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MATSUMURA et al.(10) **Pub. No.: US 2016/0003247 A1**(43) **Pub. Date: Jan. 7, 2016**(54) **SCROLL COMPRESSOR**(71) Applicant: **HITACHI APPLIANCES, INC.**,
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(57)

ABSTRACT

The purpose of the present invention is to suppress the contact between the wrap tooth tip and the tooth bottom by enlarging the tooth bottom step, and to reduce the loss owing to the gap as a result of enlarging the tooth bottom step. The fixed scroll includes a fixed scroll-side flat plate and a fixed-side wrap standing on one surface of the fixed-side plate while retaining the spiral shape. The orbiting scroll includes an orbiting-side plate and an orbiting-side wrap standing on one surface of the orbiting-side plate while retaining the spiral shape. The orbiting-side wrap orbits with respect to the fixed scroll while being in mesh with the fixed side wrap to form a compression chamber. Each of the fixed-side plate and the orbiting-side plate has the step on the tooth bottom at the inner periphery deeper than the step on the tooth bottom at the outer periphery. The step at the outer or the inner periphery, which is formed on the tooth bottom of the orbiting-side plate, has the depth smaller than the one on the tooth bottom of the fixed-side plate.

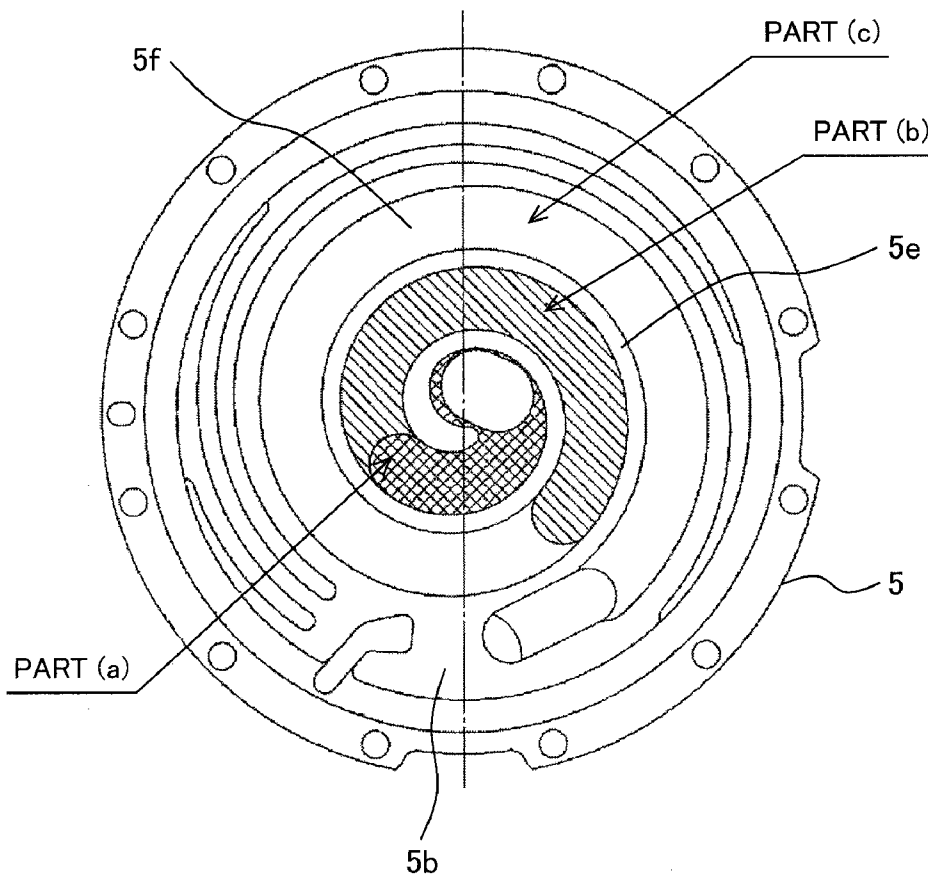


FIG. 1

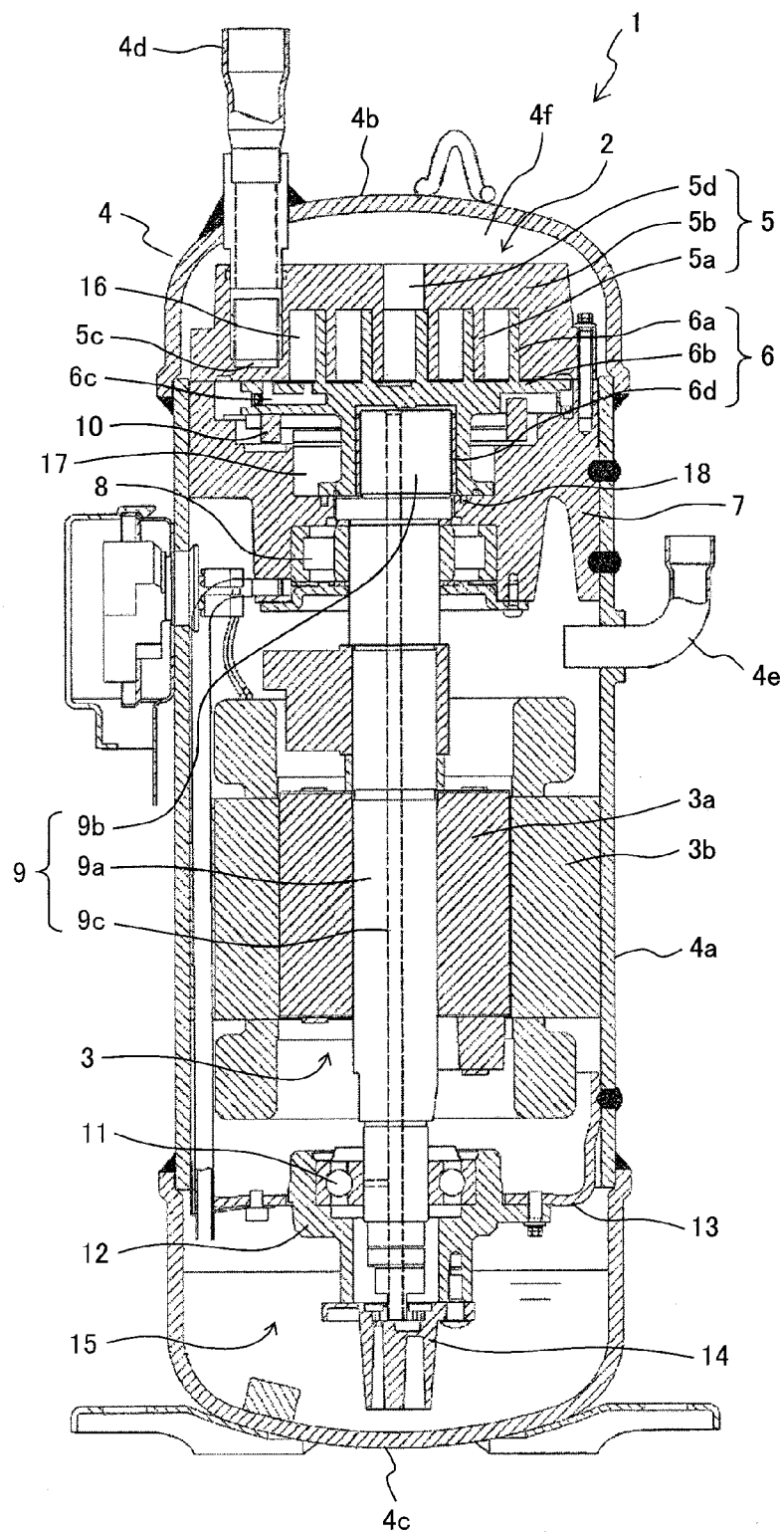
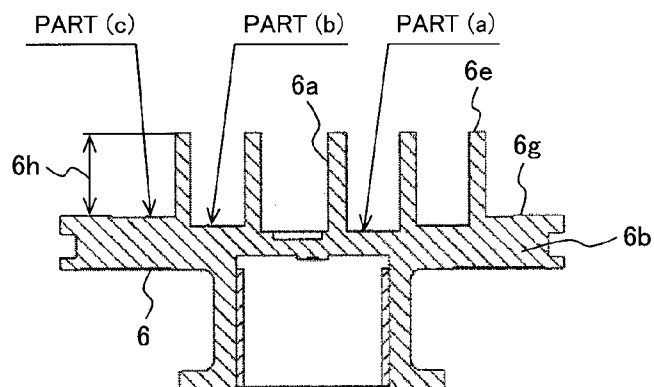
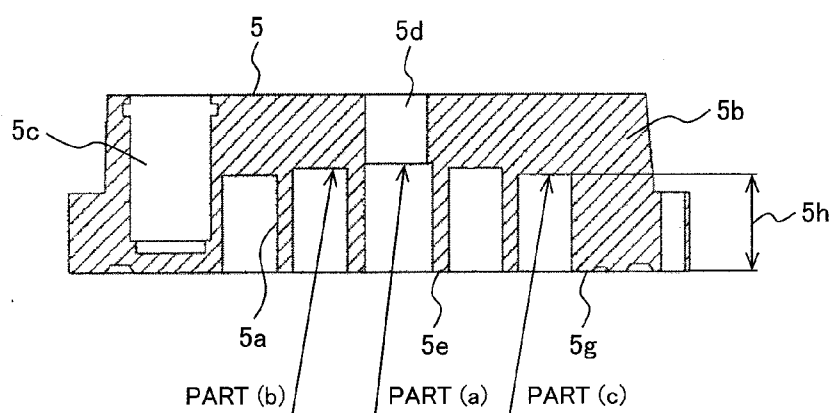


FIG. 2



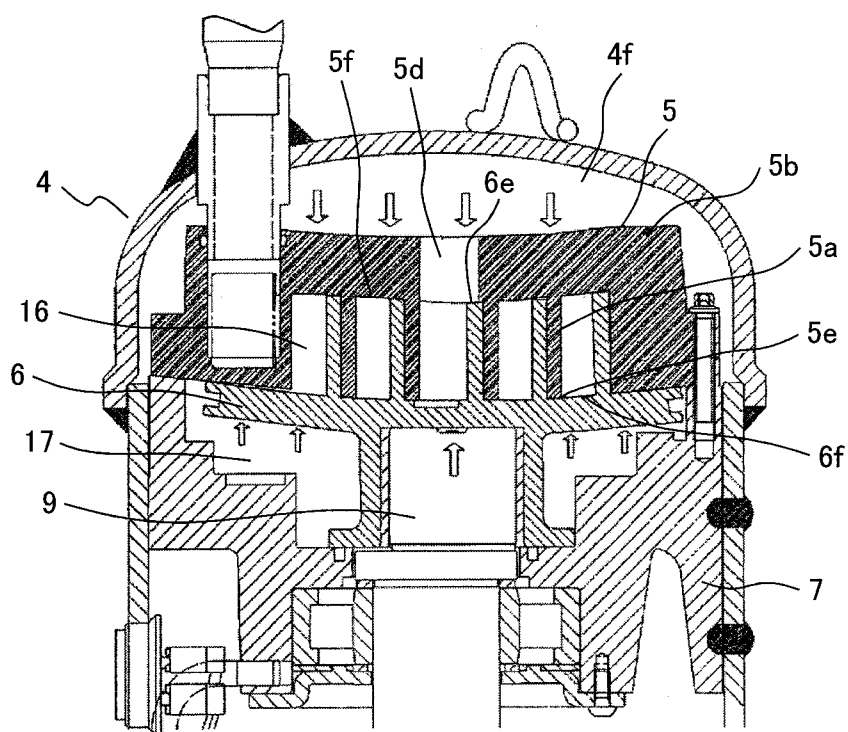


FIG. 4A

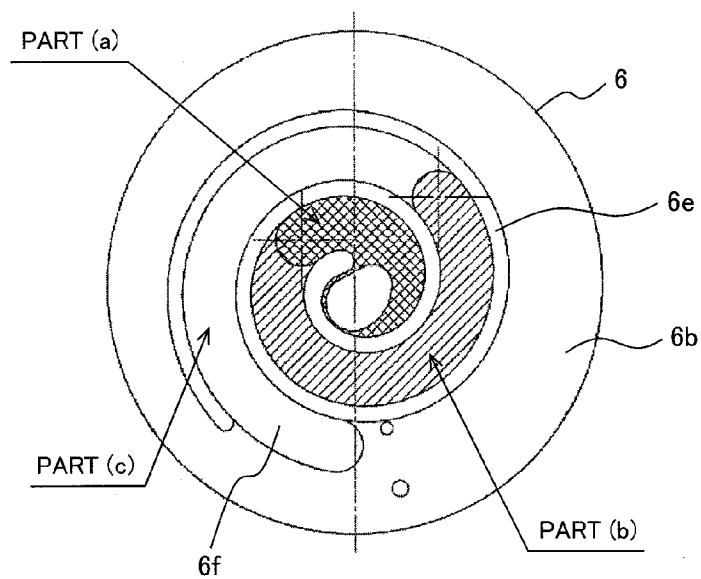


FIG. 4B

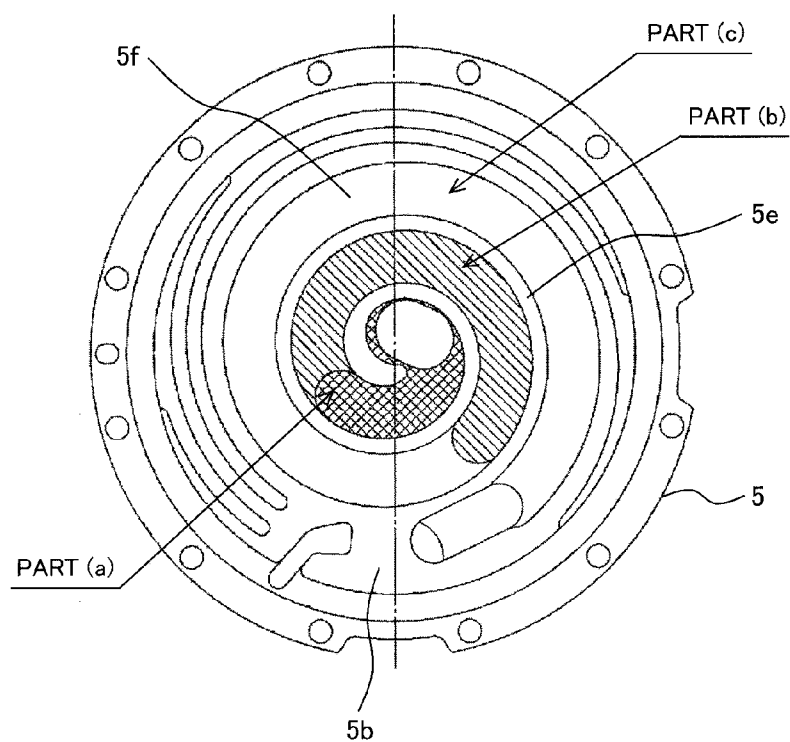
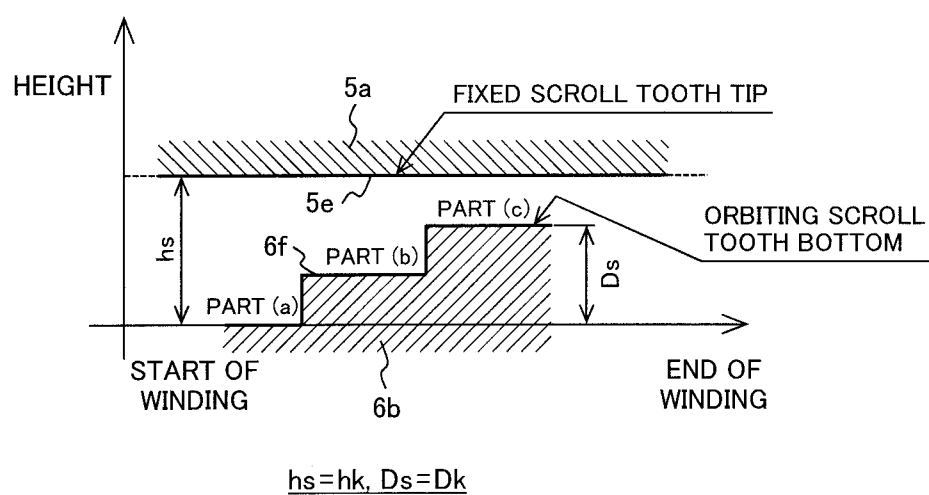


FIG. 5

ORBETING SCROLL SIDE TOOTH BOTTOM STEP



FIXED SCROLL SIDE TOOTH BOTTOM STEP

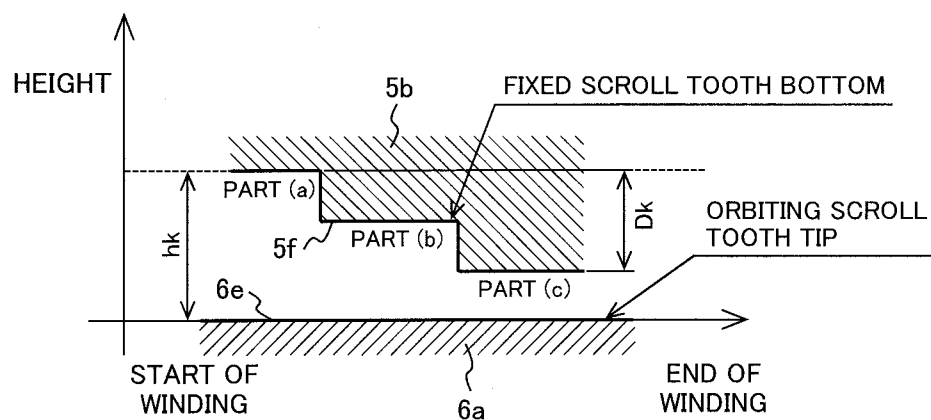


FIG. 6

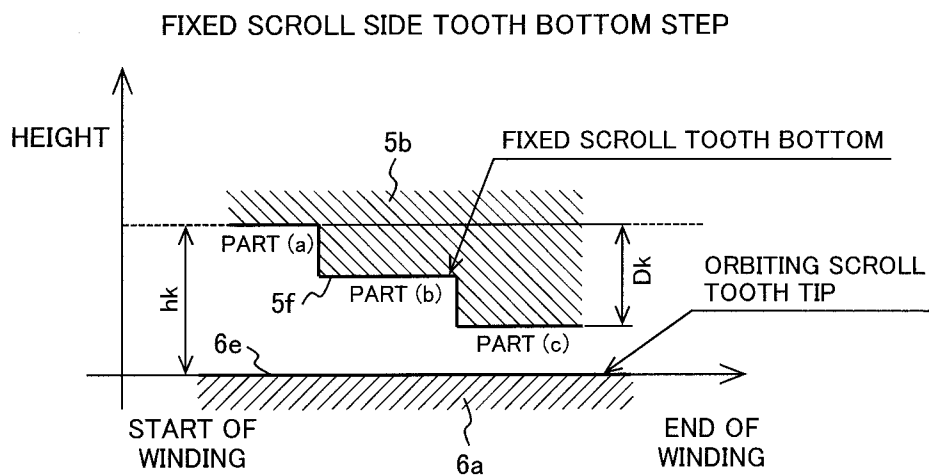
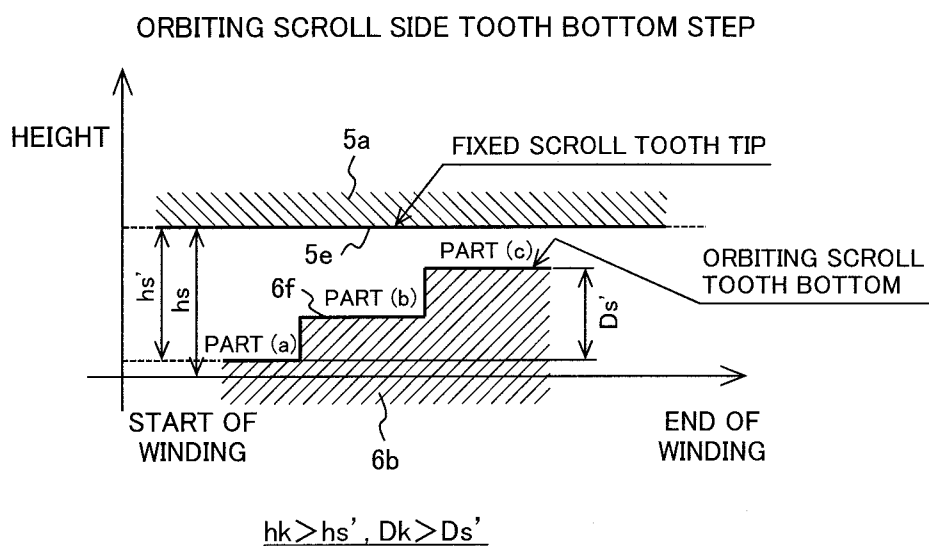


FIG. 7

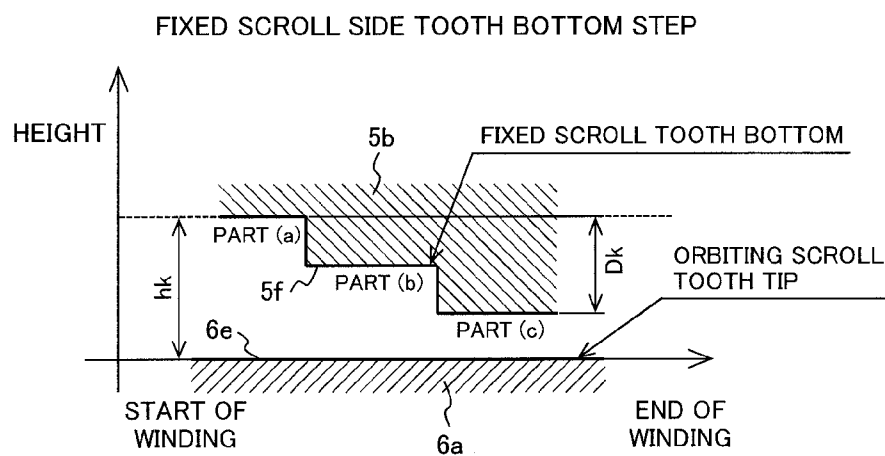
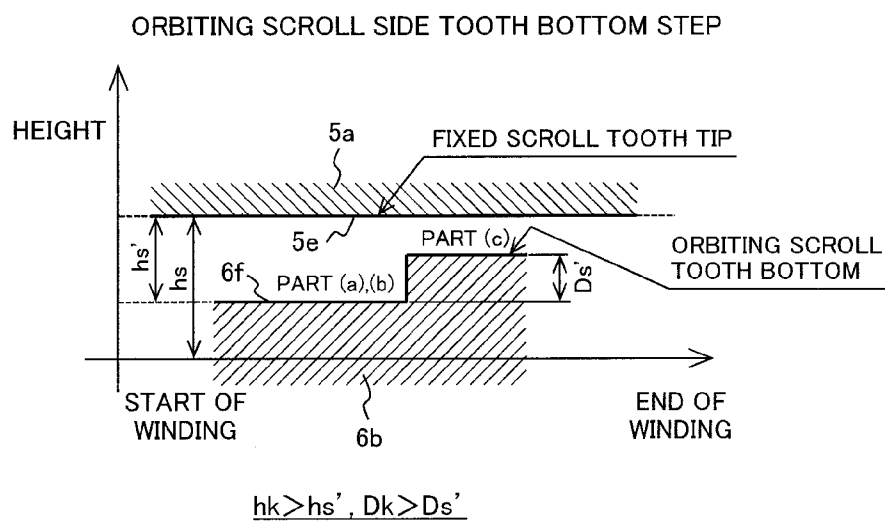
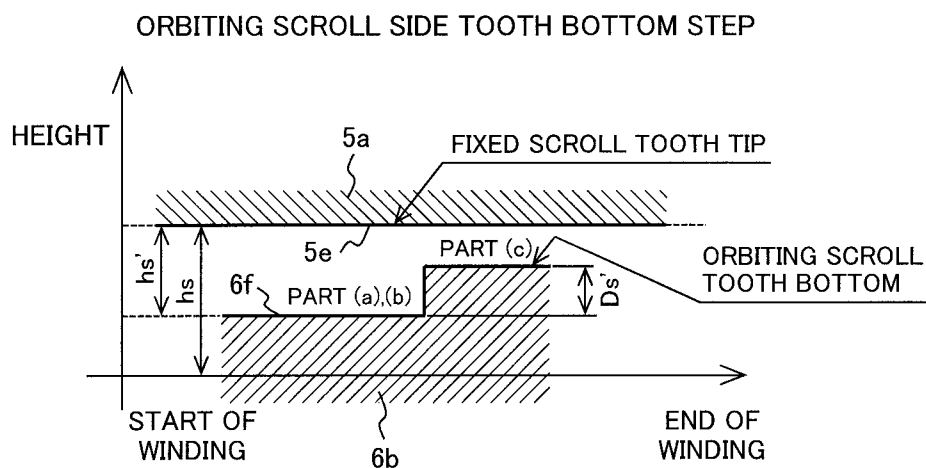
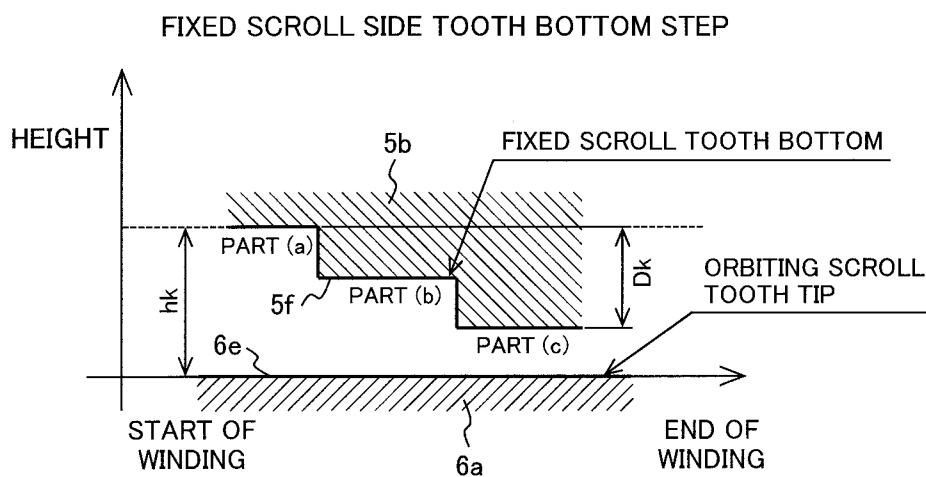


FIG. 8



$$hk > hs', 1/2Dk = Ds'$$



SCROLL COMPRESSOR

TECHNICAL FIELD

[0001] The present invention relates to a scroll compressor.

BACKGROUND ART

[0002] Japanese Patent No. 2009-281509 (Patent Literature 1) as background art of the subject technical field discloses that “There is an inclined surface having the plate thickness reduced from the outer peripheral side to the inner peripheral side preliminarily formed on the surface of the mirror plate of the orbiting scroll, which faces the mirror plate of the fixed scroll in expectation of the scroll deformation. The fixed scroll has a spiral wrap standing on the inner periphery of the flat plate, and a cylindrical mirror plate mounted on the outer periphery to surround the wrap. The orbiting scroll has a standing spiral wrap in mesh with the fixed scroll wrap on the mirror plate opposite the fixed scroll at the side of the standing wrap to form a plurality of compression chambers.” This makes it possible to “improve efficiency of the compressor by reducing the friction loss caused by deformations of the fixed scroll and the orbiting scroll” (see abstract).

CITATION LIST

Patent Literature

[0003] PTL 1: JP-A-2009-281209

SUMMARY OF INVENTION

Technical Problem

[0004] Patent Literature 1 discloses that the tooth bottoms are preliminarily formed on opposite surfaces of mirror plates of the orbiting scroll and the fixed scroll, each step of which has the depth increased from the outer peripheral side to the inner peripheral side in expectation of the scroll deformation, reducing the friction loss caused by the contact between the wrap tooth tip and the opposing tooth bottom. The thus formed tooth bottom step may suppress the contact between the wrap tooth tip and the tooth bottom. If the tooth bottom step is unnecessarily widened, the gap is generated, through which gas leaks to the inside of the compression chamber, thus increasing the loss.

[0005] It is an object of the present invention to suppress the contact between the wrap tooth tip and the tooth bottom by forming the tooth bottom step, and to reduce the loss caused by the gap generated as a result of enlarging the tooth bottom step.

Solution to Problem

[0006] The aforementioned problem may be solved by employing the structures as described in the claims.

[0007] The present invention includes a plurality of means for solving the problem, one of which will be described as an example below.

[0008] The present invention provides a scroll compressor which includes a fixed scroll including a fixed-side plate and a fixed-side wrap standing on one surface of the fixed-side plate while retaining a spiral shape, an orbiting scroll including an orbiting-side plate, and an orbiting-side wrap standing on one surface of the orbiting-side plate while retaining a spiral shape, which allows the orbiting-side wrap to be in

mesh with the fixed-side wrap for orbiting with respect to the fixed scroll to form a compression chamber, and an electric motor for driving the orbiting scroll via a crankshaft. Each tooth bottom of the fixed-side wrap and the orbiting-side wrap has a step formed to become deeper from an outer periphery to an inner periphery. The step is formed on the tooth bottom of the fixed-side wrap at the inner periphery so as to be deeper than the step formed on the tooth bottom of the orbiting-side wrap at the inner periphery.

Advantageous Effects of Invention

[0009] The present invention is capable of suppressing the contact between the wrap tooth tip and the tooth bottom by forming the tooth bottom step, and reducing the loss caused by the gap generated as a result of enlarging the tooth bottom step. Problems, structures and effects other than those described above will be specifically explained in the following embodiments.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. 1 is a longitudinal sectional view of a first embodiment of a scroll compressor.

[0011] FIG. 2 is a view showing structures of the fixed scroll and the orbiting scroll.

[0012] FIG. 3 is a schematic view representing pressure deformation of the rear part of the scroll compressor according to the first embodiment.

[0013] FIG. 4(1) is a top view of the tooth bottom of the orbiting scroll according to the first embodiment.

[0014] FIG. 4(2) is a top view of the tooth bottom of the fixed scroll according to the first embodiment.

[0015] FIG. 5 is an explanatory view showing each wrap structure of the orbiting scroll and the fixed scroll.

[0016] FIG. 6 is a view showing the first embodiment corresponding to FIG. 5.

[0017] FIG. 7 is a view showing a second embodiment corresponding to FIG. 5.

[0018] FIG. 8 is a view showing a third embodiment corresponding to FIG. 6.

DESCRIPTION OF EMBODIMENTS

[0019] Embodiments of the present invention will be described referring to the drawings.

First Embodiment

[0020] An embodiment of the scroll compressor will be described, which is configured to optimize the gap between wraps so as to suppress the load exerted to the wrap and to reduce the loss caused by leakage into the compression chamber.

[0021] FIG. 1 shows an example of the structure of the scroll compressor according to the embodiment.

[0022] A scroll compressor 1 includes a compression mechanism part 2, an electric motor 3 for driving the compression mechanism part 2, and a closed vessel 4 for storing the compression mechanism part 2 and the electric motor 3. The embodiment is formed as a vertical scroll compressor configured to have the compression mechanism part 2 disposed at the upper section in the closed vessel 2, the electric motor 3 disposed in the intermediate section, and an oil sump 15 disposed at the lower section of the closed vessel 4. The closed vessel 4 is formed by welding a lid cap 4b and a bottom cap 4c to top and bottom parts of a cylindrical chamber 4a. An

intake pipe 4d is mounted to the lid cap 4b, and a discharge pipe 4e is mounted to the side surface of the cylindrical chamber 4a. The closed vessel 4 has discharge pressure space 4f working as the discharge pressure therein. The compression mechanism part 2 and the electric motor 3 are stored in the discharge pressure space 4f. The compression mechanism part 2 includes a fixed scroll 5, an orbiting scroll 6, and a frame 7 as basic components. The fixed scroll 5 and the frame 7 are secured with a bolt, and the orbiting scroll 6 is supported with the frame 7.

[0023] FIG. 2 shows cross-sections of basic structures of the fixed scroll 5 and the orbiting scroll 6 of the scroll compressor 1 according to the embodiment. Referring to FIG. 2, consistency does not necessarily exist in the relative dimension ratio between the fixed scroll 5 and the orbiting scroll 6. The fixed scroll 5 includes a disc-like top plate (fixed-side plate 5b), a spiral fixed-side wrap 5a which stands on the inner periphery at the lower section of the fixed-side plate 5b, a cylindrical fixed-side mirror plate 5g disposed on the outer periphery of the fixed-side plate 5b to surround the wrap 5a, and an intake port 5c and a discharge port 5d which are provided at the upper section of the fixed-side plate 5b. The fixed scroll as described above is secured to the frame 7 with the bolt.

[0024] The orbiting scroll 6 includes a disc-like orbiting-side plate 6b, and a spiral orbiting-side wrap 6a, standing on the inner periphery of the orbiting-side plate 6b at the side where the fixed-side wrap 5a of the fixed scroll 5 stands. The orbiting scroll 6 is orbitally arranged so as to allow the wrap to be in mesh with the wrap of the fixed scroll 5 to form compression chambers 16. An eccentric pin 9b of a crankshaft 9 is connected to a back surface side of the orbiting scroll 6 (the lower side as shown in FIGS. 1 and 2). The orbiting motion of the orbiting scroll 6 with respect to the fixed scroll 5 ensures compression to reduce the volume thereof.

[0025] Each scroll wrap (fixed-side wrap 5a, orbiting-side wrap 6a) is formed of an involute curve of the circle as the basic curve, and has an asymmetrical scroll shape, having a compression chamber at the outer line side formed outside the wrap at a winding end side of the orbiting scroll 6 and a compression chamber at the inner line side formed inside the wrap each having the different size in the state where both scrolls are meshed with each other, and each phase is shifted at approximately 180° with respect to rotation of the shaft. The outer periphery of the frame 7 is secured to an inner wall surface of the closed vessel 4 through welding, and provided with a main bearing 8 which supports the crankshaft 9 rotatably.

[0026] An Oldham ring 10 is disposed between the back surface side of the orbiting scroll 6 and the frame 7. The Oldham ring 10 is fitted in the grooves formed in the back surface side of the orbiting scroll 6 and in the frame 7 so that the orbiting scroll 6 revolves in association with eccentric rotation of the eccentric pin 9b of the crankshaft 9 while being kept from rotating.

[0027] The electric motor 3 includes a stator 3a and a rotor 3b. The stator 3a is secured to the closed vessel through press fitting, shrink fitting and the like. The rotor 3b is rotatably disposed at the inner side of the stator 3a. The rotor 3b is secured to the crankshaft 9, through which the orbiting scroll 6 is operated by rotation of the rotor 3b.

[0028] The crankshaft 9 includes a main shaft 9a and an eccentric pin 9b, which is supported with a main bearing 8 and a sub bearing 11. The eccentric pin 9b is integrally formed

with the crankshaft 9a with eccentricity therebetween, and is inserted into an orbiting bearing 6d formed on the back surface of the orbiting scroll 6. The crankshaft 9 is driven by the electric motor 3, and the eccentric pin 9b eccentrically rotates with respect to the main shaft 9a so that the orbiting scroll 6 is driven. The crankshaft 9 includes an oil passage 9c formed therein for guiding the lubricant to the main bearing 8, the sub bearing 11 and the orbiting bearing 6d. A pump 14 is disposed at the lower end of the oil sump 15 for drawing the lubricant so as to be guided into the oil passage 9c. The sub bearing 11 is secured to the closed vessel 4 via a housing 12 and a lower frame 13. The sub bearing 11 rotatably retains one end of the main shaft 9a of the crankshaft at the side of the oil sump using a slide bearing, a roll bearing, a spherical bearing member and the like.

[0029] As the orbiting scroll 6 is orbitally operated via the crankshaft 9 driven by the electric motor 3, wraps of both the orbiting scroll 6 and the fixed scroll 5 are meshed with each other so that two differently sized compression chambers (compression chamber at inner line side, compression chamber at outer line side) are generated alternately with phase difference at 180°. The work fluid such as refrigerant gas is introduced from the intake pipe 4d into the compression chambers 16 defined by the orbiting scroll 6 and the fixed scroll 5. The refrigerant gas has its volume reduced toward the center of the scroll for compression. The compressed refrigerant gas is discharged from the discharge port 5d formed in the upper center of the fixed-side plate 5b of the fixed scroll 5 into the discharge pressure space 4f in the closed vessel 4. The gas then circulates around the compression mechanism part 2 and the electric motor 3, and flows to the outside from the discharge pipe 4e. The space within the closed vessel 4 serves as so called high pressure chamber compressor where the discharge pressure is held.

[0030] The oil path for the lubricant will be described. A back pressure chamber 17 is formed between the back surface side of the orbiting scroll 6 and the frame 7, where the pressure is kept to the intermediate level between the pressure inside the intake pipe 4d and the pressure in the discharge pressure space 4f. The back pressure chamber 17 is disposed on the path through which the lubricant is fed to the sliding part of the compression mechanism part 2 after passing through the oil passage 9c from the oil sump 15 for lubricating the orbiting bearing 6d. The flat plate 6b of the orbiting scroll 6 has a back pressure hole 6c for intermittently communicating the compression chamber 16 and the back pressure chamber 17 formed on the back surface of the orbiting scroll so that the pressure in the back pressure chamber 17 is kept to the intermediate level (hereinafter referred to as the back pressure) between the intake pressure and the discharge pressure. The resultant force of the back pressure and the discharge pressure applied to the space at the center on the inner peripheral side of a seal member 18 allows the orbiting scroll 6 to be pressed against the fixed scroll 5 from the back surface.

[0031] Then pressure deformation of the compression mechanism part 2, which occurs upon operation of the compressor, will be described.

[0032] FIG. 3 schematically shows the pressure deformation of the compression mechanism part 2 of the scroll compressor. As the drawing shows, the section above the fixed scroll 5 faces the discharge pressure space 4f so that the discharge pressure is applied to the upper surface of the fixed scroll 5. As the back surface of the orbiting scroll 6 faces the

back pressure chamber 17, the back pressure is applied to the back surface of the orbiting scroll 6 which is pushed upward (side of the fixed scroll 5).

[0033] As the scroll compressor shown in FIG. 3 is configured that the fixed scroll 5 has the outer edge of the fixed-side plate 5b secured to the closed vessel 4, it will be deformed into the convex shape directed downward as a whole (orbiting scroll side). As the orbiting scroll 6 is pushed against the fixed scroll 5 downwardly deformed into the convex shape, the respective wrap tooth tips (fixed-side wrap tooth tip 5e, orbiting-side wrap tooth tip 6e) at the center of both scrolls are brought into contact with the respective wrap tooth bottoms (fixed-side wrap tooth bottom 5f, orbiting-side wrap tooth bottom 6f) one another. Each of the fixed scroll 5 and the orbiting scroll 6 has the center part downwardly deformed into the convex shape as a whole along the deformation of the fixed scroll 5. Especially in the high-pressure ratio condition, the maximum displacement at the wrap center becomes further large, which makes each contact of the center between the fixed-side wrap tooth tip 5e and the orbiting-side wrap tooth bottom 6f, and between the fixed-side wrap tooth bottom 5f and the orbiting-side wrap tooth tip 6e excessively strong. In order to suppress the friction loss and wrap breakage owing to the excessive contact, the tooth bottom step which becomes deeper from the outer side to the center is formed on each tooth bottom of the orbiting scroll 6 and the fixed scroll 5 (fixed-side wrap tooth bottom 5f, orbiting-side wrap tooth bottom 6f), respectively. It is assumed that the tooth bottom step becomes deeper as the distance increases between the tooth bottom (fixed-side wrap tooth bottom 5f, orbiting-side wrap tooth bottom 6f) and the opposite tooth tip (fixed-side wrap tooth tip 5e, orbiting-side wrap tooth tip 6e).

[0034] Features of structures of the steps on the respective wrap tooth bottoms (fixed-side wrap tooth bottom 5f, orbiting-side wrap tooth bottom 6f) will be described.

[0035] FIG. 4 shows the orbiting scroll 6 and the fixed scroll 5 of the scroll compressor 1 as top views. FIG. 5 schematically represents the relationship between the wrap tooth tip and the tooth bottom seen from the direction of the wrap circumferential side. Referring to FIG. 4(1), the step of the orbiting-side wrap tooth bottom 6f of the orbiting scroll 6 is set to change its depth from the part (c) as the reference depth at the outermost periphery to the part (b) along the inner periphery, and further to the part (a) sequentially. In other words, the step is formed so that the part (a) at the innermost periphery becomes the deepest, and the part (c) at the outermost periphery becomes the shallowest.

[0036] Referring to FIG. 4(2), like the orbiting-side wrap tooth bottom 6f shown in FIG. 4(1), the step of the fixed-side wrap tooth bottom 5f of the fixed scroll 5 is set to change its depth from the part (c) as the reference depth to the part (b) along the inner periphery, and further to the part (a) sequentially. The steps of the orbiting scroll 6 and the fixed scroll 5 are set to have each depth equally changed. In other words, the step is formed so that the part (a) at the innermost periphery is the deepest, and the part (c) at the outermost periphery is the shallowest.

[0037] Referring to FIG. 5, the above-described step on the orbiting-side wrap tooth bottom 6f is set so that the depth is changed from the part (c) as the reference at the outermost periphery to the part (b) along the inner periphery, and further to the part (a) sequentially. Specifically, the part (a) is formed to have the depth different from the part (c) by approximately 0.02% to 0.04% of the orbiting-side wrap tooth height 6h, the

part (b) is formed to have the depth different from the part (c) by approximately 0.005% to 0.02% of the orbiting-side wrap tooth height 6h, and the part (c) is formed to have the depth of approximately 0.00% to 0.03% of the orbiting-side wrap tooth height 6h with respect to the orbiting-side mirror plate surface 6g shown in FIG. 2. The orbiting-side wrap tooth height 6h denotes the length from the orbiting-side mirror plate surface 6g to the orbiting-side wrap tooth tip 6e of the orbiting-side wrap 6a as shown in FIG. 2.

[0038] Meanwhile, the step on the fixed-side wrap tooth bottom 5f is set so that the depth is changed from the part (c) as the reference at the outermost periphery to the part (b) along the inner periphery, and further to the part (a) sequentially. Like the case as described above, the part (a) is formed to have the depth different from the part (c) by 0.02% to 0.04% of the fixed-side wrap tooth height 5h, the part (b) is formed to have the depth different from the part (c) by approximately 0.005% to 0.02% of the fixed-side wrap tooth height 5h, and the part (c) is formed to have the depth different from the fixed-side wrap tooth height 5h by the amount corresponding to the fixed-side mirror plate surface 5g shown in FIG. 2. The fixed-side wrap tooth height 5h in this case denotes the length from the fixed-side mirror plate surface 5g to the fixed-side wrap tooth tip 5e of the fixed-side wrap 5a.

[0039] Upon application of pressure and heat of the work fluid to the compression mechanism part 2 through the driven scroll compressor 1, the structure shown in FIGS. 4 and 5 serves to prevent excessive contact between the fixed-side wrap tooth bottom 5f and the orbiting-side wrap tooth tip 6e, or between the orbiting-side wrap tooth bottom 6f and the fixed-side wrap tooth tip 5e, and to ensure suppression of increase in the input by friction and improvement of reliability with respect to the wrap strength.

[0040] The scroll compressor with the structure shown in FIGS. 4 and 5 is configured that each difference in the tooth bottom steps formed on the fixed-side wrap tooth bottom 5f and the orbiting-side wrap tooth bottom 6f is equally set, resulting in unnecessary gap under the condition of maximum wrap deformation. Examinations made by the inventors have revealed the problem that under the operating condition (condition of low-speed and low-pressure ratio) of small wrap deformation, the step formed on the tooth bottom will further generate the gap, through which the refrigerant leaks between the compression chambers, resulting in the loss.

[0041] Features of the scroll compressor will be described referring to FIGS. 4 and 6 hereinafter as an embodiment for preventing increase in the loss caused by leakage of the refrigerant through the gap between the wrap tooth tip and the wrap tooth bottom.

[0042] As FIG. 4 shows, the orbiting-side wrap tooth bottom 6f and the fixed-side wrap tooth bottom 5f are formed on the wrap-forming surface of the orbiting-side plate 6b of the orbiting scroll 6 and the wrap-forming surface of the fixed-side plate 5b of the fixed scroll 5, respectively so that each step becomes deeper from the outer periphery toward the inner periphery.

[0043] FIG. 6 shows each depth of the orbiting-side wrap tooth bottom 6f and the fixed-side wrap tooth bottom 5f according to the embodiment. As for the structure described referring to FIG. 5, the step difference between the part (a) and the part (c) of the orbiting-side wrap tooth bottom 6f, and the step difference between the part (a) and the part (c) of the fixed-side wrap tooth bottom 5f are equally set by the depth ranging from 0.02% to 0.04% of the corresponding wrap

tooth height. The step difference between the part (b) and the part (c) of the orbiting-side wrap tooth bottom **6f**, and the step difference between the part (b) and the part (c) of the fixed-side wrap tooth bottom **5f** are equally set by the depth ranging from 0.005% to 0.02% of the corresponding wrap tooth height.

[0044] Meanwhile, as for the structure according to the embodiment shown in FIG. 6, the step difference between the part (a) and the part (c) of the orbiting-side wrap tooth bottom **6f** is made smaller than the step difference between the part (a) and the part (c) of the fixed-side wrap tooth bottom **5f**. Specifically, the step difference between the part (a) and the part (c) of the orbiting-side wrap tooth bottom **6f** is formed to have the resultant depth ranging from 0.005% to 0.02% of the orbiting-side wrap tooth height **6h**. Then it is made smaller than the step difference between the part (a) and the part (c) of the fixed-side wrap tooth bottom **5f** (0.02% to 0.04% of the fixed-side wrap tooth height **5h**).

[0045] Assuming that the gap between the fixed-side wrap tooth tip **5e** and the orbiting-side wrap tooth bottom **6f** is referred to as hs , and the gap between the fixed-side wrap tooth bottom **5f** and the orbiting-side wrap tooth tip **6e** is referred to as hk , the relationship of $hs=hk$ is established as shown in FIG. 5. Assuming that the step difference between the part (a) and the part (c) of the orbiting-side wrap tooth bottom **6f** is referred to as Ds , and the step difference between the part (a) and the part (c) of the fixed-side wrap tooth bottom **5f** is referred to as Dk , the relationship of $Ds=Dk$ is established as shown in FIG. 5.

[0046] Meanwhile, referring to FIG. 6, assuming that the gap between the fixed-side wrap tooth tip **5e** and the orbiting-side wrap tooth bottom **6f** is defined as hs' , and the gap between the fixed-side wrap tooth bottom **5f** and the orbiting-side wrap tooth tip **6e** is defined as hk , the relationship of $hk>hs$ is established as shown in FIG. 6. Assuming that the step difference between the part (a) and the part (c) of the orbiting-side wrap tooth bottom **6f** is defined as Ds' , and the step difference between the part (a) and the part (c) of the fixed-side wrap tooth bottom **5f** is defined as Dk , the relationship of $Dk>Ds'$ is established.

[0047] Each difference in the tooth bottom steps of the orbiting scroll **6** and the fixed scroll **5** is individually set in consideration of the applied pressure and thermal deformation which may occur in the orbiting scroll and the fixed scroll. As a result, the inner peripheral step difference Ds' (depth) of the orbiting-side wrap tooth bottom **6f** is made smaller than the inner peripheral step difference Dk (depth) of the fixed-side wrap tooth bottom **5f** so as to improve sealability by eliminating the unnecessary gap, and to suppress the loss caused by leakage of the refrigerant through the gap between the wrap tooth tip and the tooth bottom.

[0048] In the case where the scroll compressor employs the refrigerant as the work fluid especially with lower density than the R410A refrigerant, for example, an R32 refrigerant, it can be assumed that such refrigerant is likely to leak between the adjacent compression chambers because of low density. The R32 refrigerant as the high-temperature refrigerant may have its temperature high during operation. It can be assumed that the gap between the wrap tooth tip and the wrap tooth bottom is widened owing to thermal expansion. The embodiment is configured to have the tooth bottom step that allows suppression of the loss caused by leakage of the refrigerant through the gap between the wrap tooth tip and the tooth bottom. This makes it possible to provide the high-

performance scroll compressor even in the case where the single R32 refrigerant is only employed, or it is filled into the refrigeration cycle at a rate of 70% or higher.

Second Embodiment

[0049] A second embodiment of the scroll compressor according to the present invention will be described.

[0050] FIG. 7 schematically shows the structure as the view seen from the direction of the circumferential side of the wrap, representing the relationship between the wrap tooth tip and the tooth bottom. The second embodiment has the same structures as those of the first embodiment except the planar shape to be formed on the opposite surfaces of the wraps of the orbiting scroll **6** and the fixed scroll **5**. Explanations of the components with the same functions will be omitted.

[0051] Referring to FIG. 7, in this embodiment, each of the parts (b) and (a) of the orbiting-side wrap tooth bottom **6f** of the scroll compressor as shown in FIG. 5 has the same depth so that the orbiting-side wrap tooth bottom **6f** has two steps to eliminate the gap between the orbiting-side wrap tooth bottom **6f** at the winding start side as the deepest position and the fixed-side wrap tooth tip **5e**. In other words, the fixed-side wrap tooth bottom **5f** has two steps, and the orbiting-side wrap tooth bottom **6f** has the single step so that the innermost peripheral step difference Dk of the fixed-side wrap tooth bottom **5f** is made deeper than the inner peripheral step difference Ds' of the orbiting-side wrap tooth bottom **6f**. It has been confirmed that the loss may be reduced by making the depth Ds' of the inner peripheral step of the orbiting-side wrap tooth bottom **6f** substantially the same as the depth (at the part (b) at the second deepest position of the fixed-side wrap tooth bottom **5f**).

[0052] This embodiment provides the similar advantageous effects to those derived from the first embodiment. The embodiment is capable of reducing the manufacturing cost and time by decreasing man-hours for machining the steps decreased in comparison with the first embodiment. This embodiment is configured that the stepped portion from the part (b) to the part (c) is made perpendicular to the fixed-side wrap tooth tip **5e** as shown in FIG. 7. Besides the configuration as described above, it is possible to form the slope which inclines from the part (b) to the part (c) so as to change the depth smoothly. This makes it possible to reduce leakage of the refrigerant through the gap generated at the part (c) of the step. The circumferential step of the orbiting-side wrap tooth bottom **6f** may be easily subjected to high-precision machining with the end mill. The aforementioned structure of this embodiment is applicable to any of the embodiments.

Third Embodiment

[0053] A third embodiment of the scroll compressor according to the present invention will be described.

[0054] FIG. 8 schematically shows the structure as the view seen from the direction of the circumferential side of the wrap, representing the relationship between the wrap tooth tip and the tooth bottom. This embodiment has the same structures as those of the first embodiment except the planar shape to be formed on the opposite surfaces of the wraps of the orbiting scroll **6** and the fixed scroll **5**. Explanations of the components with the same functions will be omitted.

[0055] Referring to FIG. 8, in this embodiment, the orbiting-side wrap tooth bottom **6f** has two steps in the second embodiment shown in FIG. 7 so that the relationship of the

depth at the part (a) of the shallow orbiting-side wrap tooth bottom 6f with the depth at the part (a) of the fixed-side wrap tooth bottom 5f is expressed by $Ds=1/2Dk$. In other words, as FIG. 8 shows, the depth Ds' as the step difference at the innermost periphery of the orbiting-side wrap tooth bottom 6f is approximately half the depth of the step difference Dk as the deepest part of the fixed-side wrap tooth bottom 5f.

[0056] It has been confirmed that the aforementioned structure prevents contact with the wrap tooth tip, and reduces the loss. This embodiment also provides substantially the same advantageous effects as those of the first or the second embodiment. As the depth of the tooth bottom at the orbiting scroll side is set to be half the depth of the tooth bottom at the fixed scroll side, the cutting amount through machining may be reduced, thus decreasing the machining time and prolonging life of the tool.

Fourth Embodiment

[0057] A fourth embodiment of the scroll compressor according to the present invention will be described.

[0058] This embodiment has the same structures as those of the first to the third embodiments except the use of the ferrite magnet electric motor formed by embedding the ferrite magnet in the rotor of the electric motor 3 of the scroll compressor. Explanations of the components with the same functions will be omitted.

[0059] As the ferrite magnet motor is less expensive than the neodymium magnet motor, the compressor that employs the ferrite magnet motor is expected to greatly reduce the cost. However, the use of the ferrite magnet motor has the problem of lower efficiency especially in the low speed region compared with the neodymium magnet motor. Application of the first to the fourth embodiments allows the step size (depth) of the tooth bottom 6f of the orbiting scroll 6 to be smaller than the step size (depth) of the tooth bottom 5f of the fixed scroll 5. This makes it possible to improve sealability, and reduce the loss caused by leakage of the refrigerant through the gap between the wrap tooth tip and the tooth bottom, providing the highly efficient scroll compressor at a low cost even in the low-speed region.

Fifth Embodiment

[0060] A sixth embodiment of the scroll compressor according to the present invention will be described.

[0061] This embodiment has the same structures as those of the first to the fourth embodiments except employment of only the single R32 refrigerant in the scroll compressor. Explanations of the components with the same functions will be omitted.

[0062] The global warming potential (GWP) of the R32 refrigerant is 675 which is approximately one third of the R410A, thus delivering less burden on the environment. Compared with the refrigerant such as the R410A, it exhibits lower density, and is likely to leak from the sealed space. Furthermore, the use of the R32 refrigerant may increase the operation temperature, which tends to deform the wrap under the thermal influence, thus widening the gap between the tooth tip and the tooth bottom.

[0063] The single R32 refrigerant is only employed or filled into the refrigeration cycle at a rate of approximately 70% or higher through application of the first to the fourth embodiments. Then the step size (depth) of the tooth bottom 6f of the orbiting scroll 6 is made smaller than the step size (depth) of

the tooth bottom 5f of the fixed scroll 5 so as to improve sealability by eliminating the unnecessary gap, and to reduce the loss caused by leakage of the refrigerant from the gap between the wrap tooth tip and the tooth bottom. This makes it possible to provide the highly efficient scroll compressor while using the refrigerant with a small environmental load.

LIST OF REFERENCE SIGNS

- [0064] 1: scroll compressor
- [0065] 2: compression mechanism part
- [0066] 3: electric motor (3a: rotor, 3b: stator)
- [0067] 4: closed vessel (4a: cylindrical chamber, 4b: lid cap,
- [0068] 4c: bottom cap, 4d: intake pipe, 4e: discharge pipe, 4f: discharge space)
- [0069] 5: fixed scroll (5a: fixed-side wrap, 5b: fixed-side plate, 5c: intake port, 5d: discharge port, 5e: fixed-side wrap tooth tip, 5f: fixed-side wrap tooth bottom, 5g: fixed-side mirror plate surface, 5h: fixed-side wrap tooth height)
- [0070] 6: orbiting scroll. (6a: orbiting-side wrap, 6b: orbiting-side plate, 6c: back pressure hole, 6d: orbiting bearing, 6e: orbiting-side wrap tooth tip, 6f: orbiting-side wrap tooth bottom, 6g: orbiting-side mirror plate surface, 6h: orbiting-side wrap tooth height)
- [0071] 7: frame
- [0072] 8: main bearing
- [0073] 9: crankshaft (9a: main shaft, 9b: eccentric pin, 9c: oil passage)
- [0074] 10: Oldham ring
- [0075] 11: sub bearing
- [0076] 12: housing
- [0077] 13: lower frame
- [0078] 14: pump
- [0079] 15: oil sump
- [0080] 16: compression chamber
- [0081] 17: back pressure chamber

1. A scroll compressor comprising:

a fixed scroll including a fixed-side plate and a fixed-side wrap standing on one surface of the fixed-side plate while retaining a spiral shape;

an orbiting scroll including an orbiting-side plate, and an orbiting-side wrap standing on one surface of the orbiting-side plate while retaining a spiral shape, which allows the orbiting-side wrap to be in mesh with the fixed-side wrap for orbiting with respect to the fixed scroll to form a compression chamber; and

an electric motor for driving the orbiting scroll via a crankshaft,

wherein each tooth bottom of the fixed-side wrap and the orbiting-side wrap has a step formed to become deeper from an outer periphery to an inner periphery; and the step is formed on the tooth bottom of the fixed-side wrap at the inner periphery so as to be deeper than the step formed on the tooth bottom of the orbiting-side wrap at the inner periphery.

2. The scroll compressor according to claim 1,

wherein two steps are formed on the tooth bottom of the fixed-side wrap;

one step is formed on the tooth bottom of the orbiting-side wrap; and

the fixed-side wrap has the step formed on the tooth bottom at the innermost periphery deeper than the step formed on the tooth bottom of the orbiting-side wrap at the inner periphery.

3. The scroll compressor according to claim 2, wherein the step formed on the tooth bottom of the orbiting-side wrap at the inner periphery has substantially the same depth as the depth of the second deepest step formed on the tooth bottom of the fixed-side wrap.

4. The scroll compressor according to claim 1, wherein the step formed on the tooth bottom of the orbiting-side wrap at the innermost periphery has the depth substantially half the depth of the deepest step formed on the tooth bottom of the fixed-side wrap.

5. The scroll compressor according to claim 1, wherein the step formed on the tooth bottom of the orbiting-side wrap at the innermost periphery has the depth ranging from 0.005% to 0.02% of an orbiting-side wrap tooth height $6h$.

6. The scroll compressor according to claim 1, wherein the electric motor including a stator and a rotor is configured as a ferrite magnet electric motor having a ferrite magnet embedded in the rotor.

7. The scroll compressor according to claim 1, wherein an R32 refrigerant is only filled into a refrigeration cycle, or filled into the refrigeration cycle at a rate of approximately 70% or higher.

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