational shaft 7 rotates. Due to the rotation of the rotational shaft 7, the orbiting scroll 2 performs eccentric rotary motion, while being restricted from rotating about its own axis by the Oldham ring 25. Refrigerant suctioned through the suction pipe 8 into the shell 11 is drawn into a compression chamber 12 located at the outer circumferential portion among a plurality of compression chambers 12 formed between the stationary scroll body 1b of the stationary scroll 1 and the orbiting scroll body 2b of the orbiting scroll 2.

[0029] The compression chamber 12, into which gas refrigerant has been drawn, compresses the gas refrigerant by decreasing its volume while moving from the outer circumferential portion toward the center direction along with the eccentric rotary motion of the orbiting scroll 2. The gas refrigerant compressed in the compression chamber 12 is discharged from the discharge port 1a provided in the stationary scroll 1 against the valve 15 into the high-pressure space 24, and then discharged through the discharge pipe 9 to the outside of the shell 11. The amount of deformation of the valve 15 is restricted by the valve guard 14 to prevent the valve 15 from being deformed more than necessary. This prevents breakage of the valve 15.

[0030] Fig. 2 is a schematic cross-sectional view of the compression mechanism portion of the scroll compressor according to Embodiment 1. Fig. 3 shows the stationary scroll and the orbiting scroll of the scroll compressor according to Embodiment 1 when viewed from the orbiting-scroll side.

[0031] The compression mechanism portion 36 in present Embodiment 1 has a structure in which the distance between the stationary base plate 1c and the orbiting base plate 2c (hereinafter, referred to as a "base-plate to base-plate distance") increases from the outer circumferential portion of the scroll body toward its central portion in three stages of L3, L2, and L1 in the described order as shown in Fig. 2. Specifically, in the structure, the scroll body is provided with stepped portions, and the base plate is provided with stepped portions, and the stepped portions are spaced apart from each other in the scroll direction. In Fig. 3, scroll-side stepped portions provided on the orbiting scroll body 2b are denoted by reference numeral 40, while base plate-side stepped portions provided on the orbiting base plate 2c are denoted by reference numeral 41. Fig. 3 also shows reference numeral 50 which will be described later. This stepped structure is described below in detail with reference to Figs. 4 and 5.

[0032] Fig. 4 is an explanatory diagram showing a tooth height of the scroll body of the scroll compressor according to Embodiment 1. Fig. 4 is a developed view in which the scroll body is developed in the scroll direction. In Fig. 4, the horizontal axis represents an involute angle [°], and the vertical axis represents the tooth height [mm]. Fig. 5 is an explanatory diagram showing a thickness of the base plate of the scroll compressor according to Embodiment 1. Fig. 5 shows the thickness of the base plate relative to the involute angle identical to that in Fig. 4 corresponding to the developed view in Fig. 4. In Fig. 5, the horizontal axis represents the involute angle [°], and the vertical axis represents the thickness of the base plate [mm].

[0033] As shown in Fig. 4, the tooth height that is a height of the scroll body increases stepwise at an involute angle $\theta 3$, an involute angle $\theta 2$, and an involute angle $\theta 1$ in the described order from the scroll end position at the involute angle $\theta 3$ to the scroll start position at the involute angle $\theta 0$. Specifically, the scroll body includes the scroll-side stepped portions 40 such that the tooth height increases stepwise from the outer circumferential portion of the scroll body toward its central portion.

[0034] As shown in Fig. 5, the thickness of the base plate decreases stepwise at the involute angle $\theta 3$, the involute angle $\theta 2$, and the involute angle $\theta 1$ in the described order from the scroll end position at the involute angle $\theta 3$ to the scroll start position at the involute angle $\theta 0$. Specifically, the base plate is provided with the base plate-side stepped portions 41 such that the thickness of the base plate decreases stepwise from the outer circumferential portion of the base plate toward its central portion. Note that Figs. 4 and 5 show an example in which the number of steps is three. However, the number of steps is not limited thereto, but there may be any plural number of steps.

[0035] The stationary scroll 1 and the orbiting scroll 2 both have the structure described above, so that the stepped structure is formed in which the base-plate to base-plate distance increases gradually from the outer circumferential portion of the scroll body toward its central portion. That is, in the range of involute angle from $\theta 0$ to $\theta 1$, a section with a base-plate to base-plate distance L1 is formed. In the range of involute angle from $\theta 1$ to $\theta 2$, a section with a base-plate to base-plate distance L2 is formed. In the range of involute angle from $\theta 2$ to $\theta 3$, a section with a base-plate to base-plate distance L3 is formed. Note that in present Embodiment 1, the involute angle $\theta 1$, the involute angle $\theta 2$, and the involute angle $\theta 3$ are not limited to particular angles, and may be appropriately set depending on refrigerant to be used.

[0036] Note that there may be a relationship of the tooth thickness between the stationary scroll body 1b and the orbiting scroll body 2b, in which the stationary scroll body 1b and the orbiting scroll body 2b have an identical tooth thickness when they are made of the same kind of materials, or in which either the stationary scroll body 1b or the orbiting scroll body 2b, whichever has a lower material strength, has a tooth thickness greater than the other when they are made of different kinds of materials. For example, when the stationary scroll body 1b is an iron casting made of FCD450 or other material, while the orbiting scroll body 2b is a forging made of aluminum, then the forging made of aluminum has a lower tensile strength than the iron casting. In view of that, the orbiting scroll body 2b with a lower tensile strength may be formed to have a greater tooth thickness than the tooth thickness of the stationary scroll body 1b.

**[0037]** Fig. 6 is a graph showing variations in the compression chamber volume relative to the rotational phase of the orbiting scroll body in the scroll compressor according to Embodiment 1. In Fig. 6, the horizontal axis represents the rotational phase [°] of the orbiting scroll body 2b, while the vertical axis represents the compression chamber volume [cc]. In Fig. 6, the solid line shows the compression chamber volume in Embodiment 1. The dot-and-dash line shows the compression chamber volume in Comparative Example in which the scroll compressor does not have the stepped structure. Fig. 6 shows the relationship between the rotational phase and the compression chamber volume in the process of movement of the compression chamber 12 while decreasing the compression chamber volume as the compression chamber 12 moves from the outer circumferential portion toward the central portion along with the eccentric rotary motion of the orbiting scroll body 2b. Note that in Fig. 6, the first step indicates a stepped portion between the base-plate to base-plate distance L3 and the base-plate to base-plate distance L2, and the second step indicates a stepped portion between the base-plate to base-plate distance L2 and the base-plate to base-plate distance L1.

**[0038]** In Comparative Example, the scroll compressor operates in such a manner that the compression chamber volume decreases linearly. In contrast, in present Embodiment 1, the compression chamber volume decreases in the same manner as Comparative Example before the compression chamber 12 reaches the first step, however, the compression chamber volume increases when the compression chamber 12 reaches the first step, since the base-plate to base-plate distance increases from L3 to L2. Then, the compression chamber volume decreases again from the increased level. When the compression chamber 12 reaches the second step, the base-plate to base-plate distance increases from L2 to L1, so that the compression chamber volume increases again. Thereafter, the scroll compressor operates in such a manner that the compression chamber volume decreases in the same manner as Comparative Example.

**[0039]** As described above, in present Embodiment 1, the scroll compressor operates in such a manner that the compression chamber volume increases temporarily each time the compression chamber 12 reaches a stepped portion. Due to this operation, the amount of decrease in the compression chamber volume relative to the increase in the rotational phase, that is, the volume decrease rate is reduced compared to Comparative Example. With reference to Fig. 6, in Comparative Example, the compression chamber volume is decreased by Va + Vb relative to the increase in the rotational phase from θa to θb. In contrast to that, the compression chamber volume is decreased by Va in present Embodiment 1, and the volume decrease rate is reduced compared to Comparative Example. Consequently, in present Embodiment 1, the scroll compressor compresses refrigerant more slowly than in Comparative Example. Variations in the compression chamber pressure are described below with reference to Fig. 7.

**[0040]** Fig. 7 is a graph showing variations in the compression chamber pressure relative to the rotational phase of the orbiting scroll body in the scroll compressor according to Embodiment 1. In Fig. 7, the horizontal axis represents the rotational phase [°] of the orbiting scroll body 2b, while the vertical axis represents the compression chamber pressure [MPaG]. In Fig. 7, the solid line shows the compression chamber pressure in Embodiment 1. The dot-and-dash line shows the compression chamber pressure in Comparative Example in which the scroll compressor does not have the stepped structure.

**[0041]** When present Embodiment 1 and Comparative Example are compared, the compression chamber pressure rises in the same manner before the compression chamber 12 reaches the first step. Thereafter, in Comparative Example, the compression chamber pressure rises as the rotational phase increases. In contrast, in present Embodiment 1, when the compression chamber 12 reaches the first step, the compression chamber volume increases as described above, so that refrigerant in the compression chamber 12 expands and accordingly the compression chamber pressure drops. Thereafter, in present Embodiment 1, the compression chamber pressure rises again, and when the compression chamber 12 reaches the second step, the compression chamber pressure drops again. Then, the scroll compressor operates in such a manner that the compression chamber pressure rises to a high-level pressure Pd.

**[0042]** As described above, in present Embodiment 1, the scroll compressor operates in such a manner that the compression chamber pressure drops temporarily each time the compression chamber 12 reaches a stepped portion. Due to this operation, in present Embodiment 1, the orbiting scroll body 2b needs to be rotated by a greater rotational phase than that in Comparative Example by the time when the compression chamber pressure reaches the target high-level pressure Pd. With reference to Fig. 7, in Comparative Example, the compression chamber pressure reaches the high-level pressure Pd at a rotational phase θc. In contrast to that, in present Embodiment 1, the compression chamber pressure reaches the high-level pressure Pd at a rotational phase θd that is greater than the rotational phase θc. That is, in present Embodiment 1, the compression chamber pressure rises more slowly than Comparative Example. This reduces the differential pressure between the compression chambers 12 in present Embodiment 1, compared to Comparative Example. Consequently, the amount of refrigerant leakage between the compression chambers 12 is reduced. This can improve the compressor efficiency.

**[0043]** Note that in Fig. 6, the compression chamber volume sharply rises when the compression chamber 12 reaches a stepped portion, however, this is merely an example. Variations in the compression chamber volume are not limited to the manner shown in Fig. 6. That is, the compression chamber volume may be varied in a different manner depending on the stepped structure. Therefore, there may be a case where the compression chamber volume increases moderately, or a case where the compression chamber volume does not even increase. The case where the compression chamber does not even increase indicates that the volume increase rate resulting from the steps corresponds with the volume decrease rate of the scroll body, and the compression chamber volume at the point in time when the compression chamber 12 reaches a stepped portion is maintained between given rotational phases.

**[0044]** As described above, carbon dioxide alone or a refrigerant mixture containing carbon dioxide exhibits a higher pressure rise rate to a decrease in the compression chamber volume. Thus, when carbon dioxide alone or a refrigerant mixture containing carbon dioxide is compressed in the structure of Comparative Example in which the compression chamber volume decreases linearly, the pressure in the compression chamber 12 rises to the target high-level pressure Pd at a smaller rotation phase than that in Embodiment 1. Therefore, the number of scrolls of the scroll body cannot be increased.

**[0045]** In contrast to that, in present Embodiment 1, the volume decrease rate can be reduced as described above, so that even when carbon dioxide alone or a refrigerant mixture containing carbon dioxide is used, the compression chamber pressure can rise at a reduced rate to the increase in the rotational phase. With this configuration, the structure can be formed in which the number of scrolls of the scroll body is increased to increase the number of compression chambers 12. As a result of this, a scroll compressor can be obtained in which the differential pressure between the compression chambers can be reduced, and refrigerant leakage can be reduced.

**[0046]** As described above, the scroll compressor of present Embodiment 1 includes: the stationary scroll 1 including the stationary base plate 1c and the stationary scroll body 1b formed on the stationary base plate 1c; and the orbiting scroll 2 including the orbiting base plate 2c and the orbiting scroll body 2b formed on the orbiting base plate 2c, the orbiting scroll 2 being located with the orbiting base plate 2c being opposite to the stationary base plate 1c, the orbiting scroll body 2b being combined with the stationary scroll body 1b to form the compression chamber 12. The scroll compressor of present Embodiment 1 has a structure in which the base-plate to base-plate distance that is a distance between the stationary base plate 1c and the orbiting base plate 2c increases stepwise from the outer circumferential portions of the stationary scroll body 1b and the orbiting scroll body 2b toward the central portions thereof.

**[0047]** Due to this structure, even when carbon dioxide alone or a refrigerant mixture containing carbon dioxide is used as refrigerant, it is still possible to reduce refrigerant leakage between the compression chambers, and minimize performance degradation.

**[0048]** The stationary scroll body 1b and the orbiting scroll body 2b are provided with the scroll-side stepped portions 40 such that the tooth height is increased stepwise from the outer circumferential portion toward the central portion, the tooth height being a height of each of the stationary scroll body 1b and a height of the orbiting scroll body 2b. The stationary base plate 1c and the orbiting base plate 2c are provided with the base plate-side stepped portions 41 corresponding to the scroll-side stepped portions 40 of their opposite scroll body. The stationary base plate 1c and the orbiting base plate 2c are formed to have a thickness decreasing stepwise from the outer circumferential portion toward the central portion.

**[0049]** In the manner as described above, the structure can be formed, in which the base-plate to base-plate distance increases stepwise from the outer circumferential portions of the stationary scroll body 1b and the orbiting scroll body 2b toward their central portions.

**[0050]** The stationary scroll 1 and the orbiting scroll 2 are made of different kinds of materials. Either the stationary scroll body 1b or the orbiting scroll body 2b, whichever has a lower tensile strength, is formed to have a greater tooth thickness.

**[0051]** With this configuration, either the stationary scroll body 1b or the orbiting scroll body 2b, whichever has a lower tensile strength, can ensure an adequate tooth thickness, and thus maintain a sufficient strength.

## Embodiment 2

**[0052]** In Embodiment 1, the configuration has been described, in which stepped portions are provided both in the stationary scroll 1 and the orbiting scroll 2, and the base-plate to base-plate distance is longer on the central-portion side with reference to each of the stepped portions than on the outer-circumferential-portion side. In Embodiment 2 of the present disclosure, a configuration is described below, in which in addition to the configuration of Embodiment 1, the thickness of the scroll body is varied, and the volume decrease rate in the compression chamber 12 associated with the eccentric rotary motion of the orbiting scroll 2 is further reduced, so that performance can further be improved. Hereinafter, a configuration in Embodiment 2 which is different from that in Embodiment 1 is mainly described. Those configurations of Embodiment 2, the descriptions for which are not present in Embodiment 2, are same configurations as in Embodiment 1.

**[0053]** Fig. 8 is an enlarged view of the compression chamber of a scroll compressor according to Embodiment 2.

**[0054]** The stationary scroll body 1b is formed to have a tooth thickness, which is a thickness of the stationary scroll body 1b in the radial direction, such that the tooth thickness is smoothly decreased from the outer circumferential portion toward the central portion. That is, the stationary scroll body 1b is formed to have a relationship between a tooth thickness tfo on the outer-circumferential-portion side and a tooth thickness tfi on the central-portion side, which satisfies tfo > tfi. Likewise, the orbiting scroll body 2b is formed to have a tooth thickness, which is a thickness of the orbiting scroll body 2b in the radial direction, such that the tooth thickness is smoothly decreased from the outer circumferential portion toward the central portion in the scroll direction. That is, the orbiting scroll body 2b is formed to have a relationship between a tooth thickness too on the outer-circumferential-portion side and a tooth thickness toi on the central-portion side, which satisfies too > toi. However, since the scroll central portion is applied with a highest differential pressure, the scroll central portion is formed thicker than the other portions to ensure a sufficient strength.

**[0055]** There may be a relationship of the tooth thickness between the stationary scroll body 1b and the orbiting scroll body 2b, in which the stationary scroll body 1b and the orbiting scroll body 2b have an identical tooth thickness when they are made of the same kind of materials, or in which either the stationary scroll body 1b or the orbiting scroll body 2b, whichever has a lower material strength, has a tooth thickness greater than the other when they are made of different kinds of materials. In either case, in present Embodiment 2, the stationary scroll body 1b and the orbiting scroll body 2b are formed to have their respective tooth thicknesses that are smoothly decreased from the outer circumferential portion toward the central portion. Both the stationary scroll body 1b and the orbiting scroll body 2b are formed to have a tooth thickness decreasing gradually from the outer circumferential portion toward the central portion. However, either the stationary scroll body 1b or the orbiting scroll body 2b may be formed to have such a tooth thickness as described above.

**[0056]** Fig. 9 is a graph showing variations in the compression chamber volume relative to the rotational phase of the orbiting scroll body in the scroll compressor according to Embodiment 2. In Fig. 9, the horizontal axis represents the rotational phase [°] of the orbiting scroll body, while the vertical axis represents the compression chamber volume [cc]. In Fig. 9, the thick solid line shows the compression chamber volume in Embodiment 2. In Fig. 9, the thin solid line shows the compression chamber volume in Embodiment 1. The dot-and-dash line shows the compression chamber volume in Comparative Example in which the scroll compressor does not have the stepped structure.

**[0057]** In present Embodiment 2, the stationary scroll body 1b and the orbiting scroll body 2b have their respective tooth thicknesses that are decreased smoothly from the outer circumferential portion toward the central portion. Consequently, the compression chamber volume after having increased when the compression chamber 12 reaches at each step, that is, the first step and the second step, is greater than the increased compression chamber volume in Embodiment 1. The difference in the compression chamber volume between present Embodiment 2 and Embodiment 1 increases as the rotational phase increases. Due to this difference, in present Embodiment 2, the volume decrease rate in the compression chamber 12 is further reduced compared to Embodiment 1.

**[0058]** Fig. 10 is a graph showing variations in the compression chamber pressure relative to the rotational phase of the orbiting scroll body in the scroll compressor according to Embodiment 2. In Fig. 10, the horizontal axis represents the rotational phase [°] of the orbiting scroll body 2b, while the vertical axis represents the compression chamber pressure [MPaG]. In Fig. 10, the thick solid line shows the compression chamber pressure in Embodiment 2. In Fig. 10, the thin solid line shows the compression chamber pressure in Embodiment 1. The dot-and-dash line shows the compression chamber pressure in Comparative Example in which the scroll compressor does not have the stepped structure.

**[0059]** When present Embodiment 2, Embodiment 1, and Comparative Example are compared, the compression chamber pressure rises in the same manner before the compression chamber 12 reaches the first step. Thereafter, in Comparative Example, the compression chamber pressure rises as the rotational phase increases. In contrast, in present Embodiment 2 and Embodiment 1, when the compression chamber 12 reaches the first step, the compression chamber volume increases, so that refrigerant in the compression chamber 12 expands and accordingly the compression chamber pressure drops.

**[0060]** In present Embodiment 2, as described above, the compression chamber volume after having increased when the compression chamber 12 reaches the first step is greater than that in Embodiment 1. Thus, the compression chamber pressure drops to a level lower than that in Embodiment 1. Likewise, when the compression chamber 12 reaches the second step, the compression chamber pressure drops to a level lower than that in Embodiment 1. In the manner as described above, in present Embodiment 2, each time the compression chamber 12 reaches a stepped portion, the compression chamber pressure drops below that in Embodiment 1. Thus, the pressure in the compression chamber 12 rises at a slower speed than that in Embodiment 1. Therefore, in present Embodiment 2, the differential pressure between the compression chambers 12 is reduced compared to Embodiment 1, and thus the amount of refrigerant leakage between the compression chambers 12 is more significantly decreased. This can further improve the compressor efficiency.

**[0061]** As described above, in present Embodiment 2, at least one of the stationary scroll body 1b and the orbiting scroll body 2b is formed to have a tooth thickness, which is a thickness in the radial direction, such that the tooth thickness is decreased gradually from the outer circumferential portion toward the central portion. Accordingly, the volume decrease rate in the compression chamber 12 is reduced compared to that in Embodiment 1. Consequently, even when carbon dioxide alone or a refrigerant mixture containing carbon dioxide is used, the pressure can rise at a reduced rate. The pressure can rise at a reduced rate in the manner as described above, so that the scroll compressor can have such a structure that the number of scrolls of the scroll body is increased to increase the number of the compression chambers 12. As a result of this, the differential pressure between the compression chambers 12 can be reduced. In present Embodiment 2, the amount of refrigerant leakage is further reduced compared to Embodiment 1, and the compressor efficiency can be improved accordingly.

**[0062]** Note that in Embodiment 1 and Embodiment 2 described above, the stationary base plate 1c may be provided with intermediate injection ports 50 (see Figs. 3 and 8) to inject liquid refrigerant or gas refrigerant at an intermediate pressure into the compression chambers 12. In a case where liquid refrigerant is injected into the compression chambers 12, the liquid refrigerant can cool refrigerant in the compression chambers, and thus can minimize an increase in the discharge-gas temperature during operation of the scroll compressor at a high compression ratio. In a case where an economizer cycle is employed to inject gas refrigerant, the economizer cycle can increase the refrigeration capacity. Note that the injection ports 50 are located at positions shown in Figs. 3 and 8, or are located somewhere closer to the scroll center than the positions shown in Figs. 3 and 8. When the intermediate injection ports 50 communicate with the low-pressure space 23, the cooling effect in the compression chambers 12 is degraded. For this reason, the intermediate injection ports 50 are located at positions where the intermediate injection ports 50 do not communicate with the low-pressure space 23.

Reference Signs List

**[0063]** 1: stationary scroll, 1a: discharge port, 1b: stationary scroll body, 1c: stationary base plate, 2: orbiting scroll, 2b: orbiting scroll body, 2c: orbiting base plate, 2d: boss portion, 2e: orbiting bearing portion, 3: frame, 3a: bearing portion, 3b: thrust bearing portion, 4: subframe, 4a: bearing portion, 7: rotational shaft, 7a: eccentric portion, 8: suction pipe, 9: discharge pipe, 11: shell, 12: compression chamber, 14: valve guard, 15: valve, 19: stator, 20: rotor, 21: oil reservoir, 22: oil pump, 23: lower-pressure space, 24: high-pressure space, 25: Oldham ring, 36: compression mechanism portion, 37: drive mechanism portion, 40: scroll-side stepped portion, 41: base plate-side stepped portion, 50: injection port

**Claims**

1. A scroll compressor comprising:

   a stationary scroll including a stationary base plate and a stationary scroll body formed on the stationary base plate; and
   an orbiting scroll including an orbiting base plate and an orbiting scroll body formed on the orbiting base plate, the orbiting scroll being located with the orbiting base plate being opposite to the stationary base plate, the orbiting scroll body being combined with the stationary scroll body to form a compression chamber, wherein
   the scroll compressor has a structure in which a base-plate to base-plate distance that is a distance between the stationary base plate and the orbiting base plate increases stepwise from outer circumferential portions of the stationary scroll body and the orbiting scroll body toward central portions thereof.

2. The scroll compressor of claim 1, wherein

   the stationary scroll body and the orbiting scroll body are provided with scroll-side stepped portions such that a tooth height is increased stepwise from the outer circumferential portions toward the central portions, the tooth height being a height of each of the stationary scroll body and a height of the orbiting scroll body, and
   the stationary base plate and the orbiting base plate are provided with base plate-side stepped portions corresponding to the scroll-side stepped portions of an opposite scroll body, and
   the stationary base plate and the orbiting base plate are formed to have a thickness decreasing stepwise from the outer circumferential portions toward the central portions.

3. The scroll compressor of claim 1 or 2, wherein the stationary scroll and the orbiting scroll are made of different kinds of materials, and either the stationary scroll body or the orbiting scroll body, whichever has a lower tensile strength, is formed to have a greater tooth thickness.

4. The scroll compressor of any one of claims 1 to 3, wherein at least one of the stationary scroll body and the orbiting scroll body is formed to have a tooth thickness decreasing gradually from the outer circumferential portion toward the central portion, the tooth thickness being a thickness in a radial direction.

5. The scroll compressor of any one of claims 1 to 4, wherein refrigerant to be compressed in the compression chamber is carbon dioxide alone or a refrigerant mixture containing carbon dioxide.

FIG. 1

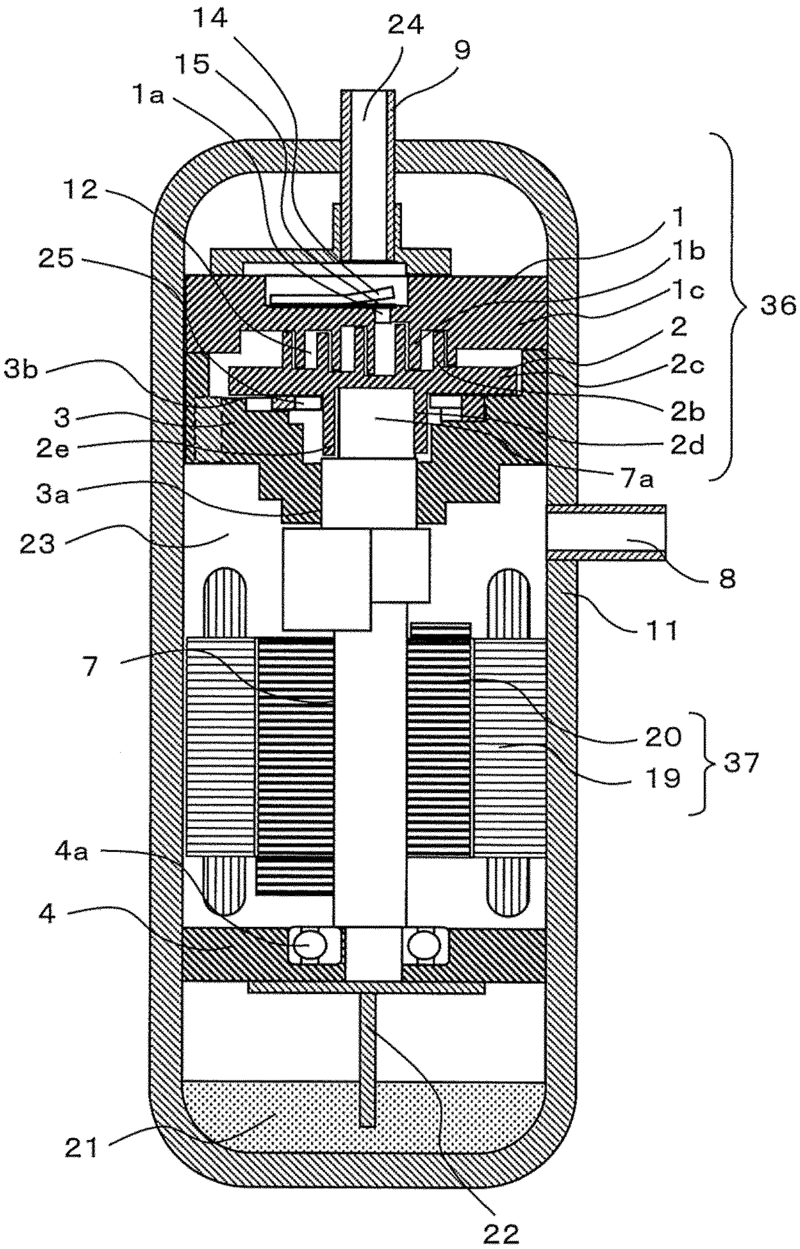

14
24
9
15
1a
12
1
1b
25
1c
36
2
3b
2c
2b
3
2d
2e
7a
3a
23
8
11
7
20
37
19
4a
4
21
22

FIG. 2

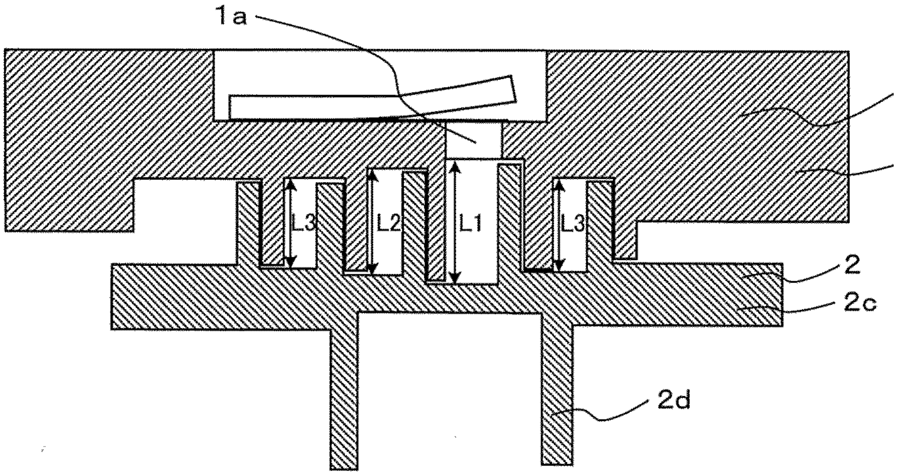



FIG. 3

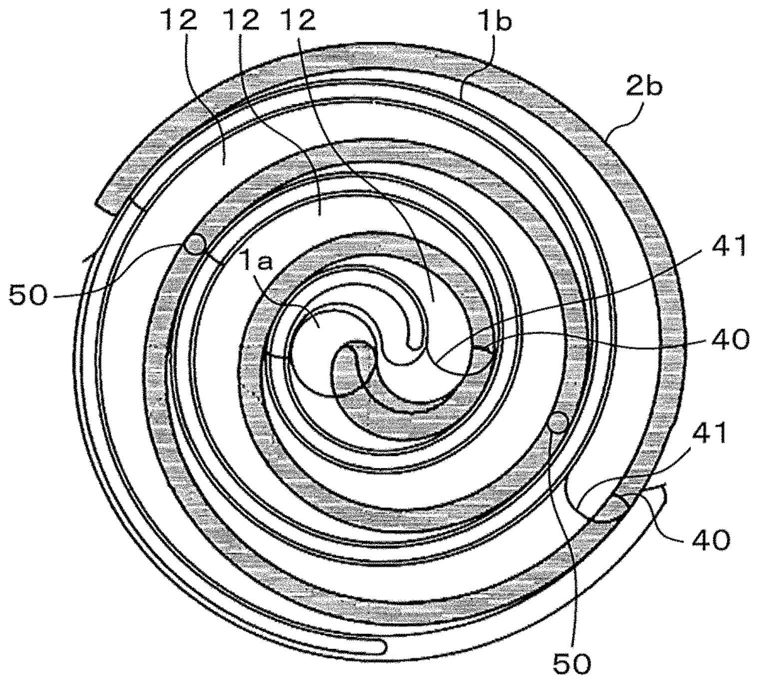


FIG. 4

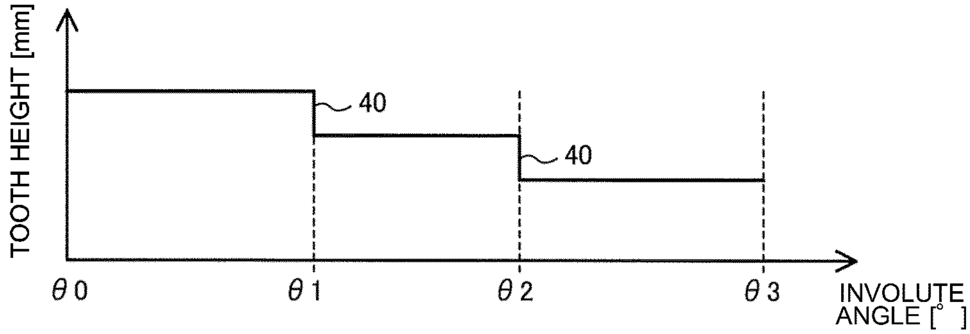

TOOTH HEIGHT [mm]
40
40
θ0
θ1
θ2
θ3
INVOLUTE ANGLE [° ]

FIG. 5

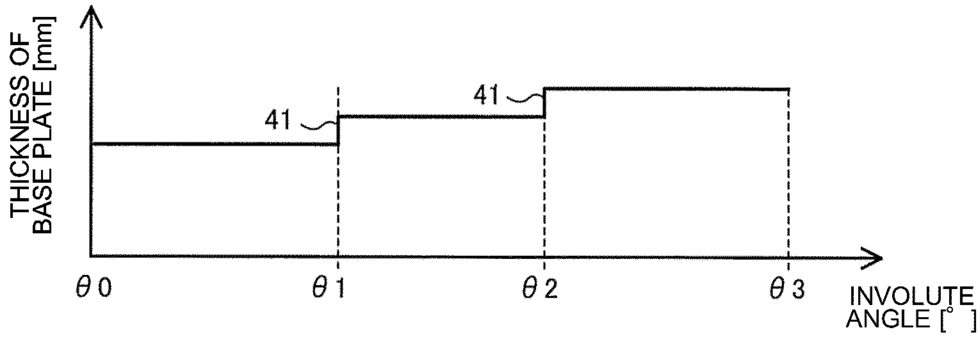

THICKNESS OF BASE PLATE [mm]
41
41
θ0
θ1
θ2
θ3
INVOLUTE ANGLE [° ]

FIG. 6

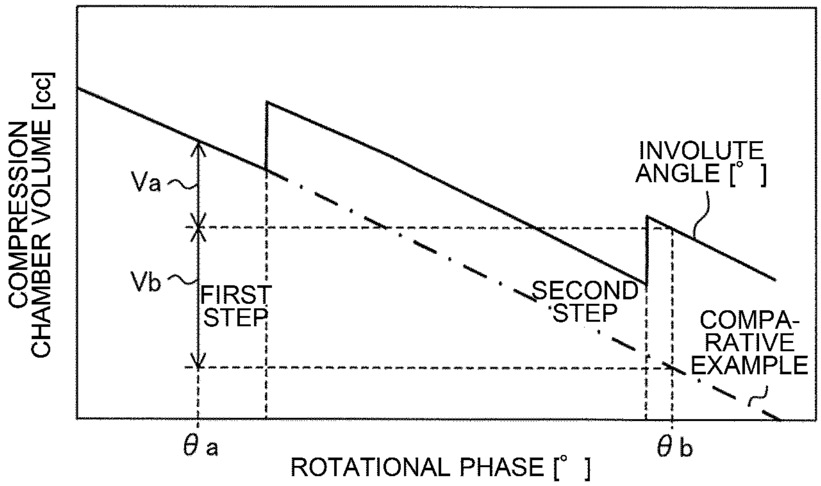

COMPRESSION CHAMBER VOLUME [cc]
Va
Vb
FIRST STEP
SECOND STEP
INVOLUTE ANGLE [° ]
COMPA-RATIVE EXAMPLE
θa
θb
ROTATIONAL PHASE [° ]

FIG. 7

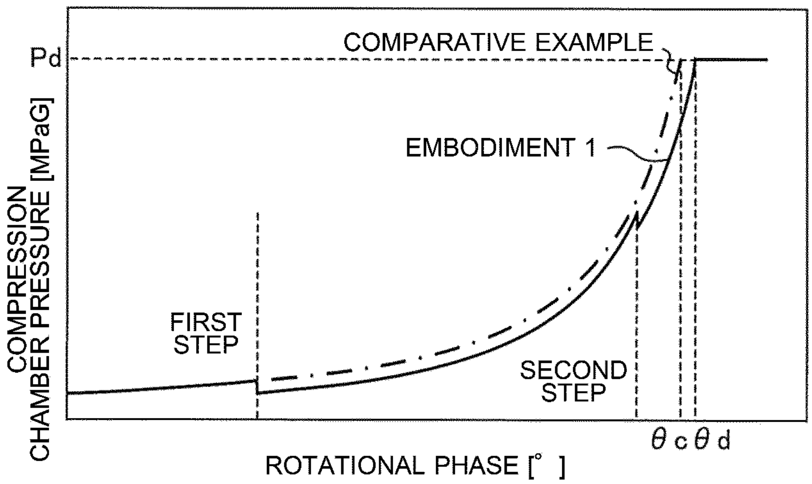

Pd
COMPARATIVE EXAMPLE
EMBODIMENT 1
COMPRESSION CHAMBER PRESSURE [MPaG]
FIRST STEP
SECOND STEP
θc θd
ROTATIONAL PHASE [° ]

FIG. 8

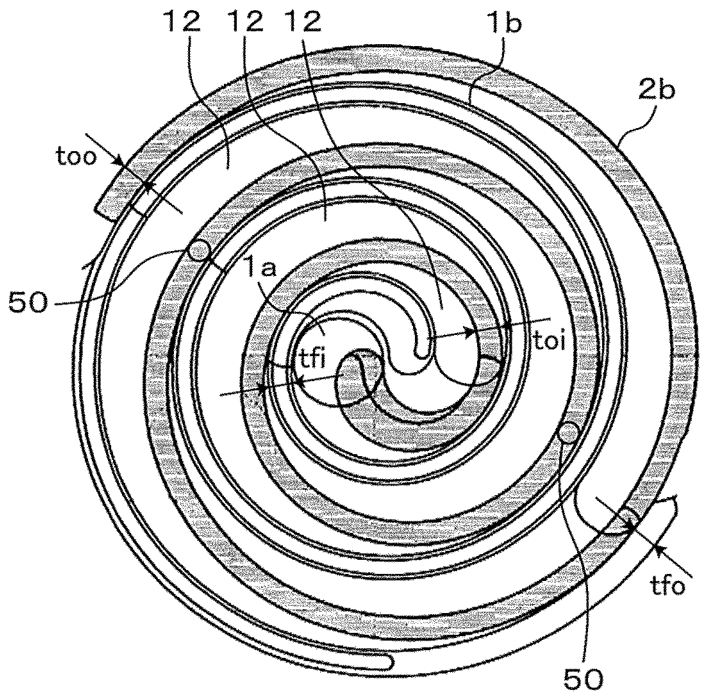


FIG. 9

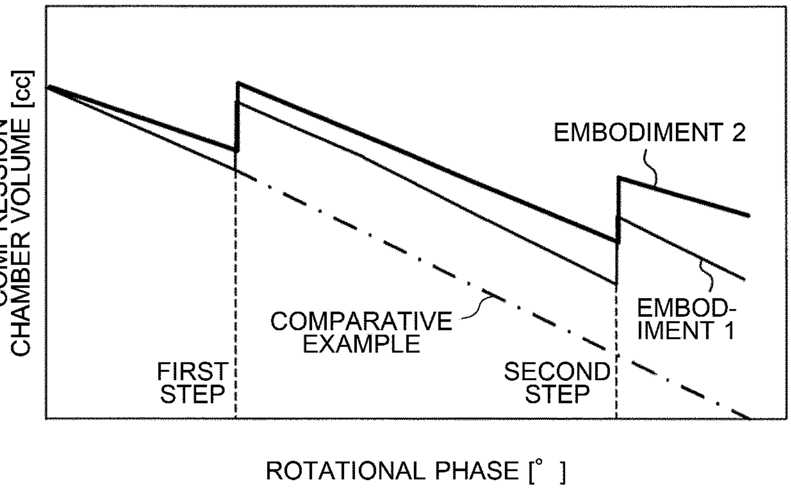
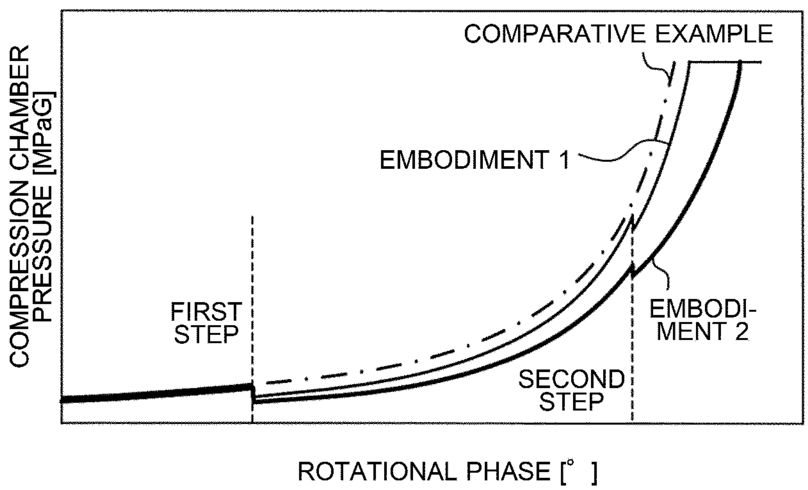

COMPRESSION CHAMBER VOLUME [cc]
EMBODIMENT 2
EMBOD-IMENT 1
COMPARATIVE EXAMPLE
FIRST STEP
SECOND STEP
ROTATIONAL PHASE [° ]

FIG. 10


COMPRESSION CHAMBER PRESSURE [MPaG]
COMPARATIVE EXAMPLE
EMBODIMENT 1
EMBODI-MENT 2
FIRST STEP
SECOND STEP
ROTATIONAL PHASE [° ]

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/040440

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F04C18/02(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. F04C18/02

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. |
|---|---|---|
| X<br>Y<br>A | WO 2014/155646 A1 (HITACHI APPLIANCES, INC.) 02 October 2014, paragraphs [0010]-[0035], fig. 1-6 & US 2016/0003247 A1, paragraphs [0020]-[0048], fig. 1-6 & EP 2980408 A1 & CN 105074218 A | 1<br>3,5<br>2,4 |
| Y | JP 4-94484 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 26 March 1992, page 2, lower left column, line 1 to lower right column, line 15 (Family: none) | 3 |

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 10 December 2019 (10.12.2019) | 24 December 2019 (24.12.2019) |

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

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

**INTERNATIONAL SEARCH REPORT**

International application No. PCT/JP2019/040440

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | JP 2005-140072 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 02 June 2005, paragraph [0033] & US 2007/0178002 A1, paragraph [0149] & WO 2005/001292 A1 & KR 10-2006-0020684 A & CN 1823226 A | 5 |
| A | JP 6180860 B2 (MITSUBISHI HEAVY INDUSTRIES, LTD.) 16 August 2017, paragraph [0034], fig. 2 (Family: none) | 2 |
| A | JP 1-159482 A (HITACHI, LTD.) 22 June 1989 (Family: none) | 1-5 |
| A | US 2008/0159893 A1 (CAILLAT, Jean-Luc M.) 03 July 2008 & WO 2008/085263 A1 & CN 101573539 A | 1-5 |

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- JP 6180860 B **[0003]**