

[54] VANE MACHINE WITH PRESSURE BIAS
AND BALANCING MEANS FOR THE
ROTARY CONTROL PORT MEMBER

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abandoned.

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[58] Field of Search 417/204; 418/75, 79, 80,
418/82, 131, 132, 133, 173, 186; 91/487,
491, 492, 503

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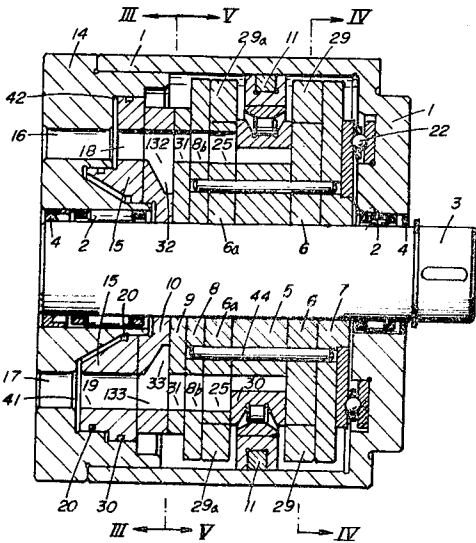
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Primary Examiner—John J. Vrablik
Attorney, Agent, or Firm—Michael S. Striker

[57] ABSTRACT

A non-rotatable control plate has a control face cooperating with the rotary control face of the rotor of a vane machine to supply through stationary control ports and rotary control ports of the rotary control plate, fluid to the expanding and contracting working chambers of the rotor at high and low pressures. The regions of the control surface between the control ports, where reversal of the fluid flow takes place, have balancing grooves filled with high pressure fluid for holding the rotary control plate against the pressure of the working chambers of the rotor, in an axially balanced position. The rotor is composed of a stack of abutting rotor members pressed together by a thrust member partially located in a thrust chamber and having an eccentric portion located in one of the end covers of the housing.

18 Claims, 6 Drawing Figures



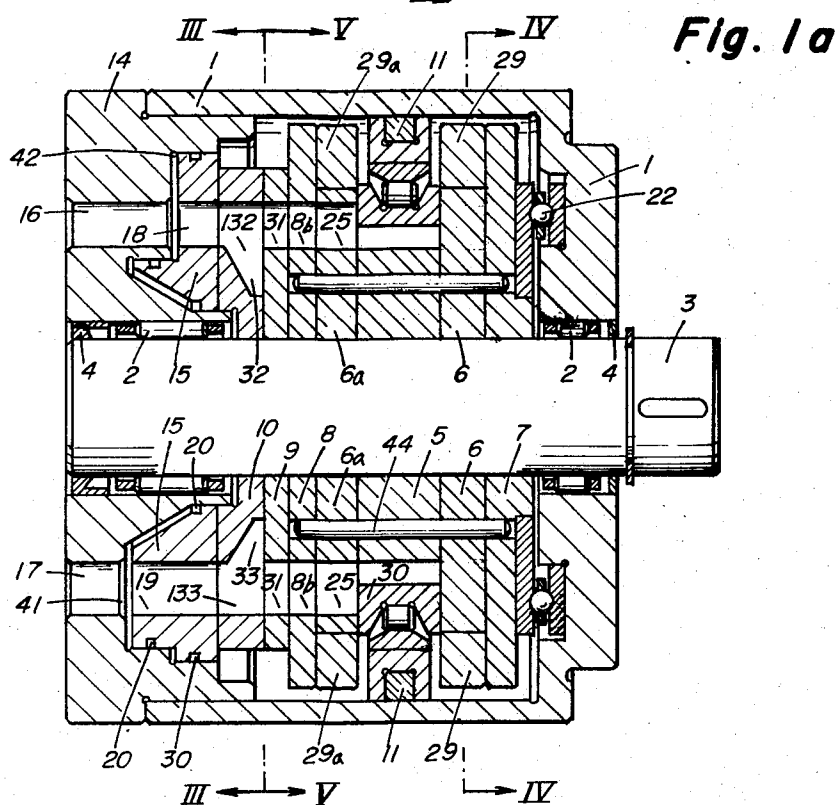
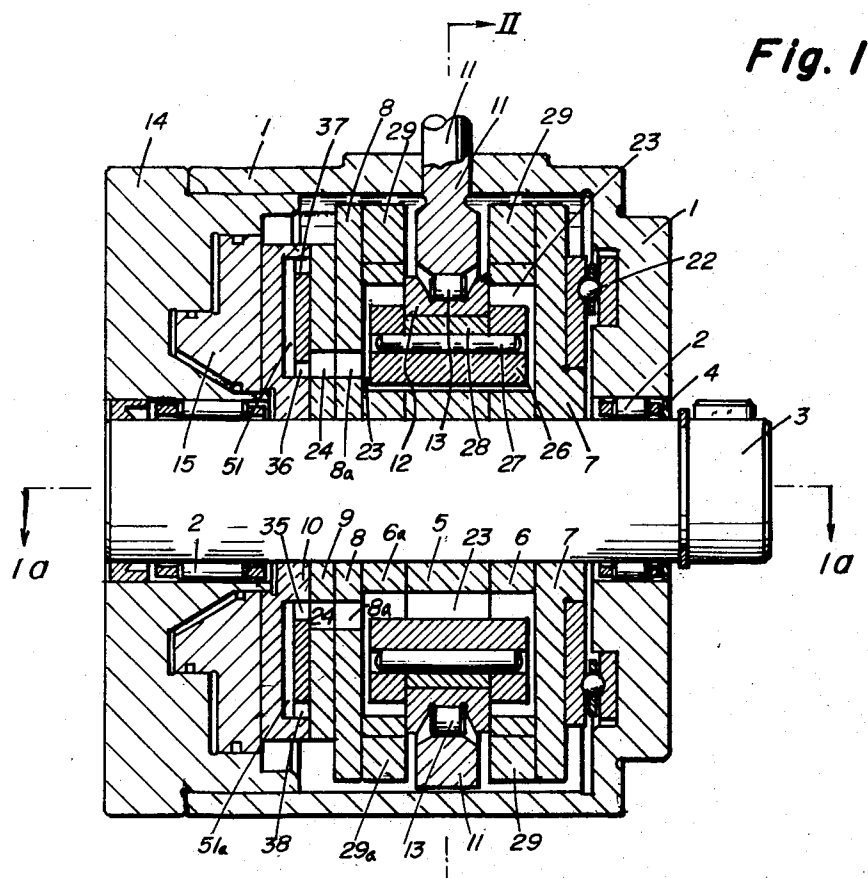


Fig. 2

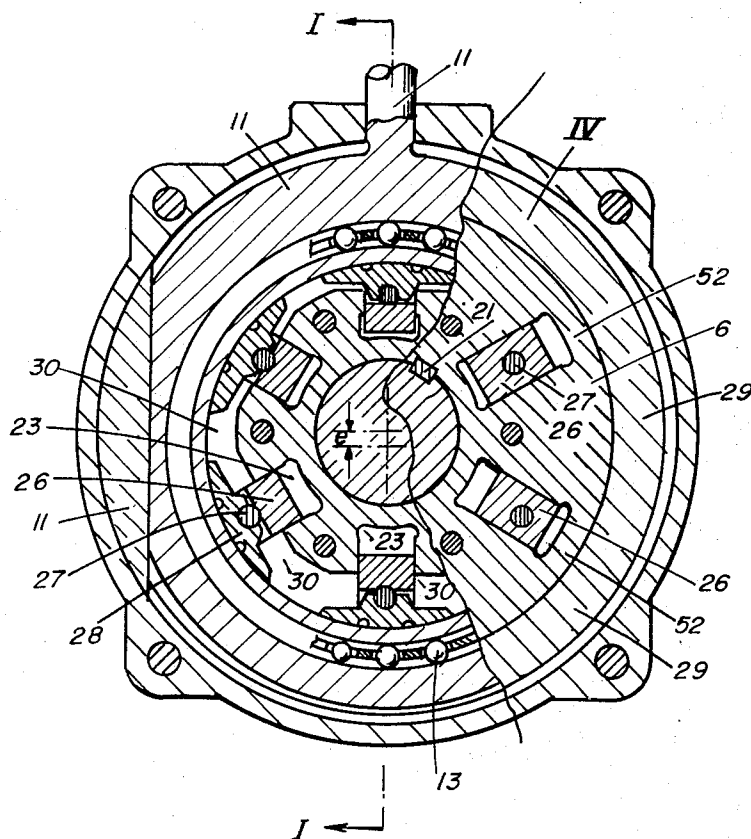


Fig. 4

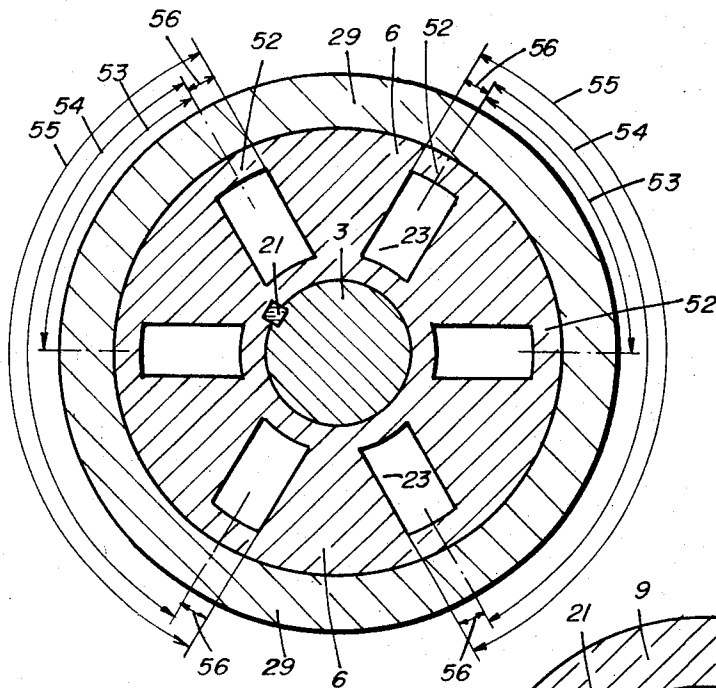


Fig. 5

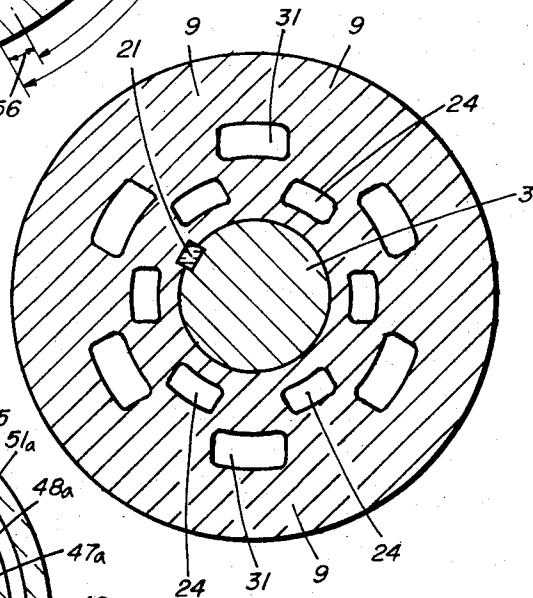
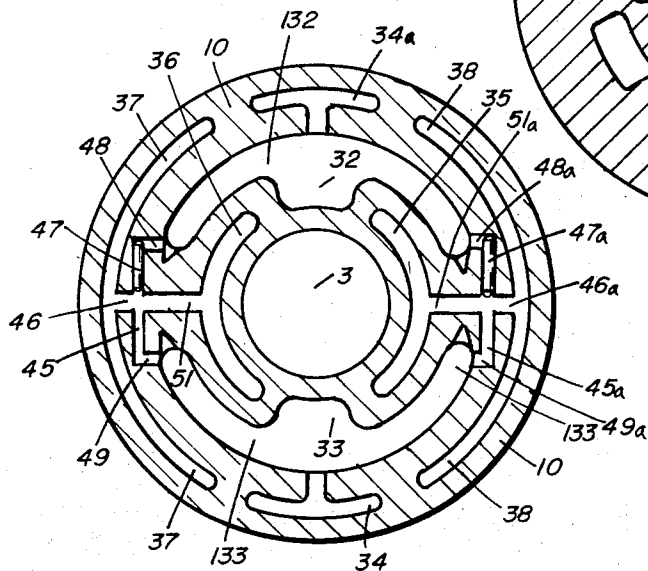


Fig. 3



VANE MACHINE WITH PRESSURE BIAS AND BALANCING MEANS FOR THE ROTARY CONTROL PORT MEMBER

The present application is a continuation application of my copending application Ser. No. 162,034 filed July 13, 1971 and now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to a fluid handling vane machine with slot chambers in the rotor, and vanes radially guided in the vane chambers, particularly a hydrostatic pump, motor or transmission, gas motor, pneumatic motor, combustion engine, compressor and the like.

It is an object of the invention to provide vane machines of this type, which are of simple construction, but nevertheless suitable for high pressure and output, while reliably operating.

Vane machines of this type are known from my German Pat. Nos. 916,739, 1,199,618, and 1,189,338, and my U.S. Pat. Nos. 2,975,716, 3,044,969 and 3,158,103. My German Pat. No. 1,199,282 and U.S. Pat. No. 3,158,103 disclose how a vane machine of this type can also be used for gas operation and liquid operation.

These machines were, however, expensive to manufacture, and unsuited for operation at very high pressures of several hundred atmospheres. Particularly the manufacture of the slot chambers, and the making of the required aligned bores in the rotor portions was expensive and time-consuming. Furthermore, the connecting bolts by which the portions of the rotor were held together, expand at very high pressures and open a gap between the eccentric reaction ring and the respective abutting rotor walls which has a thickness of several thousandths or hundredths millimeter so that at high pressures, leakage developed at these places. Furthermore, the bolts, which are during each revolution once relaxed in the low pressure zone, and then again tensioned in the high pressure zone, were subject to fatigue after several hundreds of hours of operation, which occasionally caused breaking of the bolts holding the rotor portions together, and destruction of the machine.

In copending German and Austrian applications, it has been proposed to fit the rotor members between stationary surfaces on the end walls of the stator so that the bolts can be omitted. Simple centering pins are used in aligned holes of the rotor portions for preventing relative rotation of the same. Machines of this type can be operated at fairly high pressures, but have not been found completely reliable at very high pressures and rotary speeds since an overheating between the outer rotary control surface of the rotor and the adjacent cooperating stationary control surface of the stator takes place which causes fusing of the parts, and destruction of the machine.

In accordance with the invention, it has been recognized that the running hot of the relatively moving control surfaces can occur in vane machines of the above-explained type in which the slot chambers, where the vanes are mounted, have to be subjected to high pressure far before the outer and inner dead center positions so that they are capable to seal the vane chamber passing respective dead center position which requires at least the same high pressure. Over more than 180° of a revolution, high pressure fluid enters the slot

chambers. From the slot chambers and from the vane chambers which are in the process of having the flow reversed, a pressure from the center of the rotor acts against the outer rotary control plate, and presses the same, particularly in the regions where the flow is reversed against the stationary control surface of the substantially stationary, non-rotatable control plate. This pressure is so high that it causes a direct contact between the control surfaces, and overheating of the same. The measures taken in accordance with the prior art are insufficient to prevent the overheating which takes place in the region where the flow is reversed by the control ports of the stationary surface which communicate with the inlet and outlet of the machine.

SUMMARY OF THE INVENTION

In accordance with the invention, in at least one stationary or substantially stationary surface, peripheral grooves are provided in the region where the flow is reversed between the control ports of the stationary surface, which grooves are connected with a high pressure chamber of the machine to exert pressure in axial direction on the rotary control plate. The circumferential extension of the grooves is at least the angular distance between two adjacent vanes of the rotor.

When the balancing grooves according to the invention are properly dimensioned and positioned, the running hot of the known vane machines is prevented even at high pressures above 300 atmospheres, and also at very high rotary speeds. The outlet of the machine can be substantially increased with simple and inexpensive means which are effective when the teaching of the invention is observed.

In machines of this type, the central rotor portion and the side wall rotor portions are frequently pressed of sintered metals which cause some leakage at very high pressures, and breaking of projecting portions bounding the outer ends of the slot chambers. In this manner, the use of the pressed rotor portions was limited to low pressure operation. In accordance with the invention, machines having pressed rotor portions can be reliably used at very high pressure and output, if the rotor side walls are surrounded by a tightly fitting impermeable metal ring. In this manner, the radial and tangential pressure resistance of the rotor side walls is increased to such an extent that the pressed rotor side walls also sustain very high pressures of several hundred atmospheres, and can be made of porous metal, for example sinter metal. The reinforcing rings around the rotor side walls are preferably made of tension resistant material, for example steel tube. In this manner, the efficiency of the machine is again increased, and its price reduced, since sintered pressed material can be used for this rotor center portion and for the rotor side walls eliminating expensive machining and drilling operations.

It is also a feature of the invention that axially outward of the rotor side walls, end portions of the rotors are provided which are metal plates, impermeable to the fluid, and consisting, for example, of steel, so that no liquid or gas can escape from the rotor means in axial direction through the pressed rotor side walls.

In a preferred embodiment of the machine, a controlling thrust body is provided with at least one eccentric shoulder and inserted into respectively formed thrust chamber portions of a housing cover of the machine for being forced by the pressure of fluid in said thrust

chamber portions against a rotary control portion of the machine for sliding thereon in tightly sealing engagement during operation of the machine, thereby pressing all portions of the rotor together and onto a thrust bearing at the opposite rotor end while a balancing groove adjacent the control ports of a stationary control face prevents heating and friction between the stationary and rotary control faces of the device.

Further objects of the invention particularly the dimensioning and placing of the balancing grooves, and the effects obtained by the same will be described with respect to the drawing.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an axial sectional view illustrating an embodiment of the invention taken on line I—I in FIG. 2;

FIG. 1a is an axial sectional view taken on line Ia—Ia in FIG. 1;

FIG. 2 is a cross-sectional view partly taken in FIG. 1 along the line II, and partly taken on line IV—IV in FIG. 1a, as shown in the area IV in FIG. 2;

FIG. 3 is a cross-sectional view taken in FIG. 1a along the line III—III in FIG. 1a;

FIG. 4 is a cross-sectional view taken along line IV—IV in FIG. 1a; and

FIG. 5 is a cross-sectional view taken on line V—V in FIG. 1a.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the embodiment illustrated in the drawing, a drive shaft or output shaft 3 is mounted in bearings 2 of a housing 1, 14 for rotation with the rotor means including the central rotor portion 5, the rotor side wall portions 6, 6a surrounded by identical rings 29, 29a, two end portions 7 and 8, and a rotary control plate 9, see FIG. 5. Sealing means 4 prevent fluid losses out of the housing. As it is known for machines of this type, a reaction ring 12 is mounted by means of a bearing 13 in an adjusting device 11 by which the eccentricity of the reaction ring 12 relative to the axis of shaft 3 can be adjusted. The annular lateral faces of the reaction ring 12 are in sliding engagement with the rotating rotor side walls 6 and 6a. Vanes 26 are mounted in slot chambers 23 in the central rotor portion 5 and in the rotor side walls 6, 6a outside of rotor portion 5, and have pivot pins 27 supporting slide shoes 28 for angular movement. By means of the adjusting means 11, the volumes of the working chambers which may include vane chambers or intervane spaces 30 between adjacent vanes 26 radially outward of the central rotor portion 5, the slot chambers which are formed in slots 23 by the vanes 26, or both, can be varied, but it is also possible to omit the adjusting means 11 and to provide a reaction ring 12 which has a constant eccentricity and is fixedly mounted on the housing. The working chambers can be either pump chambers or motor chambers.

The vanes 26 have an axial extension greater than the axial thickness of the central rotor portion 5, so that the vane ends are guided in slots 23 provided in the side walls 6, 6a, and slide in the slots of the rotor portions 5 and 6 in substantially radial direction inward and outward under the control of the inner surface of reaction ring 12.

The arrangement assures a complete sealing of the vane chambers 30 between the vanes 26, and between the slot chambers 23.

The supply and discharge of the working fluid, which may be a liquid or gas, into and out of the expanding and contracting working chambers 23 and 30 is provided by inlet and outlet means 16, 17, one of which supplies fluid while the other discharges fluid, depending on the use of the machine as pump or motor. Inlet and outlet means 16 and 17 communicate with both working chambers 23, 30 through conduits, passages and ports 16, 18, 32, 132, 24, 35, 25, alternating in rotor side wall portion 6a with slot chambers 23, openings 8a, 8b in rotor end portion 8, and passages 36, 31, 33, 133, 19, and 17, as will be explained hereinafter in greater detail so that the fluid flows into the expanding working chambers 23, 30, and out of the contracting working chambers 23, 30. The housing end wall on the left of FIG. 1, which is part of the cover 14 attached to the main housing 1, provides two eccentric pressure chambers 41 and 42 which act on a pressure member or thrust member 15 which is movable in axial direction and has fluid conduits 18 and 19 so that the fluid pressure in the chambers 41 and 42 presses the pressure means 15 with the non-rotatable control plate 10 against the rotary control plate 9 for obtaining a good seal.

The non-rotatable, substantially stationary control plate 10, FIG. 3, can be mounted on the pressure means 15, or form a part of the same, while the rotary control plate 9, FIG. 5, provided at the end of the rotor means 5, 6, 7, 8, can also serve as the end plate 8 and be integral with the illustrate end plate 8.

The control ports 35, 36, 132, 32, 133, 33 in the stator control plate 10, see FIG. 3, the pressure grooves 34, and the rotor ports 31 and 24, see FIG. 5, are described in a copending application, and not an object of the invention, but shown in order to facilitate the understanding of the disclosed embodiment.

Rotary control ports 24 and 31 in the rotary control plate 9, see FIG. 5, pass during rotation of the rotor over the stationary control ports 132, 32, 35, 133, 33, 36 of the non-rotatable control plate 10, so that the supply and discharge of the working fluid to and from the working chambers 23, 30 is controlled and limited.

By the arcuate ports 132 and 133, and rotor ports 31 the vane chambers 30 are provided with fluid, and by the ports 35, 36, and the radial inner bulges 32, 33 of the ports 132 and 133, the slot chambers 23 are provided with fluid. The ports 132, 32, 35, 133, 33, 36 are connected with the inlet and outlet means 16 and 17 and the channels 18 and 19. The ports 35 and 36 are connected with the channel 18 and 19 which at the moment has higher fluid pressure. The bearing cushions 34, 34a are hydrostatic bearings, which are connected with the adjacent control ports 32 and 33. The inner rotary control ports 24, see FIGS. 1 and 5, are connected with the slot chambers 23, respectively, preferably each channel 24 with a slot chamber 23.

One of the stationary control ports 132, 133 has high pressure fluid, and the other low pressure fluid. When the inner control ports 24 of the rotor control plate 9 pass one of the bulges 32, 33 of the control ports 132, 133, and control ports 31 and openings 25 in plate 6a pass control ports 132, 133, the respective channels and associated working chambers, namely slot chambers 23 and vane chambers 30, respectively, are supplied with high pressure fluid and low pressure fluid once during each revolution. The control ports 24 for the slot chambers 23 communicate during rotation in clockwise direction as viewed in FIG. 3, first with the high pressure groove 36, then with the inner bulge 32 of control port 132, then with high pressure groove 35, and finally with the inner bulge 33 of control port 133. During communication with one of the bulges 32 or 33, the slot chambers 23 receive fluid, and during communication with the other bulge, they expel fluid, irrespective of whether the machine operates as a pump or hydraulic motor. When passages 24 pass over high pressure grooves 35, 36, the slot chambers 23 are filled with high pressure fluid, and take a little fluid from the grooves 35, 36, and then again expel the fluid, and the high pressure in the slot chambers 23 is maintained, since the pressure remains the same during passage over grooves 35, 36, and the small amount of fluid received and discharged has no pumping of motor effect.

When the vanes 26 are in a position bounding a vane chamber or intervane space 30 in which high pressure prevails, the vanes 26 remain in pressed against the reaction ring 12 due to the high pressure in the slot chambers 23. Since the slot chambers 23 receive alternately high pressure and low pressure fluid from inlet and outlet means 16, 17, they act as working chambers. For example, fluid flows out of slot 23 when they pass port portion 33 and at the same time, the vanes 26 move radially inward in the slots due to the action of the reaction ring 12 so that the slot chambers 23 contract. Fluid entering the expanding slot chambers 23 from port portion 33 fills the slot chambers. If the rotor is driven, the slot chambers 23 are pump chambers, and if pressure fluid is supplied to the inlet, the rotor is driven so that the machine operates as a motor. In any event, the vane chambers 30 contract and expand due to the eccentricity of the reaction ring 12, and also act as working chambers communicating through control ports 132 and 133 and openings 31, 25 with inlet and outlet means 16-19. Between the high pressure zone and the low pressure zone, the working chambers pass through two dead center positions. The passage through the dead center positions takes place during the passing of the region between the high pressure and low pressure ports 132 and 133, or between the low pressure and high pressure ports 133 and 132 in an axial plane of symmetry of the part-circular ports 132 and 133. During the passage of the respective rotor ports, unstable pressure conditions develop in the working chambers 23, 30 and the rotor passages 24, 31, which means that the pressure increases from low pressure to high pressure, or even higher when the working chamber, which is closed in the reversing zone, passes from the low pressure zone to the high pressure zone. The pressure is reduced from high pressure to low pressure when the respective working chamber passes from the high pressure zone to the low pressure zone across the respective flow reversal region in which the working chamber is

closed. If the respective slot chamber were supplied with low pressure fluid adjacent the low pressure zone, when the respective working chamber and vane chamber 30 passes through the flow reversal region, the increasing and varying pressure in the closed vane chamber 30 during the flow reversal would be a higher pressure than the pressure in the adjacent slot chamber 23 between the low pressure zone and the high pressure zone, so that the working fluid would escape from the closed vane chamber at the reversal region into the adjacent slot chamber where low pressure prevails, which would cause very high volumetric losses of the machine which would be intolerable for practical operations.

Accordingly, in the non-rotatable control plate 10, control ports 35 and 36 are provided in the regions where the flow is reversed, and these ports 35 and 36 are connected with high pressure zones of the machine at all times. FIG. 3 and FIG. 1 show channels 51, 51a connecting ports 36, 35 with channels 45, 45a and channels 46, 46a connecting channels 51, 51a with grooves 37, 38 in the stationary control plate 10. FIG. 1a shows a horizontal section in which the inlet and outlet means 16, 17 communicate through control ports 32, 132, 24 with slot chambers 23, and through control ports 33, 133, 31, 25 with the vane chambers 30.

In this manner, it is assured that the slot chambers 23 which bound the vane chambers 30 during the reversal of the flow, are supplied with the higher pressure fluid acting in the machine, so that accordingly the respective vanes 26, 27, 28 in the respective slot chambers 23, reliably seal the vane chambers 30 which are in the reversal process.

In accordance with the invention, it has been recognized that the machines constructed as explained above are not suitable for extremely high pressures and rotary speeds, since at very high pressures, and at high rotary speeds, an overheating of the non-rotatable control plate 10 and of the rotary control plate 9 takes place due to frictional engagement.

In accordance with the invention, it is recognized that during the flow reversal, the pressure prevailing in the vane chambers 30 in which the fluid flow is reversed, is higher than the pressure in the low pressure zone of the machine, and that the pressure prevailing in the slot chambers bounding the vane chambers passing through the reversal zone, is substantially equal to the pressure in the high pressure zone of the machine. Consequently, a fluid pressure is exerted against the rotary control plate 9 out of the vane chambers 30 and slot chambers 23 which are involved in the reversal of the flow. This pressure extends from the center of the rotor toward the axial end of the rotor means toward the non-rotatable and substantially stationary control plate 10. The rotary control plate 9 is pressed in the regions where the flow is reversed, with great force against the stationary control plate 10 so that at very high rotary speed and pressure, the film of fluid in the gap between the control plate 10 and the rotary control plate 9 is crushed so that the two control plates frictionally engage each other which causes running hot and fusing of the parts.

In accordance with the invention, the substantially stationary non-rotatable control plate 10 is provided with a part-circular control groove 37 and an opposite control groove 38 near the periphery of control plate 10, as best seen in FIG. 3. Connecting conduit means

45 to 49 assure that the balancing groove 37 or 38, or both, is always supplied with the fluid at the higher pressure. The balancing grooves 37 and 38 according to the invention are open toward the rotary control plate 9, which has a continuous surface in this region so that balancing grooves 37, 38 are closed by the rotary control plate 9. Balancing grooves 37 or 38 extend in circumferential direction so far that the fluid pressure therein and in the adjacent regions of the gap between the control plates 9 and 10, together corresponds to fluid pressure produced by the vane chambers 30 which cause the reversal of the fluid flow, and by the slot chambers 23, act in opposite directions on the rotary control plate 9. The balancing chamber 37 or 38 is arranged radially outward of the part-circular control ports 32 and 33. It is advantageous to make the circumferential extension of the balancing grooves 37, 38 so that they extend over two or three slot chambers 23 which are located on the other side of the rotary control plate 9. The dimensioning of the balancing chambers 37 and 38 is also influenced by the speed of revolution, and of the highest fluid pressure of the machine. At low pressures and rotary speeds, the balancing groove 37 or 38 can be made shorter.

Due to the arrangement of the balancing chambers or grooves 37 and/or 38 the result is obtained that the rotary control plate 9 runs without friction floating between rotor end portions 8 and non-rotatable control plate 10, while the pressures of the balancing chambers 37, 38 oppose the pressures of the slot chambers 23 and vane chamber 30 participating in the reversal of fluid. If the balancing grooves 37 and 38 are properly dimensioned and placed, the rotary control plate 9 floats in such a manner that the leakage in the respective region is very small. In this manner, the invention makes it possible to operate a vane machine, as described, also at very high pressures of several hundred atmospheres and at very high rotary speeds of several thousands of revolutions per minute, without necessitating the screwing together of the several rotor portions of axially extending bolts. The rotor portions 5, 6, 7, 8, 9 are held together due to the axial pressure exerted by the balancing chambers 37, 38 which, together with pressure thrust member 15, urge the entire rotor means against the thrust bearing 22 and the end wall of housing 1.

It is necessary that the balancing grooves 37 or 38 are connected by a connecting means with the high pressure region of the machine. As shown in FIG. 3, channels 46, 46a connect the balancing grooves 37 or 38, respectively, to a cylinder conduit 45, and conduit portions 48 and 49 connect the cylinder conduit portion 45 with the control ports 132 and 133. A control valve member 47 in the cylinder portion 45 effects the connection of the conduit portion 45, 45a, with the control port 132 or 133, whichever has the higher pressure, so that the balancing grooves 37 and 38 are connected by conduits 46, 46a, 48, 48a, 49, 49a with the control port where the higher pressure prevails.

If higher pressure would prevail in control port 132 shown in FIG. 3, the pressure in conduit 48 would be higher than the pressure in conduit 49 and valve member 37 would be shifted into conduit portion 45, closing the connection between balancing groove 37 with the now low pressure control port 33, and opening conduit 48 for the passage of pressure fluid from control port 32 through conduit 46 into balancing chamber 37.

The machine according to the present invention is particularly efficient and reliable for use with very high pressures and rotary speeds, if all portions of the rotor are pressed together in axial direction by the pressure means 15, and when the non-rotatable control plate 10 is mounted on pressure means or thrust member 15, or is a part of the same. In accordance with the invention, it is then necessary to dimension the pressure means 15 and the pressure chambers 41 and 42 so that pressure means 15 is pressed by the fluid pressure in pressure chambers 41, 42 with such a force against the rotor means 5, 6, 7, 8, 9 that the axial pressure is sufficient to overcome the total sum of the opposed fluid pressures due to the arrangement of the balancing grooves 37 and/or 38. The correct dimensioning of the pressure chambers 41 and 42 of the pressure means 15 is influenced to a great extent by the arrangement of the present invention.

A particular simplification of the machines according to the invention will be made possible due to the fact that by arrangement of the balancing grooves 37 and/or 38, an opposing pressure chamber at one shoulder of the chambers of the end of pressure means 15 remote from the pressure chambers 41 and 42 can be omitted. The same purpose serves also the radial widening of the control ports 132 and 133. In accordance with the invention, the entire counterpressure chamber of the pressure means 15, which produces pressure opposing the pressure in the pressure chambers 41 and 42 can be omitted due to an increase of the dimension of the ports 132 and/or 133, for example, by pressure chambers 32, 33 shown in FIG. 3.

Due to this arrangement, the machine is simplified as compared with machines of the prior art of the same type, and can be operated at a higher speed and at higher pressure.

Due to the construction of the pressure means 15, and of the control plates 9 and 10 for use at high pressure and speed, it is possible to eliminate the threaded pressure bolts which are required in accordance with the prior art for holding the rotor portions together in axial direction. In the vane machine of the invention, it is sufficient to provide the rotor portions 5 to 9 with bores, and to insert into the bores axially extending aligning rods or pins, as shown in FIG. 1, provided that the flow cross sections of the fluid filled pressure chambers 41 and 42 are accordingly dimensioned. The bolt heads and nuts can be omitted, which was not possible in the prior art without disturbances. The rotor end portion 7 is rotatably mounted on the axial thrust bearing 22, which may be a roller bearing or a hydrodynamic or hydrostatic bearing. The fluid pressures in the pressure chambers 41 and/or 42 press the cover member 14 and the control plate 10 towards the rotary control plate 9 which presses the rotor portions 6, 5, 7 against the axial bearing 22. In this manner, the expensive nuts and bolts can be omitted, although the machine reliably operates at high pressure at high speed.

The cutouts 35, 36 in the stationary control plate 10 are preferably connected by channels 51, 51a with the respective groove 37 and 38.

It has been found to be extremely expensive to machine the rotor plate portions 5 and 6 by milling or grinding operations. It is far preferably to construct the rotor portions 5 and 6 in the manner disclosed in my U.S. Pat. No. 3,417,706 with open slots, and the rotor

side walls with uninterrupted outer projections radially outwardly of the slots so that these rotor portions can be precisely produced of pressed sinter metal powder. This pressed and sintered material is porous and permits the passage of a few cubic millimeter fluid. This is acceptable at average fluid pressures at which the efficiency of the machine is not substantially reduced. Particularly, the tangential support of the vanes in the slots of the pressed rotor portions 5 and 6 was found to be sufficient for average pressures. For very high pressures, losses due to leakage of fluid through the porous walls becomes too great, particularly for machines which are designed in accordance with the invention for very high pressure. It is therefore also a feature of the invention, that the rotor end portions 7 and 9 are not made or pressed of a porous material, but of an impermeable material, while the inner rotor portions 5 and 6 are pressed of porous sinter metal.

In order to avoid leakage of fluid through the porous projection radially outward of the slot chambers 23 in the rotor side walls 6, in accordance with the invention, a non-porous ring 29 is fitted onto the periphery of each rotor side wall 6.

As shown in FIG. 4, the slot chambers 23 are closed in outward radial direction by projections 52 in the rotor side wall 6, and a ring 29 consisting of impermeable material, for example a steel tube, surrounds the rotor side walls 6.

It is also preferred to press each rotor side wall portions 6, 6a into rings 29, 29a when the rotor side wall portions 6, 6a are pressed of the powdered sintered material. It is also possible, to press the rotor side wall portions 6, 6a onto the end walls 7, consisting of steel, during the pressing and shaping of the rotor side walls 6, 6a of the powdered material, such as sinter metal.

When the rods or pins 44 are fitted and inserted into corresponding bores aligned in rotor portions 5 and 6, and in rotor end portions 7 and 8, the composite rotor is sufficiently strong to support the vanes 26 at high pressure in tangential direction.

It is difficult to exactly align the bores in rotor end portions 7 and 8 with the bores in rotor portions 5 and 6, since rotor end portions 7 and 8 are not pressed but consist of steel, for example, which requires drilling, while the inner rotor portions 5 and 6, which are pressed, have pressed bores.

In accordance with the invention, the rods or pins 44 could be only inserted into the rotor portions 5 and 6, 6a if the strength of the rotor side walls 6, 6a is reinforced by the surrounding steel rings 29, 29a. It is also possible to radially reinforce the projections 52 which are located outward of the slot chambers 23 in the rotor side wall portions 6.

The rotor portions 5 to 9 are connected by a key 21 with the shaft 2 for rotation, and in such a manner that small axial displacements of the rotor portions 5 to 9 on shaft 3 are possible, as may be required when all rotor portions are pressed in axial direction against the thrust bearing 22 by the pressure exerted by pressure chambers 41 and 42.

FIG. 4 illustrates in which zones the slot chambers 23 participate with the reversal of the flow. The angular distance 53 indicates the angular spacing between the planes of symmetry of two slot chambers. Not more than three slot chambers 23 can limit the flow reversal, or participate in the same. The angular distance 54 corresponding to three slot chambers 23 are located in the

flow reversal region, and subjected to high pressure. Since the slot chambers 23 are extended beyond the planes of symmetry of the vanes for a distance 56, the maximum angular extension of the flow reversal regions is increased to the angular distance 55. Since the entire region is a region in which the slot chambers 23 are subjected to high pressure, the balancing groove 37 or 38 is to extend in circumferential direction for the angular distance 55, in accordance with the theoretical assumptions.

However, in actual conditions, fluid from other ports in the rotary control plate 9 or in the non-rotatable control plate 10 enter into the gap between rotary control plate 9 and non-rotatable control plate 10. Since this fluid cannot immediately be pressed out of the gap between the control plates, the balancing chambers 37, 38 can be shortened in circumferential direction, under some circumstances to a substantial degree. The measurements of the balancing chambers 37, 38, of the pressure means 15, and the pressure chambers 41 and 42 must be selected for high pressures and high rotary speed accurately, and as required for the specific operational conditions.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of vane machines having an axially balanced valve plate differing from the types described above.

While the invention has been illustrated and described as embodied in a stationary control surface having inlet and outlet ports defining regions of flow reversal, and balancing grooves in these regions, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

I claim:

1. Vane machine comprising housing means having an axis, and a non-rotatable control surface perpendicular to said axis and formed with at least one pair of part-circular stationary control ports, said housing means having inlet and outlet means communicating with said stationary control ports; a reaction ring mounted in said housing means eccentric to said axis; rotor means mounted in said housing for rotation about said axis and having circumferentially spaced slot chambers and vanes in said slot chambers cooperating with said reaction ring and forming between each other contracting and expanding working chambers for high pressure and low pressure fluid, said rotor means having at one end a rotary control face confronting said non-rotatable control surface and having rotary control ports communicating with said working chambers and passing said stationary control ports alternately whereby high pressure is exerted between portions of said non-rotatable control surface and said rotary con-

trol face and also in those regions between said stationary control ports where the flow of fluid into said working chambers is reversed; said non-rotatable control surface having a balancing groove in at least one of said regions, confronting said rotary control face and being closed by the same, said balancing groove extending in circumferential direction substantially the angular distance between two of said vanes, said stationary control surface communicating with connecting conduit means for connecting said balancing grooves with a high pressure zone of the machine so that said rotary control face is maintained in a frictionless balanced position.

2. Vane machine as claimed in claim 1 wherein a balancing groove is located on said stationary control surface in each of said regions radially outward of said stationary control ports.

3. Vane machine as claimed in claim 1 wherein said connecting conduit means includes two conduit portions connecting said balancing groove with said pair of stationary control ports, and a shiftable valve member in said conduit means shifted by the high pressure fluid in one stationary control port to move to a position establishing communication between said high pressure control port and said balancing groove and blocking flow between the other low pressure control port and said balancing groove.

4. Vane machines as claimed in claim 1 wherein said housing means include two end walls at opposite ends of said rotor means, a pressure thrust means mounted on one of said end walls for axial movement with said non-rotatable control surface, said one end wall and said pressure thrust means forming between each other pressure chambers for pressing said control surface against said rotary control plate and the same against said end of said rotor means so that the other end of said rotor means abuts the other end wall of said housing means.

5. Vane machine as claimed in claim 4 wherein said rotor means includes a plurality of axially adjacent rotor portions; comprising a thrust bearing on said other end wall of said housing means for axially supporting the other end of said rotor means so that said pressure thrust means, said control surface, said rotary control plate and said rotor portions are pressed against each other in axial direction.

6. Vane machine as claimed in claim 5 wherein at least said rotor portions have axially aligned bores, and wherein said rotor means include rods in said bores preventing relative angular displacement of said rotor portions without pressing the same against each other.

7. Vane machine as claimed in claim 1 wherein said rotor means includes a central rotor portion and two side wall portions formed with said slot chambers and guiding said vanes, two end portions for closing said slot chambers, one of said end portions forming said one end of said rotor means; wherein at least said side wall portions are pressed of a porous material; and further comprising reinforcing impermeable metal rings surrounding said side wall portions to reduce fluid losses.

8. Vane machine as claimed in claim 7 wherein said two end portions are metal plates made of an impermeable material.

9. Vane machine as claimed in claim 1 wherein said part-circular stationary control ports in said surface have ends equally spaced from an axial plane of sym-

metry passing through said regions; and wherein two part-circular balancing grooves are located, respectively, in said regions crossing said plane of symmetry and being symmetrical to the same.

10. Vane machine as claimed in claim 1 wherein said housing means includes a non-rotatable plate having said control surface and located adjacent said rotary control plate so that the latter slides on said control surface during rotation of said rotor means and rotary control plate.

11. A vane machine comprising housing means having an axis; fluid containing thrust chamber means including at least one eccentric thrust chamber portion and communication means communicating to a high pressure zone in the machine; a fluid flow controlling thrust body including at least one eccentric shoulder thereon, being axially moveable in said thrust chamber means, sealing on respective walls thereof and having a substantially non-rotatable control surface substantially perpendicular to said axis and formed with at least one pair of substantially part-circular stationary control ports, said housing means having inlet and outlet means communicating with said stationary control ports; a reaction means mounted in said housing means eccentric to said axis; rotor means mounted in said housing means for rotation about said axis, said rotor means consisting of a plurality of abutting members and having circumferentially spaced slot chambers and vanes in said slot chambers cooperating with said reaction means and forming between each other contracting and expanding working chambers for high pressure and low pressure fluid, said rotor means having at one end a rotary control face confronting said stationary control surface and having rotary control ports communicating with said working chambers and passing said stationary control ports alternately whereby high pressure is exerted between portions of said non-rotatable control surface and said rotary control face, between said control ports and also in those regions between said faces where the flow of fluid is reversed; a bearing means provided on the other end of a portion of said rotor means for bearing said rotor means in axial direction thereon whereby the pressure fluid in at least one portion of said thrust chamber means presses said thrust body against said rotor means, said control faces together and into sliding and sealing engagement, said plurality of rotor members together, and said rotor means against said thrust bearing means.

12. The vane machine of claim 11 wherein a balancing groove is provided in said non-rotatable control surface in the said regions where the flow of fluid to said working chambers is reversed, said balancing groove confronting said rotary control face and being closed by the same, said balancing groove extending in circumferential direction substantially the angular distance between two of said vanes, said balancing groove being provided with conduit means for connecting said balancing groove with a high pressure zone of the machine.

13. The machine of claim 11 wherein said balancing groove extends in circumferential direction over more than the angular distance between two of said vanes.

14. The machine of claim 11 wherein fluid flows from said balancing groove into said zone between said control faces where the flow of fluid to said working chambers is reversed, thereby providing fluid pressure forces between said control faces in said region.

13

15. The machine of claim 11 wherein a pair of balancing grooves is provided in said non-rotatable control surface.

16. The machine of claim 11 wherein passage means extend from said control ports through said thrust body into said ports in said housing means.

17. The machine of claim 11 wherein fluid flow control recess means are provided in said thrust body, extending radially from portions of said control ports into portions of said non-rotating control surface; passage means extend from said slot chambers in said rotor means through portions of said rotor means in said rotary control face, forming additional rotary control ports therein, which pass along said fluid flow control recess means alternately for passing fluid into and out of said slot chambers when said slot chambers are contracting and expanding while said vanes cooperating with said reaction means move in said slots.

18. A vane machine comprising a housing having end covers; rotor means rotatably mounted in said end covers, and having a central rotor member and outer rotor members at the axial ends of said central rotor member, said outer rotor members extending radially beyond the central member, at least said central rotor member being formed with slots at least in said central rotor member; an annular eccentric reaction member surrounding said central rotor member; vanes located in said slots for sliding movement in radial outward and inward direction, said vanes forming working chambers within said annular reaction member and outside of said rotor means for taking in an expelling fluid into

14

and out of said working chambers; said rotor means being provided with passages through at least one of said outer rotor members for providing communication between said working chambers and a rotary control face at the outer end of one of said outer rotor members; and a thrust member partially located within one of said end covers, said one end cover forming a thrust chamber having an eccentric portion, said thrust member having an eccentric portion and being partially located in said thrust chamber closing the same in one axial direction, said eccentric portion of said thrust member extending into said eccentric portion of said thrust chamber, a centric portion of said thrust member extending into a centric portion of said thrust chamber so that said thrust member divides said thrust chambers into two thrust chamber portions and closes both said thrust chamber portions in one axial direction, said thrust member having a stationary control face at the axial end of said thrust member which abuts against said rotary control face of said outer rotor member, said thrust member having fluid passages extending from said thrust chamber portions and through said stationary control face of said thrust member for forming inlet and outlet ports for fluid, the cross sectional areas of said thrust chamber portions being wider than the cross sectional areas of the high pressure fluid areas between said stationary control face and said rotary control face so that the fluid in at least one of said thrust chambers presses said thrust member against said rotary control face.

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