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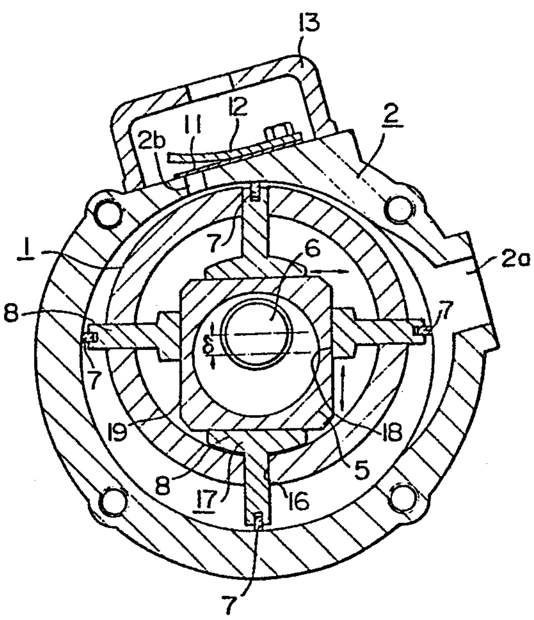
(54) **Rotary-vane type fluid machine.**

(57) A rotary-vane type fluid machine is constructed such that a rotor (1) is caused to rotate within a casing (2) to increase or decrease the volume of a space created between the outer periphery of the rotor (1) and the inner wall surface of the casing (2) by vane structures (8) which rotate together with the rotor (1) to thereby transfer a fluid by pressure in accordance with the variation in volume of said space. The vane structure (8) has two vanes disposed in substantially symmetrical relationship with respect to a shaft (6) of the rotor and fixed so that they can not moved relative to each other. The fluid machine also comprises a crank mechanism (3, 4, 3a, 4a) which causes the vane structure (8) to radially advance the retreat in order to reciprocally vary a distance between a center of the shaft (6) and a tip end (7) of one vane and a distance between the center of the shaft (6) and a tip end (7) of the other vane in accordance with the rotation of the rotor (1).

FIG. I



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ROTARY-VANE TYPE FLUID MACHINE

BACKGROUND OF THE INVENTION:

FIELD OF THE INVENTION:

The present invention relates to a rotary-vane type fluid machine wherein a rotor is caused to rotate within a casing to increase or decrease the volume of a space created between the outer periphery of the rotor and the inner wall surface of the casing by vanes caused to rotate jointly with the rotor, to thereby transfer fluid by pressure in accordance with the variation in volume of the space.

DESCRIPTION OF THE PRIOR ART:

This type of fluid machine is well known, for example, as an internal combustion engine disclosed in the specification of the United States Patent No. 3, 121, 421, or as a fluid compressor disclosed in the specification of the United States Patent No. 2, 827, 226, or as a pump disclosed in the specification of the United States Patent No. 2, 816, 702.

However, in the above-mentioned prior art fluid machine, in order to prevent a fluid from reversely flowing through an interspace between a tip end of the vane and the inner wall surface of a cylinder, a hydraulic pressure, compression gas pressure, or spring force is caused to act on a rear end (radially inward end) of the vane, to thereby cause the tip end of the vane to be pressed against the inner wall surface of the cylinder. For this reason, the fluid machine suffers from a great mechanical loss. Besides, wear pieces produced from the vane and cylinder due to a sliding contact between both are carried into the discharged fluid, with the result that a secondary accident occurs.

Further, since it is difficult at all times to keep the pressure acting on the rear end of the vane or the reaction force from the inner wall surface of the cylinder constant, there occurs a so-called "chattering phenomenon" that the vane repeates its rapid advancing and retreating movements in the radial directions, whereby noises are generated.

SUMMARY OF THE INVENTION:

OBJECT OF THE INVENTION:

A principal object of the invention is to provide a rotary-vane type fluid machine which enables a substantially zero clearance to be established between the tip end of the vane and the inner wall surface of the cylinder without pressing the vane against the latter.

Another object of the invention is to provide a rotary-vane type fluid machine which enables a force urging the vane radially outwardly of the rotor to be always kept constant.

STATEMENT OF THE INVENTION:

The characterizing feature of the present invention lies in the provision of vane structures each of which two vanes are located substantially symmetrically with respect to a shaft intended to rotate the rotor and are fixed such that they can not move relative to each other, and in the provision of a crank mechanism which causes the vane structures to radially advance and retreat in order to reciprocally vary the distance between a center of the shaft and a tip end of one vane and the distance between the center of the shaft and a tip end of the other vane in accordance with the rotation of the rotor.

In more detail, the characterizing feature of the present invention is directed to a rotary-vane type fluid machine which comprises

a cylindrical rotor formed with at least one pair of slits at the mutually opposite 180°-spaced positions of its outer periphery including a boss portion at its disc-shaped portion formed in a part of the interior thereof, said boss portion having a shaft secured thereto,

a cylindrical casing in which the rotor is received in such a manner that it approaches to the inner wall surface of the casing at one place, said casing including a suction port and a discharge port,

side plates respectively attached to both end faces of the casing each including bearing for supporting the shaft and being provided with slider-carrying boss portion inwardly projectively of which center is eccentric from the center of the shaft in a direction opposite to the position at which the rotor approaches the inner wall surface of the casing, at least a slider fitted onto the slider-carrying boss portion of said side plate and rotatably supported thereby and including flat surfaces at its outer mutually opposite positions,

vane structures each including two vanes inserted into the slits provided at the mutually opposite positions of the rotor and guided thereby, guided-by-slider portions guided by the flat surfaces of the slider and connecting pieces intended to fix the pair of vanes so as not to contact with the shaft.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 is a front sectional view of a fluid machine according to an embodiment of the present invention;

Fig. 2 is a side sectional view of Fig. 1;

Fig. 3 shows a rotor of Fig. 1 and Fig. 3a is a front view, Fig. 3b is a sectional view taken along the line III-0-III of Fig. 3a, and Fig. 3c is a sectional view showing a state wherein a shaft is fixed to the rotor shown in Fig. 3a;

Fig. 4a is a sectional view of a side plate of Fig. 2, in which a bearing receiving portion is omitted, and Fig. 4b is a right side view of Fig. 4a;

Fig. 5a is a front view of a slider of Fig. 1 and Fig. 5b is a sectional view taken along the line V-0-V of Fig. 5a;

Fig. 6a is a front view, as taken from the side of a guided-by-slider portion, of a vane structure shown in

Fig. 1, Fig. 6b is a partially sectioned side view of Fig. 6a, and Fig. 6c is a right side view of Fig. 6b;

Fig. 7 is a view for explaining the principle of the fluid machine shown in Fig. 1;

Figs. 8 is views for explaining the action of the vane shown in Fig. 1; and

Fig. 9 is a partial enlarged view of an improved tip seal portion.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

A fluid machine according to an embodiment of the present invention will now be described by referring to Figs. 1 and 2. Fig. 1 is a front sectional view and Fig. 2 is a side sectional view thereof. In the Figures, a reference numeral 1 denotes a rotor, a reference numeral 2 denotes a casing, and reference numerals 3 and 4 denote side plates. Further, reference numerals 5 to 10 respectively denote a slider, a shaft, a tip seal, a vane, a side plate cover, and a shaft seal. As shown in detail in Fig. 3, the rotor 1 is formed into a cylindrical shape and is formed with radially extending slits 16 at angular intervals of 90° in outer periphery. The rotor 1 is also formed, at its central part of its axis, with a disc-shaped portion 1a which is formed, at its central part, with a boss portion 1b. A reference numeral 1c is a space through which the vane 8 is moved. The casing 2 is formed with a suction port 2a and a discharge port 2b. This discharge port 2b is attached with a discharge valve 11 and a discharge-valve keeper 12, which are covered by a cover 13 for the discharge chamber. Within the casing 2, the rotor 1 is mounted by bearings 14 and 15 of the side plates 3 and 4 so that its outer periphery can be approached, at one place, to the inner wall surface of the casing 2. The side plates 3, 4 are respectively formed with slider-carrying bosses 3a, 4a in such a manner that these bosses are made eccentric, by a distance of δ, from the center of the bearings 14, 15 as shown in Fig. 1, and in a direction spaced apart 180° from the position at which the rotor 1 approaches the inner wall surface of the cylinder 2 as shown in Figs. 2 and 3. The slider-carrying bosses 3a, 4a constitute a part of a crank mechanism involved.

The slider 5, which constitutes a part of the crank mechanism, comprises, as shown in Fig. 5, a fitting hole 5a which is rotatably fitted onto the slider-carrying boss 3a or 4a and flat surfaces 19, 19 provided at two opposed outer peripheral positions in which a corresponding guided-by-slider portions 18 of vane structures 17 shown in detail in Fig. 6 are guided as the rotor 1 is rotated. In this embodiment, the flat surfaces 19 are provided, respectively, on four sides of the square slider 5 so as to guide two vane structures, or four vanes 8. The vane structure 17 comprises a pair of such vanes 8, 8 which are disposed at its two opposed positions spaced 180° from each other as shown in Fig. 6, connecting pieces 20, 20 for connecting the vanes 8, 8 to each other, and the guided-by-slider portions 18, 18 brought into sliding contact with the flat surfaces 19 of the slider 5. The connecting pieces 20 are intended to hold the vanes 8, 8 in the same plane and, in this embodiment, they are disposed in a manner that they are allowed substantially to oppose each other. The connecting pieces 20 are provided, therebetween, with an elliptical hole 21 so that the vanes may be kept out of contact with the shaft when the shaft is inserted therebetween. The vane structure 17 is substantially U-shaped in section and is provided with the vanes 8, 8 at the opposed portions of the U-shape, respectively. The vane structure 17 is also provided with guided-by-slider portions 18, 18 at the foot portion of the U-shape where the vanes 8, 8 are connected by means of the connecting pieces 20, 20, said guided-by-slider portions 18, 18 being guided by the flat surfaces 19, 19 of the slider 5 as stated above. When the vane structure 17 is assembled into the rotor 1 and onto the sliders 5, 5 which are mounted onto the slider-carrying bosses 3a, 4a, the concaved portions of the two-U-shaped vane structures 17 are arranged to oppose each other in a state wherein one of the two is inclined at an angle of 90° with respect to the other, and in this state the vane structures 17 are assembled onto the sliders 5, 5.

This compressor is assembled as follows. For example, the casing 2 is fixed to the side plate 4 in a state wherein this side plate 4 is located at the lower side, and then the slider 5 is fitted onto the boss portion 4a of the side plate 4. Next, the rotor 1 to which the shaft 6 is fixed as shown in Fig. 3c is held in a posture wherein the shaft 1 is erected vertically. The elliptical hole 21 of the vane structure 17 is fitted over the shaft 6 in a state wherein the A side shown in Fig. 6b is located at the lower side. The vanes 8, 8 are inserted into the slits 16, 16 of the rotor 1 while, on the other hand, the guided-by-slider portions 18, 18 are fitted onto the flat surfaces 19, 19 of the slider 5. Thereafter, the other vane structure 17 is assembled. Namely, the vane structure 17 is inclined at an angle of 90° with respect to the previous vane structure 17 and the A side shown in Fig. 6b is turned upside. In this state, similarly, the elliptical hole 21 is fitted over the shaft 6 and the vanes 8, 8 are inserted into the slits 16, 16. Then, the slider 5 is fitted into the guided-by-slider portions 18, 18 which are located upside of the vane structure 17. Thereafter, the slider-carrying boss portion 3a of the side plate 3 is fitted into the fitting hole 5a of the slider 5 and is fixed thereto. When the members are assembled in the above-mentioned manner, the rotor 1 is caused to rotate by the shaft 6, so that the vanes 8 are also caused to rotate. At this time, the guided-by-slider portions 18 of the vane structure 17 are caused to slide, in the directions indicated in Fig. 1 by arrows, on the flat surfaces 19 of the sliders 5 which rotate about the axis of the slider-carrying bosses 3a, 4a of the side plates 3, 4, whereby the compression action of the compressor is performed.

Next, the operational principle of the compressor thus assembled with now be described in connection with Fig.

7. For clarifying the explanation, it is assumed that the compressor of Fig. 7 has only one vane structure 17 equipped with one pair of vanes 8. The point 0 is a center of the rotor 1, i.e., an axial center of the shaft 6. Accordingly, the center line $\ell 1$ of the vanes 8 inserted into two opposed slits 16 of the rotor 1 unavoidably passes through the point 0 regardless of the rotational angle θ of the rotor 1. The point A is a center of the slider-carrying bosses 3a, 4a of the side plates 3, 4. As stated before, the slider 5 is formed, at its outer periphery, with four parallel flat surfaces 19, 19 centering the point A. The vane structure 17 is formed with the guided-by-slider portions 18, 18 extending in the direction perpendicular to center line $\ell 1$. By way of these guided-by-slider portions 18, 18, the vane structure 17 is slidably fitted onto the two flat surfaces 19, 19 of the slider 5. Accordingly, a center line between the guided-by-slider portions 18, 18 of the vane structure 17, i.e., a perpendicular bisector $\ell 2$ of the vane structure 17 unavoidably passes through a rotational center of the slider 5 regardless of the rotational angle θ of the rotor 1, or the point A. That is to say, the angle $\angle OBA$, which is formed by connecting the two fixed points O and A spaced by a distance of δ from each other with the intersection B of the center line $\ell 1$ of the vane structure 17 and the perpendicular bisector $\ell 2$ of the vane structure 17, is 90°.

This indicates that the point B (the center of gravity of the vane structure 17) is located on the circumference of a circle of which center is a middle point C between the points O and A and the radius is $\delta/2$, regardless of the rotational angle θ of the rotor 1. Further, since the angle <BCA which is formed by the lines $\overline{CB}$ and $\overline{CA}$ and the angle <BOA which is formed by the lines $\overline{OB}$ and $\overline{OA}$ have a relation of the central angle and the angle of circumference with respect to the common circular arc AB, the following relationship is formed.

$$<BCA = 2 \times <BOA = 2\theta \qquad \ldots\ldots\ldots\ldots\ (1)$$

From the above formula (1), it will be seen that, as the rotor 1 rotates, the center B of gravity of the vane structure 17 moves, at an angular velocity as twice as that of the rotor 1, on the circumference of a circle of which center is the middle point C between the rotational center O of the rotor 1 and the rotational center A of the slider 5 and the radius is $\delta/2$ which is equal to a half of the amount δ of eccentricity between the center O and the center A.

Reference will now be made to how the vane structure 17 moves through the slits 16 of the rotor 1. The distance $\overline{OB}$ between the center O of the rotor 1 and the center B of gravity of the vane structure 17 is expressed as follows.

$$\overline{OB} = \overline{OA} \times \cos(<BOA) = \delta \times \cos\theta \qquad \ldots\ (2)$$

This indicates that the vane structure 17 reciprocates within the slits 16 of the rotor 1 with a stroke of 2δ and a cycle of which one rotation of the rotor 1 is one cycle.

In this embodiment, each of opposite outer ends of the vanes 8 is made an arc of a circle having a radius of r and the distance between the center B of gravity and the center D of E of such arc is so set as to have the following value.

$$\overline{DB} = \overline{EB} = \ell = (D_R/2 + \delta - r)$$

At this time, the loci which are described by the centers D and E of the curved surfaces R of the outer ends of the vanes 8 are expressed in the form of a polar coordinate as follows.

$$r_{DE} = \ell + \delta \cos \theta \quad (0 \leqq \theta \leqq 360°) \quad ..... (3)$$

The curve which is expressed by the above formula (3) is indicated in Fig. 7 as a closed curve Cl. At this time, the locus which is described by the curved surface R of the outer end of the vane 8 is an envelope C2 formed when the circles whose radius is r are arranged on the closed curve Cl. In this embodiment, a closed curve C3 which is outwardly displaced by a fixed amount of Δr from the closed curve C2 is used as the profile of the inner wall surface of the casing 2. In this embodiment, the gap Δr created between the tip end of the vane 8 and the inner wall surface of the casing 2 is sealed by the tip seal 7.

Note here the following. A curve (such as, for example, a true circle approximate to the closed curve C3) other than the closed curve C3 may be used as the profile of the inner wall surface of the casing 2. In this case, the gap between the tip end of the vane 8 and the inner wall surface of the cylinder 2 is periodically slightly varied with the rotation of the rotor 1. However, if the tip seal 7 can be more or less advanced or retreated within a groove 8a at the tip end of the vane 8 in accordance with the variation in said gap, it will be possible to effect an always perfect sealing with respect to the gap.

Although the foregoing explanation has been made in connection with one vane structure 17, the same can apply to another vane structure 17 which have been slidably inserted into the other pair of slits 16 provided in the rotor 1. This vane structure 17 is displaced from the previous vane structure 17 by the rotational angle of 90° of the rotor 1 and, in this state, make their radial movements with respect to the rotor 1 in the same manner as in the foregoing explanation.

The space which is defined by the outer periphery of the rotor 1, the vanes 8, the inner wall surface of the cylinder 2 and the side plates 3, 4 performs its compression action as indicated in (a) to (h) of Fig. 8. In (a) and (b) of Fig. 8, the space discharges fluid from the discharge port 2b and, in (c) and (d) of Fig. 8, it sucks fluid from the suction port 2a. After passing through the stages of (e) and (f) of Fig. 8, the space compresses fluid in the stages of (g) and (h) of Fig. 8 and, in (a) of Fig. 8, starts discharging fluid. In this way, the space is repeatedly decreased and increased in volume, thereby repeatedly to discharge and suction fluid, thus to perform its compression action as the compressor. In this embodiment, since the vanes 8 are arranged to project at four places from the outer periphery of the rotor 1, four suctions and discharges are effected per rotation of the rotor 1.

In this way, according to the fluid machine of this embodiment, the vanes are mechanically brought into sliding contact with the inner wall surface of the casing unlike the fluid machine of prior art in which the former are brought into sliding contact with the latter by use of back pressure. Therefore, it is impossible that the vanes are radially inwardly retreated with an increase in pressure of the compression chamber and that, therefore, the chattering phenomena take place. Further, since it is unnecessary to apply the back pressure, it is also unnecessary to separate oil used to apply the back pressure in a high pressure chamber. Accordingly, the space which is intended to be used for oil separation as well as for oil reception becomes unnecessary. As a result, it becomes possible to reduce the fluid machine in size as well as in weight. Further, there is produced no mechanical wear due to pressing the vanes against the inner wall surface of the casing by using the back pressure and, at the same time, the power for driving the rotor to rotate in such a condition is unnecessary. As a result, the fluid machine of this embodiment is high in durability as well as in working efficiency.

In the above-mentioned embodiment, two connecting pieces were used for connecting the vanes 8 in such a manner that they form an elliptic hole therebetween. However, a single connecting piece may be used to connect the pair of vanes 8. Further, in the above-mentioned embodiment, two sliders are used, but the invention permits the use of only one slider. Further, in the above-mentioned embodiment, the disc-shaped portion having the boss portion is provided at the central part of the rotor 1, but the invention permits the formation of it at the end portion thereof.

Further, in the above-mentioned embodiment, the description was made of the fluid machine wherein two vane structures are provided. According to the invention, however, even when one vane structure is used, the fluid machine can operate without any inconvenience. At this time, two suctions and discharges are performed per rotation of the rotor 1.

Since the above-mentioned embodiment was described in particular connection with the compressor, the tip seal 7 was provided at the tip end of the vane. However, when the fluid machine is used as a pump, this tip seal 7 may be omitted. In this case, the discharge valve 11 which is provided with respect to the discharge port 2b may be omitted.

Further, according to the invention, the back surface of the tip seal may be urged by means of a spring. In this case, the spring may be a one which has an urging force much weaker than that of a spring used to urge the entire vane as in the prior art. Accordingly, the mechanical loss resulting from the sliding contact between the tip seal and the inner wall surface of the cylinder is decreased to a substantially ignorable value.

Particularly, as shown in Fig. 9, the tip seal 7 is formed with a shoulder portion 7d in addition to merely urging by means of a spring 7a, which shoulder portion 7d is caused to oppose a shoulder portion 7c of a tip-seal insertion hole 7b. This construction offers the advantage that when the tip seal 7 is worn and as a result the shoulder portions 7d and 7c are allowed to contact with each other, the tip seal 7 is prevented from being further extruded outwards, with the result that a zero clearance is provided between the tip seal 7 and the inner wall surface of the cylinder.

Further, in the above-mentioned embodiment, a pair of vanes are disposed within one plane which passes through the center of the shaft, but the vanes may define a specified angle with respect to this plane, or may be disposed symmetrically about the center of the shaft.

According to the present invention, since the vanes are so arranged as to be radially advanced and retreated by means of a crank mechanism, it is impossible that the tip ends of the vanes are pressed against the inner wall surface of the cylinder. Accordingly, it is possible to make substantially zero clearance between the tip ends of the vanes and the inner wall surface of the cylinder.

By arranging the vanes as above, it is possible to decrease the mechanical loss which results from the sliding contact between the tip ends of the vanes and the inner wall surface of the cylinder, thereby to make it possible to obtain a highly efficient fluid machine.

Further, according to the present invention, no reaction force from the inner wall surface of the cylinder is allowed substantially to act on the vanes and, on the other hand, the radially outward advancement of the vanes is regulated by the crank mechanism. As a result, it is impossible that the vanes make their irregular advancing and retreating movements for themselves. As a result, no chattering which produces noises occurs.

WHAT IS CLAIMED IS:

1. A rotary-vane type fluid machine comprising a cylinder whose inner wall surface is shaped into a substantially true circle, a cylindrical rotor located within said cylinder and eccentircally disposed with a substantially zero clearance with respect to a part of the inner wall surface of said cylinder, a shaft fixed to said circular rotor in such a manner that it passes through a center of the rotor and extends axially thereof and a plurality of vanes which are caused to rotate together with said rotor and to radially advance and retreat during the rotation, characterized in that said fluid machine including

at least one vane structure in which two vanes are disposed in substantially symmetrical relationship with respect to said shaft and fixed so that they can not move relative to each other; and

a crank mechanism which causes said vane structure to advance and retreat in radial direction to thereby reciprocally vary a distance between a center of said shaft and a tip end of one vane and a distance between the center of said shaft and a tip end of the other vane in accordance with the rotation of said rotor.

2. A rotary-vane type fluid machine comprising

a cylindrical rotor formed with at least one pair of slits at the mutually opposite positions of its outer periphery including a boss portion at its disc-shaped portion formed in a part of the interior thereof, said boss portion having a shaft secured thereto,

a cylindrical casing in which said rotor is received in such a manner that it approaches to the inner wall surface thereof at one place including a suction port and a discharge port,

side plates respectively attached to both end faces of said casing each including bearing for supporting said shaft and being provided with slider-carrying boss portion inwardly projectively of which center is eccentric from the center of said shaft in a direction opposite to the position at which said rotor approaches said inner wall surface of said casing,

at least a slider fitted onto said slider-carrying boss portion of said side plate and rotatably supported thereby and including flat surfaces at its outer mutually opposite positions,

vane structures each including two vanes inserted into said slits provided at the mutulally opposite positions of said rotor and guided thereby, guided-by-slider portions guided by said flat surfaces of said slider and connecting pieces intended to fix said pair of vanes so as not to contact with said shaft.

3. A rotary-vane type fluid machine according to claim 1 or 2, charactrerized in that said vanes each is provided with a tip seal on the tip end thereof.

4. A rotary-vane type fluid machine according to claim 3, characterized in that said vanes each includes a

spring means which is intended radially outwardly to urge a rear end of said tip seal, and a regulating means which is intended to regulate the amount of radially outward movement of said tip seal due to the action of said spring means.

5. A rotary-vane type fluid machine according to claim 2, characterized in that said disc-shaped portion having said boss portion is formed at the central part of the axis of said rotor.

6. A rotary-vane type fluid machine according to claim 2, characterized in that said sliders are fitted onto said slider-carrying portions of said side plates, respectively.

7. A rotary-vane type fluid machine according to claim 2, characterized in that said two vanes are connected by two connecting pieces in such a manner that said two connecting pieces form an elliptic hole therebetween so as not to contact with said shaft.

FIG. 1

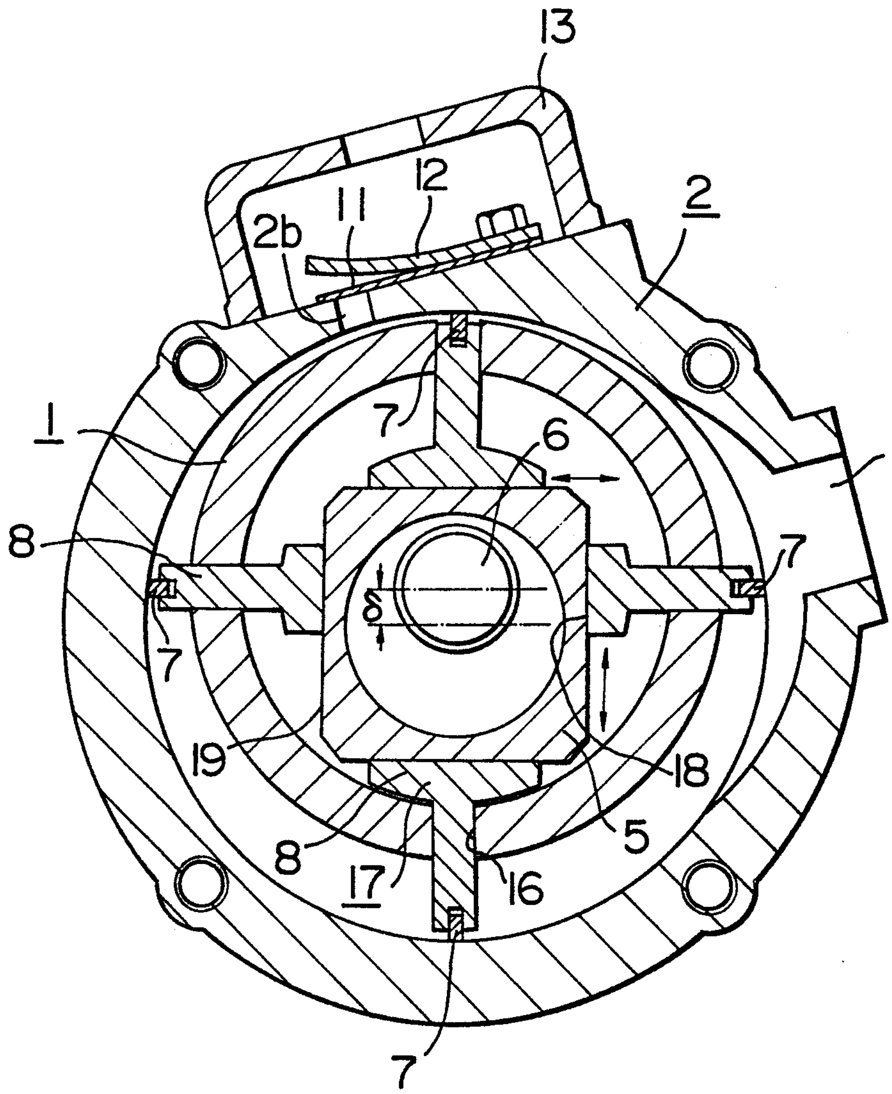

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FIG. 2

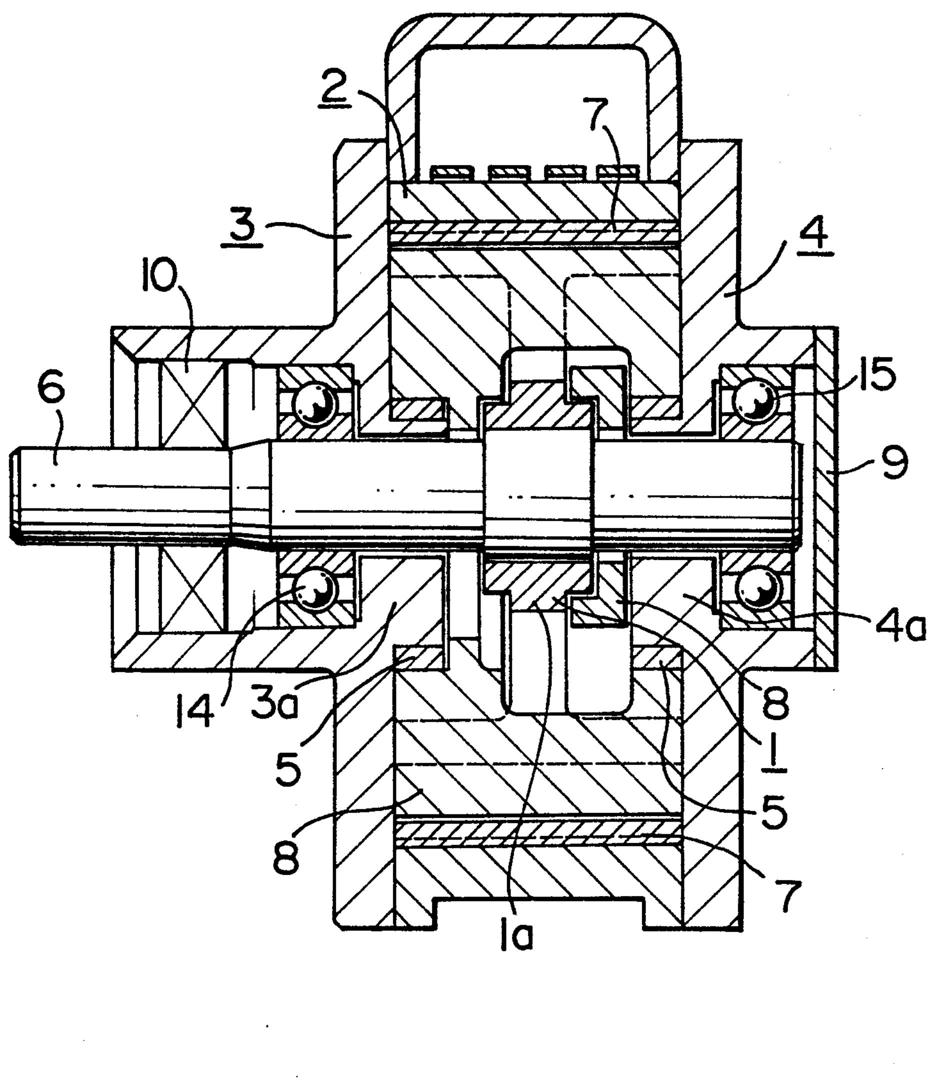

FIG.3a

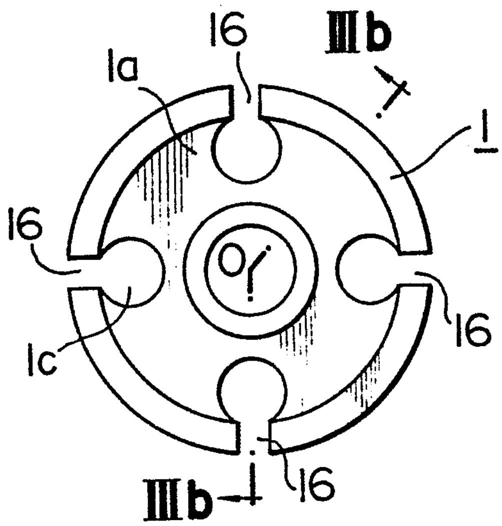

FIG.3b

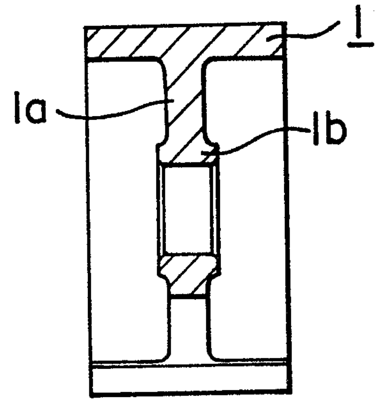

FIG.3c

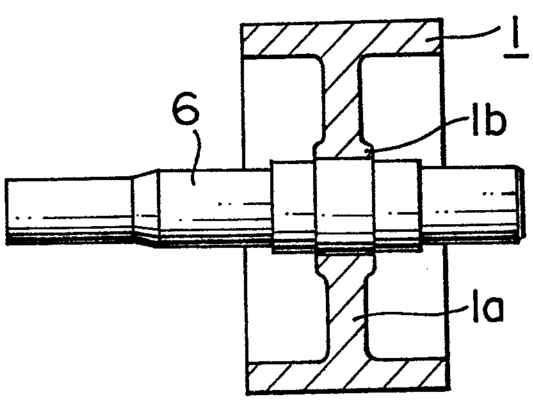

FIG.4a

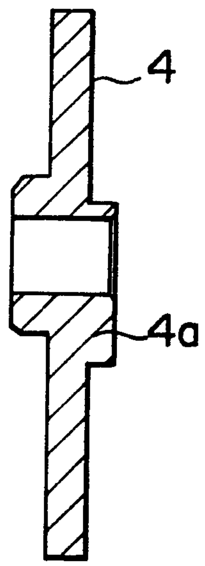

FIG.4b

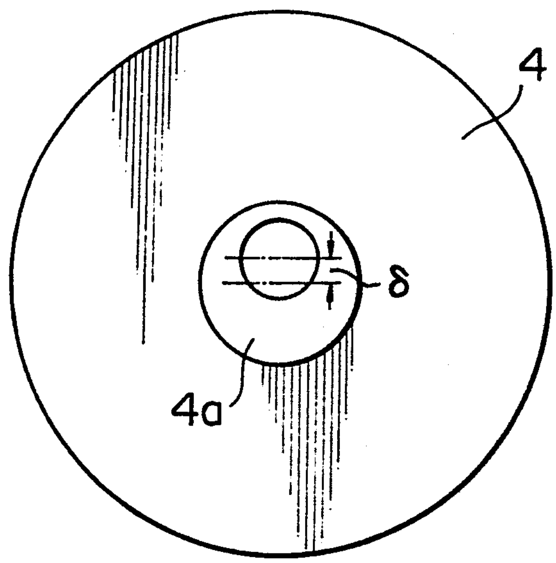

FIG.5a

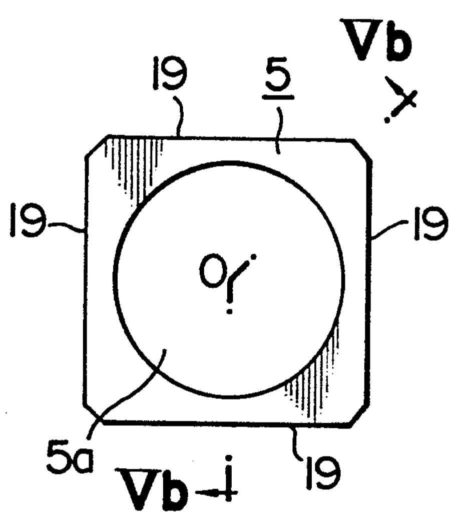

FIG.5b

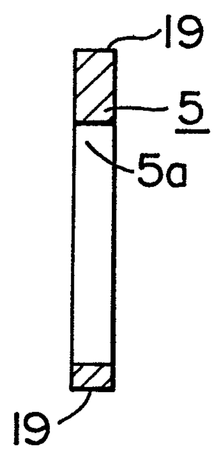

FIG.6a

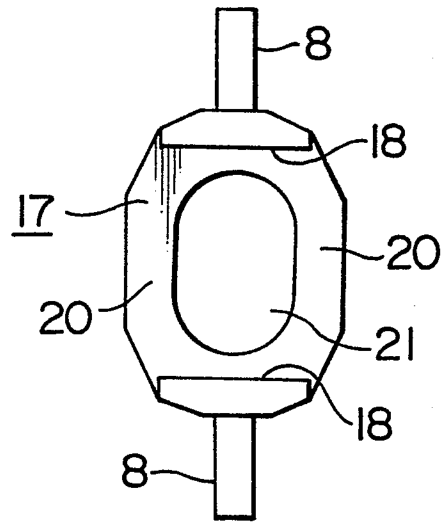

FIG.6b

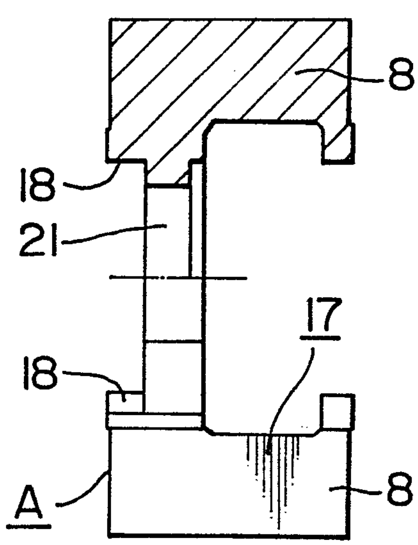

FIG.6c

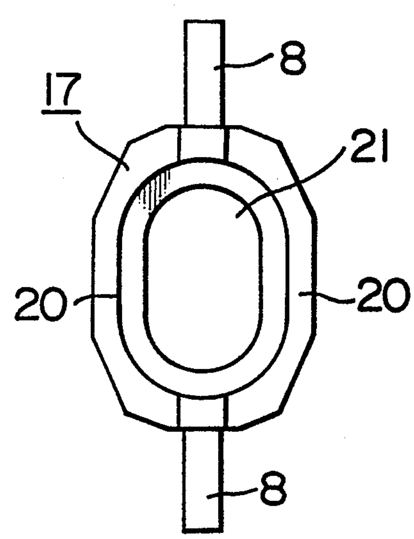

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FIG. 7

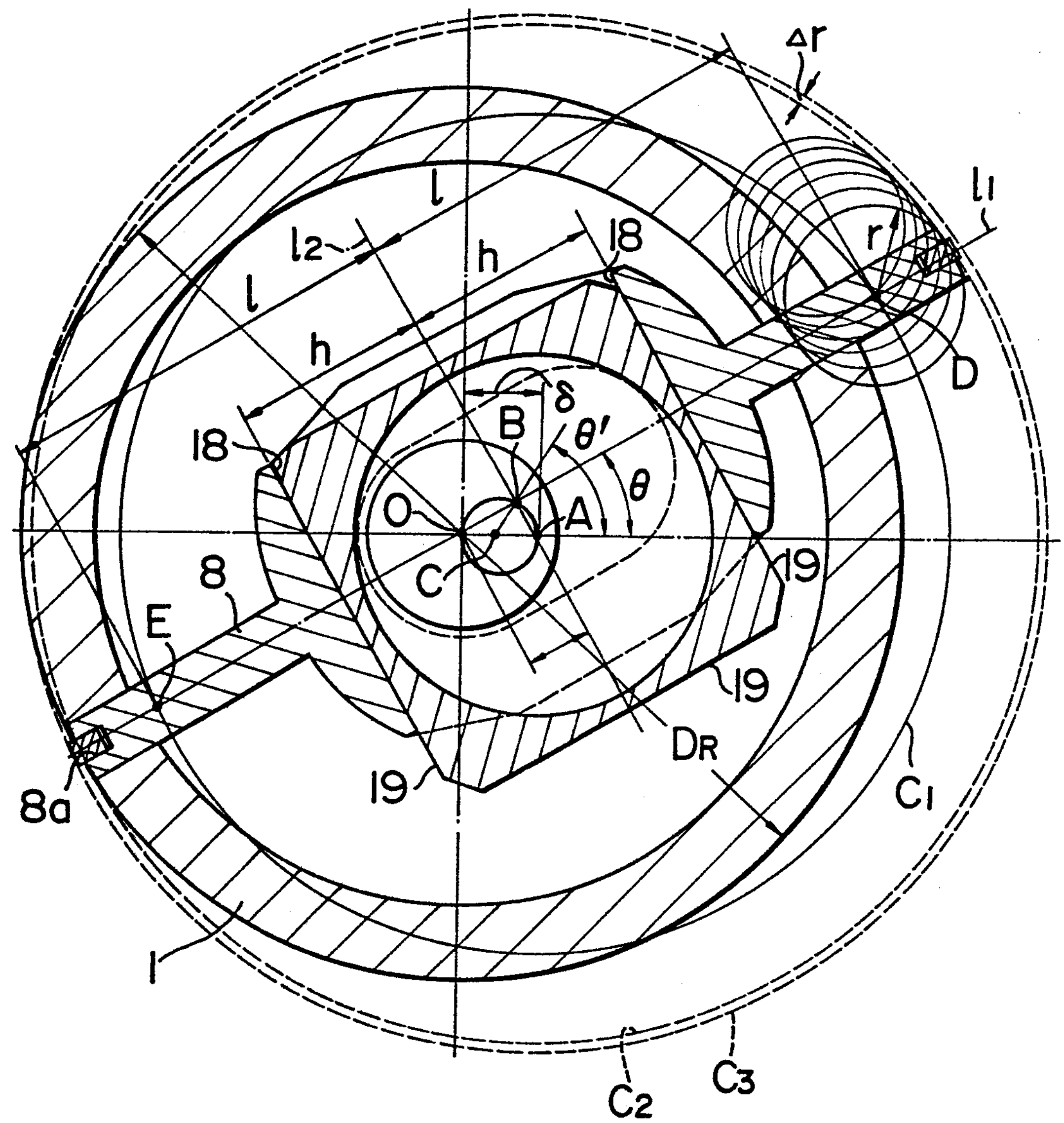

FIG.8

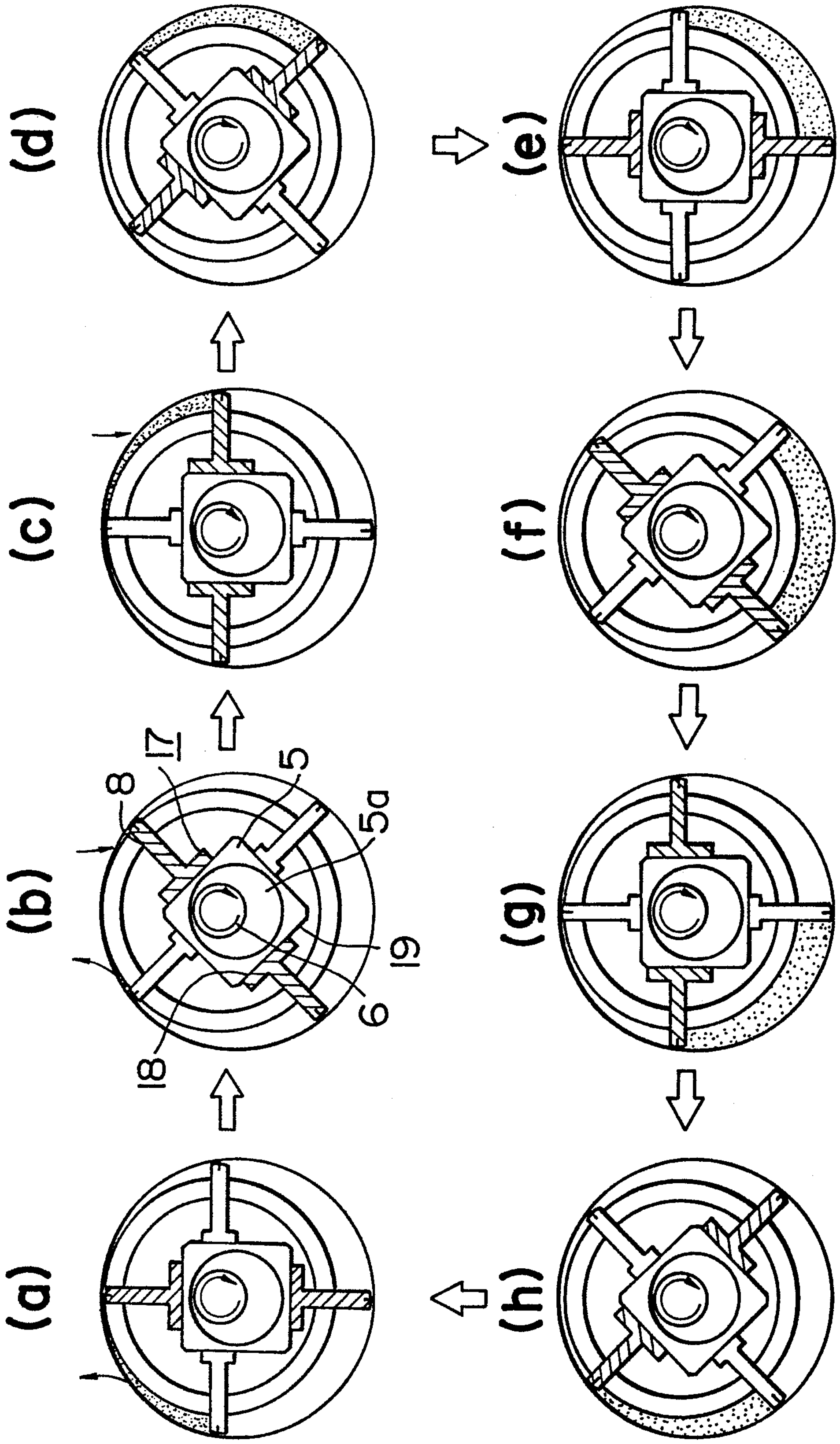

FIG. 9