(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 857 679 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
**21.11.2007 Bulletin 2007/47**

(21) Application number: **06728664.1**

(22) Date of filing: **06.03.2006**

(51) Int Cl.:
***F04C 2/344*** *(2006.01)* ***F04C 15/00*** *(2006.01)*

(86) International application number:
**PCT/JP2006/304245**

(87) International publication number:
**WO 2006/095673 (14.09.2006 Gazette 2006/37)**

(84) Designated Contracting States:
**DE ES FR GB IT**

(30) Priority: **08.03.2005 JP 2005063960**

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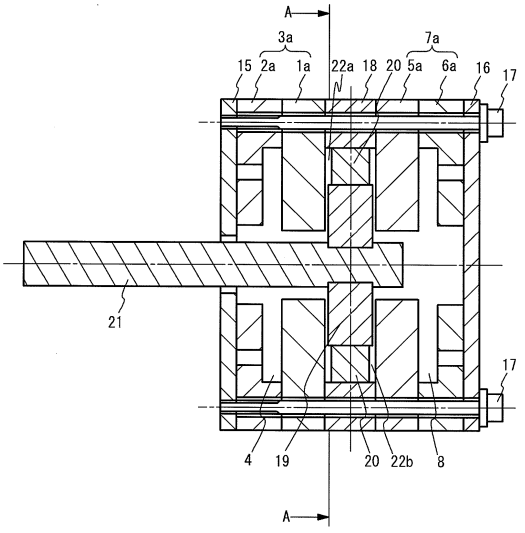
(54) **VANE PUMP**

(57) A vane pump 100 that is provided with, inside a case, a cam ring 18, a rotor 19 that is disposed inside this cam ring 18 so as to be freely rotatable, a plurality of vanes 20 that is accommodated in each of a plurality of vane grooves that is radially formed in this rotor 19 and slides along the cam surface of the cam ring 18 accompanying the rotation of the rotor 19, and a front combination side plate 3a and a rear combination side plate 7a that are disposed on opposite sides of the rotor 19 and the vanes 20. In the vane pump 100, the front combination side plate 3a is a combination side plate formed by a first front plate 1a and a second front plate 2a, the rear combination side plate 7a is a combination side plate formed by a first rear plate 5a and a second rear plate 6a, and the front combination side plate 3 a and the rear combination side plate 7a have an identical rigidity and are symmetrically disposed with respect to the rotor 19.

FIG. 3

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## Description

TECHNICAL FIELD

**[0001]** The present invention relates to a vane pump that has a pair of side plates, each side plate being disposed on opposite sides of a rotor.

BACKGROUND ART

**[0002]** Pumps that generate a fluid pressure include, for example, trochoidal pumps, gear pumps, and piston pumps. A vane pump, which is known as one mode of such a pump, is used, for example, as a pump for supplying a pressurized fluid to the power steering apparatus of an automobile. Generally, this vane pump includes a cam ring that has an elliptical through hole formed therein. In addition, a rotor that is rotated due to a drive shaft is accommodated inside the cam ring. A plurality of radially disposed vane grooves is provided in this rotor, and a vane is accommodated in each of the vane grooves so as to be able to slide.

**[0003]** When the rotor rotates, the vanes are urged in a radial direction by, for example, centrifugal force, and rotate along with the rotor while in contact with the cam surface on the inner circumference of the cam ring. When the rotor and the vanes rotate in this manner, the volume of the working chamber changes, this working chamber being defined by adjacent vanes and the cam surface on the inner circumference of the cam ring. Thus, the intake, pressurization, and discharge of the fluid can be carried out by using this change in volume.

**[0004]** In addition, in such a vane pump, side plates that form a portion of the working chamber may be disposed on opposite sides the rotor and the vanes. In order to generate a high pressure by using a vane pump of this type, it is important to reduce and maintain the gaps between the rotor and vanes and these side plates (referred to as "side clearance"). Thus, various technologies have been proposed that have the object of reducing and maintaining this side clearance.

**[0005]** For example, in Patent Document 1 the following technology has been proposed. According to Patent Document 1, in a vane pump that is provided with a movable side plate on one side, a pressurized fluid having a pressure Pout that is discharged from the working chamber is caused to flow, at the pump intake section, into the vane back pressure chambers that are provided at the bottom of each vane groove. The pressurized fluid having this pressure Pout is further pressurized to a pressure Pv when each of the vanes in the pump discharge section is pressed against the inner circumferential surface of the cam ring. Subsequently, the pressurized fluid having this pressure Pv flows into a back pressure chamber that is formed by the movable side plate. In this vane pump, because the pressure Pv is larger than the pressure Pout, the movable side plate is urged from the back pressure chamber side toward the side of the rotor and the vanes. As a result, it is possible to reduce and maintain the side clearances.

**[0006]** [Patent Document 1] Japanese Patent Application Publication No. 6-207587

DISCLOSURE OF THE INVENTION

[Problems to be Solved by the Invention]

**[0007]** In a typical vane pump, including the one described above, frequently the shape of a back pressure chamber is determined by taking into consideration the ease of manufacturing. Thus, side clearances may be comparatively wide because the effect of urging a movable side plate becomes insufficient. This is because the pumping capacity is established in the case in which this pump is designed for high viscosity fluids or in the case in which a certain amount of bending in the side plate is permitted because the pump is designed for low pressure use. However, when a low viscosity fluid such as light oil is pressurized in such a vane pump so as to try to attain a high pressure, the movable side plate becomes bent and much of the fluid leaks. Thus, a highly pressurized fluid cannot be delivered under pressure by this pump. In addition, in such a pump, a stationary side plate may be deformed due to the pressure inside the pump during the operation of the pump. When the side clearances increase due to this deformation, the amount of leakage of the pressurized fluid increases.

Thus, similarly, the pump cannot supply a fluid that has been highly pressurized.

**[0008]** In consideration of the problems described above, it is an object of the present invention to provide a vane pump that can advantageously maintain side clearances by suppressing to a minimum the bending of the side plates when assembled and suppressing to a minimum the deformation of the side plates even during the operation of the pump.

[Means to Solve the Problems]

**[0009]** The vane pump according to the present invention is provided, inside a case, with a cam ring, a rotor that is disposed inside the cam ring so as to be freely rotatable, a plurality of vanes that is accommodated in a plurality of vane grooves that is radially formed in the rotor and slides along the cam surface of the cam ring accompanying the rotation of the rotor, and side plates that are disposed on opposite sides of the rotor and the vanes, and is characterized in that the side plates have an identical rigidity and are disposed symmetrically with respect to the rotor.

**[0010]** According to the present invention, the side plates that are fastened to opposite side surfaces of the rotor and the vanes have a symmetrical structure that encloses the rotor. Thus, minute deformations in proximity to the axial center that occur when fastened by bolts to the side surface of the cam ring and deformations that

are caused by pressure inside the pump become symmetrical because the rotor is enclosed between side plates. Because the symmetry between the side plates can be ensured in this manner, it is possible to maintain a pressure distribution of the pressurized fluid that is applied to opposite side surfaces of the rotor and the vanes to be symmetrical. Therefore, it is possible to suppress advantageously the deformation of the rotor and the vanes, and it is possible to suppress scorching due to a high surface pressure state that is produced by the rotor and the vanes coming into contact with the side plates.

**[0011]** In addition, in the present invention, each of combination side plates may be formed by identical materials and by identical shapes. Thereby, it is possible to further increase the symmetry between a pair of first plates that is deformed due to the pressure inside the pump.

**[0012]** In addition, in the present invention, the side plates may be a combination side plate made by a first plate and a second plate, and a back pressure chamber into which the pressurized fluid is caused to flow may be provided between the first plate and the second plate. Thereby, it is possible to separately manufacture the combination side plates as two parts, the first plate and the second plate, and thus it is possible to manufacture the side plates that form the back pressure chamber simply and inexpensively.

**[0013]** In addition, the vane pump according to the present invention is provided, in a case, with a cam ring, a rotor that is disposed inside the cam ring so as to be freely rotatable, a plurality of vanes that is accommodated in a plurality of vane grooves that is radially disposed in the rotor and slides along the cam surface of the cam ring accompanying the rotation of the rotor, and side plates that are disposed on opposite sides of the rotor and the vanes, characterized in that a bolt is inserted into a center hole in at least one of the side plates.

**[0014]** According to the present invention, it is possible to apply a compression force on the first plate by tightening a linking bolt that fastens the first plate and the second plate. Thereby, it is possible to increase the rigidity of the first plate, and thus it is possible to suppress the deformation of the first plate that is due to the pressure inside the pump. Thereby, because an excess side clearance is not necessary in order to prevent scorching between the rotor, the vanes, and the first plate, it is possible to reduce the side clearance further.

**[0015]** In addition, in the present invention, each of the side plates may be a linked combination side plate in which a first plate and a second plate are held together by a linking bolt, the linking bolt is inserted into a center hole in the second plate, and fastened in an internal thread that is formed in a center hole in the first plate. Thereby, it is possible to increase the rigidity of the center hole vicinity of the first plate.

**[0016]** In addition, in the present invention, the linking bolt may be a hollow bolt. Thereby, interference between the linking bolt and the drive shaft that is coupled with the rotor can be avoided, and it is possible thereby to dispose the combination side plate in the vane pump.

**[0017]** In addition, in the present invention, a back pressure chamber into which pressurized fluid is caused to flow may be provided between the first plate and the second plate. Thereby, because it is possible to separately manufacture the side plates as two parts, the first plate and the second plate, it is possible to manufacture the side plates that form the back pressure chamber easily and inexpensively.

**[0018]** In addition, in the present invention, the linked combination side plates and the cam ring may be fastened by fastening bolts that are disposed in the outer circumferential portion thereof, and a compression force may be applied in advance to the center hole vicinity of the first plate by tightening the linking bolt. In this manner, when the linked combination side plates are fastened by bolts at the outer circumferential vicinity of the cam ring, the center hole vicinity of the first plate is deformed towards the rotor side due to the influence of the fastening force. By using this structure, by tightening the linking bolt, a compression force that is in a direction opposite to the direction of the deformation in the center hole vicinity of the first plate can be applied in advance before deformation, and thus it is possible to suppress the deformation of the first plate.

**[0019]** In addition, in the present invention, both of the side plates may be linked combination side plates. In the case in which both of the side plates are linked combination side plates, these side plates have a symmetrical structure that encloses the rotor. Thus, it is possible to maintain the symmetry of the pressure distribution of the fluid that is applied to the opposite side surfaces of the rotor and the vanes.

**[0020]** In addition, in the present invention, one of the side plates may be the linked combination side plate, and the other may be the combination side plate. In this case, including the linked combination side plate, by tightening the linking bolt in advance by an amount of tightening that allows for the deformation of the other combination side plate, it is possible to ensure the symmetry of the distribution of the fluid pressure that is applied to opposite sides of the rotor and the vanes. Thereby, it is possible to suppress advantageously the deformation of the rotor and the vanes, and it is possible to suppress scorching due to a high surface pressure state that is produced by the rotor and the vanes coming into contact with each of the first plates.

**[0021]** In addition, in the present invention, one of the side plates may be a linked combination side plate, and the other may be a movable side plate that freely slides in an axial direction. In this case, furthermore, it is possible to set the deflection of the flatness of the contact face of this movable side plate with the rotor and the vanes.

**[0022]** In addition, in the present invention, one of the side plates may be the movable combination side plate that freely slides in an axial direction, and the other may

be the combination side plate. Due to this structure, similar to the linked combination side plate, this movable combination side plate can suppress the deformation of the first plate by increasing the rigidity in proximity to a shaft center. Furthermore, it is possible to set the deflection of the flatness of the contact face of this movable combination side plate with the rotor and the vanes.

**[0023]** In addition, in the present invention, one of the side plates may be the movable combination side plate that freely slides in an axial direction, and the other may be the linked combination side plate. In this case, furthermore, because it is possible to set the amount of tightening of the linking bolt 9 on the combination side plate side, there is a high degree of freedom to change the rigidity.

**[0024]** In addition, in the present invention, one of the side plates may be the movable combination side plate that freely slides in an axial direction, and the other may be the movable side plate. In this case, furthermore, it is possible to set the deflection of the flatness of the contact face with the rotor and the vanes.

**[0025]** In addition, in the present invention, one of the side plates may be the movable combination side plate the freely slides in an axial direction. In this case, furthermore, because these side plates have a symmetrical structure that encloses the rotor, it is possible to maintain the symmetry of the pressure distribution of the fluid that is applied to the opposite side surfaces of the rotor and the vanes.

[Effects of the Invention]

**[0026]** According to the present invention, it is possible to provide a vane pump that can suppress to a minimum the bending of the side plates during assembly, can suppress to a minimum the deformation of the side plates even during the operation of the pump, and can maintain the side clearances advantageously.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0027]**

[FIG. 1]
FIG. 1 is an external view of a vane pump according to the present invention.
[FIG. 2]
FIG. 2 is a cross-sectional drawing of the vane pump according to the present invention.
[FIG. 3]
FIG. 3 is a cross-sectional drawing that shows an example of a pressurized portion of the vane pump according to the present invention, in which both of a pair of side plates are combination side plates.
[FIG. 4]
FIG. 4 is a cross-sectional drawing of a pressurized portion of the vane pump according to the present invention along the line A-A in FIG. 3.
[FIG. 5]
FIG. 5(a) and FIG. 5(b) show drawings for explaining the combination side plates of the vane pump according to the present invention.
[FIG. 6]
FIG. 6 is a cross-sectional drawing that shows an example of the pressurized portion of the vane pump according to the present invention in which both side plates are linked combination side plates.
[FIG. 7]
FIG. 7 is a cross-sectional drawing that shows an example of the pressurized portion of the vane pump according to the present invention in which one of the side plates is the linked combination side plate and the other is the combination side plate.
[FIG. 8]
FIG. 8 is a cross-sectional drawing that shows an example of the pressurized portion of the vane pump according to the present invention in which one of the side plates is the linked combination side plate and the other is a movable side plate.
[FIG. 9]
FIG. 9 is a cross-sectional drawing that shows an example of the pressurized portion of the vane pump according to the present invention in which one of the side plates is a movable combination side plate and the other is a combination side plate.
[FIG.10]
FIG. 10 is a cross-sectional drawing that shows an example of the pressurized portion of the vane pump according to the present invention in which one of the side plates is the movable combination side plate and the other is the linked combination side plate.
[FIG.11]
FIG. 11 is a cross-sectional drawing that shows an example of the pressurized portion of the vane pump according to the present invention in which one of the side plates is the movable combination side plate and the other is the movable side plate.
[FIG. 12]
FIG. 12 is a cross-sectional drawing that shows an example of the pressurized portion of the vane pump according to the present invention in which both of the side plates are the movable combination side plates.

BEST MODES FOR CARRYING OUT THE INVENTION

**[0028]** Below, best modes of carrying out the present invention will be explained.

First Embodiment

**[0029]** FIG. 1 is an external view of a vane pump 100. As shown in FIG. 1, a case of the vane pump 100 is formed such that a head flange cover 10 is fastened to a center case 11, for example, by press fitting or a bolt fastening, and a case rear cover 12 is fastened to the

center case 11 by fastening bolts 13. In addition, FIG. 2 is a cross-sectional drawing of the vane pump 100 that is shown in FIG. 1. The vane pump 100 accommodates a pressurized portion inside the case.

**[0030]** FIG. 3 is a cross-sectional drawing of this pressurized portion that isolates and shows the portion that is enclosed by the circle in FIG. 2. As shown in FIG. 3, a front combination side plate 3 a and a rear combination side plate 7a are disposed on the sides of a cam ring 18. Furthermore, a front cover 15 is disposed on the side surface of a front combination side plate 3a. Similarly, a rear cover 16 is disposed on the side surface of a rear combination side plate 7a. The front combination side plate 3a is structured by a first front plate 1a and a second front plate 2a. Similarly, the rear combination side plate 7a is structured by a first rear plate 5a and a second rear plate 6a. In each of the members described above, a plurality of concentrically disposed through holes is formed in the outer circumferential portion, and furthermore, internal threading is formed in the through holes in the front cover 15. The pressurized portion that is shown in FIG. 3 is integrally formed by inserting a fastening bolt 17 into a through hole from the front cover 15 side and fastening the fastening bolt 17 to the rear cover 16. A rotor 19 and vanes 20 are accommodated inside the cam ring 18.

**[0031]** FIG. 4 is a cross-sectional drawing along line A-A of the pressurized portion that is shown in FIG. 3. As shown in FIG. 4, the cam ring 18 has a through hole that is elliptically formed, and the rotor 19 is accommodated inside the cam ring 18. A plurality of radially formed grooves that extend in a radial direction is arranged at equal intervals in the circumferential direction on the outer circumferential surface of the rotor 19. The vanes 20, which can slide in a radial direction, are accommodated in respective grooves, and are continuously pressed against the inner circumferential surface of the cam ring 18 by being urged in the radial direction by, for example, centrifugal force. The rotor 19 is linked to a drive shaft 21 by fitting the drive shaft 21, which includes a corresponding spline shaft, into a spline hole that is formed at the center of rotation of the rotor 19. The drive shaft 21 rotates due to the drive force of an internal combustion engine or the like. Working chambers 23 are formed in the spaces that are enclosed by two adjacent vanes 20 and the cam ring 18. As shown in FIG. 3, the wall surfaces of each working chamber 23 in the axial direction are the first front plate 1a and the first rear plate 5a. The volume of the working chamber 23 expands and contracts accompanying the rotation because the inner circumferential surface of the elliptically shaped through hole of the cam ring 18 forms a portion of the wall surface of the working chamber 23.

**[0032]** In FIG. 4, intake ports 24 that each draw the fluid into the vane pump and discharge ports 25 that discharge the pressurized fluid to the outside are formed in the first rear plate 5a. The first front plate 1a is also structured similarly. The intake ports 24 are formed at positions in the circumferential direction, at which a suction force is generated due to the volume of the working chambers 23 expanding, and in the radial direction, that correspond to the working chambers 23. In addition, the discharge ports 25 are formed at positions in the circumferential direction, at which a pressure is generated due to the volume of the working chambers 23 contracting, and in the radial direction, that correspond to working chambers 23.

**[0033]** In this structure, when the drive shaft 21 is rotated, the volume of the working chamber 23 expands and contracts accompanying this rotation. Thus, during a volume expanding step of the working chamber 23, a suction force is generated accompanying the expansion of the volume, and the working chamber 23 draws the fluid from the outside portion through the intake port 24 that is formed in a side plate. As the rotation of the drive shaft 21 advances, among the vanes 20 that form the working chamber 23, the vane 20 that is disposed toward the back with respect to the direction of the rotation passes by the intake port 24 and the working chamber 23 become a closed space. Then, as the rotation of the drive shaft 21 advances further, the working chamber 23 reaches a volume contraction step, and the fluid is pressurized accompanying the contraction of the volume. Among the vanes 20 that form the working chamber 23, when the vane 20 that is disposed toward the front with respect to the direction of rotation passes by the discharge port 25, the fluid, which has become highly pressurized, is discharged from the discharge port 25 to the outside portion.

**[0034]** In relation to this, as shown in FIG. 3, when the front combination side plate 3a and the rear combination side plate 7a are each fastened by the fastening bolts 17 to the side faces of the cam ring 18, due to the fastening force, as shown in FIG. 5(a), a center hole vicinity 26 of the first front plate 1a may be deformed toward the rotor side. This is similar in the first rear plate 5a as well. In addition, during the operation of the pump, the first front plate 1a and the first rear plate 5a may also deform due to the internal pressure of the pump. In the present embodiment, as shown in FIG. 3, the front combination side plate 3 a and the rear combination side plate 7a are symmetrically structured so as to enclose the rotor 19. Furthermore, these combination side plates are formed so as to have identical shapes and have the same rigidity by using identical members.

**[0035]** By using the symmetric structure that has been described above, the minute deformations of the center hole vicinities 26 of the front combined side plate 3a and the rear combination side plate 7a that occur when the they are fastened to the side surface of the cam ring 18 by the fastening bolts 17 and the deformations that are caused by the pressure inside the pump become symmetric as the rotor is enclosed by both of the combined side plates. By ensuring the symmetry of the deformations between each of the combined side plates in this manner, the symmetry of the distribution of the fluid pres-

sure that is applied to the opposite side surfaces of the rotor 19 and the vanes 20 can be ensured. Therefore, it is possible to suppress advantageously the deformation of the rotor 19 and the vanes 20, and it is possible to suppress scorching due to a high surface pressure state that is produced by the rotor 19 and the vanes 20 coming into contact with the combination side plates. In addition, because these combined side plates are formed so as to have identical shapes and identical rigidity by using the identical members, it is possible to increase further the symmetry of the front combination side plate 3a and the rear combination side plate 7a that have been deformed due to the pressure inside the pump and the like.

**[0036]** In addition, in the present embodiment, a stepped through hole is formed in the inner circumferential surface in the second front plate 2a. A front back pressure chamber 4 is formed by the cylindrical space that is defined by the step of this inner circumferential surface and the wall surface on the second front plate 2a side of the first front plate 1a. Similarly, a stepped through hole is also formed in the second rear plate 6a, and a cylindrical rear back pressure chamber 8 is thereby formed. The front back pressure chamber 4 and the rear back pressure chamber 8 communicate, via communication ducts (not illustrated), with each of the discharge ports 25 that are shown in FIG. 4, and pressurized fluid that has attained a high pressure is caused to flow toward each of the back pressure chambers.

**[0037]** Because the back pressure chambers 4 and 8 are formed in the manner described above, these combination side plates can each be manufactured separately as two parts, the first front plate 1a and the second front plate 2a, and the first rear plate 5a and the second rear plate 6a, respectively. Thus, it is possible to manufacture the side plates that form the back pressure chambers easily and inexpensively.

Second Embodiment

**[0038]** FIG. 6 is a cross-sectional drawing of the pressurized portion, and the present embodiment can be accommodated in the portion that is enclosed by the circle in FIG. 2 in place of the pressurized portion that is shown in FIG. 3. A front combination side plate 3b is structured by a first front plate 1b and a second front plate 2b. Similarly, a rear combination side plate 7b is structured by a first rear plate 5b and the second rear plate 6b. A stepped through hole is formed in the inner circumferential surface of the second front plate 2b. In addition, the cylindrical space that is defined by the step in the inner circumferential surface and the wall surface on the second front plate 2b side of the first front plate 1b forms a front back pressure chamber 4. Similarly, a stepped through hole is also formed in the second rear plate 6b, and a cylindrical rear back pressure chamber 8 is formed. The front back pressure chamber 4 and the rear back pressure chamber 8 communicate by a communication ducts (not illustrated) with each of the discharge ports that are shown in FIG. 4, and a pressurized fluid that has attained a high pressure is caused to flow into each of the back pressure chambers. Through holes are formed in the first front plate 1b and the first rear plate 5b at their respective axial centers, and furthermore, internal threads 14 are formed in these through holes. In addition, a counter bore 32 that accommodates the bolt head of a linking bolt 9 is formed at the axial center of the side surface of the second front plate 2b on the front cover 15 side. Similarly, a counter bore 32 that accommodates the bolt head of a linking bolt 9 is formed at the axial center of the side surface of the second rear plate 6b on the rear cover 16 side. The linking bolt 9 links together the first front plate 1b and the second front plate 2b. Similarly, the linking bolt 9 links together the first rear plate 5b and the second rear plate 6b. The linking bolts 9 that are used are hollow, and the drive shaft 21 is accommodated inside the linking bolts 9.

**[0039]** In relation to this, when the front combination side plate 3b and the rear combination side plate 7b are fastened by the fastening bolts 17 to the side surfaces of the cam ring 18, in the case in which there is no linking bolt 9, the center hole vicinities 26 of the first front plate 1b and the first rear plate 5b may each deform toward the rotor 19 side, similar to the deformation that is shown in FIG. 5(a), due to the fastening force. When such deformation occurs, the symmetry of the fluid pressure that is applied to opposite sides of the rotor 19 and the vanes 20 may be broken, and as a result, the rotor 19 and the vanes 20, for which the center hole vicinities 26 serve as a supporting point, may break down. As a result, the position and amount of the gap between the rotor 19, the vanes 20, and each of the side plates becomes imprecise. Furthermore, during the operation of the pump, the position and amount of this gap changes accompanying the rotation of the rotor 19 and the vanes 20, and these cannot be known. When such a condition occurs, scorching may occur when the rotor 19 and the vanes 20 come into contact with the first front plate 1b and the first rear plate 5b to produce a high surface pressure state.

**[0040]** However, in the present embodiment, as shown in FIG. 5(b), it is possible to suppress the deformation described above to a given constant level by applying in advance a compression force that is in a direction that is opposite to the direction of the deformation by tightening the linking bolts 9 in the center hole vicinities 26 of the first front plate 1b and the first rear plate 5b. In addition, because the deformation of these center hole vicinities 26 can be suppressed to a given constant level, the symmetry of a first side clearance 22a and a second side clearance 22b on opposite sides of the rotor 19 can be ensured at a given constant level. Thus, it is possible to maintain a symmetrical distribution of the fluid pressure that is applied to opposite side surfaces of the rotor 19 and the vanes 20, and it is possible to suppress thereby scorching of the rotor 19 and the vanes 20. In addition, if the deformation in the center hole vicinities 26 and the deformation of each of the first plates 1b and 5b due to

the fluid pressure described above are ascertained as known values by experimentation and the like, it is possible to set the amount of the tightening of the linking bolt 9 such that the first side clearance 22a and the second clearance 22b can be ensured at a given constant amount. In addition, by applying a compression force by tightening the linking bolts 9, it is possible to increase the rigidity of the center hole vicinities 26 of the first front plate 1b and the first rear plate 5b. By increasing the rigidity in this manner, the deformation of the first front plate 1b and the first rear plate 5b due to the pressure inside the pump can be suppressed. Thereby, in the case in which there is a concern that the side plates would usually be deformed, normally, it is necessary to ensure a wide first side clearance 22a and the second side clearance 22b in order to prevent scorching between the side plates, the rotor 19, and the vanes 20. However, in the present embodiment, these side clearances can be further reduced. In addition, normally, in order to change the rigidity of the side plates, the plate thickness of the side plates is changed, the material is changed, or the shape is changed. However, in the present embodiment, in addition to these methods, it is possible to change the rigidity of the first front plate 1b and the first rear plate 5b, which are portions of the side plate, according to the amount of tightening of the linking bolts 9, and thus there is a high degree of freedom to change the rigidity of the side plates.

**[0041]** In addition, similar to the first embodiment, because the front combination side plate 3b and the rear combination side plate 7b that enclose the rotor 19 have a symmetrical structure, the present embodiment can also ensure a symmetrical distribution of the fluid pressure that is applied to opposite side surfaces of the rotor 19 and the vanes 20, and it can prevent thereby scorching of the rotor. In addition, similar to the first embodiment, because the first front side plate 3b can be separated into two members, the first front plate 1b and the second front plate 2b, the parts manufacturing for forming the front back pressure chamber 4 is simple. The first rear side plate 7b is identical in this respect. Thus, the parts manufacturing is inexpensive and suitable for mass production. Note that similar to the first embodiment, the front combination side plate 3b and the rear combination side plate 7b may be identical members and have identical rigidity. In addition, according to the structure of the vane pump, the linking bolts 9 that are used need not be hollow, and may be any suitable bolt.

Third Embodiment

**[0042]** The pressurized portion that is shown in FIG. 7 is a cross-sectional drawing of a pressurized portion that is provided with a front combination side plate 3b for one among the pair of side plates. This pressurized portion can be accommodated in the portion that is enclosed by the circle in FIG. 2 in place of the pressurized portion that is shown in FIG. 3. In addition, this pressurized portion is one in which the front combination side plate 3 a of the pressurized portion that is shown in FIG. 3 is replaced by the front combination side plate 3b of the pressurized portion described in the second embodiment.

**[0043]** Even if only one side plate is a front combination side plate 3b that is fastened together by a linking bolt 9, as in this pressurized portion, similar to the embodiment 2, for a deformation such as that shown in FIG. 5(a), it is possible to suppress the deformation of the center hole vicinity 26 of the front plate 1b by tightening the linking bolt 9. In addition, because it is possible to suppress deformation that is caused by the pressure inside the pump by tightening the linking bolt 9 to increase the rigidity of the center hole vicinity 26, it is possible to reduce the side clearance 22a further. Furthermore, if a deformation similar to that shown in FIG. 5(a) and a deformation of the first front plate 1b and the first rear plate 5a on opposite sides of the rotor 19 and the vanes 20 that is caused by the pressure inside the pump are ascertained as known values by experimentation and the like, it is possible to set the amount of tightening of the linking bolt 9 so as to enable ensuring the first side clearance 22a and the second side clearance 22b that are at given constant amounts. By tightening the linking bolt 9 by this tightening amount, it is possible to ensure the symmetry of the distribution of the fluid pressure that is applied to the opposite side surfaces of the rotor 19.

**[0044]** In addition, in the pressurized portion that is shown in FIG. 8, a rear ring 29a that can accommodate a front plate 5c is provided on the side surface of the cam ring 18 instead of the rear combination side plate 7a that is shown in FIG. 7, and the first rear plate 5c is accommodated inside the rear ring 29a. This first rear plate 5c is a movable side plate that freely slides in an axial direction. Furthermore, a second rear plate 6c is provided to the rear ring 29a on a side away from the cam ring 18. The second rear plate 6c is a cylindrical member, and a step is formed on the inner circumferential surface thereof. A rear back pressure chamber 8 is formed by the space that is defined by the step of this inner circumferential surface and the wall surface of the second rear plate 6c that is opposite to the rotor, and pressurized fluid is caused to flow in through communication ducts (not illustrated). In addition, the second rear plate 6c accommodates a movable side plate set spring 27a inside the cylinder. Due to this movable side plate set spring 27a and the pressure of the pressurized fluid, the first rear plate 5c is urged toward the rotor 19 side.

**[0045]** In the case of this pressurized unit, the deformation of the first front plate 1b, similar to the deformation that is shown in FIG. 5(a), and the deformations of the first front plate 1b and the first rear plate 5c due to the pressure inside the pump can be suppressed by tightening the linking bolt 9, similar to the pressurized portion that is shown in FIG. 7 and described above. Thereby, similar to the cases described above, it is possible to ensure the symmetry of the distribution of the fluid pressure that is applied to the opposite side surfaces of the

rotor 19 and the vanes 20. Note that in the pressurized portions that are shown in FIG. 7 and FIG. 8, for the combination of the pair of side plates that enclose the rotor 19, a structure may be used in which the side plates of the front side and the side plates of the rear side are interchanged.

Fourth Embodiment

**[0046]** The pressurized portion that is shown in FIG. 9 provides a rear ring 29b that can accommodate one among a pair of side plates, and the movable combination side plate 7d is accommodated inside this rear ring 29b. This movable rear combination side plate 7d freely slides the combination side plate 7b in an axial direction. This combination side plate 7b is that of the pressurized portion that is shown in FIG. 6 to FIG. 8 and described above. The pressurized portion that is shown in FIG. 9 can be accommodated in the portion that is enclosed by the circle in FIG. 2 in place of the pressurized portion that is shown in FIG. 3. In addition, in this pressurized portion, the rear combination side plate 7a of the pressurized portion of the first embodiment that is shown in FIG. 3 is replaced with the movable rear combination side plate 7d. Furthermore, among the side surfaces of the rear ring 29b, the side surface that is away from the cam ring 18 is provided with a third rear plate 31. The movable rear combination side plate 7d that is provided in the pressurized portion that is shown in FIG. 9 is formed by using the linking bolt 9 to fasten together the first rear plate 5d and the second rear plate 6d. The third rear plate 31 is a cylindrical member that forms a rear back pressure chamber 8 inside thereof and accommodates a movable side plate set spring 27b. Communication ducts (not illustrated) cause the pressurized fluid to flow into this rear back pressure chamber 8. Due to this pressure of the pressurized fluid and the movable side plate set spring 27b, the movable rear combination side plate 7d is urged toward the rotor 19 side.

**[0047]** In the case of this pressurized portion as well, similar to the pressurized portion in FIG. 7, by increasing the rigidity, it is possible to suppress the deformation of the second rear plate 5d that is caused by pressure inside the pump. In addition, by allowing for the deformation of the first front plate 1a and the first rear plate 5d on the sides of the rotor 19 when tightening the linking bolt 9 by a suitable amount, similarly, it is possible to ensure the symmetry of the distribution of the fluid pressure that is applied to opposite side surfaces of the rotor 19 and the vanes 20. Furthermore, by providing the movable rear combination side plate 7d that can move in the axial direction, it is possible to set the deflection of the flatness of the contact face with the rotor 19 and the vanes 20.

**[0048]** In addition, the pressurized portion that is shown in FIG. 10 is provided with the movable rear combination side plate 7d on one side and is provided with the front combination side plate 3b, which has been described above, on the other side. In the case of this pressurized portion as well, it is possible to suppress the deformation of the first front plate 1b, which is similar to the deformation that is shown in FIG. 5(a). In addition, it is possible to suppress the deformation of the first front plate 1b and the first rear plate 5d due to the pressure inside the pump by increasing the rigidity. In addition, by allowing for the deformation of the first front plate 1b and the first rear plate 5d on opposite sides of the rotor 19 when tightening the linking bolt 9, similarly, it is possible to ensure the symmetry of the distribution of the fluid pressure that is applied to the opposite side surfaces of the rotor 19 and the vanes 20. In addition, similar to the pressurized portion that is shown in FIG. 9, by providing the movable rear combination side plate 7d that can move in the axial direction, it is possible to set the deflection of the flatness of the contact face with the rotor 19 and the vanes 20. Furthermore, because it is possible to set the amount of tightening of the linking bolt 9 for both the first front plate 1b and the first rear plate 5d, there is a high degree of freedom to change the rigidity.

**[0049]** In addition, the pressurized portion that is shown in FIG. 11 is provided with a movable front combination side plate 3d on one side, and is provided with the first rear plate 5c, which is a movable side plate, on the other side. This movable front combination side plate 3d has a structure that is identical to that of the movable rear combination side plate 7d of the pressurized portion that is shown in FIG. 10. In the case of this pressurized pump as well, by allowing for the deformation of the first front plate 1d and the first rear plate 5c that are on opposite sides of the rotor 19 when tightening the linking bolt 9 by an appropriate amount, it is possible to ensure the symmetry of the distribution of the fluid pressure that is applied to the opposite side surfaces of the rotor 19 and the vanes 20. In addition, by increasing the rigidity, it is possible to suppress the deformation of the first front plate 1d that is caused by the pressure inside the pump. In addition, similar to FIG. 9 and FIG. 10, by providing the movable front combination side plate 3d that can freely slide in the axial direction, it is possible to set the deflection of the flatness of the contact face with the rotor 19 and the vanes 20.

**[0050]** In addition, the pressurized portion that is shown in FIG. 12 is one in which the pair of plates that encloses the rotor 19 are both formed as movable combination side plates. As shown in FIG. 12, these side plates are the movable front combination side plate 3d and the movable rear combination side plate 7d. In the case of this pressurized portion as well, by increasing the rigidity, it is possible to suppress the deformation of the first front plate 1d and the first rear plate 5d that is caused by pressure inside the pump. In addition, by allowing for the deformation of the first front plate 1d and the first rear plate 5d that are on the opposite sides of the rotor 19 when tightening the linking bolt 9 by an appropriate amount, it is possible to maintain the symmetry of the distribution of the pressurized fluid pressure that is applied to opposite sides of the rotor 19. In addition,

similar to FIG. 9, FIG. 10, and FIG. 11, by providing the movable front combination side plate 3d and the movable rear combination side plate 7d that freely slide in the axial direction, it is possible to set the deflection of the flatness of the contact face with the rotor 19 and the vanes 20. Furthermore, because the pair of side plates that enclose the rotor 19 is symmetrical, the symmetry of the distribution of the fluid pressure that is applied to the opposite sides of the rotor 19 and the vanes 20 can be further ensured. Therefore, it is possible to suppress the deformation of the rotor 19 and the vanes 20 advantageously, and it is possible to suppress scorching due to a high surface pressure state that is produced by the rotor 19 and the vanes 20 coming into contact with each of the combination side plates 3d and 7d. Note that an identical material may be used for and an identical shape may be applied to these combination side plates 3d and 7d, and they may be formed so as to have an identical rigidity. In this case, it is possible to increase the symmetry between the front combination side plate 3d and the rear combination side plate 7d. In addition, in the pressurized portions that are shown in FIG. 9, FIG. 10, and FIG. 11, for the combination of the pair of side plates that enclose the rotor 19, a structure may be used in which the side plates of the front side and the side plates of the rear side are interchanged.

**[0051]** According to these embodiments, it is possible to realize a vane pump that can suppress to a minimum the bending of the side plates during installation, that can suppress to a minimum the deformation of the side plates even during the operation of the pump, and that can advantageously maintain side clearances.

**[0052]** While the preferred embodiments of the present invention have been explained above in detail, the present invention is not limited by these particular embodiments, and various modifications and changes are possible that are within the scope of the present invention that is recited within the claims.

## Claims

1. A vane pump comprising, inside a case, a cam ring, a rotor that is disposed inside the cam ring so as to be freely rotatable, a plurality of vanes that is accommodated in each of a plurality of vane grooves that is radially formed in the rotor and slides along a cam surface of the cam ring accompanying the rotation of the rotor, and side plates that are disposed on opposite sides of the rotor and the vanes, wherein:

   the side plates have an identical rigidity and are disposed symmetrically with respect to the rotor.

2. The vane pump according to claim 1, wherein each of the side plates are formed by identical members and by identical shapes.

3. The vane pump according to claim 1 or 2, wherein each of the side plates is a combined side plate comprising a first plate and a second plate and has a back pressure chamber into which a pressurized fluid is caused to flow between the first plate and the second plate.

4. A vane pump comprising, inside a case, a cam ring, a rotor that is disposed inside the cam ring so as to be freely rotatable, a plurality of vanes that is accommodated in each of a plurality of vane grooves that is radially formed in the rotor and slides along the cam surface of the cam ring accompanying the rotation of the rotor, and side plates that are disposed on the opposite sides of the rotor and the vanes, wherein:

   a bolt is inserted into a center hole of at least one of the side plates.

5. The vane pump according to claim 4, wherein each of the side plates is a linked combination side plate in which a first plate and a second plate are held together by a linking bolt, and the linking bolt is inserted into a center hole of the second plate and fastened in an internal thread that is formed in a center hole of the first plate.

6. The vane pump according to claim 4 or 5, wherein the linking bolt is a hollow bolt.

7. The vane pump according to any one of claims 4 to 6, wherein a back pressure chamber into which a pressurized fluid is caused to flow is provided between the first plate and the second plate.

8. The vane pump according to any one of claims 4 to 7, wherein the linked combination side plate and the cam ring are fastened by a fastening bolt that is disposed on the outer circumference portion thereof, and a compressing force is applied in advance to a center hole vicinity of the first plate by tightening the linking bolt.

9. The vane pump according to any one of claims 4 to 8, wherein both of the side plates are the linked combination side plates.

10. The vane pump according to any one of claims 4 to 8, wherein one of the side plates is the linked combination side plate, and the other is the combination side plate.

11. The vane pump according to any one of claims 4 to 8, wherein one of the side plates is the linked combination side plate, and the other is a movable side plate that freely slides in an axial direction.

**12.** The vane pump according to any one of claims 4 to 8, wherein one of the side plates is a movable combination side plate that freely slides in an axial direction, and the other is the combination side plate.

**13.** The vane pump according to any one of claims 4 to 8, wherein one of the side plates is the movable combination side plate that freely slides in an axial direction, and the other is the linked combination side plate.

**14.** The vane pump according to any one of claims 4 to 8, wherein one of the side plates is the movable combination side plate that freely slides in an axial direction, and the other is the movable side plate.

**15.** The vane pump according to any one of claims 4 to 8, wherein one of the side plates is a movable combination side plate that freely slides in an axial direction.

FIG. 1

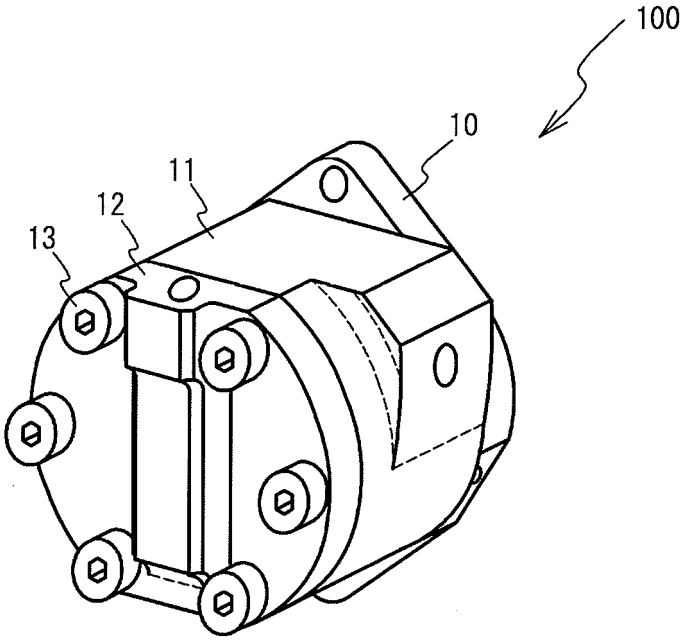


FIG. 2

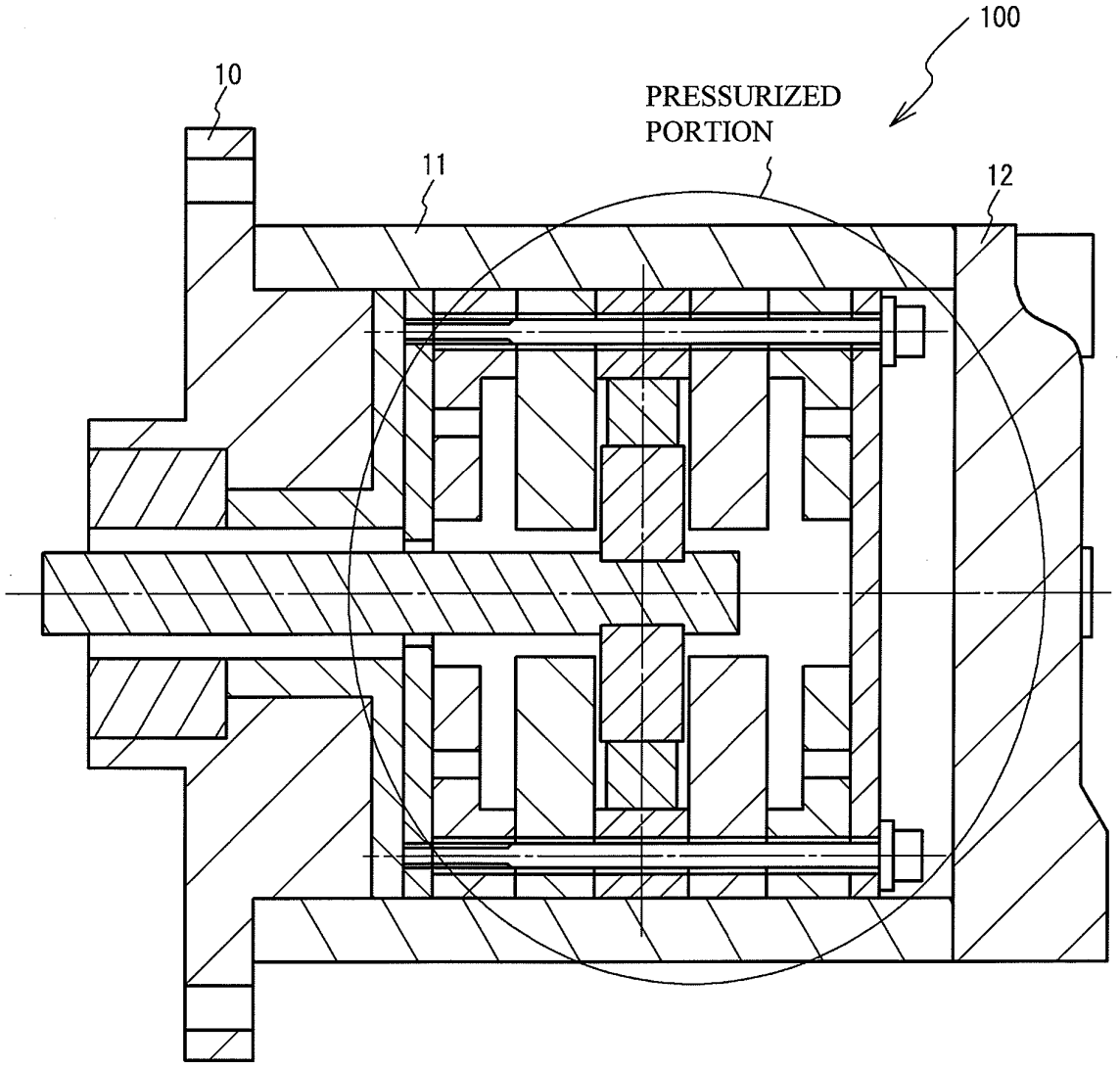


FIG. 3

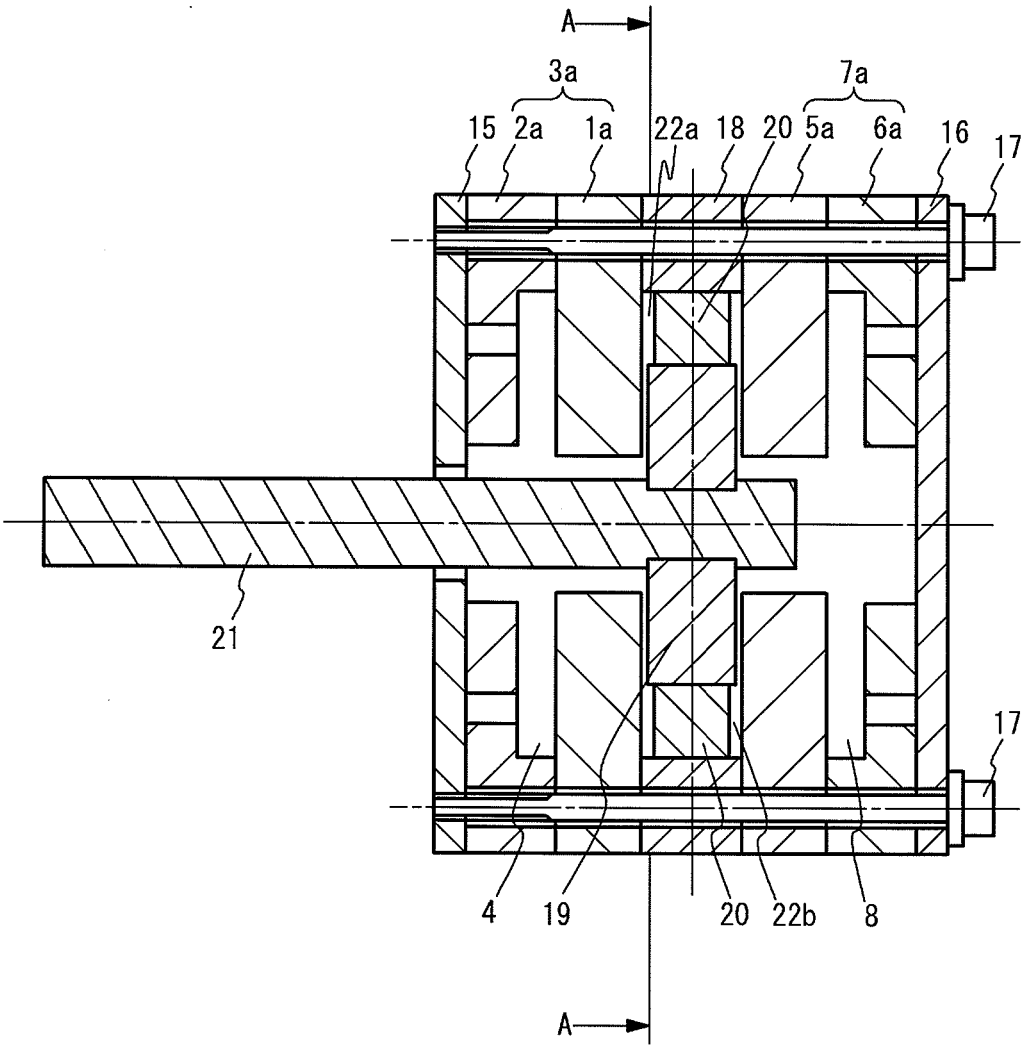


FIG. 4

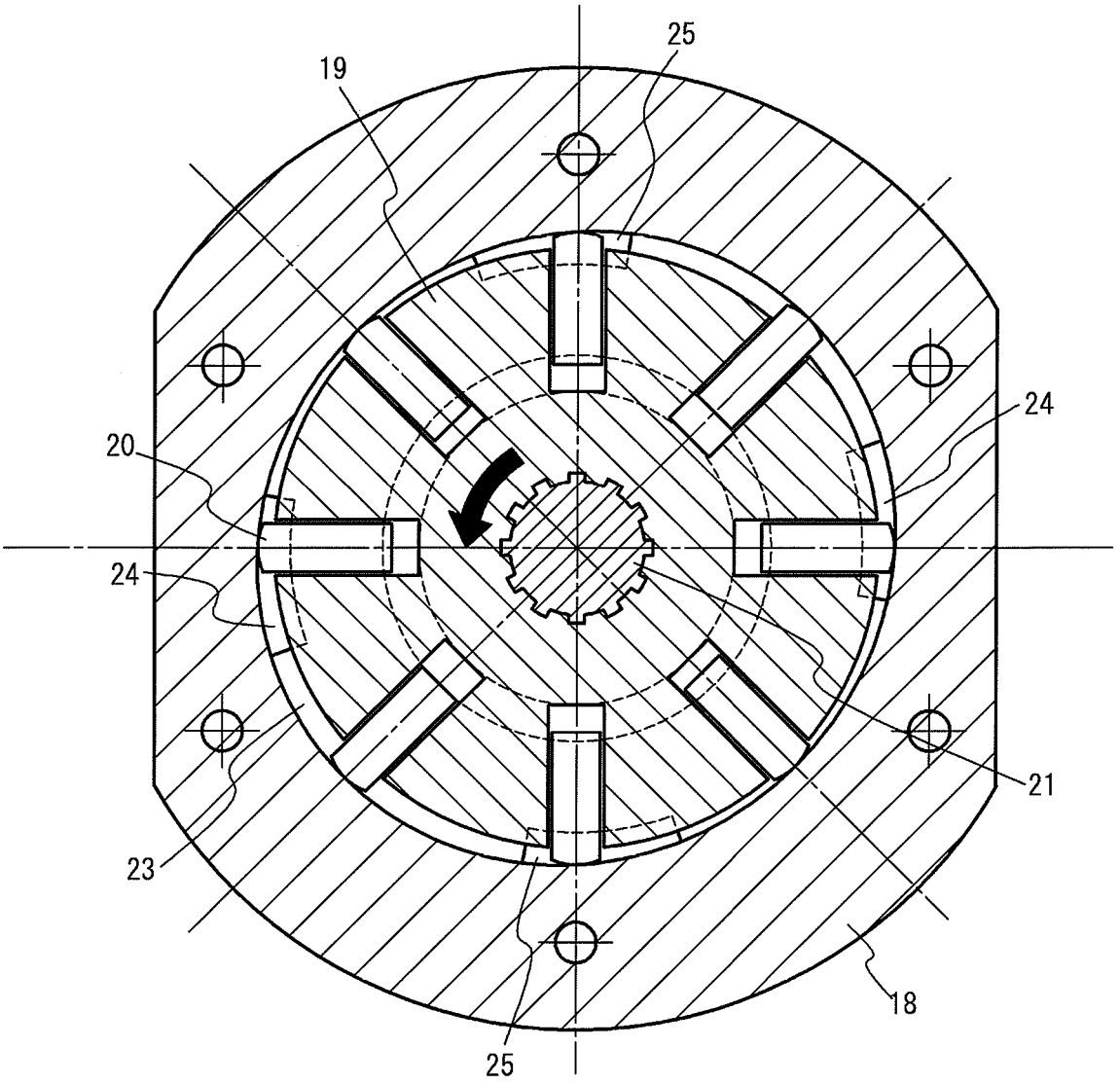


FIG. 5(a)

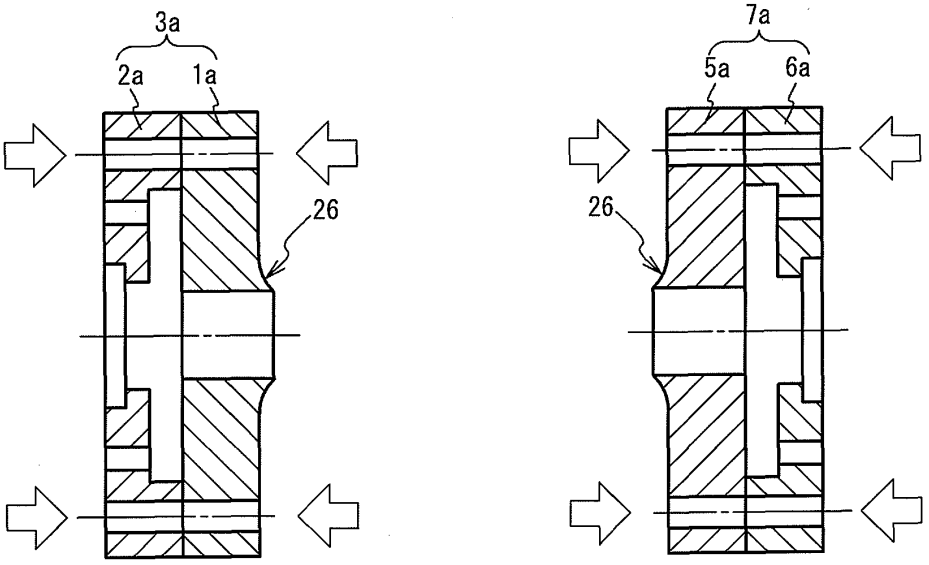



FIG. 5(b)

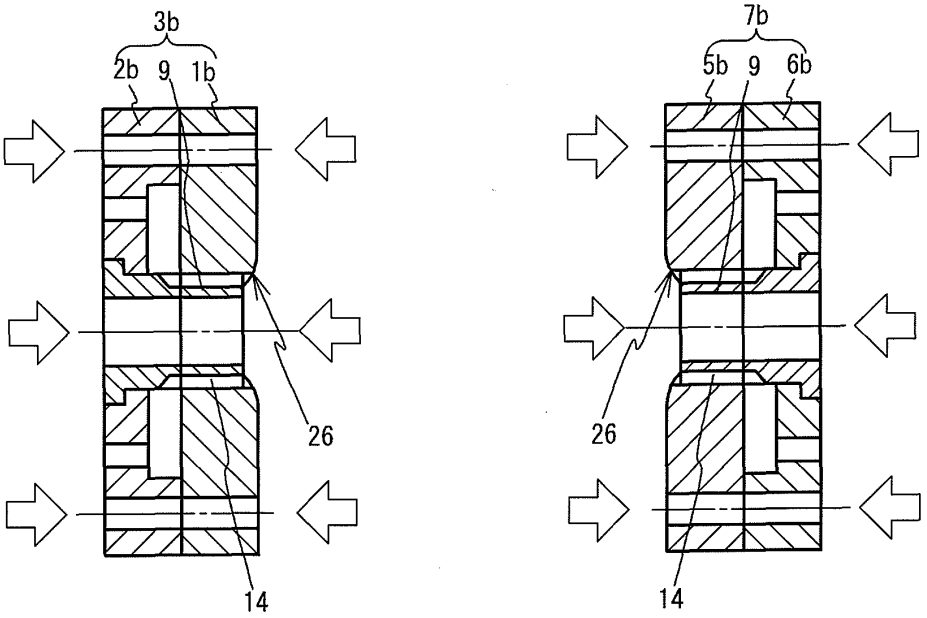


FIG. 6

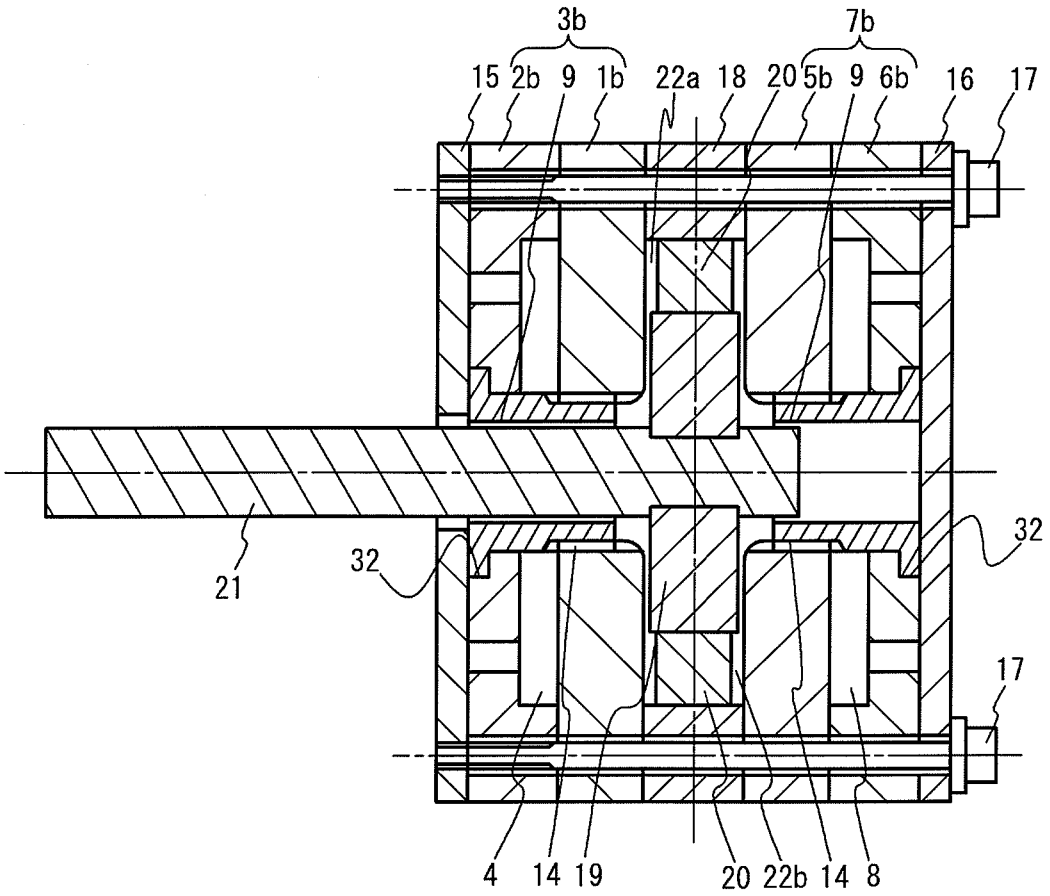


FIG. 7

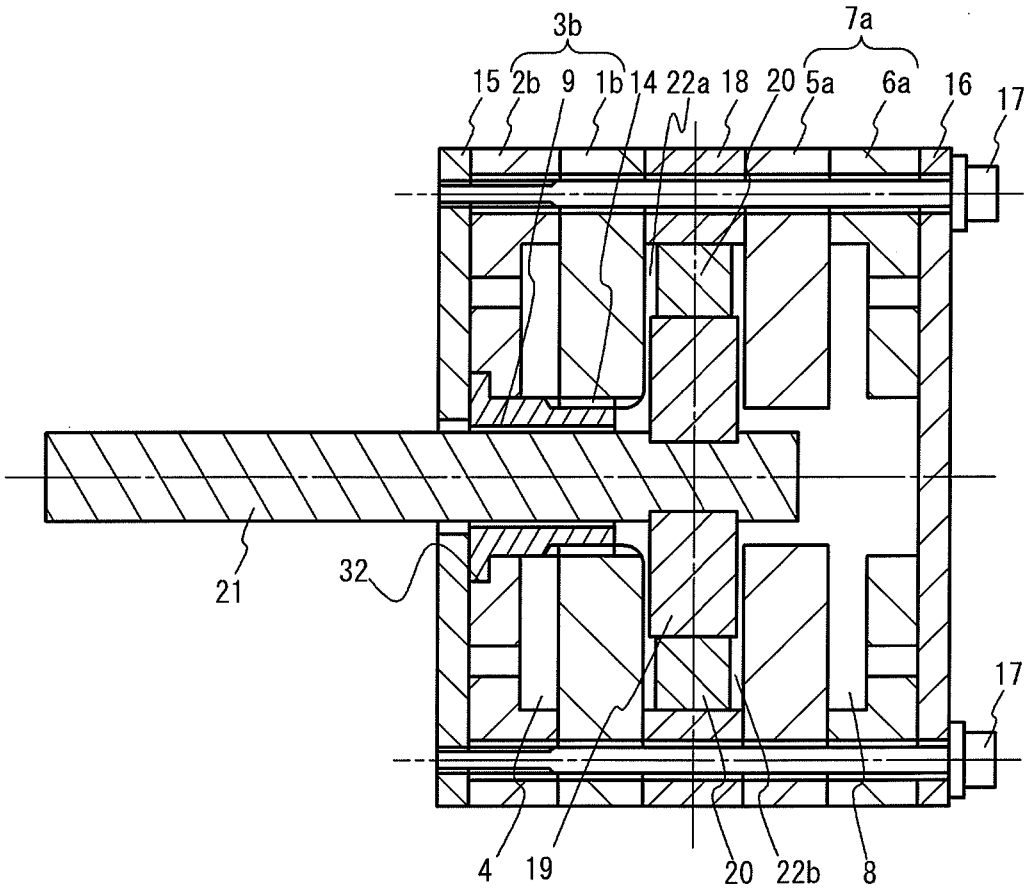


FIG. 8

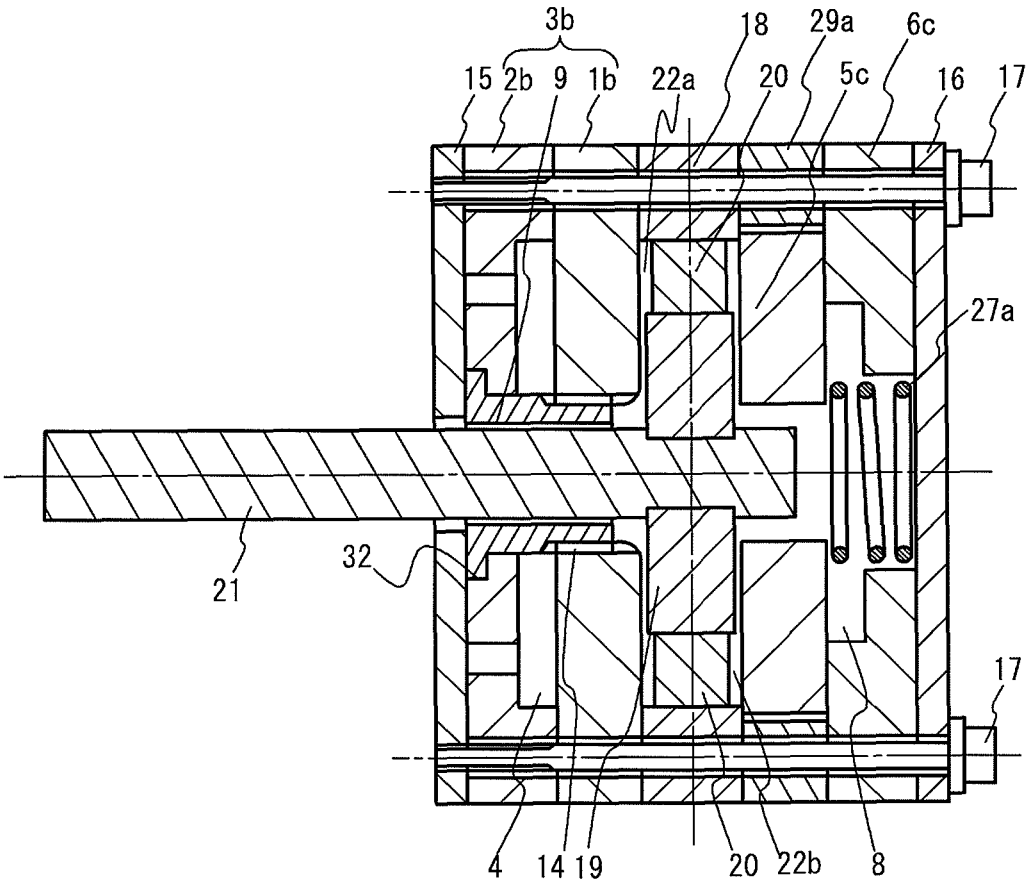
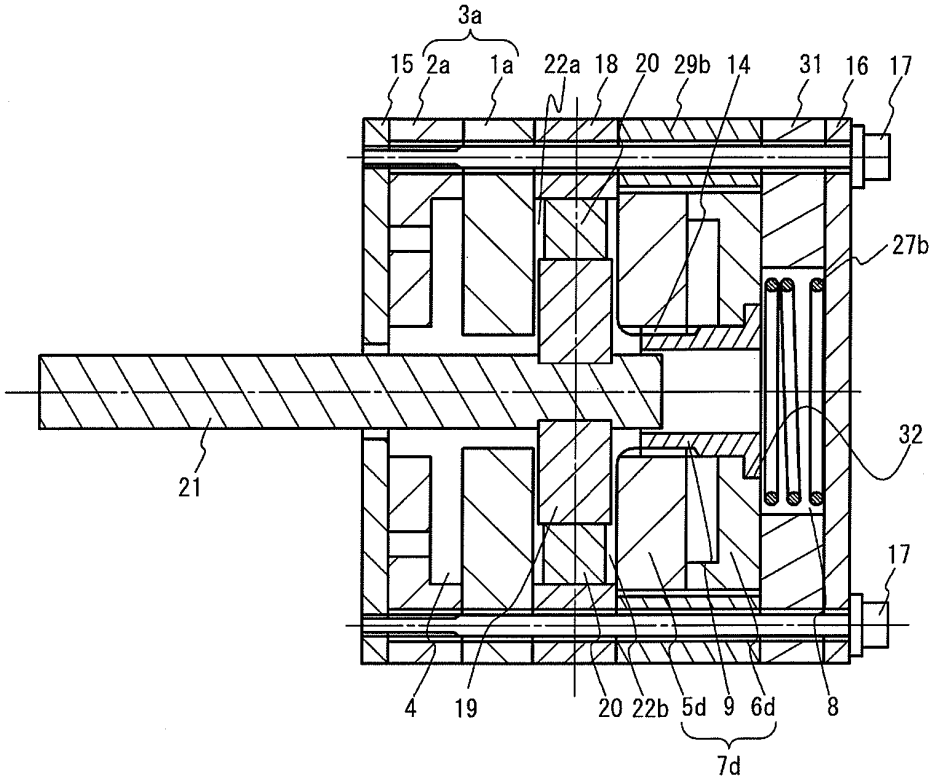


FIG. 9


3a
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2a
1a
22a
18
20
29b
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31
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19
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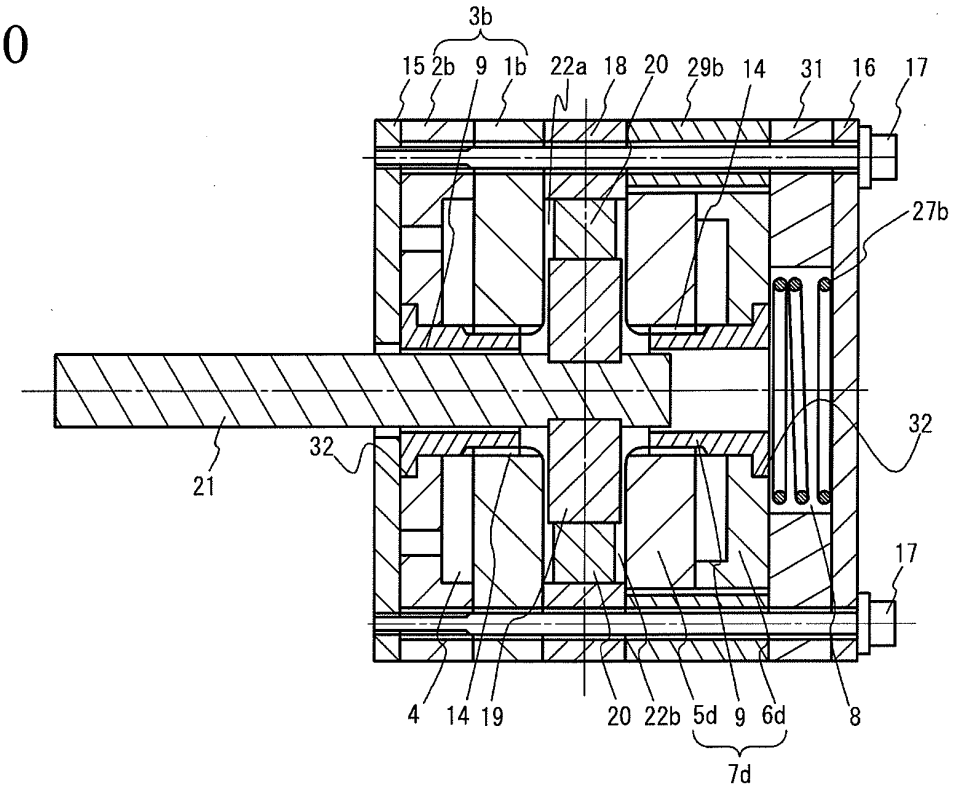
22b
5d
9
6d
8
7d

FIG. 10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22b
5d
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6d
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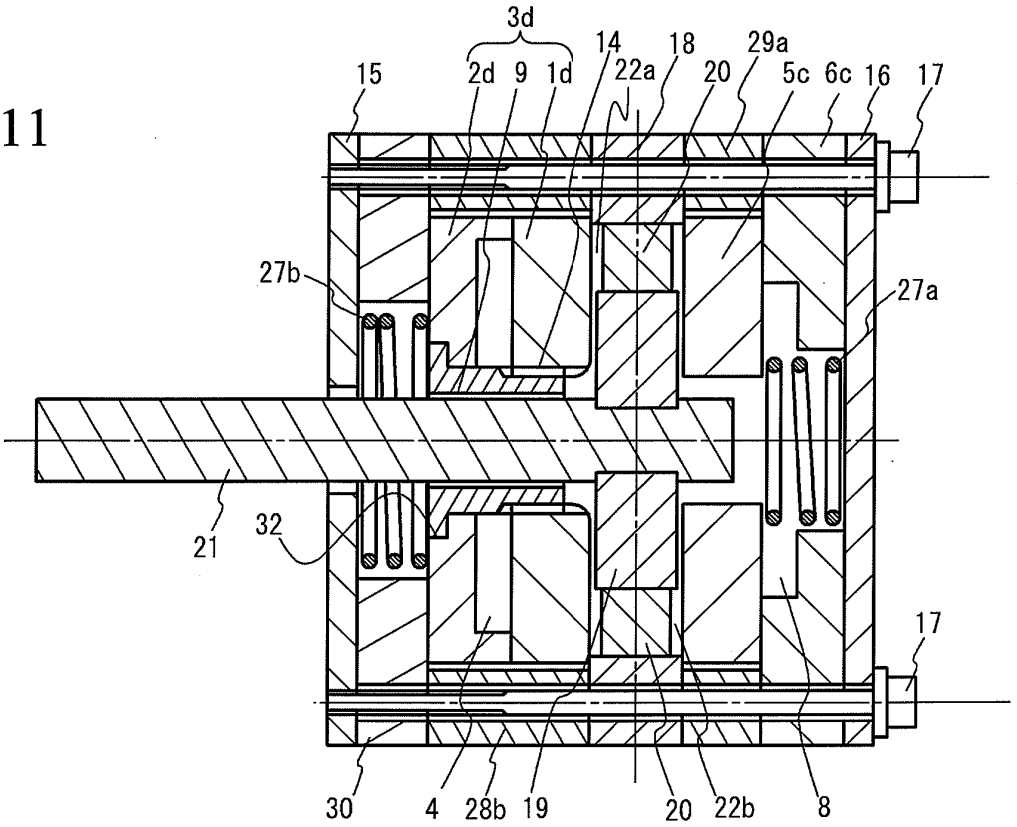
7d

FIG. 11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28b
19
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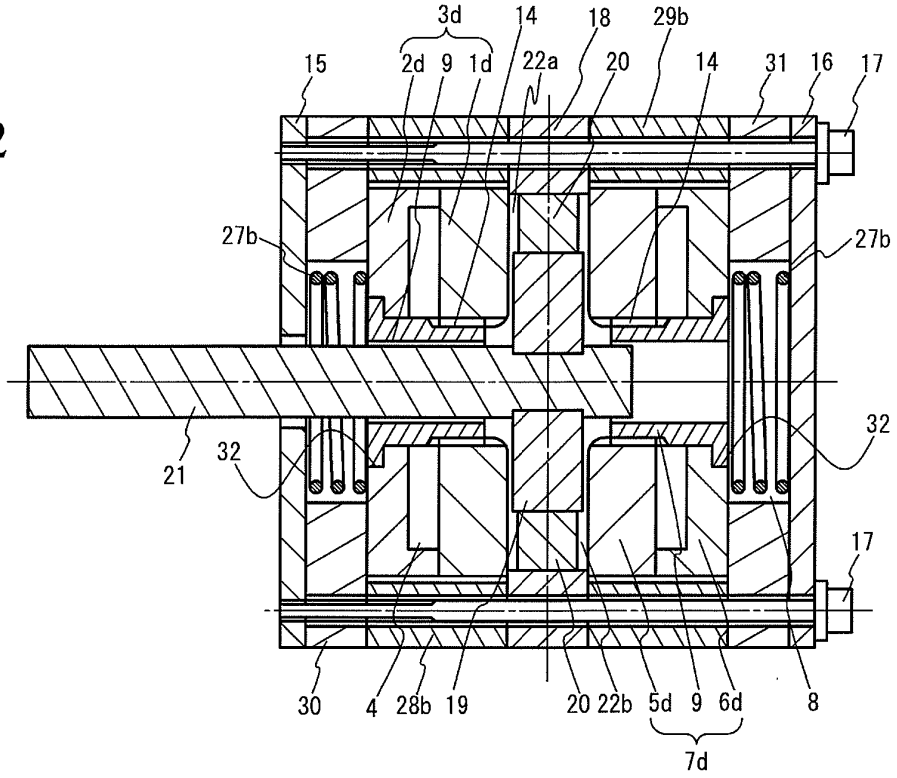
22b
8

FIG. 12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28b
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22b
5d
9
6d
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7d

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2006/304245

A. CLASSIFICATION OF SUBJECT MATTER
***F04C2/344***(2006.01), ***F04C15/00***(2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04C2/344, F04C15/00, F04C18/344, F04C27/00, F04C29/00, F03C2/00-2/30

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2006
Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>A | JP 2000-512714 A (Luk Fahrzeug-Hydraulik GmbH. & Co., KG.),<br>26 September, 2000 (26.09.00),<br>Full text<br>& EP 910746 A1 & GB 2329678 A<br>& US 6123532 A & WO 1998/046884 A1 | 1-2<br>3-4 |
| X<br>A | JP 2000-145664 A (Ebara Corp.),<br>26 May, 2000 (26.05.00),<br>Figs. 6, 8, 11<br>& EP 1113175 A1 & US 6629829 B1<br>& WO 2000/014411 A1 | 1-2<br>3-4 |

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

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

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 27 April, 2006 (27.04.06) | 16 May, 2006 (16.05.06) |
| Name and mailing address of the ISA/<br>Japanese Patent Office<br><br>Facsimile No. | Authorized officer<br><br>Telephone No. |

Form PCT/ISA/210 (second sheet) (April 2005)

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2006/304245

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>A | JP 50-27601 B1 (Ott Eckerle),<br>09 September, 1975 (09.09.75),<br>Page 2, left column, line 2 to right column, line 1; Figs. 3 to 4<br>& US 3597130 A & DE 1728050 A1<br>& FR 2024060 A6 & GB 1276177 A<br>& SU 378031 A3 | 3<br>5-15 |
| X<br>A | Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 15494/1977(Laid-open No. 106602/1977)<br>(Ebara Corp.),<br>10 February, 1977 (10.02.77),<br>Full text<br>(Family: none) | 3<br>5-15 |
| X<br>A | Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 4592/1986(Laid-open No. 116189/1987)<br>(The Japan Steel Works, Ltd.),<br>23 July, 1987 (23.07.87),<br>Page 5, line 13 to page 6, line 10; Fig. 1<br>(Family: none) | 4<br>5-15 |

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2006/304245

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

A common matter pertaining to the inventions in Claims 1-3 is such a point that the side plates of the vane pump are disposed symmetric with respect to the rotor at the same rigidity. By this structure, the pressure distribution of the pressurizing fluid applied to both side surfaces of the rotor and the vane is maintained symmetrically.

A common matter pertaining to the inventions in Claims 4-15 is such a point that a bolt is inserted into the center hole of at least one of the side plates of the vane pump. By this structure, the rigidity of the side plates is increased.

As a result, since both inventions are not so technical related so as to

(continued to extra sheet)

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

the

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, payment of a protest fee..

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2006/304245

Continuation of Box No.III of continuation of first sheet(2)

involve one or more of the same or corresponding special technical features, they are not considered to be so linked as to form a single general inventive concept.

Form PCT/ISA/210 (extra sheet) (April 2005)

## REFERENCES CITED IN THE DESCRIPTION

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

### Patent documents cited in the description


- JP 6207587 A **[0006]**