

[54] **INNER VANE FOR ROTARY DEVICES**

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[58] Field of Search **418/268, 269, 82, 26, 180**

[56] **References Cited**

UNITED STATES PATENTS

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[57] **ABSTRACT**

A sliding-vane rotary moving-fluid device. Radially slidable in each rotor slot are an outer vane and a thinner contiguous inner vane. Selected outward pressures on the inner vane and on leading and trailing portions of the outer vane provide proper net pressure distributions for tracking of the outer vane on a cam ring while traversing sealing spaces and port spaces alternately during rotation.

11 Claims, 2 Drawing Figures

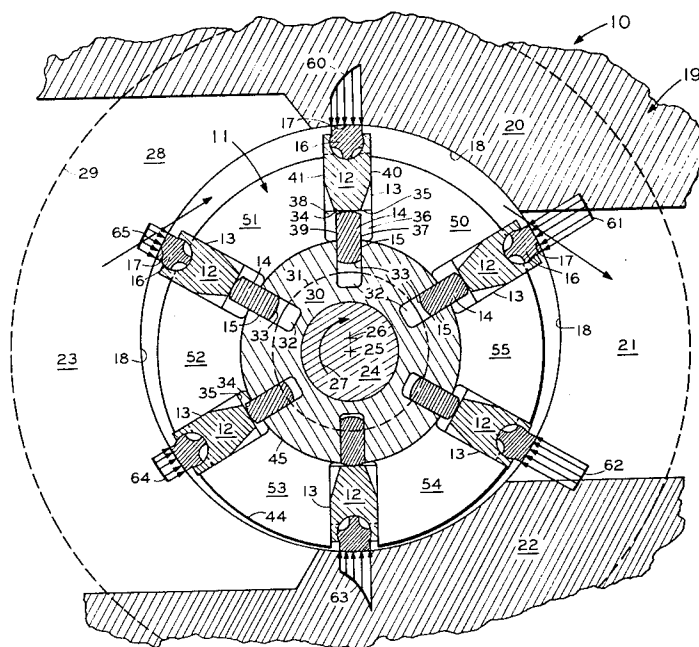


FIG. 1

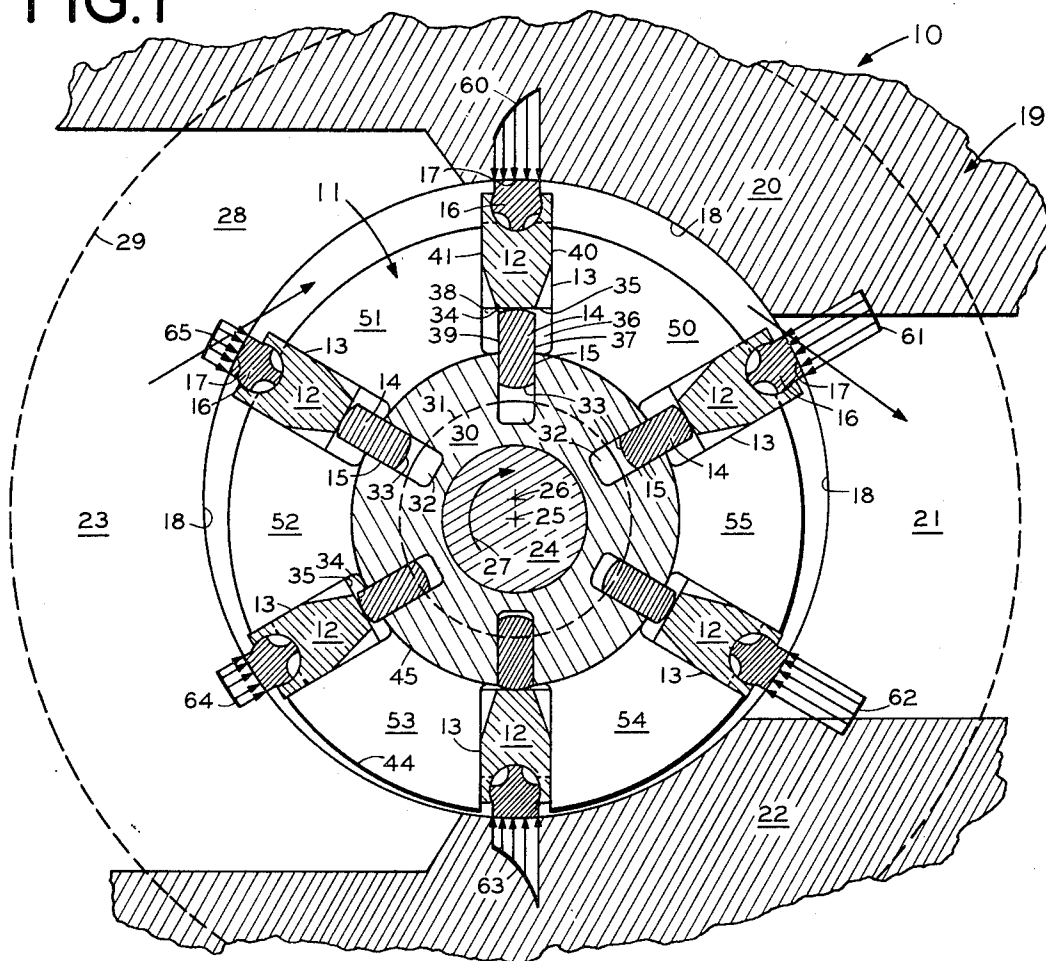
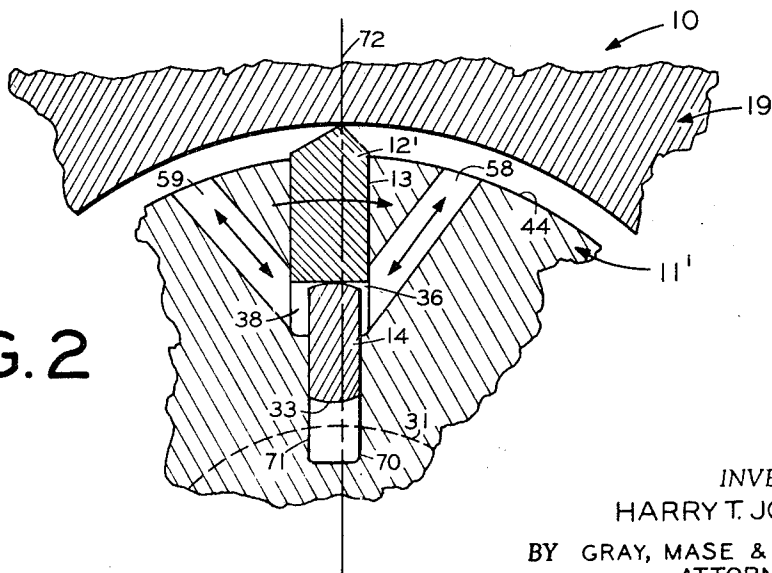


FIG. 2



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INNER VANE FOR ROTARY DEVICES

BACKGROUND OF THE INVENTION

This invention relates to sliding-vane rotary moving-fluid devices. It has to do particularly with improvements in the distribution of pressure on the vanes to provide optimum tracking of the vanes on the cam ring while minimizing wear on the relatively moving surfaces. The problems of imperfect tracking and excessive wear in sliding-vane rotary moving-fluid devices, such as pumps and motors, have been serious and persistent ones. The present invention provides substantial improvements in dealing with both problems.

The present invention provides undervane hydrostatic pressure distributions that cause the vane assembly to track the cam ring contour without lifting off the cam surface, while avoiding any excessive loading between the vane tip and the cam surface. This requires variation in the undervane pressure distributions during rotation, because the hydrostatic pressure forces on the vane tip bearing surface vary according to whether inlet pressure or outlet pressure is present ahead of the vane assembly and according to which pressure is present behind the vane assembly during its rotation. The variations that take place in the radially inward forces on the vane tip bearing surface depend also on the contour of the tip surface and on whether the tip is designed for boundary lubrication or to promote hydrodynamic lubrication.

The undervane pressure distributions for the various positions of the vane assembly need not provide exact hydrostatic balance. In fact a controlled radial unbalance is generally preferable to assure proper tracking of the vane tip on the cam ring. In proper tracking, the bearing surface of the vane tip is provided with sufficient outward loading to maintain substantial contact with the cam ring. The tip supports the net radial acceleration loading of the vane assembly and the selected hydrostatic radial unbalance applied to the vane. During inward stroking the tip also supports the resulting radial drag forces.

SUMMARY OF THE INVENTION

A typical sliding-vane rotary moving-fluid device according to the present invention comprises a cylindrical rotor having outer vanes slidable in substantially radial outer vane slots therein and inner vanes slidable in substantially radial inner vane slots extending inwardly from the outer vane slots, the tip of each outer vane maintaining substantial contact with the inner cylindrical surface of a cam surrounding the rotor as it traverses sealing spaces and port spaces alternately during rotation; pressure means for maintaining the outer edge of each inner vane in contact with a portion of the inner edge of the adjacent outer vane, to form a leading chamber in the outer vane slot inside the inner edge of the outer vane and ahead of the leading surface of an outer portion of the inner vane and to form a trailing chamber in the outer vane slot inside the inner edge of the outer vane and behind the trailing surface of an outer portion of the inner vane; and means for applying a predetermined sequence of forces during rotation to each leading chamber and to each trailing chamber. The outer edge of the inner vane in each slot typically is thinner than the inner edge of the outer vane therein and contacts it in a region between the leading surface and the trailing surface of the outer vane.

The pressure means typically comprises means for continuously applying fluid pressure against the inner edge of the inner vane, as by communicating a region contiguous to the inner edge of the inner vane with a region in the device having a fluid pressure therein that is greater than the lowest pressure encountered by the outer vanes.

The force applying means typically comprises means for communicating each leading chamber with the region between the rotor and the cam immediately ahead of the outer vane during rotation, and means for communicating each trailing chamber with the region between the rotor and the

cam immediately behind the outer vane during rotation. Typical communicating means may comprise an opening in the rotor extending between the leading chamber in each outer vane slot, the trailing chamber in the next outer vane slot ahead, and a region of the outer surface of the rotor between the slots, or separate passages may be provided in the rotor from the leading and trailing chambers to respective regions of the outer surface of the rotor immediately ahead of and behind the outer vane slot.

The areas of the inner edge of the outer vane in the leading and trailing chambers and the area of the inner edge of the inner vane are selected such that the pressures thereon provide a predetermined distribution of net forces on the tip of the outer vane for maintaining proper tracking of the tip with the cam during rotation. The tip of each outer vane typically either is shaped to maintain substantial contact with the inner surface of the cam essentially along a line substantially parallel to the leading and trailing edges of the outer vane, or else comprises a pivotable member having a substantial surface in substantial contact with the inner surface of the cam.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a transverse cross-sectional view of a typical sliding-vane rotary moving-fluid device according to the present invention.

FIG. 2 is a similar view of a portion of a device similar to that of FIG. 1 but with differences in some details.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, a sliding-vane rotary moving-fluid device 10 is shown similar to the device in FIG. 3 of United States Pat. application, Ser. No. 15,377 of David L. Thomas for "Vane Tracking in Rotary Devices," and including a preferred embodiment of the present invention. For convenience, the device of FIG. 1 is described herein as a single-lobe pump. From the disclosure of such an embodiment, it will be apparent how the invention can be modified in routine ways for incorporation in other rotary moving-fluid devices such as fluid motors and other pumps, which may have more than one lobe, such as the pumps and other devices disclosed in the patent application mentioned above and in U.S. Pat. Nos. 3,407,742 and 3,514,232.

A cylindrical rotor 11 has outer vanes 12 slidable in substantially radial outer vane slots 13 therein, and inner vanes 14 slidable in substantially radial inner vane slots 15 extending inwardly from the outer vane slots 13. The tip 16 of each outer vane 12 maintains substantial contact, as indicated at 17, with the inner cylindrical surface 18 of a cam 19 surrounding the rotor 11 as the vane 12 traverses sealing spaces 20, 22 and port spaces 21, 23 alternately during rotation. A very thin film of lubricant normally is present in the region of substantial contact at 17 between the tip 16 of the outer vane 12 and the inner cylindrical surface 18 of the cam 19.

The rotor 11 is rigidly mounted on a shaft 24 having an axis 25, the position of which may either be fixed or variable with respect to the axis 26 of the inner cylindrical surface 18 of the cam 19. The shaft 24 and the rotor 11 thereon rotate in a clockwise direction as is indicated by the arrow 27. The space between the rotor 11 and the cam 19 is enclosed by an end plate 28 fixedly mounted at each end of the cam 19 in close slidable substantial contact with the rotor 11, a thin film of lubricant normally being present between the rotor 11 and each end plate 28. The periphery of the end plate 28 in FIG. 1 is indicated at 29.

The end plate 28 contains an annular chamber 30 between the shaft 24 and the surface 31 for communicating a region 32 contiguous to the inner edge 33 of each inner vane 14 with a region in the device 10 having a fluid pressure therein that is greater than the lowest pressure encountered by the outer vanes 12. In the pump of FIG. 1 this region can conveniently be the port 21, where outlet pressure is present, or any other conveniently located region having a suitable pressure greater

than the inlet pressure at the port 23. In a fluid motor the chamber 30 would communicate with an inlet port or other region having suitable pressure greater than the outlet pressure of the motor.

The communicating chamber 30 thus provides pressure means for maintaining the outer edge 34 of each inner vane 14 in contact with a portion of the inner edge 35 of the adjacent outer vane 12, to form a leading chamber 36 in the outer vane slot 13 inside the inner edge 35 of the outer vane 12 and ahead of the leading surface 37 of an outer portion of the inner vane 14, and to form a trailing chamber 38 in the outer vane slot 13 inside the inner edge 35 of the outer vane 12 and behind the trailing surface 39 of an outer portion of the inner vane 14. Since the annular chamber 30 communicates the regions 32 with the region of relatively high pressure at all positions of the rotor 11, the relatively high fluid pressure is continuously applied against the inner edge 33 of each inner vane 14.

The outer edge 34 of the inner vane 14 in each slot 13, is thinner than the inner edge 35 of the outer vane 12 therein and contacts it in a region between the leading surface 40 and the trailing surface 41 of the outer vane 12.

An annular portion of the rotor 11 approximately midway between its ends is cut out from the outer surface 44 to an inner surface 45, thus forming an opening 50, 51, 52, 53, 54, 55 in the rotor 11 extending between the leading chamber 36 in each outer vane slot 13, the trailing chamber 38 in the next outer vane slot 13 ahead, and a region of the outer surface 44 of the rotor 11 between the successive slots 13. The openings 50-55 communicate each leading chamber 36 with the region between the rotor 11 and the cam 19 immediately ahead of the outer vane 12 during rotation while at the same time communicating each trailing chamber 38 with the region between the rotor 11 and the cam 19 immediately behind the outer vane 12 during rotation. Thus the openings 50-55 apply a predetermined sequence of forces, by virtue of the pressures in the regions ahead and behind, to each leading chamber 36 and to each trailing chamber 38 during rotation of the rotor 11.

In FIG. 2, showing a modified form of the device of FIG. 1, the outer vane 12' is so designated because it differs from the outer vanes 12 in FIG. 1, being a single member without a separate tip 16, and differing in shape from the outer vanes 12 in FIG. 1. The rotor 11' in FIG. 2 is so designated because it differs from the rotor 11 of FIG. 1, having separate passages 58, 59 rather than the continuous openings 50-55. The passage 58 in the rotor 11' communicates from the leading chamber 36 of the outer vane slot 13 to the region of the outer surface 44 of the rotor 11 immediately ahead of the outer vane slot 13. Similarly the passage 59 communicates from the trailing chamber 38 to the region of the outer surface 44 immediately behind the outer vane slot 13. Thus a leading passage 58 communicates each leading chamber 36 with the region between the rotor 11' and the cam 19 immediately ahead of the outer vane 12' during rotation, and a trailing passage 59 communicates each trailing chamber 38 with the region between the rotor 11' and the cam 19 immediately behind the outer vane 12' during rotation, to apply a predetermined sequence of forces during rotation to each leading chamber 36 and to each trailing chamber 38.

In both forms of the device, the areas of the inner edge 35 of the outer vane 12 or 12' in the leading chamber 36 and the trailing chamber 38 and the area of the inner edge 34 of the inner vane 14 are selected such that the pressures on the areas provide a predetermined distribution of net forces on the tip of the outer vane 12 or 12' for maintaining proper tracking of the tip with the cam 19 during rotation.

Suitable distributions of force in the device of FIG. 1 are represented by the lengths of the arrows and the shapes of the curves at 60-65. When the tip 16 of an outer vane 12 is in substantial contact, as indicated at 17, with the pumping lap space 20 of the cam 19, the distribution of forces on the tip 16 is approximately as indicated at 60, varying from a relatively low force on the trailing end of the tip 16 to a substantially higher

force at the leading end. The forces on outer vane tips 16 in the outlet port space 21 of the cam 19 are approximately as shown at 61 and 62, being the same relatively high pressure over the entire outer surface of each outer vane tip 16. The force distribution on the outer surface of an outer vane tip 16 in substantial contact with the sealing lap space 22 of the cam 19 is approximately as shown at 63, being relatively high at the trailing edge of the tip 16 and relatively low at the leading edge. The forces on outer vane tips 16 in the inlet port space 23 of the cam 19 are approximately as shown at 64 and 65, being the same relatively low pressures over the entire outer surface of each outer vane tip 16.

The location and the width of the inner vane 14 determine the magnitude of the controlled radial hydrostatic unbalance on both the pumping lap space 20 and the sealing lap space 22. The unbalance on the inlet port 23 is a function of the width of the inner surface 33 of the inner vane 14 and the magnitude of the pressure differential between the inlet port 23 and the outlet port 21. The radial hydrostatic pressure on the outlet port 21 is balanced, since the entire vane assembly is exposed to the outlet pressure. The ability of the vane assembly to track on the outlet port 21 thus depends on the accelerations that are produced, as determined by the contour of the inner surface 18 of the cam ring 19 throughout the outlet port space 21.

The use of the inner vane 14 as disclosed herein enables a net radially outward force to be applied to the vane assembly to assure tracking that is independent of the rotational speed of the device, except on the outlet port 21. The selection of the undervane pressure distribution to provide the proper net force is determined by the pressure distribution on the bearing surface 17 of the tip 16 in FIG. 1.

In FIG. 2 an additional degree of freedom is provided in controlling the distribution of forces. In FIG. 2 the tip of the outer vane 12' is shaped to maintain substantial contact with the inner surface 18 of the cam 19 essentially along a line between the leading and trailing edges of the outer vane 12'. Considering a plane 72 through the line of substantial contact and parallel to the leading edge 70 and the trailing edge 71 of the inner vane slot 15, the distribution of forces is a function of the position of the plane 72 between the edges 70 and 71.

A larger unbalance could be provided by communicating the full outlet pressure to the entire inner edge 35 of the outer vane 12, 12', but this would overload the bearing surface of the vane tip on the inlet port 23, and the unbalance would be greater than is necessary for proper operation in the lap spaces 20 and 22. The use of the separate inner vane 14 enables the designer to provide the optimum magnitude of unbalance in each lap space 20, 22, while minimizing the loading of the tip of the outer vane 12, 12' on the inlet port 23.

The contact between the outer edge 34 of the inner vane 14 and the inner edge 35 of the adjacent outer vane 12 provides a positive seal between the leading chamber 36 and the trailing chamber 38 in the outer vane slot 13 when the vane assembly is subjected to a differential pressure. The radially outward differential pressure provided in the region 32 to the inner vane 14 assures proper outward stroking of the outer vane 12, 12' on the inlet port 23.

While the forms of the invention herein disclosed constitute presently preferred embodiments, many others are possible. It is not intended to mention all of the possible equivalent forms or ramifications of the invention. It is to be understood that the terms used herein are merely descriptive rather than limiting, and that various changes may be made without departing from the spirit or scope of the invention.

I claim:

1. A sliding-vane rotary moving-fluid device, comprising: a cylindrical rotor having outer vanes slidable in substantially radial outer vane slots therein and inner vanes slidable in substantially radial inner vane slots extending inwardly from the outer vane slots, the tip of each outer vane maintaining substantial contact with the inner cylindrical surface of a cam surrounding the rotor as it traverses

ses sealing spaces and port spaces alternately during rotation;

pressure means for maintaining the outer edge of each inner vane in contact with a portion of the inner edge of the adjacent outer vane, to form a leading chamber in the outer vane slot inside the inner edge of the outer vane and ahead of the leading surface of an outer portion of the inner vane and to form a trailing chamber in the outer vane slot inside the inner edge of the outer vane and behind the trailing surface of an outer portion of the inner vane; and

means for applying a predetermined sequence of forces during rotation to each leading chamber and to each trailing chamber.

2. A device as in claim 1, wherein the outer edge of the inner vane in each slot is thinner than the inner edge of the outer vane therein and contacts it in a region between the leading surface and the trailing surface of the outer vane.

3. A device as in claim 1, wherein the pressure means comprises means for continuously applying fluid pressure against the inner edge of the inner vane.

4. A device as in claim 3, wherein the pressure applying means comprises means for communicating a region contiguous to the inner edge of the inner vane with a region in the device having a fluid pressure therein that is greater than the lowest pressure encountered by the outer vanes.

5. A device as in claim 4, wherein the force applying means comprises means for communicating each leading chamber with the region between the rotor and the cam immediately

ahead of the outer vane during rotation.

6. A device as in claim 5, wherein the force applying means comprises also means for communicating each trailing chamber with the region between the rotor and the cam immediately behind the outer vane during rotation.

7. A device as in claim 6, wherein the communicating means comprise an opening in the rotor extending between the leading chamber in each outer vane slot, the trailing chamber in the next outer vane slot ahead, and a region of the outer surface of the rotor between the slots.

8. A device as in claim 6, wherein the communicating means comprise passages in the rotor from the leading and trailing chambers to respective regions of the outer surface of the rotor immediately ahead of and behind the outer vane slot.

9. A device as in claim 6, wherein the areas of the inner edge of the outer vane in the leading and trailing chambers and the area of the inner edge of the inner vane are selected such that the pressures thereon provide a predetermined distribution of net forces on the tip of the outer vane for maintaining proper tracking of the tip with the cam during rotation.

10. A device as in claim 1, wherein the tip of each outer vane is shaped to maintain substantial contact with the inner surface of the cam essentially along a line substantially parallel to the leading and trailing edges of the outer vane.

11. A device as in claim 1, wherein the tip of each outer vane comprises a pivotable member having a substantial surface in substantial contact with the inner surface of the cam.

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