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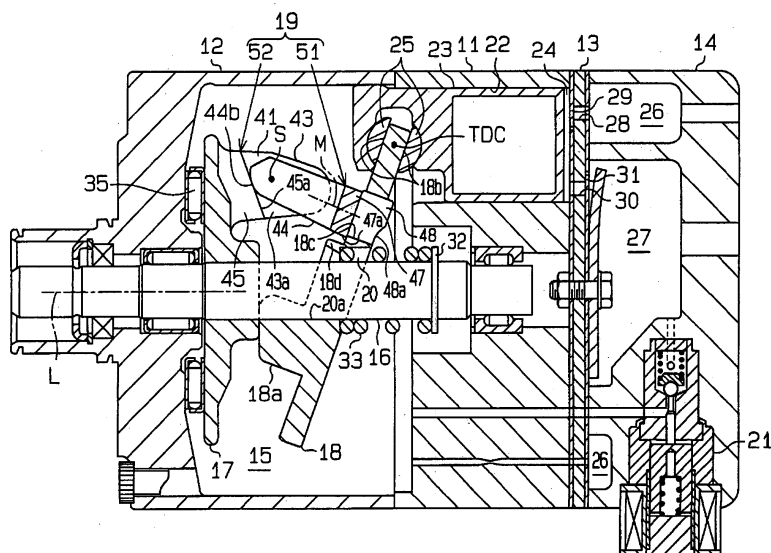
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### (54) Hinge mechanism for a variable displacement compressor

(57) A variable displacement compressor has a housing, a piston, a drive shaft, a rotor, a cam plate and a hinge mechanism. The hinge mechanism between the rotor and the cam plate guides the cam plate to incline and slide relative to the drive shaft. Thus, the displacement volume of the compressor is varied. The rotation of the drive shaft is converted to the reciprocation of the

piston through the rotor, the hinge mechanism and the cam plate. The hinge mechanism includes first and second hinge elements that are respectively provided on the rotor and on the cam plate and engage each other. At least one of the first and second hinge elements has a degree of freedom for motion against the rotor and/or the cam plate to which it belongs.

**FIG. 1**



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## Description

### BACKGROUND OF THE INVENTION

**[0001]** The present invention relates to a variable displacement piston type compressor for use in a vehicle air conditioner.

**[0002]** Unexamined Japanese Patent Publication No. 9-203377 discloses a variable displacement compressor of such type. FIG. 14 illustrates a partially longitudinal cross-sectional view of a variable displacement compressor according to a prior art. A housing 101 of the compressor defines a cylinder bore 101a that accommodates a piston 102. A drive shaft 103 is rotatably supported by the housing 101. A rotor 104 is connected to the drive shaft 103 so as to rotate integrally therewith. A swash plate 105 is supported by the drive shaft 103 so that it slides and inclines relative to the drive shaft 103. The piston 102 engages the periphery of the swash plate 105 through a pair of shoes 107. A hinge mechanism 108 is interposed between the rotor 104 and the swash plate 105.

**[0003]** Accordingly, the rotation of the drive shaft 103 is converted to the reciprocation of the piston 102 through the rotor 104, the hinge mechanism 108 and the swash plate 105, while the swash plate 105 is guided by the hinge mechanism 108 to slide on the drive shaft 103 in accordance with the inclination of the swash plate 105. Thus, the displacement volume of the compressor is varied.

**[0004]** The hinge mechanism 108 includes a pair of first protrusions 108a (only one is shown in FIG. 14), a second protrusion 108b and a cam surface 108c. The first protrusions 108a extend from the rotor 104 toward the swash plate 105. The second protrusion 108b extends from the swash plate 105 toward the rotor 104. The distal end of the second protrusion 108b is inserted between the first protrusions 108a. The cam surface 108c is formed at the proximal portion of the first protrusions 108a. The first protrusions 108a and the second protrusion 108b contact with a certain amount of area to engage each other so that the rotation of the rotor 104 is transmitted to the swash plate 105 through the hinge mechanism 108. The distal end of the second protrusion 108b slidably contacts the cam surface 108c so that axial load that acts on the swash plate 105 due to compression reactive force is received by the cam surface 108c through the second protrusion 108b.

**[0005]** In the hinge mechanism 108, the first protrusions 108a and the second protrusion 108b are integrally formed with the rotor 104 and the swash plate 105, respectively. An unwanted feature is that as the swash plate 105 inclines to twist the second protrusion 108b by the pair of first protrusions 108b due to offset axial load based upon the compression reactive force, sliding resistances increase between the side surfaces of the first protrusions 108a and the second protrusion 108b and between the distal end of the second protrusion

108b and the cam surface 108c due to the contact of the edge. This leads to early abrasion of each sliding surface. In other words, durability of the hinge mechanism 108 is deteriorated, and unsmooth operation of the hinge mechanism 108 leads to deteriorated controllability for the displacement volume of the compressor. Therefore, there is a need for a variable displacement compressor that improves durability of a hinge mechanism and that ensures smooth operation of the hinge mechanism.

### SUMMARY OF THE INVENTION

**[0006]** In accordance with the present invention, a variable displacement compressor has a housing, a piston, a drive shaft, a rotor, a cam plate and a hinge mechanism. The housing defines a cylinder bore. The piston is accommodated in the cylinder bore. The drive shaft is rotatably supported by the housing. The rotor is connected to the drive shaft so as to rotate integrally with. The cam plate is supported by the drive shaft so as to slide and incline relative to the drive shaft and is operatively connected to the piston. The hinge mechanism is interposed between the rotor and the cam plate and guides the cam plate to incline and slide relative to the drive shaft. Thus, the displacement volume of the compressor is varied. The rotation of the drive shaft is converted to the reciprocation of the piston through the rotor, the hinge mechanism and the cam plate. The hinge mechanism includes a first hinge element and a second hinge element. The first hinge element is provided on the rotor. The second hinge element is provided on the cam plate and is engaged with the first hinge element. At least one of the first and second hinge elements has a degree of freedom for motion against the rotor and/or the cam plate to which the hinge element having the degree of freedom for motion belongs.

**[0007]** Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0008]** The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1 is a longitudinal cross-sectional view of a variable displacement compressor according to a first preferred embodiment of the present invention;

FIG. 2 is a side view of a hinge mechanism accord-

ing to the first preferred embodiment of the present invention;

FIG. 3 is a plan view of the hinge mechanism according to the first preferred embodiment of the present invention;

FIG. 4 is a hinge element of a swash plate according to the first preferred embodiment of the present invention;

FIG. 5 is an enlarged longitudinal cross-sectional view of a hinge mechanism according to a second preferred embodiment of the present invention;

FIG. 6 is a plan view of a hinge mechanism according to a third preferred embodiment of the present invention;

FIG. 7 is an enlarged side view of a hinge mechanism according to a fourth preferred embodiment of the present invention;

FIG. 8 is an enlarged longitudinal cross-sectional view of a hinge mechanism according to a fifth preferred embodiment of the present invention;

FIG. 9 is a plan view of a hinge mechanism according to a sixth preferred embodiment of the present invention;

FIG. 10 is an enlarged longitudinal cross-sectional view of a hinge mechanism according to a seventh preferred embodiment of the present invention;

FIG. 11 is an enlarged perspective view of the hinge mechanism according to the seventh preferred embodiment of the present invention;

FIG. 12 is a longitudinal cross-sectional view of a hinge mechanism according to an eighth preferred embodiment of the present invention;

FIG. 13 is a plan view of the hinge mechanism according to the eighth preferred embodiment of the present invention; and

FIG. 14 is a partially longitudinal cross-sectional view of a variable displacement compressor according to a prior art.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0009]** A first preferred embodiment of the present invention will now be described with reference to FIGs. 1 through 4. The present invention is applied to a variable displacement compressor for a refrigerant circuit of a ve-

hicle air conditioner in the first preferred embodiment. The left side and the right side respectively correspond to the front side and the rear side of the compressor in FIG. 1.

**[0010]** FIG. 1 illustrates a longitudinal cross-sectional view of the variable displacement compressor according to the first preferred embodiment of the present invention. A housing of the compressor includes a cylinder block 11, a front housing 12 and a rear housing 14. The front housing 12 is fixedly connected to the front end of the cylinder block 11. The rear housing 14 is fixedly connected to the rear end of the cylinder block 11 through a valve plate assembly 13.

**[0011]** A crank chamber 15 is defined between the cylinder block 11 and the front housing 12. A drive shaft 16 is rotatably supported by the housing and extends through the crank chamber 15 from the front housing 12 to the cylinder block 11. The drive shaft 16 is rotated by the power transmitted from an engine (not shown) for traveling a vehicle.

**[0012]** In the crank chamber 15, a rotor 17 made of cast iron is fixedly connected to the drive shaft 16 so as to rotate integrally therewith. The front end surface of the rotor 17 and the facing inner wall surface of the front housing 12 interpose a thrust bearing 35. The crank chamber 15 accommodates a swash plate or a cam plate 18. The swash plate 18 is made of iron series metal, such as iron and iron alloy. The swash plate 18 is formed by forging.

**[0013]** A through hole 20 is formed at the center of the swash plate 18. The drive shaft 16 extends through the through hole 20. The swash plate 18 is supported by the drive shaft 16 through an inner surface 20a of the through hole 20 in such a manner that the swash plate 18 inclines and slides relative to the drive shaft 16. A circular clip 32 is fitted on the drive shaft 16 on the rear side to the swash plate 18. A coil spring 33 for increasing inclination angle of the swash plate 18 is arranged between the circular clip 32 and the swash plate 18 so as to urge the middle portion of the swash plate 18 forward.

**[0014]** A hinge mechanism 19 is interposed between the rotor 17 and the swash plate 18. The hinge mechanism 19 includes a first hinge element 52 provided on the rotor 17 and a second hinge element 51 provided on the swash plate 18. The swash plate 18 is coupled to the rotor 17 through the hinge mechanism 19 and is supported by the drive shaft 16 through the inner surface 20a of the through hole 20. Accordingly, the swash plate 18 is integrally rotatable with the rotor 17 and the drive shaft 16, while it is inclinable relative to the drive shaft 16 in accordance with sliding movement in the direction of the axis L of the drive shaft 16.

**[0015]** Incidentally, with respect to the swash plate 18, the inner surface 20a of the through hole 20 is treated by induction hardening for improving sliding performance against the drive shaft 16 and for improving abrasion resistance.

**[0016]** A plurality of cylinder bores 22 (one of them

shown in FIG. 1) extends through the cylinder block 11 and is arranged around the axis L of the drive shaft 16 at equiangular positions. Each of the cylinder bores 22 accommodates a single-headed piston 23 so as to be reciprocated therein. The front and rear openings of each cylinder bore 22 are respectively closed by the top end surface of the piston 23 and the front end surface of the valve port assembly 13. Thus, a compression chamber 24 is defined in each of the cylinder bores 22 and varies its volume in accordance with the reciprocation of the respective piston 23. Each of the pistons 23 engages the outer periphery of the swash plate 18 through a pair of semispherical shoes 25. Accordingly, the rotation of the swash plate 18 in accordance with the rotation of the drive shaft 16 is converted to the reciprocation of the piston 23 through the shoes 25.

**[0017]** Incidentally, with respect to the swash plate 18, sliding surfaces 18b against the respective shoes 25 are treated by induction hardening for improving sliding performance against the shoes 25 and for improving abrasion resistance.

**[0018]** A suction chamber 26 and a discharge chamber 27 are defined between the valve plate assembly 13 and the rear housing 14. The refrigerant gas in the suction chamber 26 is introduced into the compression chamber 24 through a suction port 28 and a suction valve 29 as each piston 23 moves from its top dead center to its bottom dead center. The suction port 28 and the suction valve 29 are formed in the valve plate assembly 13. The refrigerant gas in the compression chamber 24 is compressed to a predetermined pressure value as the piston 23 moves from the bottom dead center to the top dead center. The compressed refrigerant gas is discharged to the discharge chamber 27 through a discharge port 30 and a discharge valve 31, which are formed in the valve plate assembly 13.

**[0019]** The compressor optionally varies its displacement volume and regulates its displacement volume in such a manner that a control valve 21 adjusts pressure in the crank chamber 15. In other words, pressure differential between the crank chamber 15 and the compression chambers 24 is varied by the control valve 21 in response to variation of the pressure in the crank chamber 15. As a result, the inclination angle of the swash plate 18 is varied, and the stroke of the piston 23 is adjusted.

**[0020]** As the pressure in the crank chamber 15 decreases, the swash plate 18 is pushed by the coil spring 33 to increase its inclination angle. Thus, the strokes of the pistons 23 increase, and the displacement volume of the compressor increases. The front end surface of the swash plate 18 has a portion 18a for regulating maximum inclination angle. The portion 18a also serves as a balance weight. The maximum inclination angle of the swash plate 18 is regulated in such a manner that the portion 18a contacts the rear end surface of the rotor 17, as shown in FIG. 1.

**[0021]** On the other hand, as the pressure in the crank

chamber 15 increases, the swash plate 18 resists against the coil spring 33 to decrease its inclination angle. Thus, the strokes of the pistons 23 decrease, and the displacement volume of the compressor decreases.

The minimum inclination angle of the swash plate 18 is regulated by the circular clip 32 and the coil spring 33.

**[0022]** FIG. 2 illustrates a side view of the hinge mechanism 19 according to the first preferred embodiment of the present invention. FIG. 3 illustrates a plan view of the hinge mechanism 19 according to the first preferred embodiment of the present invention. Now referring to FIGs. 1 through 3, an engaging recess 41 is formed at the rear end of the rotor 17 and faces a point TDC of the swash plate 18. The point TDC is a center of the hypothetical spherical surface of the shoes 25 when the piston 23 is positioned at a top dead center. The engaging recess 41 is defined by a pair of first protrusions 43 that extend toward the swash plate 18. The first protrusions 43 are respectively disposed at the rear end on a preceding side and on a following side in the rotational direction of the rotor 17.

**[0023]** A pair of second protrusions 44 extends toward the rotor 17 and is arranged at the front end of the swash plate 18 so as to face the engaging recess 41. The second protrusions 44 are respectively disposed on a preceding side and on a following side in the rotational direction of the drive shaft 16 so as to interpose a hypothetical plane including the axis L and the point TDC. Each of the distal ends of the second protrusions 44 fits into the engaging recess 41. Each of the second protrusions 44 includes a side surface 44a that faces away from each other. Each of the side surfaces 44a contacts a side surface 43a of the first protrusion 43 with a certain amount of area. The side surfaces 43a partially form the inner surface of the engaging recess 41. Accordingly, the rotational power of the rotor 17 is transmitted to the swash plate 18 through one of the first protrusions 43 (the side surfaces 43a) and one of the second protrusions 44 (the side surfaces 44a).

**[0024]** Incidentally, to improve general-purpose property, with respect to the compressor of the first preferred embodiment, the hinge mechanism 19 is symmetrically formed relative to the hypothetical plane including TDC and the axis L along the rotational direction of the drive shaft 16 so as to appropriately respond either rotational direction of the drive shaft 16, even if a mounted engine rotates in either direction.

**[0025]** A cam portion 45 for receiving axial load is formed on the proximal portion of each first protrusion 43 in the engaging recess 41. The cam portions 45 and the first protrusions 43 constitute the first hinge element 52 on the side of the rotor 17. The rear end surface of each cam portion 45 facing the swash plate 18 forms a cam surface 45a that protrudes toward the rear side as it approaches the drive shaft 16. Each of the second protrusions 44 forms a convex circular arc surface 44b and slidably contacts the cam surface 45a of the corresponding cam portion 45 by the circular arc surface 44b.

Accordingly, the axial load that acts on the swash plate 18 due to the compression reactive force is received by the cam surfaces 45a of the cam portions 45 through the circular arc surfaces 44b of the second protrusions 44, respectively.

**[0026]** With respect to the prior art shown in FIG. 14, the hinge mechanism 108 includes the single and relatively large-scaled second protrusion 108b. However, in the first preferred embodiment, the second protrusion 108b of the prior art is divided into the two second protrusions 44. The above structure ensures the same width for receiving axial load as that of the second protrusion 108b of the prior art and lightens the swash plate assembly 18, 51 by changing the structure of the second protrusion 108b of the prior art to a hollow structure.

**[0027]** As the compressor increases its displacement volume, the distal ends of the second protrusions 44 rotate around a central axis S of the circular arc surfaces 44b in the clockwise direction in FIG. 1, while they move on the cam surfaces 45a of the respective cam portions 45 away from the drive shaft 16. Thus, the hinge mechanism 19 guides to increase the inclination angle of the swash plate 18. On the contrary, when the compressor reduces its displacement volume, the distal ends of the second protrusions 44 rotate around the central axis S of the circular arc surfaces 44b in the counterclockwise direction in FIG. 1, while they move on the cam surfaces 45a of the cam portions 45 to approach the drive shaft 16. Thus, the hinge mechanism 19 guides to reduce the inclination angle of the swash plate 18.

**[0028]** Incidentally, the first hinge element 52 and the second hinge element 51 slide on each other at sliding surfaces, such as the side surfaces 43a, 44a of the respective first and second protrusions 43, 44, the circular arc surfaces 44b of the respective second protrusions 44, and the cam surfaces 45a of the respective cam portions 45. The above sliding surfaces are treated by induction hardening for improving their sliding performance and abrasion resistance.

**[0029]** In the second hinge element 51, the induction hardening may exclusively be treated at a portion including the side surfaces 44a and the circular arc surfaces 44b or may entirely be treated. Particularly, the former treatment restrains the distortion and crack of the second hinge element 51 of the swash plate 18 due to heat affection of the hardening. Incidentally, the induction hardening may be treated only at portions including the side surfaces 43a and the cam surfaces 45a or may be treated at the entire first hinge element 52. Particularly, the former treatment restrains the distortion and crack of the first hinge element 52 due to heat affection of the hardening.

**[0030]** As shown in FIGs. 1 through 3, the second hinge element 51 is separately formed from the swash plate 18. The second hinge element 51 includes a base plate or a base 47 and a pair of second protrusions 44 that extend from the front end surface of the base plate 47. The swash plate 18 is made of iron series metal and

is formed by forging. On the other hand, the second hinge element 51 is made of aluminum series metal, such as aluminum and aluminum alloy. That is, the second hinge element 51 is made of different material from that of the swash plate 18, and the second protrusions 44 and the base plate 47 are integrally formed by forging or by molding. With respect to the swash plate 18, the sliding surfaces 18b against the shoes 25 and the inner surface 20a of the through hole 20 are polished and treated by induction hardening before the second hinge element 51 is assembled to the swash plate 18.

**[0031]** In the second hinge element 51, a shaft 48 is integrally formed at the center of the rear end surface of the base plate 47 and extends vertically relative to the base plate 47. In the swash plate 18, a shaft hole 18c is recessed inwardly from the sliding surfaces 18b against the shoes 25 and extends in thickness of the swash plate 18. The second hinge element 51 is loosely fitted into the shaft hole 18c of the swash plate 18 by the shaft 48.

**[0032]** Accordingly, referring to FIG. 4, the diagram illustrates the second hinge element 51 according to the first preferred embodiment of the present invention. The second hinge element 51 is rotatable on the swash plate 18 relative to an axis M of the shaft 48 (or the shaft hole 18c). Namely, the second hinge element 51 has the degree of freedom for rotation against the swash plate 18 to which the second hinge element 51 belongs. The rotation of the second hinge element 51 is regulated in a predetermined angular range in such a manner that an end surface 47a of the base plate 47 near the drive shaft 16 contacts the wall surface of a step or a regulating means 18d formed on the front end surface of the swash plate 18.

**[0033]** Incidentally, referring back to FIGs. 1 and 2, a lightening recess 48a is formed at the distal end of the shaft 48 on the side near the drive shaft 16 so that the swash plate 18 avoids interfering with the coil spring 33 when positioned at the maximum inclination angle.

**[0034]** The following advantageous effects are obtained from the first preferred embodiment.

(1) The second hinge element 51 has the degree of freedom for motion against the swash plate 18. Accordingly, even if offset axial load due to the compression reactive force acts on the inclined swash plate 18 to twist the second protrusions 44 in the engaging recess 41, stress due to the inclined swash plate 18 moves the second hinge element 51 so that the second protrusions 44 avoid twisting in the engaging recess 41. As a result, the side surfaces 44a of the respective second protrusions 44 and the side surfaces 43a of the respective first protrusions 43 contact each other with a certain amount of area, while the circular arc surfaces 44b of the respective second protrusions 44 and the cam surfaces 45a of the respective cam portions 45 contact each other with a line. Thus, no edge abuts

at each sliding surface. Accordingly, the hinge mechanism 19 smoothly moves, and the displacement volume of the compressor smoothly varies.

(2) The second hinge element 51 on the swash plate 18 has the degree of freedom for rotation. In comparison to a hinge mechanism that has a degree of freedom for sliding, the second hinge element 51 effectively avoids the second protrusions 44 from twisting in the engaging recess 41.

(3) The rotation of the second hinge element 51 is regulated in a predetermined angular range in such a manner that the second hinge element 51 contacts the step 18d formed on the swash plate 18. Accordingly, the second hinge element 51 is prevented from excessively rotating on the swash plate 18 so that noise due to collision between the second protrusions 44 and the first protrusions 43 is reduced. The structure for regulating the rotation of the second hinge element 51 helps to assemble the swash plate assembly 18, 51 to the compressor, that is, the structure helps to easily insert the second protrusions 44 into the engaging recess 41. Namely, for example, without the structure for regulating the rotation of the second hinge element 51, the rotation of the second hinge element 51 must be temporarily regulated to fit the second protrusions 44 into the engaging recess 41. Accordingly, a jig for regulating the rotation of the second hinge element 51 is required so that assembling becomes complicated.

(4) Since the second hinge element 51 has the degree of freedom for motion against the swash plate 18, that is, since the second hinge element 51 is separately formed from the swash plate 18, the shape of the swash plate 18 becomes simple. Accordingly, the swash plate 18 employs forging as a manufacturing procedure because forging provides better yield and easy after-machining in comparison to molding. Even if the second hinge element 51 needs to be separately formed and assembled to the swash plate 18, costs are reduced for manufacturing the compressor. Incidentally, the swash plate 18 formed by forging has relatively high hardenability in comparison to the one formed by molding.

The separately formed swash plate 18 and the second hinge element 51 permit appropriate selection for their respective material. Accordingly, in the first preferred embodiment, the swash plate 18 is made of iron series metal that has relatively high relative density for ensuring its strength and for ensuring moment for stable variation of the displacement volume. Additionally, the second hinge element 51 that is arranged at an offset position on the swash plate 18 is made of aluminum series metal that has relatively low relative density for balancing

around the axis L of the swash plate assembly 18, 51. The second hinge element 51 made of light aluminum series metal helps the balance weight 18a for balancing around the axis L of the second hinge element 51 to be compact. This leads to the lightened swash plate assembly 18, 51 and to the lightened compressor.

Furthermore, the second hinge element 51 made of aluminum series metal that is different from that of the first hinge element 52 made of cast iron effectively prevents a same-metal phenomenon due to slide between the first hinge elements 52. The same-metal phenomenon means that mutually same metals lead to inconveniences such as an increase in coefficient of friction.

(5) In the first and second hinge elements 51, 52 for the hinge mechanism 19, the second hinge element 51 is separately formed from the swash plate 18. Accordingly, a depth for fitting the shaft 48 into the shaft hole 18c may be relatively long in the direction of the axis M so that the swash plate 18 supports the second hinge element 51 in stable. As a result, for example, the second hinge element 51 may be rotated in stable relative to the swash plate 18 so as to avoid twisting of the second protrusions 44 in the engaging recess 41. This leads to smooth operation of the hinge mechanism 19 and to smooth variation of the displacement volume of the compressor.

Namely, for example, according to a second preferred embodiment of FIG. 5 which will be described later, when the first hinge element 52 is separately formed from the rotor 17, the distal end of the shaft 55 needs consideration for not protruding the distal end of the shaft 55 from the shaft hole 17a including dimensional tolerance so as to avoid interference between the shaft 55 and the thrust bearing 35 (See FIG. 1) that is arranged on the front end surface of the rotor 17. Accordingly, the depth for fitting between the shaft 55 and the shaft hole 17a tends to become small in the direction of the axis M so that the rotor 17 supports the first hinge element 52 in unstable.

(6) When the swash plate 18 is separately formed from the second hinge element 51, the second hinge element 51 does not interfere with the approach of a grind stone to the sliding surface 18b in a polishing process of the sliding surfaces 18b that slide on the shoes 25 before the second hinge element 51 is assembled to the swash plate 18. Therefore, workability of the swash plate 18 becomes better. In other words, the second hinge element 51 does not need to consider the interference when the sliding surfaces 18b are polished and permits free determination of its shape and also permits ideal shape for transmitting power and for guiding incli-

nation of the swash plate 18.

(7) The second hinge element 51 includes a pair of the second protrusions 44 that are integrated with each other and is rotatable on the swash plate 18. In comparison to a plurality of the second protrusions 44 that are individually rotatable on the swash plate 18, the structure of the second hinge element 51 for rotation, that is, the structure for increasing the degree of freedom, may be simple in the first preferred embodiment. Additionally, a plurality of the integrated second protrusions 44 leads to easy setting in high accuracy the width between the side surfaces 44a of the respective second protrusions 44. The width largely affects the smooth operation of the hinge mechanism 19.

(8) The swash plate 18 that is separately formed from the second hinge element 51 is treated by hardening at sliding surfaces 18b against the shoes 25 and the inner surface 20a of the through hole 20 that slides on the drive shaft 16 before the second hinge element 51 is assembled to the swash plate 18. Accordingly, the second hinge element 51 does not receive heat affection due to hardening and avoids distortion due to the heat affection. No modification for distortion of the second hinge element 51 is required, but the hinge mechanism 19 smoothly operates so that costs are reduced for manufacturing the compressor.

**[0035]** A second preferred embodiment of the present invention will now be described with reference to FIG. 5. The components that are different from those of the first preferred embodiment are only described. The same reference numerals denote the substantially identical components to those of the first preferred embodiment, and the description is omitted.

**[0036]** FIG. 5 illustrates an enlarged longitudinal cross-sectional view of the hinge mechanism 19 according to the second preferred embodiment of the present invention. In the second preferred embodiment, the second hinge element 51 is integrally formed with the swash plate 18, while the first hinge element 52 is separately formed from the rotor 17. The first hinge element 52 integrally forms a base plate 56, a pair of the first protrusions 43 and a pair of the cam portions 45. The first protrusions 43 extend from the rear end surface of the base plate 56. The cam portions 45 are formed on the proximal portions of the respective first protrusions 43. The rotor 17 that is separately formed from the first hinge element 52 is simple and may apply forging as a manufacturing procedure.

**[0037]** The first hinge element 52 is loosely fitted into a shaft hole 17a at a shaft 55 thereof. The shaft 55 extends from the front end surface of the base plate 56. The shaft hole 17a is formed through the rotor 17. Accordingly, the first hinge element 52 is rotatable on the

rotor 17 around the axis M of the shaft 55 (or the shaft hole 17a) that is parallel with the axis L of the drive shaft 16. Namely, the first hinge element 52 has the degree of freedom for rotation against the rotor 17. The rotation of the first hinge element 52 is regulated in a predetermined angular range on the rotor 17 in such a manner that an end surface 56a facing the drive shaft 16 contacts the wall surface of the step 17b that is formed on the rotor 17.

**[0038]** In the second preferred embodiment, the first hinge element 52 is rotatable on the rotor 17. Accordingly, even if the swash plate 18 inclines to twist the second protrusions 44 in the engaging recess 41 by the axial load due to the compression reactive force, stress due to the inclination rotates the first hinge element 52 around the axis M on the rotor 17 so as to prevent the swash plate 18 from twisting the second protrusions 44.

**[0039]** A third preferred embodiment of the present invention will now be described with reference to FIG. 6. The components that are different from those of the first preferred embodiment are only described. The same reference numerals denote the substantially identical components to those of the first preferred embodiment, and the description is omitted.

**[0040]** FIG. 6 illustrates a plan view of the hinge mechanism 19 according to the third preferred embodiment of the present invention. In the third preferred embodiment, the engaging recess 41 is formed between a pair of the second protrusions 44 in the second hinge element 51. The rotor 17 includes the single first protrusion 43 at its rear end surface facing the engaging recess 41. The first protrusion 43 extends toward the swash plate 18. The distal end of the first protrusion 43 is inserted in the engaging recess 41. The first protrusion 43 has a pair of side surfaces 43b, while each of the second protrusions 44 has a side surface 44c that is a part of the inner surface of the engaging recess 41. The side surfaces 43b of the first protrusion 43 contact the side surfaces 44c with a certain amount of area. Accordingly, the rotational power of the rotor 17 is transmitted to the swash plate 18 through one of the side surfaces 43b of the first protrusion 43 and one of the side surfaces 44c of the respective second protrusions 44.

**[0041]** The second hinge element 51 includes the cam portion 45 at the proximal portions of the second protrusions 44 in the engaging recess 41. The distal end of the first protrusion 43 forms a convex circular arc surface 43d and slidably contacts a cam surface 45c of the cam portion 45. Accordingly, the axial load that acts on the swash plate 18 due to the compression reactive force is received by the cam surface 45c of the cam portion 45.

**[0042]** A fourth preferred embodiment of the present invention will now be described with reference to FIG. 7. The components that are different from those of the first preferred embodiment are only described. The same reference numerals denote the substantially identical components to those of the first preferred embodi-

ment, and the description is omitted.

**[0043]** FIG. 7 illustrates an enlarged side view of the hinge mechanism 19 according to the fourth preferred embodiment of the present invention. In the fourth preferred embodiment, the side surface 43a of the first protrusion 43 includes a guide groove 43c that extends along the direction of the cam surface 45a of the cam portion 45. The side surface 44a of the second protrusion 44 includes a guide protrusion 44d on the central axis S of the circular arc surface 44b, and the guide protrusion 44d is engagedly inserted in the guide groove 43c for guiding the swash plate 18 to incline and slide relative to the drive shaft 16.

**[0044]** Even if the compression reactive force that acts on the swash plate 18 disappears due to the stop of the compressor, or even if the compression reactive force that acts on the swash plate 18 decreases due to the operation of the compressor in a minimum displacement volume, the swash plate assembly 18, 51 engages the rotor 17 by the engagement between the guide groove 43c and the guide protrusion 44d. As a result, the swash plate assembly 18, 51 is prevented from rattling due to vibration of a vehicle, with a consequence of preventing noise generated on the compressor.

**[0045]** A fifth preferred embodiment of the present invention will now be described with reference to FIG. 8. The components that are different from those of the first preferred embodiment are only described. The same reference numerals denote the substantially identical components to those of the first preferred embodiment, and the description is omitted.

**[0046]** FIG. 8 illustrates an enlarged longitudinal cross-sectional view of the hinge mechanism 19 according to the fifth preferred embodiment of the present invention. In the fifth preferred embodiment, a slider 57 is interposed between the circular arc surface 44b of the second protrusion 44 and the cam surface 45a of the cam portion 45. Namely, the second protrusion 44 (the circular arc surface 44b) and the cam portion 45 (the cam surface 45a) slidably contact each other through the slider 57.

**[0047]** The slider 57 includes a concave circular arc surface 57a and a planar surface 57b. The concave circular arc surface 57a slides on the circular arc surface 44b of the second protrusion 44. The planar surface 57b slides on the cam surface 45a. Accordingly, the cam portion 45 and the slider 57 contact each other with a certain amount of area, and the second protrusion 44 and the slider 57 contact each other with a certain amount of area. The areal contacts reduce abrasion of the cam surface 45a and the circular arc surface 44b. That is, the areal contacts contribute to improved durability of the hinge mechanism 19.

**[0048]** A sixth preferred embodiment of the present invention will now be described with reference to FIG. 9. The components that are different from those of the first preferred embodiment are only described. The same reference numerals denote the substantially identical

components to those of the first preferred embodiment, and the description is omitted.

**[0049]** FIG. 9 illustrates a plan view of the hinge mechanism 19 according to the sixth preferred embodiment of the present invention. In the sixth preferred embodiment, the drive shaft 16 rotates in the direction of an arrow R, and the hinge mechanism 19 is particularly configured to appropriately handle a state when the drive shaft 16 rotates in the direction of the arrow R.

**[0050]** Namely, with respect to the hinge mechanism 19, a cam portion 45A and a second protrusion 44A shown in the lower side of FIG. 9 in a compression cycle mainly receive the axial load that acts on the swash plate 18 based upon the compression reactive force, while the first protrusion 43 and another second protrusion 44B shown in the upper side of FIG. 9 in a suction cycle transmit power from the rotor 17 to the swash plate 18. Then, with respect to the second protrusions 44A, 44B, when absolute amount of load, variation of the load and its variation rate are considered, the second protrusion 44A for receiving the axial load is hard in strength than the second protrusion 44B for power transmission.

**[0051]** Then, in the sixth preferred embodiment, the cam surface 45a of the cam portion 45A for receiving the axial load is widened than the cam surface 45a of the cam portion 45B for power transmission, while the second protrusion 44A for receiving the axial load is thicker than the second protrusion 44B for power transmission. Thus, the width of the circular arc surface 44b of the second protrusion 44A is predetermined to be wide. Accordingly, the strength of the second protrusion 44A for receiving the axial load is improved. In comparison to the thickened second protrusions 44A, 44B, an increase in weight is relatively small, while durability of the hinge mechanism 19 is ensured at equivalent level in the sixth preferred embodiment.

**[0052]** A seventh preferred embodiment of the present invention will now be described with reference to FIGs. 10 and 11. The components that are different from those of the first preferred embodiment are only described. The same reference numerals denote the substantially identical components to those of the first preferred embodiment, and the description is omitted.

**[0053]** FIG. 10 illustrates an enlarged longitudinal cross-sectional view of the hinge mechanism 19 according to the seventh preferred embodiment of the present invention. FIG. 11 illustrates an enlarged perspective view of the hinge mechanism 19 according to the seventh preferred embodiment of the present invention. In the seventh preferred embodiment, a slider 60 is supported by the drive shaft 16 so as to slide in the direction of the axis L. A fulcrum shaft 60a is formed with the slider 60 and inclinably supports the swash plate 18.

**[0054]** With respect to the hinge mechanism 19, the cam portion 45 is omitted from the first hinge element 52, and the first and second hinge elements 52, 51 engage each other through link arms 61.

**[0055]** Namely, the second hinge element 51 includes

the single second protrusion 44. An insertion hole 44e is formed through the distal end of the second protrusion 44 in the direction perpendicular to the axis L of the drive shaft 16. The first hinge element 52 includes the single first protrusion 43 that radially extends from the outer periphery of the rotor 17. An insertion hole 43e is formed through the distal end of the first protrusion 43 in the direction perpendicular to the axis L of the drive shaft 16.

**[0056]** A pair of the link arms 61 is arranged on each side of the distal ends of the first and second protrusions 43, 44 and each of the link arms 61 has through holes 61 a, 61 b at both ends. One end of each link arm 61 is pivotally supported through the through hole 61 a by a pin 62 that is inserted into the through hole 43e of the first protrusion 43. The other end of each link arm 61 is pivotally supported through the through hole 61 b by another pin 63 that is inserted through the through hole 44e of the second protrusion 44. Accordingly, the swash plate 18 inclines around the pins 62, 63 in accordance with slide on the drive shaft 16.

**[0057]** According to the seventh preferred embodiment, the second hinge element 51 is rotatable on the swash plate 18. Accordingly, even if the swash plate 18 inclines to twist the second protrusion 44 between the link arms 61 by the axial load due to the compression reactive force, stress due to the inclination rotates the second hinge element 51 around the axis M on the swash plate 18 so as to prevent the second protrusion 44 from twisting between the link arms 61.

**[0058]** An eighth preferred embodiment of the present invention will now be described with reference to FIGs. 12 and 13. The components that are different from those of the first preferred embodiment are only described. The same reference numerals denote the substantially identical components to those of the first preferred embodiment, and the description is omitted.

**[0059]** FIG. 12 illustrates a longitudinal cross-sectional view of the hinge mechanism 19 according to the eighth preferred embodiment of the present invention. FIG. 13 illustrates a plan view of the hinge mechanism 19 according to the eighth preferred embodiment of the present invention. In the eighth preferred embodiment, the second hinge element 51 includes the single second protrusion 44. A through hole 44f is formed through the distal end of the second protrusion 44. A pin 65 is fixedly inserted into the through hole 44f in the direction perpendicular to the axis L of the drive shaft 16. With respect to the first hinge element 52, a cam groove 43f is formed in each of the first protrusions 43. The second protrusion 44 is inserted in between the first protrusions 43 so as to permit power transmission from the rotor 17 to the swash plate 18 by contacting the side surfaces 43a, 44a through a washer 67 and to slidably contact the inner surface of the cam groove 43f by a cylindrical surface 65a of both sides of the pin 65 that is inserted into the cam groove 43f.

**[0060]** Accordingly, the axial load that acts on the swash plate 18 due to the compression reactive force

and the like is received by the inner surface of the cam groove 43f of the first protrusion 43 through the pin 65 of the second hinge element 51. When the swash plate 18 varies its inclination angle, the hinge mechanism 19 guides to increase the inclination angle of the swash plate 18 in such a manner that the pin 65 (the cylindrical surface 65a) moves away from the drive shaft 16 along the inner surface of the cam groove 43f on the side of the rotor 17, while the distal end of the second protrusion 44 rotates around a central axis of the pin 65.

**[0061]** According to the eighth preferred embodiment, the second hinge element 51 is rotatable on the swash plate 18. Accordingly, even if the swash plate 18 inclines to twist the second protrusion 44 between the first protrusions 43 and also inclines to twist the pin 65 in the cam groove 43f by the axial load due to the compression reactive force, stress due to the inclination rotates the second hinge element 51 around the axis M on the swash plate 18 so as to avoid their twisting.

**[0062]** The present invention is not limited to the embodiments described above but may be modified into the following alternative embodiments.

**[0063]** In alternative embodiments to those of the above first and third through eighth preferred embodiments, the second hinge element 51 is made of iron series sintered metal. In alternative embodiments to those of the above second preferred embodiment, the first hinge element 52 is made of iron series sintered metal. Accordingly, the sintered metal effectively holds lubricating oil so that sliding performance and seizure resistance improve between the first and second hinge elements 52, 51. Incidentally, the lubricating oil is supplied to the crank chamber 15 with its mist contained in the refrigerant gas.

**[0064]** In alternative embodiments to those of the above preferred embodiments, the second hinge element 51 is rotatable on the swash plate 18, while the first hinge element 52 is rotatable on the rotor 17.

**[0065]** In alternative embodiments to those of the above second preferred embodiment, the first protrusion 43 is only rotatable on the rotor 17 in the components 43, 45 of the first hinge element 52, while the cam portion 45 is fixed to the rotor 17. Similarly, in alternative embodiments to those of the above third preferred embodiment, the second protrusion 44 is only rotatable on the swash plate 18 in the components 44, 45 of the second hinge element 51, while the cam portion 45 is fixed to the swash plate 18.

**[0066]** In alternative embodiments to those of the above first and third through eighth preferred embodiments, a plurality of the second protrusions 44 is separately formed, and each of the second protrusions 44 is individually rotatable on the swash plate 18.

**[0067]** In alternative embodiments to those of the above preferred embodiments, a plane bearing or a rolling bearing is interposed between the shaft portion 48 or 55 and the shaft hole 18c or 17a, respectively. Also, solid lubricant such as fluororesin and molybdenum di-

sulfide is applied on at least one of the outer circumferential surface of the shaft portion 48 or 55 and the inner circumferential surface of the shaft hole 18c or 17a, respectively. Accordingly, the second hinge element 51 smoothly rotates on the swash plate 18 according to the first and third through eighth preferred embodiments or the first hinge element 52 smoothly rotates on the rotor 17 according to the second preferred embodiment. As a result, the swash plate 18 smoothly varies its inclination angle. That is, the compressor smoothly varies its displacement volume.

**[0068]** In alternative embodiments to those of the above preferred embodiments, at least one of the first and second hinge elements 52, 51 includes a shaft hole, while the rotor 17 or the swash plate 18 on which the hinge element is arranged includes a shaft portion. Also, a pair of the first hinge element 52 and the rotor 17 or a pair of the second hinge element 51 and the swash plate 18 respectively includes shaft holes, and a shaft member is interposed between the shaft holes by inserting the shaft member into the shaft holes.

**[0069]** In alternative embodiments to those of the above preferred embodiments, the first hinge element 52 or the second hinge element 51 has the degree of freedom for slide relative to the rotor 17 or the swash plate 18, respectively.

**[0070]** In alternative embodiments to those of the above preferred embodiments, at least one of the first and second hinge elements 52, 51 has two dimensional degree of freedom for motion against the rotor 17 or the swash plate 18 on which the hinge element is arranged. For example, one of the first and second hinge elements 52, 51 has the degree of freedom for rotation and for slide relative to the rotor 17 or the swash plate 18, respectively.

**[0071]** In alternative embodiments to those of the above preferred embodiments, an engaging groove is recessed in a merely disc-shaped rotor (for example, the shape from which the first and second hinge elements 52, 51 are omitted in the above preferred embodiments) or a disc of a swash plate.

**[0072]** In alternative embodiments to those of the above preferred embodiments, the compressor is a variable displacement compressor that has a double-headed piston.

**[0073]** In alternative embodiments to those of the above preferred embodiments, the compressor is a wobble type variable displacement compressor that has a wobble plate or a cam plate.

**[0074]** Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.

**[0075]** A variable displacement compressor has a housing, a piston, a drive shaft, a rotor, a cam plate and a hinge mechanism. The hinge mechanism between the rotor and the cam plate guides the cam plate to incline

and slide relative to the drive shaft. Thus, the displacement volume of the compressor is varied. The rotation of the drive shaft is converted to the reciprocation of the piston through the rotor, the hinge mechanism and the cam plate. The hinge mechanism includes first and second hinge elements that are respectively provided on the rotor and on the cam plate and engage each other. At least one of the first and second hinge elements has a degree of freedom for motion against the rotor and/or the cam plate to which it belongs.

## Claims

1. A variable displacement compressor comprising a housing defining a cylinder bore, a piston accommodated in the cylinder bore, a drive shaft rotatably supported by the housing, a rotor connected to the drive shaft so as to rotate integrally with, a cam plate supported by the drive shaft so as to slide and incline relative to the drive shaft, the cam plate being operatively connected to the piston, and a hinge mechanism interposed between the rotor and the cam plate, the hinge mechanism guiding the cam plate to incline and slide relative to the drive shaft, whereby the displacement volume of the compressor is varied, the rotation of the drive shaft being converted to the reciprocation of the piston through the rotor, the hinge mechanism and the cam plate, **characterized in that** the hinge mechanism includes a first hinge element provided on the rotor and a second hinge element provided on the cam plate, the second hinge element being engaged with the first hinge element, and **characterized in that** at least one of the first and second hinge elements has a degree of freedom for motion against the rotor and/or the cam plate to which the hinge element having the degree of freedom for motion belongs.
2. The variable displacement compressor according to claim 1, wherein at least one of the first and second hinge elements has the degree of freedom for rotation in such a manner that the hinge element is pivotally supported by the rotor and/or the cam plate to which the hinge element having the degree of freedom for rotation belongs.
3. The variable displacement compressor according to any one of claims 1 and 2, wherein at least one of the rotor and the cam plate that includes the hinge element having the degree of freedom for motion has a regulating means for contacting to regulate a motion range of the hinge mechanism.
4. The variable displacement compressor according to any one of claims 1 through 3, wherein the first hinge element has a first protrusion arranged on the

rotor, the first protrusion extending toward the cam plate, the second hinge element having a second protrusion arranged on the cam plate, the second protrusion extending toward the rotor and receiving rotational power from the rotor by engagedly contacting the first protrusion, one of the first and second hinge elements including a receiving portion for receiving axial load at its proximal portion of the protrusion, the receiving portion receiving axial load that acts on the cam plate in such a manner that the receiving portion slidably contacts a distal end of the protrusion of the other of the first and second hinge elements.

5. The variable displacement compressor according to claim 4, wherein the hinge mechanism further includes a slider that is interposed between the receiving portion and the distal end of the protrusion of the other of the first and second elements. 5
6. The variable displacement compressor according to any one of claims 1 through 4, wherein the hinge mechanism further includes a pin that is connected to one of the first and second hinge elements, the other of the first, and second hinge elements including a cam groove, the pin being inserted through the cam groove. 10
7. The variable displacement compressor according to any one of claims 4 and 5, wherein at least one of the first and second protrusions is plurally provided, the plurally provided protrusions being integrated with each other, the integrated plurally provided protrusions has the degree of freedom for motion against the rotor and/or the cam plate to which the integrated plurally provided protrusions belongs. 15
8. The variable displacement compressor according to claim 7, wherein the number of plurally provided protrusions is two. 20
9. The variable displacement compressor according to claim 8, wherein the drive shaft is rotated in a predetermined direction, the two provided protrusions being disposed in the predetermined direction, one of the provided protrusions on a preceding side in the predetermined direction being formed thicker than the other of the provided protrusions on a following side in the predetermined direction. 25
10. The variable displacement compressor according to claim 7, wherein both the first and second protrusions are plurally provided, each number of the plurally provided protrusions being respectively two. 30
11. The variable displacement compressor according to any one of claims 7 through 10, wherein at least one of the first and second hinge elements includes: 35

a base having two surfaces;  
a plurality of the protrusions extending from one of the surfaces of the base; and  
a shaft formed on the other of the surfaces of the base.

12. The variable displacement compressor according to any one of claims 1 through 11, wherein the hinge element having the degree of freedom for motion is made of a material that is smaller in relative density than the rotor and/or the cam plate to which the hinge element belongs. 40
13. The variable displacement compressor according to claim 12, wherein the hinge element having the degree of freedom for motion is made of aluminum series metal, while the rotor and/or the cam plate to which the hinge element belongs is made of iron series metal. 45
14. The variable displacement compressor according to any one of claims 1 through 13, wherein one of the first and second hinge elements includes a guide protrusion while the other of the first and second hinge elements includes a guide groove, the guide protrusion engaging the guide groove for guiding the cam plate to incline and slide relative to the drive shaft. 50
15. The variable displacement compressor according to any one of claims 1 through 14, wherein the cam plate is manufactured by forging. 55
16. The variable displacement compressor according to any one of claims 1 through 15, wherein at least one of the first and second hinge elements is made of iron series sintered metal.
17. The variable displacement compressor according to any one of claims 1 through 16, wherein the compressor is a piston type.

FIG. 1

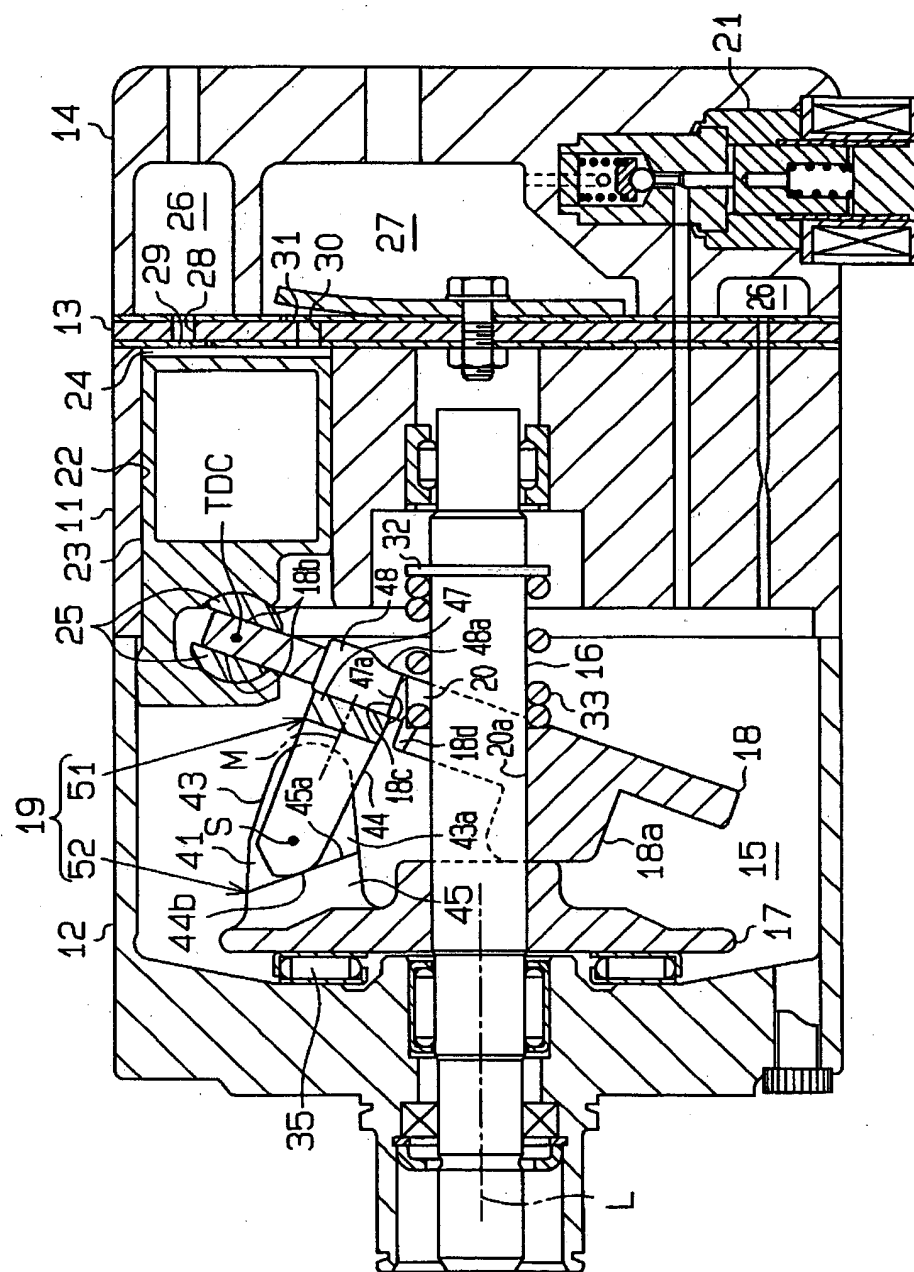


FIG. 2

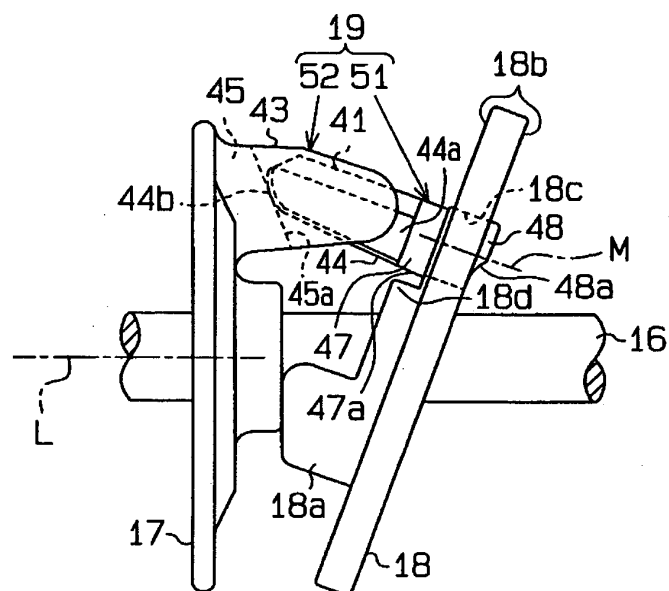


FIG. 3

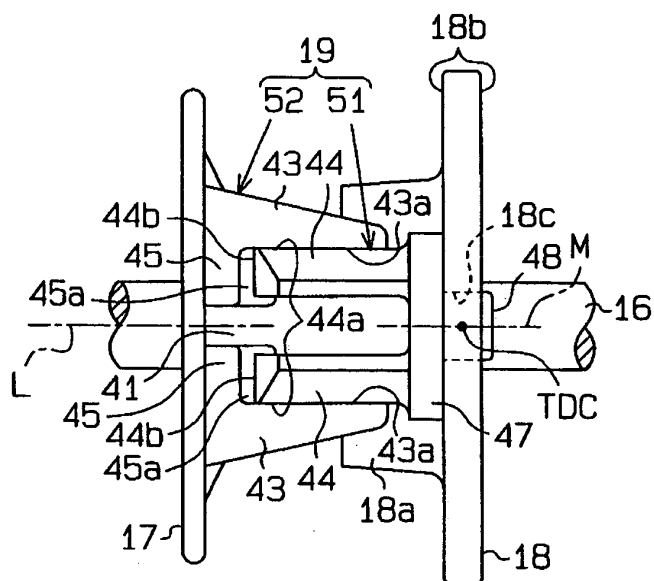
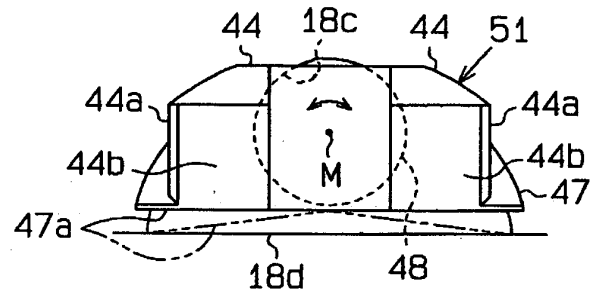


FIG. 4



**FIG. 5**

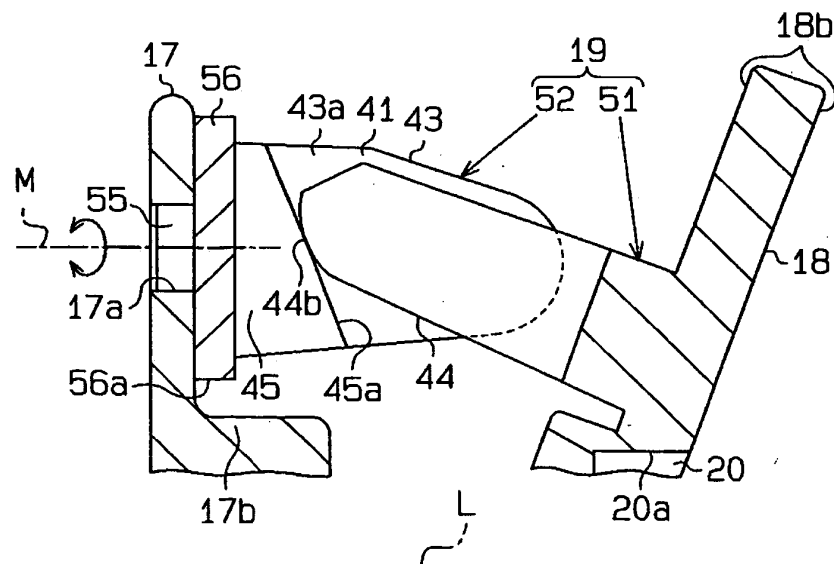


FIG. 6

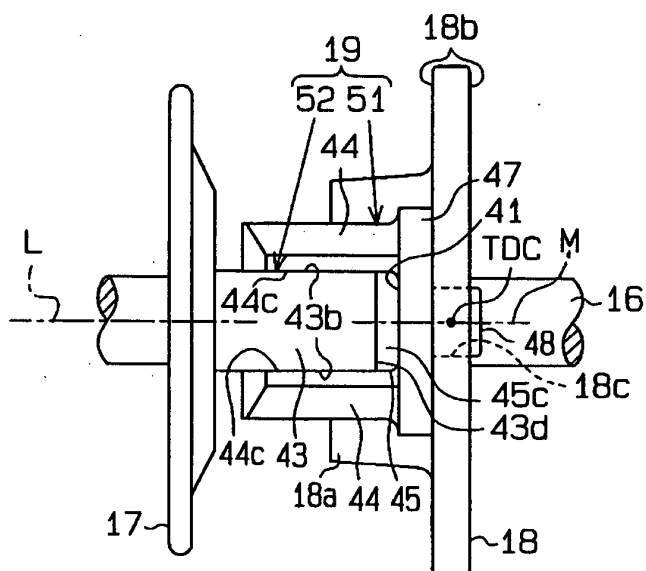


FIG. 7

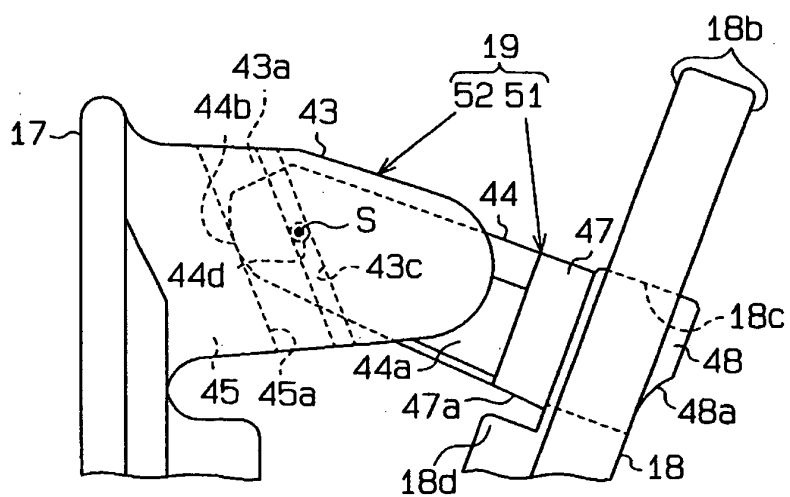


FIG. 8

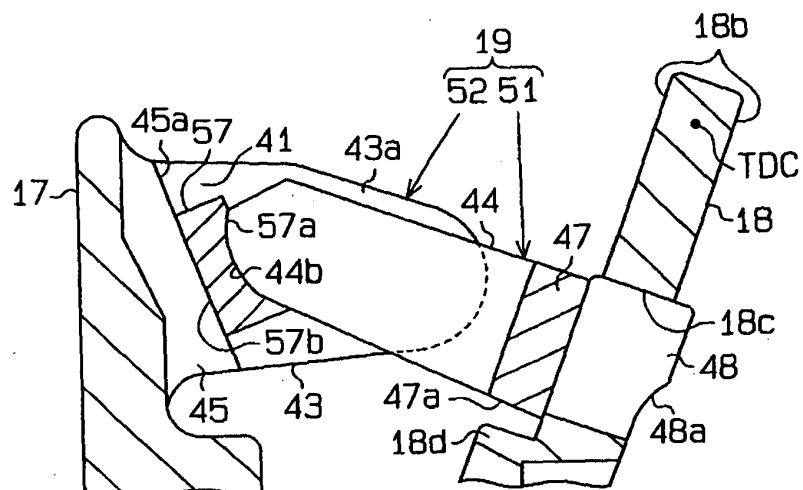


FIG. 9

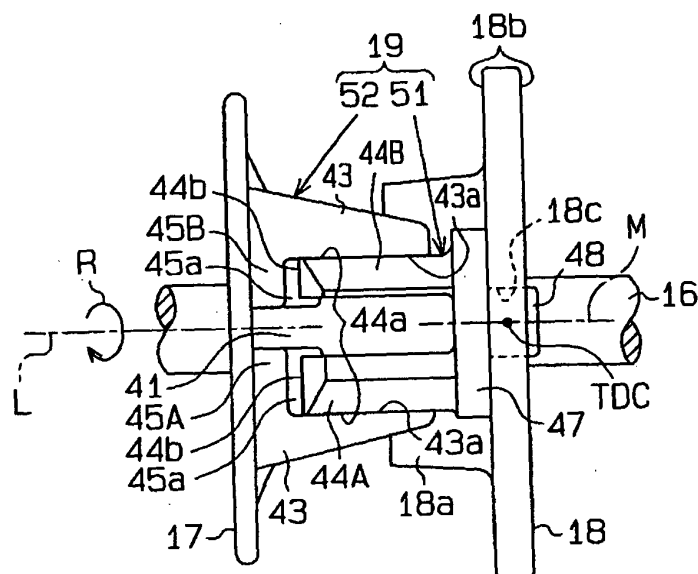


FIG. 10

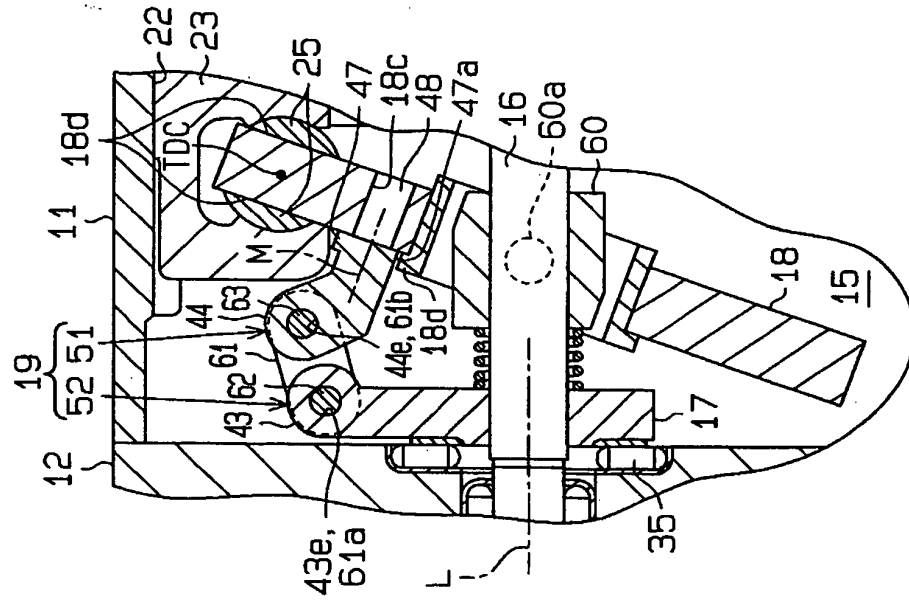
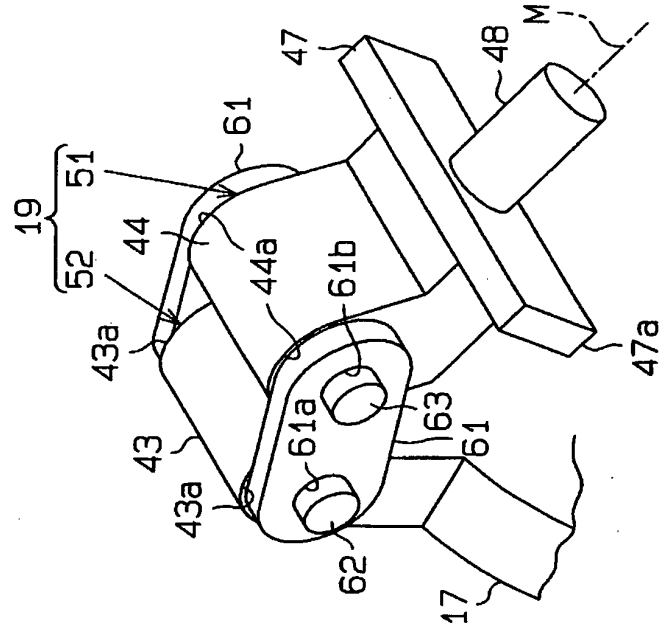
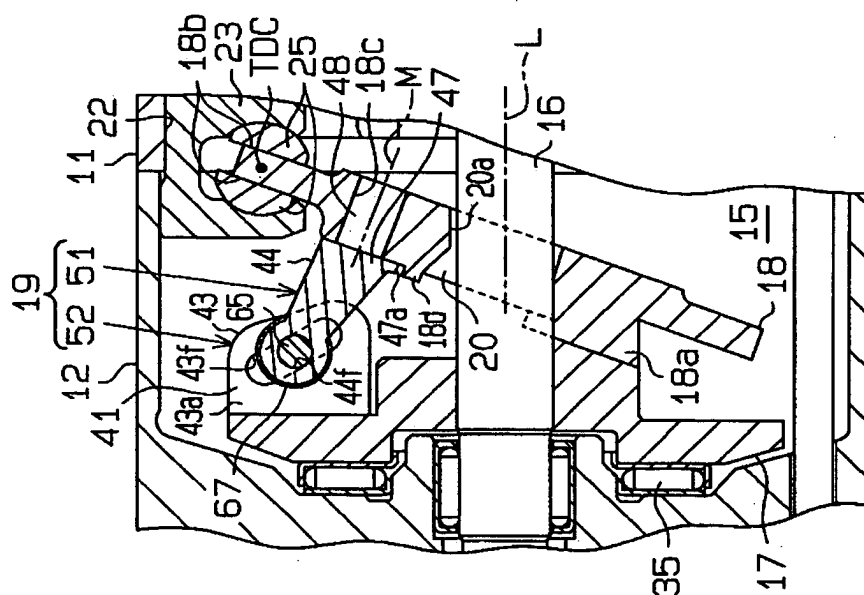


FIG. 11



**FIG. 12**



**FIG. 13**

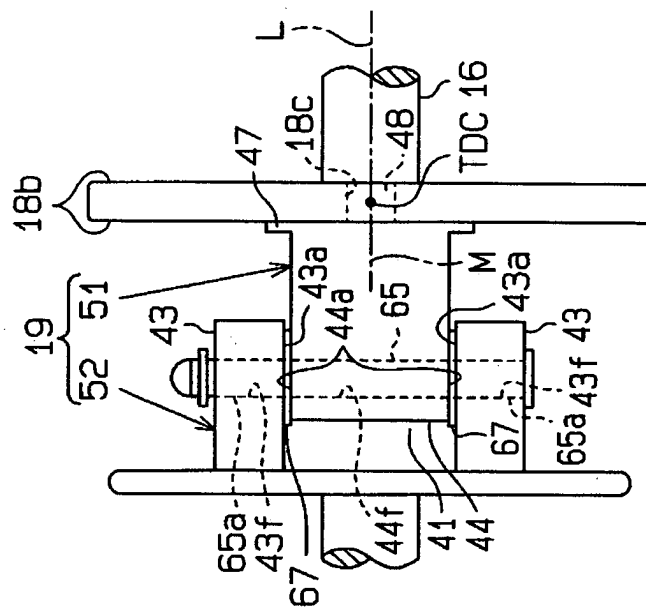


FIG. 14 (PRIOR ART)

