

Description

[0001] The present invention relates to variable displacement compressors that may be used for vehicle air conditioning systems. The present invention also relates to methods for manufacturing such compressors.

[0002] As shown in FIG. 8, Japanese Laid-open Patent Publication No. 11-264371, which corresponds to US Patent No. 6,276,904, teaches a variable displacement compressor 100 having one-head pistons. The compressor 100 includes a drive shaft 101 that is rotatably driven by a vehicle engine (not shown) via a clutch (not shown). A swash plate 102 is slidably mounted on the drive shaft 101 and is inclined relative to the drive shaft 101. Rotation of the drive shaft 101 is transmitted to the swash plate 102 via a rotor 103 and a hinge mechanism 104. The rotor 103 is fixedly mounted on the drive shaft 101. A piston 106 is connected to the swash plate 102 via a shoe 105, so that the piston 106 can reciprocate within a cylinder bore 107 in order to draw a refrigerant gas into the cylinder bore 107 and then compress and discharge the refrigerant gas. The inclination angle of the swash plate 102 can be changed by sliding or pivoting about the drive shaft 101, so that the stroke length of the piston 106 can be varied in order to adjust the intake and discharge volume of the refrigerant gas.

[0003] The rotor 103 includes a base 108, supporting arms 109 and a counterweight 110. These parts are manufactured as a single, integral piece using a casting process. The base 108 is mounted on the drive shaft 101. The supporting arms 109 are included within the hinge mechanism 104 that also serves as a torque transmission mechanism. The counterweight 110 serves to balance the weight of the rotor 103 such that the center of gravity of the rotor 103 is positioned on the rotational axis of the drive shaft 101. The hinge mechanism 104 further includes a hinge pin 111 that is mounted on the swash plate 102.

[0004] It is one object of the present teachings to provide improved variable replacement compressors that can reduce material costs and manufacturing costs. It is another object of the present teachings to provide an alternative design for the above-described known compressor.

[0005] In one aspect of the present teachings, variable displacement compressors are taught that include a rotor that has been press-formed from a plate or plate material. The rotor may be fixedly mounted on a drive shaft and may be coupled to a swash plate via a hinge device. The rotor optionally may define a portion of the hinge device. Further, the hinge device preferably permits the swash plate to rotate with the rotor as well as the drive shaft. The hinge device also may permit the swash plate to change its inclination angle relative to the rotor as well as the drive shaft. The swash plate may be coupled to a piston that slidably disposed within a cylinder bore. Naturally, such compressors may include a plurality of pistons coupled to the swash plate and each

piston may be reciprocally disposed in a respective cylinder bore. During operation of the compressor, the piston(s) may reciprocate within the cylinder bore(s) in order to compress a refrigerant gas (cooling medium).

[0006] In one embodiment of the present teachings, the rotor may be formed from a flat plate, e.g., a cold-rolled steel plate or a plate made of SC steel, e.g., S35C and S45C. The rotor may be formed from such a plate by punching (and/or perforating), bending and squeezing the plate. For example, the plate may be punched to form an intermediate product that has a predetermined outer contour. The intermediate product may, e.g., include a base portion, a counterweight and support arms (link portion) that are formed integrally with each other.

[0007] The intermediate product may be perforated at the same time or before the punching operation so as to provide perforations and an axial hole. The intermediate product may then be further processed to obtain a finished rotor. For example, the support arms may be bent to have a suitable configuration for connecting to the swash plate. In addition, the hinge device may preferably include the support arms and the support arms may cooperate with a hinge pin. The hinge pin may be mounted on the swash plate. Furthermore, the peripheral portion of the axial hole may be squeezed to form a boss portion having an insertion hole and the drive shaft may be fixedly fitted within the insertion hole. The counterweight and the perforations may serve to adjust the center of gravity of the entire rotor such that the center of gravity is positioned on the rotational axis of the rotor. The rotational axis of the rotor preferably aligned with the rotational axis of the drive shaft.

[0008] If the plate is press-formed according to the present teachings in order to form a one-piece rotor, the rotor may have improved strength and may be lightweight in comparison with the above-described cast-formed rotor. In addition, a cast-formed rotor may include excess projections that are typically formed due to the casting process. However, the press-formed rotor naturally will not include such excess projections, thereby ensuring that the rotor has the correct (desired) weight. Further, it is typically necessary to cut or finish a cast-formed rotor after casting in order to eliminate such excess projections. However, if the rotor is formed using a press-forming process, no cutting operations (or only minimal cutting operations) will be required to obtain a finish rotor. Furthermore, it is not necessary to join separate parts in order to manufacture press-formed rotors according to the present teachings. Therefore, manufacturing costs and manufacture time may be reduced as compared to known cast-formed rotors.

[0009] In another aspect of the present teachings, methods for manufacturing variable displacement compressors are taught that may include press-forming a plate in order to form a rotor. The press-forming operation may include punching (and/or perforating), bending and squeezing the plate. According to the present meth-

ods, lightweight, one-piece rotors can be manufactured at lower costs.

[0010] Additional objects, features and advantages of the present invention will be readily understood after reading the following detailed description together with the claims and the accompanying drawings, in which:

FIG. 1 is a vertical cross-sectional view of a representative variable displacement compressor;
 FIG. 2 is a front view of a representative rotor;
 FIGS. 3(A) to 3(G) are views illustrating various representative steps for manufacturing the representative rotor,
 FIG. 4 is a front view of an alternative hinge device that may be utilized with the representative compressor;
 FIG. 5 is a plan view of the hinge device of FIG. 4;
 FIG. 6 is a front view of another alternative hinge device that may be utilized with the representative compressor;
 FIG. 7 is a plan view of the hinge device of FIG. 6; and
 FIG. 8 is a vertical, cross-sectional view of a known variable displacement compressor.

[0011] In one embodiment of the present teachings, variable displacement compressors may include a swash plate that is mounted on a drive shaft in an inclined position relative to the drive shaft. A piston may be coupled to the swash plate, so that the piston reciprocates within a cylinder bore as the swash plate rotates. A rotor may be fixed to the drive shaft. A hinge device may be disposed between the rotor and the swash plate. Optionally, the rotor may define a portion of the hinge device. Further, the hinge device preferably connects the rotor to the swash plate in order to permit the swash plate to change its inclination angle relative to the drive shaft when the rotor causes the swash plate to rotate. The stroke length of the piston may be varied in response to changes in the inclination angle of the swash plate. The rotor may be press-formed from a plate and may include a base portion and support arms formed integrally with the base portion. Further, the base portion may be fixed to the drive shaft and the support arms may constitute an element of the hinge device.

[0012] Therefore, by appropriately choosing the plate material that is utilized to form the rotor, the rotor may have increased strength and may be lighter in weight than known rotors. In addition, the press-formed rotor also may be formed to have the correct weight during the press-forming step, because it will not be necessary to remove excess projections that are typically formed using a casting process. Further, because the rotor is press-formed from a plate, post-pressing cutting operations can be reduced or eliminated, as compared to cast-formed rotors, thereby reducing manufacturing time and manufacturing costs. Furthermore, if it is not necessary to join separate parts in order to manufacture

the press-formed rotor (i.e., a one-piece rotor is manufactured directly from the plate), production efficiency may be improved.

[0013] In another embodiment of the present teachings, a counterbalancing device may adjust the center of gravity of the rotor so as to position the center of gravity at the rotational axis of the rotor. Thus, the counterweight device may be utilized in order to ensure that the rotor rotates in a stable manner.

[0014] In another embodiment of the present teachings, the support arms may be bent by a predetermined angle relative to a flat surface of the base portion. In this case, at least a portion of the support arms is positioned within a plane that projects from the base portion, which plane preferably is substantially perpendicular to the axial direction of the drive shaft. Therefore, the rotor may have a compact construction with respect to its diametrical direction. If the hinge device also includes a hinge pin that engages the support arms, the degree of freedom in determining the relative position between the support arms and the hinge pin may be improved.

[0015] In another embodiment of the present teachings, the counterbalancing device may include at least one perforation formed in the base portion. Therefore, the center of gravity of the rotor can be easily adjusted by appropriately setting the position, configuration or the size of the perforation(s). In addition, the weight of the entire rotor can be reduced by providing the perforation(s).

[0016] In another embodiment of the present teachings, the counterbalancing device may include a counterweight disposed on the base portion. The counterweight may be positioned opposite to the support arms with respect to the rotational axis. Therefore, the center of gravity of the rotor can be easily adjusted by appropriately selecting the configuration, weight and/or the size of the counterweight. Such a counterweight may be formed by various methods. For example, the counterweight optionally may be formed by extending the outer periphery of the base portion, by increasing the thickness of the outer peripheral portion of the base portion, or by folding the outer peripheral portion of the base portion.

[0017] In another embodiment of the present teachings, methods for forming a variable displacement compressor may include press-forming a single plate or plate material in order to form the rotor. The rotor preferably includes a base portion integrally attached to one or more support arms. The base portion may then be fixedly coupled to the drive shaft. The support arms optionally may constitute an element of the hinge device. The press forming step may include punching (including perforating), bending and squeezing the plate. Therefore, the rotor can be easily manufactured at lower costs as compared to cast-formed rotors. In addition, because the plate can be formed into a substantially finished rotor by the press-forming operation, post-pressing cutting operations can be reduced or eliminated. Further, be-

cause the support arms may be formed integrally with the base portion, the rotor may be formed as a one-piece element. Therefore, the number of steps for manufacturing the rotor can be reduced in comparison with known rotor manufacturing steps, in which parts of the rotor are formed separately from each other and thereafter are joined to each other.

[0018] Each of the additional features and teachings disclosed above and below may be utilized separately or in conjunction with other features and teachings to provide improved variable displacement compressors and methods for designing and manufacturing such compressors. A representative example of the present invention, which example utilizes many of these additional features and teachings both separately and in conjunction, will now be described in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of skill in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detail description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Moreover, various features of the representative example and the dependent claims may be combined in ways that are not specifically enumerated in order to provide additional useful embodiments of the present teachings.

[0019] A representative variable displacement compressor 30 of the present teachings will now be described in further detail with reference to the drawings. Referring to FIGS. 1 to 3, the variable displacement compressor 30 may comprise a housing and the housing generally may include, e.g., a front housing 1, a cylinder block 2 and a rear housing 3. The front housing 1 may be joined to the front end (left end as viewed in FIG. 1) of the cylinder block 2. The rear housing 3 may be joined to the rear end of the cylinder block 2 via a valve plate 4. Naturally, other housing configurations may be suitably utilized with the present teachings.

[0020] A crank housing 5 may be defined by and within the front housing 1 and the cylinder block 2. A drive shaft 6 may extend through the crank housing 5. The front portion of the drive shaft 6 may be rotatably supported by the front housing 1 and the rear portion of the drive shaft 6 may be rotatably supported by the cylinder block 2. The drive shaft 6 may be coupled to an outside drive source, e.g., a vehicle engine (not shown), via a clutch mechanism, e.g., an electromagnetic clutch (not shown). Therefore, the drive shaft 6 may be rotatably driven by the drive source when the clutch is engaged.

[0021] A rotor 7 may be disposed within the crank chamber 5 and may be fixedly mounted on the drive shaft 6, so that the rotor 7 can rotate with the drive shaft 6. A swash plate 8 also may be disposed within the crank

chamber 5. Preferably, the swash plate 8 is slidably fitted onto the drive shaft 6 via an insertion hole 8a that is formed in the central portion of the swash plate 8. A hinge mechanism 20 may be interposed between the rotor 7 and the swash plate 8, so as to couple the rotor 7 to the swash plate 8. The hinge mechanism 20 may include support arms 23 and a hinge pin 9. The support arms 23 may be integrally formed with the rotor 7, as shown more clearly in FIG. 2. One or more slots or holes 26 may be defined within the support arms 23 and the hinge pin 9 may be disposed within the slot(s) 26. In addition, the hinge pin 9 may be mounted on the swash plate 8.

[0022] A plurality of cylinder bores 2a (only one cylinder bore is shown in the drawings for purposes of illustration) may be defined within the cylinder block 2 and may be positioned at predetermined intervals around a rotational axis L of the drive shaft 6. A rear side (right side portion as viewed in FIG. 1) of a piston 11 may be received within each of the cylinder bores 2a. The front end of the piston 11 may be connected to the peripheral portion of the swash plate 8 via a pair of shoes 12. In this case, the piston 11 can slide relative to the swash plate 8 in the rotational direction of the swash plate 8 but can move together with the swash plate 8 in the forward and rearward directions (i.e., left and right directions as viewed in FIG. 1). Therefore, the rotation of the drive shaft 6 may be transmitted to each piston 11 as reciprocating movement along the axial direction of the corresponding cylinder bore 2a, via the rotor 7, the hinge mechanism 20, the swash plate 8 and the corresponding shoes 12.

[0023] A suction chamber 3a and a plurality of discharge chambers 3b corresponding to the cylinder bores 2a may be defined within the rear housing 3 and may oppose the valve plate 4. Each of the cylinder bores 2a may communicate with the suction chamber 3a and the corresponding discharge chamber 3b via a suction port 4a and a discharge port 4c that are respectively defined within the valve plate 4. A suction valve 4b may be attached to the valve plate 4 and may serve to open and close the suction ports 4a. A discharge valve 4d also may be attached to the valve plate 4 and may serve to open and close the discharge ports 4c. Therefore, as the piston 11 moves from the upper dead center to the lower dead center, refrigerant gas within the suction chamber 3a will be drawn into the cylinder bore 2a via the suction port 4a and the suction valve 4b. Then, as the piston 11 moves from the lower dead center to the upper dead center, the refrigerant gas within the cylinder bore 2a may be compressed to a predetermined pressure and then may be discharged into the discharge chamber 3b through the discharge port 4c and the discharge valve 4d.

[0024] A bleed gas port 15 may be defined within the valve plate 4 and may permit the crank chamber 5 to communicate with the suction chamber 3a. A gas supply channel 16 may be defined through the cylinder block

2, the valve plate 4 and the rear housing 3. The gas supply channel 16 may permit the crank chamber 5 to communicate with the discharge chambers 3b. A displacement control valve 17 may be located within a portion of the gas supply channel 16. The displacement control valve 17 may preferably be an electromagnetic valve. The displacement control valve 17 may control the flow rate of the refrigerant gas flowing through the gas supply channel 16, so that the pressure within the crank chamber 5 can vary or change (i.e., increase or decrease). As the pressure within the crank chamber 5 is thus varied or changed, the difference between the pressure within the crank chamber 5 and the pressure within the cylinder bores 2a that may be applied to the front side and the rear side of each piston 11, respectively. As a result, the inclination angle of the swash plate 8 can be varied to effect a change in the stroke length of the pistons 11. In this manner, the discharge rate of the refrigerant gas can be adjusted during operation of the compressor.

[0025] The construction of the rotor 7 will now be further described with reference to FIGS. 1 and 2. In addition to the support arms 23, the rotor 7 may include a base portion 22 and a counterweight 24. The base portion 22 may be fixed to the drive shaft 6 and the counterweight 24 may serve to counterbalance the weight of the support arms 23. These portions 22, 23 and 24 may be formed integrally with each other by press-forming a cold-rolled steel plate or a plate made of SC steel, e.g., S35C and S45C in order to manufacture the rotor 7.

[0026] In one representative example, the base portion 22 may have a substantially disk-like configuration. A through-hole 22a may be formed in a central portion of the base portion 22. The drive shaft 6 may be inserted into the through-hole 22a and may be fixed in position relative to the base portion 22, so that the base portion 22 will rotate together with the drive shaft 6. The through-hole 22a may be formed within a boss portion 22c that is disposed at the central portion of the base portion 22 and extends rearward (rightward in FIG. 1) along the drive shaft 6. A thrust bearing 25 may be interposed between the front surface of the base portion 22 and the inner wall of the front housing 1. Preferably, the thrust bearing 25 may be arranged so as to surround, or substantially surround, the drive shaft 6. Therefore, when a reaction force is applied to the piston 11 during the compression operation, which force is caused by the reciprocating movement of the piston 11, the front housing 1 may receive this reaction force via the shoes 12, the swash plate 8, the hinge mechanism 20 and the thrust bearing 25.

[0027] The support arms 23 may be disposed at an uppermost position of the rear surface of the base portion 22, which position opposes to an upper dead center position D of the swash plate 8 that defines the top clearance of the piston 11. The support arms 23 may be positioned on the right and left sides of the rotational axis L of the drive shaft 6, as shown in FIG. 2. In addition,

the support arms 23 may be bent substantially perpendicular to and from right and left edges of the upper peripheral portion of the base portion 22, respectively. Further, rear ends of the support arms 23 may extend obliquely downward from the respective support arms 23, so that the support arms 23 may have substantially inverted V-shaped configurations. As a result, the support arms 23 may be positioned within a plane that projects from the base portion 22, which plane preferably is substantially perpendicular to the axial or longitudinal direction of the drive shaft 6. Therefore, the relative position between the support arms 23 and the hinge pin 9 can be easily set. In addition, the rotor 7 may have a compact size with regard to the diametrical direction. As noted above, elongated slots 26 may be defined within the rear ends of the support arms 23.

[0028] The counterweight 24 may be formed integrally with the lower portion of the rear side of the base portion 22. Because the support arms 23 are disposed on the upper side of the rotor 7, the center of gravity of the rotor 7 may be upwardly offset from the rotational axis L of the drive shaft 6. Therefore, the counterweight 24 may be positioned on the lower side of the rotor 7 that is the opposite side to the support arms 23 with respect to the rotational axis L. The center of gravity of the rotor 7 may be suitably adjusted, e.g., by modifying the outer configuration, by forming appropriate perforations and/or by changing the thickness of the rotor 7. Moreover, the peripheral portion of the rotor 7 may be bent. In the representative embodiment shown in the drawings, three perforations 27 are formed in the base portion 22 on the side adjacent to the support arms 23 of the base portion 22. Because no perforations are formed in the opposite side, the opposite side will have a greater weight. Naturally, the number, sizes, positions or other properties of the perforations 27 may be suitably determined in order to impart appropriate properties to the counterweight 24.

[0029] Thus, in this representative embodiment, the counterweight 24 and the perforations 27 of the rotor 7 may cooperate to provide a counterbalancing function. Therefore, the center of gravity of the rotor 7 may be positioned at the rotational axis of the rotor 7 (i.e., the rotational axis L of the drive shaft 6).

[0030] The hinge pin 9 that is an element on the other side of the rotor 7 will now be further described. As described above, the swash plate 8 may have a substantially disk-like configuration with the central insertion hole 8a. The insertion hole 8a may be configured such that the swash plate 8 can incline relative to the drive shaft 6. A projection 8b may be formed on the front surface of the swash plate 8 and may extend forwardly of the swash plate 8 toward the rotor 7. The hinge pin 9 may be mounted on the front end of the projection 8b and may extend substantially horizontally. The ends of the hinge pin 9 may slidably engage the respective slots 26 of the support arms 23. A slide guide for the swash plate 8 may be defined by the hinge pin 9 and the slots

26 of the support arms 23 and an axial slide support on the drive shaft 6 provided by the insertion hole 8a. Therefore, the swash plate 8 can incline relative to the drive shaft 6 while also sliding along the direction of the rotational axis L of the drive shaft 6.

[0031] A representative method for manufacturing the rotor 7 by press forming a plate will now be described with reference to FIGS. 3(A) to 3(C). For example, as an initial step, a flat plate W as shown in FIG. 3(A) may be prepared with a predetermined size and configuration, e.g. a square configuration. For example, the plate W may be made of cold-rolled steel or SC steel, e.g., S35C and S45C.

[0032] Then, as a second step, the plate W may be perforated or punched in order to obtain an intermediate product S, as shown in FIGS. 3(B) and 3(C). The intermediate product S may include, e.g., the base portion 22, the support arms 23 and the counterweight 24. A central, circular hole 22b may be defined within the base portion 22. The support arms 23 may extend substantially horizontally from the right and left sides of the upper portion of the base portion 22. The counterweight 24 may extend over substantially an angle of 180 along the lower portion of the base portion 22. The perforations 27 may be formed within base portion 22 in the upper portion on the side of the support arms 23. Further, after this second step, the intermediate product S may still have a flat configuration. In addition, this second step may be performed in a single step or may be a two-stage step in which the plate W is first formed with the predetermined outer contour and then the hole 22b and perforations 27 are separately formed.

[0033] Thereafter, a third step may be performed to squeeze (and expand) the peripheral portion of the central circular hole in order to form the boss portion 22c having the through hole 22a, as shown in FIGS. 3(D) and 3(E). In this case, the boss portion 22c will extend or project from the rear side of the base portion 22 by a predetermined distance, as shown in FIG. 3(E).

[0034] Finally, a fourth step may be performed to bend the support arms 23 in the direction toward the rear side of the base portion 22, as shown in FIGS. 3(F) and 3(G). Naturally, this four-step press-forming operation is merely one representative method for forming the rotor 7 and these steps may be augmented, eliminated or modified as appropriate.

[0035] In the intermediate product S shown in FIG. 3(B), the counterweight 24 may be formed to have a substantially semi-circular configuration around the rotational axis of the base portion 22. On the other hand, the support arms 23 extend outside beyond the arc line (indicated by chain lines) that is an extension of the outer contour of the counterweight 24. Cutouts S1 may be formed in the intermediate product S and may extend from predetermined peripheral points to a position adjacent to the base of the respective support arms 23. Therefore, the folding lines of the support arms 23 may be defined to extend adjacent to the extension line of

the outer contour of the counterweight 24, so that the support arms 23 can be easily bent. In addition, because the support arms 23 are configured to have inverted V-shaped configurations, the support arms 23 may extend toward the central portion of the base portion 22 and within the plane that projects from the base portion 22 and is substantially perpendicular to the rotational axis of the drive shaft 6. As a result, the required length of the support arms 23 for engaging the hinge pin 9 can be easily ensured.

[0036] Preferably, after press-forming the rotor 7, the sliding surfaces of the rotor 7, e.g., the inner surfaces of the slots 26 of the support arms 23 and the through hole 22a, and a contact surface 22b of the thrust bearing 25, optionally may be treated by a high-frequency hardening process or other processes in order to increase the strength and wear resistance of the rotor 7.

[0037] As described above, the rotor 7 (which may include the base portion 22, support arms 23 and the counterweight 24) may be integrally press-formed from a cold-rolled steel plate or a plate made of SC steel. Therefore, the rotor 7 may have improved strength and may be lightweight. In addition, the rotor 7 will not include excess projection(s) that result when a rotor is integrally formed using a casting process. This feature also ensures that the rotor 7 will be relatively lightweight.

[0038] In addition, the use of the plate as a material for the rotor 7 and the incorporation of the press-forming operation may reduce cutting operations and may reduce manufacturing time. Thus, manufacturing costs can be reduced.

[0039] Further, because the rotor 7 may be formed with a substantially finished configuration by press-forming and without the need for any additional operations, the number of cutting steps can be reduced. Furthermore, because the rotor 7 (e.g., the base portion 22, the support arms 23 and the counterweight 24) are formed into one piece, the number of rotor parts may be reduced to only one. Moreover, the number of manufacturing steps also may be reduced and it is not necessary to perform a joining or attaching step in order to manufacture a rotor having a plurality of parts.

[0040] The present teachings are not limited to the representative embodiment described above, but may be modified in various ways. For example, in an alternative embodiment shown in FIGS. 4 and 5, a hinge mechanism 20A that corresponds to the hinge mechanism 20 of the above representative embodiment may include substantially C-shaped support arms 23A that correspond to the support arms 23. A pair of hinge pins 9A may correspond to the hinge pin 9 mounted on the swash plate 8 and may include spherical ends 9A1 that slidably engage the respective support arms 23A. The chain lines in FIGS. 4 and 5 indicate the configuration of the support arms 23A before they are bent to have the C-shaped configurations. According to this arrangement, substantially the same operation and effects as the representative embodiment may be attained.

[0041] The above alternative embodiment may be further modified as shown in FIGS. 6 and 7. For example, cylindrical holes may be defined within support arms 23B and the cylindrical holes may slidably receive the spherical ends 9A1 of the hinge pins 9A. In this embodiment, the support arms 23B may be positioned on the upper side of the base portion 22 as indicated by chain lines in FIG. 6. According to this arrangement as well, substantially the same operation and effects as the representative embodiment may be attained.

[0042] Furthermore, in the representative embodiment, the combination of the counterweight 24 on the lower side of the base portion 22 and the perforations 27 formed in the base portion 22 performs the function of adjusting the center of gravity of the rotor 7. However, the counterweight 24 or the perforations 27 may be eliminated. Moreover, the counterweight 24 and the perforations 27 are not required to be disposed at a predetermined section of the rotor 7. However, the center of gravity of the entire rotor is preferably adjusted so as to be positioned at the rotational axis L.

[0043] Moreover, the bending directions and the positions of the support arms 23 (23A, 23B) may be suitably modified. For example, although the support arms 23 extend perpendicularly outward from the base portion 22 in the second step and are bent inward toward the rear surface of the base portion 22 in the fourth step in the above representative embodiment, support arms 23 may be formed by cutting lines, and then bending the cut portions. The cutting lines may be disposed inside of an imaginary arc line that is an extension of the outer contour of the counterweight 24 and the cutting lines preferably correspond to the contour of support arms 23.

Claims

1. A variable displacement compressor (30) comprising:

a drive shaft (6) having a rotational axis L,
 a press-formed rotor (7) having a base portion (22) and at least one support arm (23, 23A, 23B), the base portion being fixedly coupled to the drive shaft,
 a swash plate (8) pivotally mounted on the drive shaft in an inclined position relative to the drive shaft, the at least one support arm being coupled to the swash plate, wherein the inclination angle of the swash plate can change relative to the drive shaft when the rotor rotates with the swash plate, and
 a piston (11) coupled to the swash plate, whereby the piston reciprocates within a cylinder bore (2a) when the swash plate rotates, wherein the stroke length of the piston varies in response to changes in the inclination angle of the swash plate.

2. A variable displacement compressor as in claim 1, further including a counterbalancing device (24, 27) that is arranged and constructed to adjust the center of gravity of the rotor so as to position the center of gravity at the rotational axis of the rotor.
3. A variable displacement compressor as in claim 2, wherein the counterbalancing device includes at least one perforation (27) formed in the base portion.
4. A variable displacement compressor as in claim 2 or 3, wherein the counterbalancing device includes a counterweight (24) disposed on the base portion, the counterweight being positioned opposite to the support arm with respect to the rotational axis.
5. A variable displacement compressor as in any of claims 1-4, wherein the at least one support arm is bent relative to a planar surface of the base portion, such that the at least one support arm is substantially positioned within a plane that is (a) parallel or substantially parallel to the rotational axis L of the drive shaft and is (b) perpendicular, or substantially perpendicular, to the planar surface of the base portion.
6. A variable displacement compressor as in any of claims 1-5, wherein an elongated slot (26) is defined in the at least one support arm and a hinge pin (9) slidably couples the at least one support arm to the swash plate.
7. A method for making a variable displacement compressor (30), comprising:

press-forming a single plate (W) in order to form a rotor (7) having at least one support arm (23, 23A, 23B) integrally formed with a base portion (22),
 fixedly coupling the base portion to a drive shaft (6) of the variable displacement compressor, and
 slidably coupling the at least one support arm to a swash plate (8) of the variable displacement compressor, the swash plate being coupled to a piston (11) slidably received within a cylinder bore (2a).

8. A method as in claim 7, further including forming at least one perforation (27) in the base portion, the at least one perforation serving to adjust the center of gravity of the rotor.
9. A method as in claim 7 or 8, further including forming a counterbalance weight (24) on the base portion on the side opposite to the at least one support arm with respect to a rotational axis L of the drive

shaft.

10. A method as in any of claims 7-9, further including:

punching the plate in order to form the rotor with 5
two support arms (23, 23A, 23B) extending out-
wardly from the base portion, and
bending a base of each support arm proximal
to the base portion, wherein the support arms
are bent so as to be disposed in a plane that is 10
(a) parallel, or substantially parallel, to a rota-
tional axis L of the drive shaft and (b) perpen-
dicular, or substantially perpendicular to a pla-
nar surface of the rotor.

15

20

25

30

35

40

45

50

55

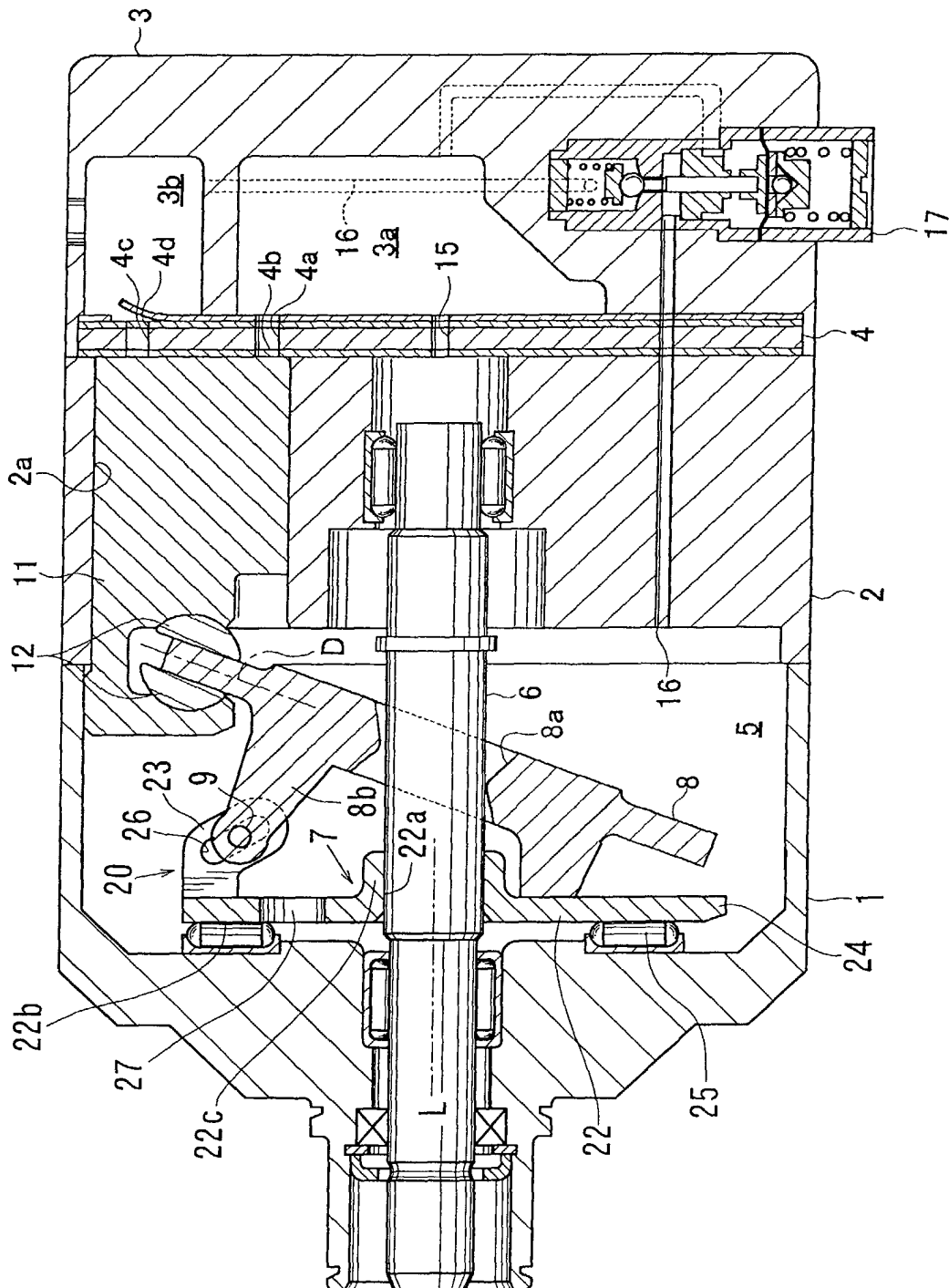


FIG. 1

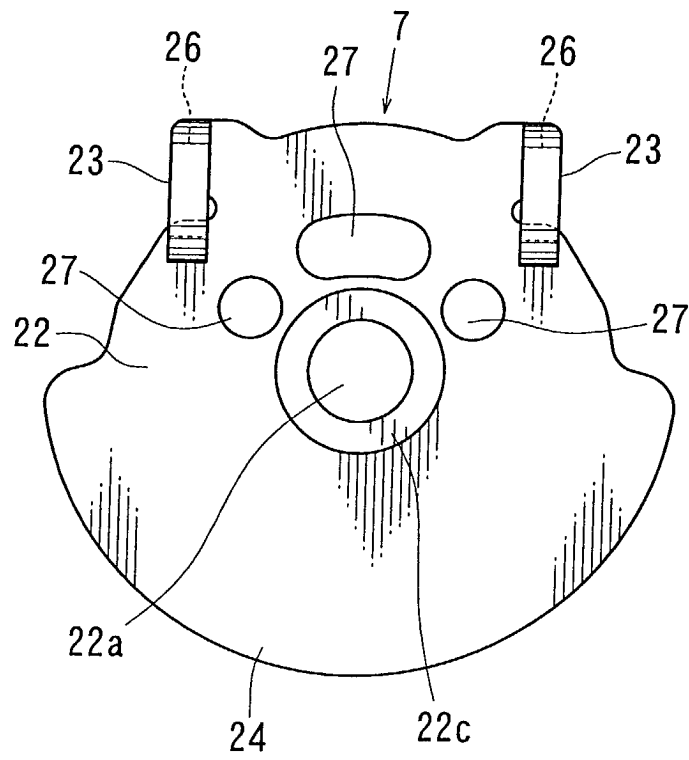


FIG. 2

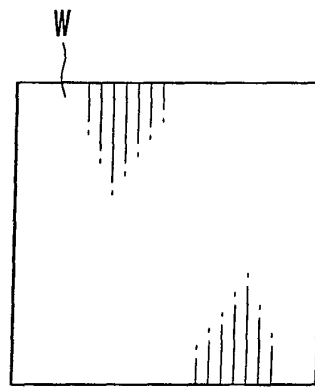


FIG. 3 (A)

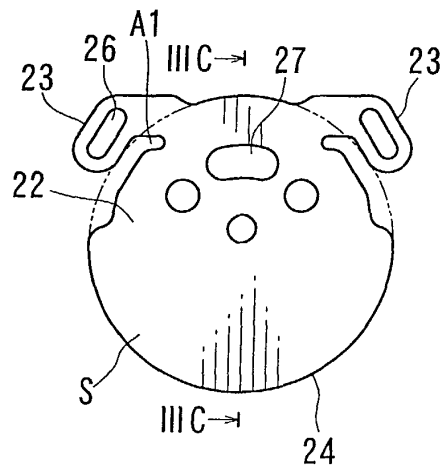


FIG. 3 (B)

III C-III C section

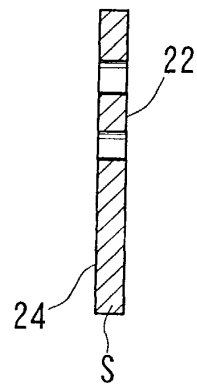


FIG. 3 (C)

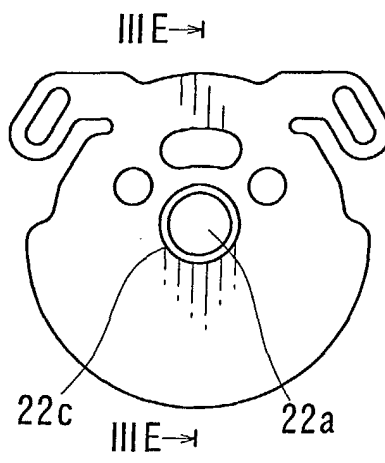


FIG. 3 (D)

III E-III E section

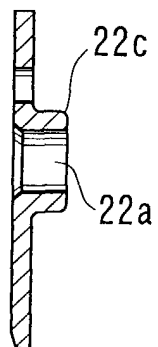


FIG. 3 (E)

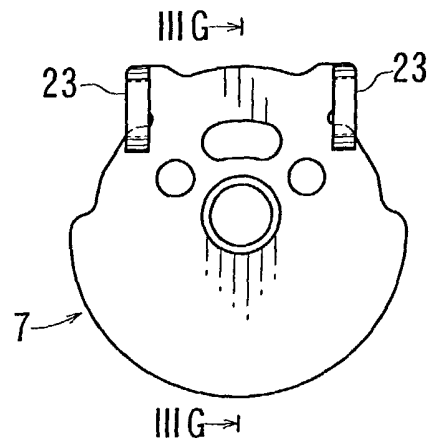


FIG. 3 (F)

III G-III G section

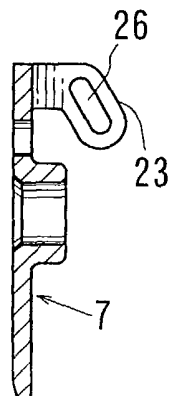


FIG. 3 (G)

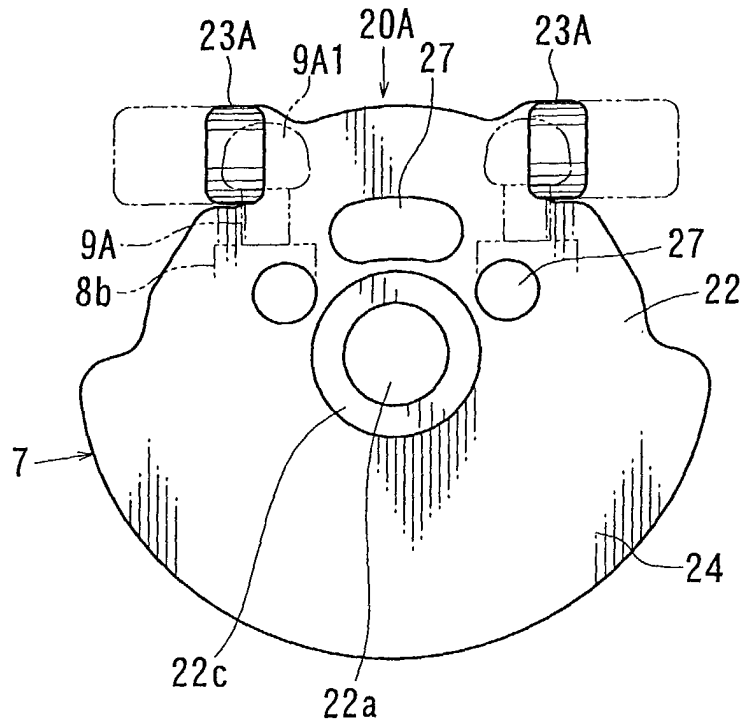


FIG. 4

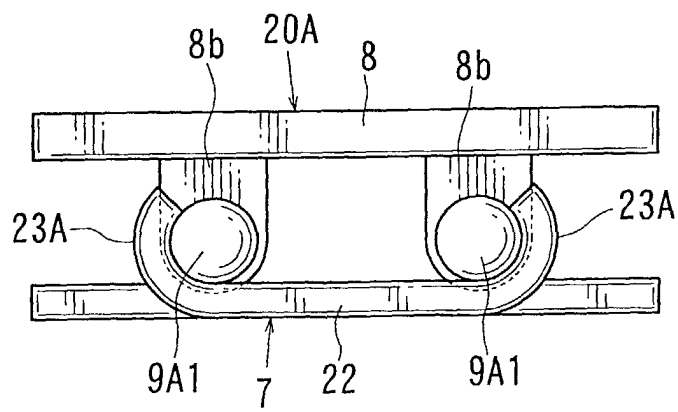


FIG. 5

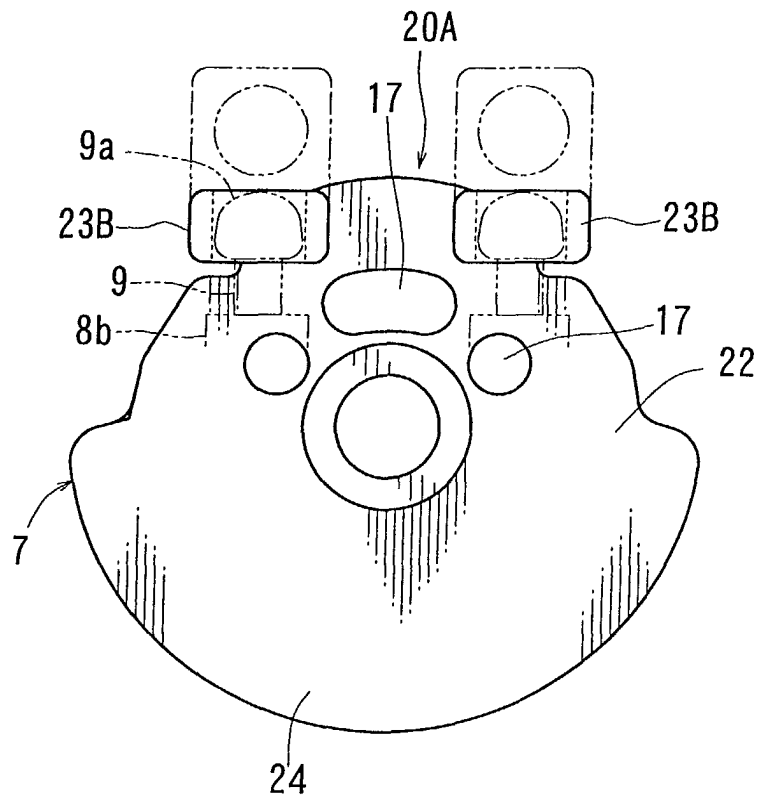


FIG. 6

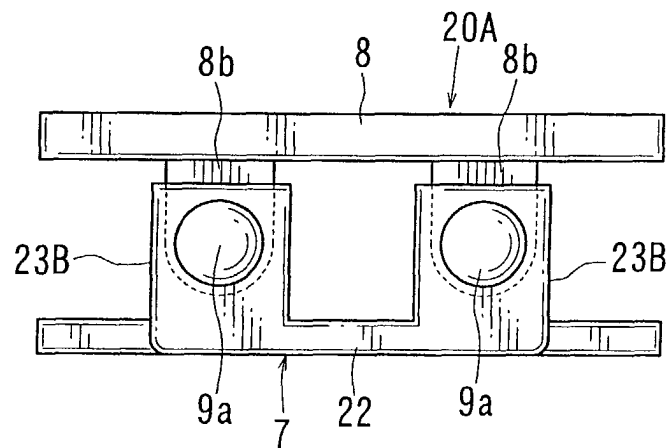


FIG. 7

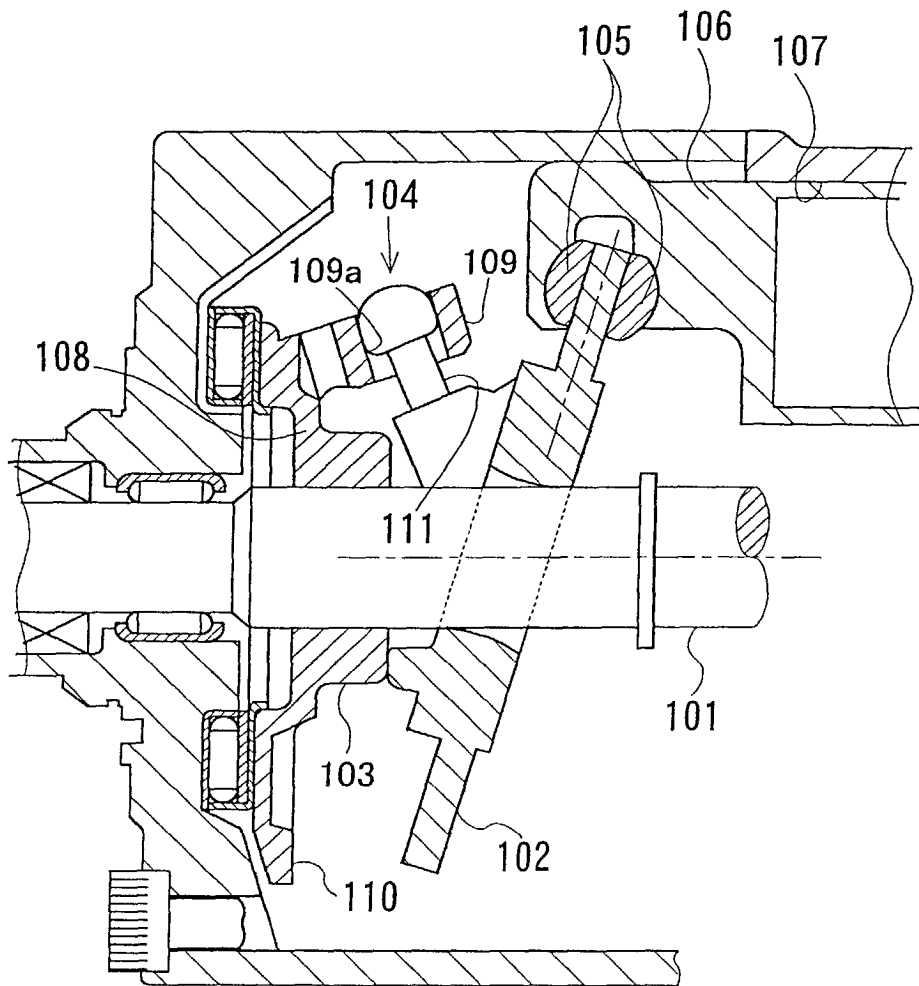


FIG. 8
RELATED ART