ROTOR-STATOR GEAR SET IN A HYDRAULIC MOTOR-PUMP DEVICE

Filed Sept. 27, 1967

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ABSTRACT OF THE DISCLOSURE

A rotor-stator gear set for a fluid pressure device of the gerotor type which can be used both as a motor and as a pump. The stator includes a stator ring having a plurality of pockets and a corresponding plurality of cylindrical vanes rotatably carried in the pockets for working in gear relation with the rotor to provide alternately expanding and contracting fluid chambers between the stator and the rotor as the rotor moves hypocycloidally within the stator. The diameters of the vanes to provide hydrodynamic oil film spaces between the vanes and the walls of the pockets. The stator ring is made of sintered or cast iron and the walls of the pockets are lined with a thin layer if impervious or all impervious material to ensure the hydrodynamic oil film. The impervious material has a low coefficient of friction and is less hard than is the material of which the vanes are constructed so that high points on the impervious liner are worn off under load. The liner may be made of a sprayed or baked-on fluorocarbon resin or may comprise a copper plate. If the stator ring is made of sintered iron it may be plastic impregnated to render it fluid impervious.

Background of the invention

This invention pertains generally to the filed of fluid motor-pump units and more particularly to such units which employ a rotor-stator gear set generally referred to in the art as gerotors.

Motor-pump hydraulic devices of the gerotor type are useful in a variety of applications where low speed, high torque rotary drives are required such as augers, conveyors, vehicle wheel drives, etc., and comprises an internally toothed or lobed stator and an externally toothed rotor which is positioned eccentrically within the stator. The stator has a greater number of teeth or lobes than does the rotor and as the stator and the rotor are rotated relative to one another the rotor moves through a hypocycloidal curve to form alternately expanding and contracting chambers between each pair of adjacent teeth of the internally toothed stator and each tooth of the rotor.

Because of the peculiar construction and operation of gerotor type gear sets the machining operations of the stator and the rotor heretofore required very close tolerances which, of course, increased the cost of production. Furthermore because of the substantial pressures to which the gerotor may be subjected the stator and the rotor were generally made of metal having high strength characteristics but also having relatively high coefficients of friction, thereby increasing the power losses within the gerotor as well as increasing the operating temperature and the heat transferred to the fluid operating or being pumped by the gerotor.

An object of the present invention is not only to improve the operating and performance characteristics of gerotors but also to reduce the production costs by minimizing difficult close-tolerance machining of the stator and by utilizing materials of construction which improve the manufacturing costs.

Summary of the invention

With this object and others in view, the present invention may be summarized as comprising a hydrostatic device of the gerotor type including a rotor and a stator wherein the stator comprises a stator ring having an inner peripheral wall, a plurality of fragmentarily cylindrically shaped walls opening to the inner peripheral wall and forming a corresponding plurality of radially spaced pockets and a corresponding plurality of cylindrically shaped vanes providing teeth or lobes carried in the pockets for cooperating in gear relation with the teeth of the rotor. The diameters of the pocket walls are larger than the diameters of the vanes whereby the vanes are journaled for rotation within the pockets and whereby a hydrodynamic oil film space is provided between the walls of the pockets and the vanes as the rotor moves hypocycloidally within the stator.

In operation the rotor engages and makes actual contact only with those vanes situated on one side of a diametrical line which intersects the axis of the rotor moves hypocycloidally in the stator. The remaining vanes are engaged by the rotor and a torque applied by the rotor to the engaged vanes rotates these vanes within their respective pockets, thereby substantially reducing friction losses between the teeth of the rotor and the vanes.

The present invention also features novel combinations of materials of construction to further reduce friction losses, to increase performance, to reduce wear and to lengthen the useful life of the device. The vanes are made of metal of a given hardness and the walls of the pockets which journal the vanes are lined with a thin layer of material which not only has a low coefficient of friction but which has a hardness less than the hardness of the vanes whereby high points formed on the pocket walls will wear off under load and the contours of the pocket walls will conform to the contours of the vanes. The pocket liner material may be metal such as copper or may be plastic such as fluorocarbon resin, both of which have a low coefficient of friction and both of which are impervious to maintain the hydrodynamic oil film between the vanes and the walls of the pockets.

The stator ring may be formed in a molding operation using cast iron or may be sintered iron formed in a stamping and sintering operation as will be understood by those skilled in the art. In the latter construction the sintered iron may be plastic impregnated to render the stator ring impervious and to prevent dissipation of the hydrodynamic oil film between the pocket walls and the vanes.

Many other features, advantages and additional objects of the present invention will become manifest to those versed in the art upon making reference to the detailed description which follows and the accompanying sheet of drawings in which preferred structural embodiments incorporating the principles of the present invention are shown by way of illustrative example only.

Brief description of the drawing

FIGURE 1 is an elevational view of a gear set of the gerotor type for functioning as a fluid pump and as a fluid motor and constructed in accordance with the principles of the present invention.

FIGURE 2 is a greatly enlarged and fragmentary cross-sectional view of one embodiment of a stator vanes and an adjacent portion of the stator ring.

FIGURE 3 is similar to FIGURE 2 but illustrates another embodiment of the invention.

Description of the preferred embodiments

A fluid pressure device comprising a gear set of the gerotor type for functioning as a fluid pump and as a fluid motor and constructed in accordance with the principles.
of the present invention is indicated generally at reference numeral 10 in FIGURE 1. The device 10 may be more particularly characterized as comprising an internally toothed rotor 11 and an externally toothed rotor 12.

The teeth or lobes of the rotor 12 comprise convexly-shaped portions 13 angularly spaced about a central axis of the rotor and separated by concavely-shaped portions formed in an outer wall 16 of the rotor. The teeth of the stator 11 comprise a plurality of angularly spaced cylindrically shaped members or vanes 17 which are housed in a casing 19 of the rotor 12 and which engage the convexly-shaped walls forming recesses or pockets 18 opening to an inner peripheral wall 19 of an annularly shaped stator ring member 20.

The number of teeth of the rotor 12 is preferably one less than the number of teeth of the stator 11. In the embodiment illustrated the rotor 12 has a total of six teeth while the stator 11 has one more than the rotor or seven teeth.

The axis of the rotor 12 is eccentrically disposed with respect to a central axis of the stator 11 and as the rotor 12 is rotated relative to the stator 11 the rotor teeth 13 mesh with the stator teeth or vanes 17 to impart a hypocycloidal path of movement to the rotor 12 whereby it orbits about the central axis of the stator six times, corresponding to the number of teeth of the rotor 12, for each revolution of the rotor 12.

During this hypocycloidal movement of the rotor 12 the teeth or lobes 13 thereof form, in combination with the teeth 17 of the stator 11 and the inner peripheral wall 19 of the stator ring 20, alternately expanding and contracting fluid chambers indicated respectively at reference numerals 21c–21e. In other words, assuming that the rotor 12 is being rotated about its central axis in the direction indicated by the arrow at reference numeral 22, the fluid chamber 21a has contracted to its minimum volume and further rotation of the gear 12 will have the effect of expanding the volume of this chamber. Chamber 21b is approaching its minimum volume and chambers 21c and 21d are being contracted. Chambers 21e, 21f and 21g are expanding and of course further rotation of the rotor 12 from the position thereof shown in FIGURE 1 will have the effect of also expanding chamber 21a.

When the device 10 is being utilized as a fluid motor means are provided for communicating the expanding fluid source of power to the contracting chambers which communicate with the expanding chambers. Suitable means may be utilized for communicating the fluid chambers alternately and successively with the fluid inlet and outlet openings are known in the art and are disclosed, for example, in Holllis W. White, Jr. et al. U.S. Patent No. 3,288,034.

Although the externally toothed rotor 12 is described herein as being rotatable within and orbitally moveable relative to the internally toothed enveloping stator 11, either member can be fixedly arranged relative to the other. Furthermore, one member can be arranged to rotate only while the other member orbits only, as will be understood by those skilled in the art. Thus the rotor 12 may be a fixed member and the stator 11 a movable member as desired.

In the illustrated embodiment of the invention the teeth 13 and the interconnecting arcuately shaped surface 14 of the rotor 12 and the vanes 17 of the stator 11 are constructed and arranged so that the rotor 12 only contacts the vanes 17 which are disposed on one side of a diametrical line which intersects the central axis of the rotor 12 as well as that particular chamber, such as chamber 21a in the arrangement of parts shown in FIGURE 1, which has contracted to its minimum volume. In FIGURE 1 such diametrical line is indicated in broken lines at reference numeral 22. Thus the teeth 13 which form the contracting chambers 21b, 21c and 21d are in engagement with the vanes 17 in the relative positions of the stator 11 and the rotor 12 shown in FIGURE 1, whereas the rotor teeth partially forming the expanding chambers 21e, 21f and 21g are in slightly spaced relation with their corresponding vanes 17.

In this disposition and direction of rotation of the parts shown in FIGURE 1, the vanes 17 will rotate inter-clockwise due to the vanes action. Vanes adjacent to chambers 21b, 21c and 21d will rotate if the device is being used as a motor. Vanes adjacent to the chambers 21f, 21g and 21e will rotate if the device is being used as a pump.

The diameters of the pocket or recess walls 18 are generally larger than the diameters of the vanes 17, as a consequence of which the vanes are capable of moving slightly not only toward the axis of the stator ring 20 but from side to side. The teeth 13 of the rotor 12 are constructed and arranged to permit such movement of the vanes as the rotor 12 rotates and orbits within the stator 11 and as a consequence the peripheral surfaces of the vanes 17 are urged slightly outwards in the peripheral direction whereby the pressure of the operating fluid such as oil, thereby providing a hydrodynamic oil film between the vanes 17 and the pockets 18. The film does not only increases the performance characteristics of the device 10 by reducing the frictional forces between the vanes and the pockets and thus reducing the power losses of the rotor 12, but also by reducing wear and increasing the overall operating life of the device 10.

The spacing between the walls of the vanes indicated in FIGURE 1 at reference numeral 17' and 17" and the walls of their respective pockets has been greatly exaggerated merely to illustrate this hydrodynamic oil film space.

One aim of the present invention as mentioned hereinafore is to reduce manufacturing costs by reducing the requirements of close tolerance machining. According to the present invention the stator ring 20 is formed of cast iron in a casting operation or is formed of sintered iron in an operation involving the process of compacting powdered metal in a die under pressure and then heating the pressed powder in a sintering operation. Both of these manufacturing techniques are known and understood by those skilled in the art.

FIGURES 2 and 3 are greatly enlarged representations of that portion of a vane 17 and of the stator ring 20 encircled in the dot-dashed line indicated at reference numeral 26 in FIGURE 1. FIGURE 2 illustrates an embodiment of the present invention utilizing a cast iron stator ring 20, whereas in FIGURE 3 the stator ring is made of sintered iron.

In accordance with the principles of this invention, after the stator ring 20 has been cast or sintered the pockets walls 18 are lined with a thin layer of another material such as plastic or copper. The purposes of the liner are at least threefold: (1) to obviate close machining of the pocket walls 18 in order to have good bearing surfaces for the vanes 17; (2) to increase performance of the hydrostatic device 10 by reducing frictional losses between the vanes 17 and the stator ring 20 and (3) to maintain the hydrodynamic oil film between the adjacent peripheral walls of the vanes 17 and the pocket walls 18.

To achieve these goals the liner or coating of material applied to the pockets of the cast or sintered iron stator rings 20 is constructed of material having a hardness which is less than the hardness of the metal vanes 17 whereby irregular contours and high points of the liner are smoothed under the load of the vane to conform to the vane contour. The liner material is also chosen because of its low coefficient of friction, thereby reducing frictional forces and wear of the liner. Furthermore the liner material is impervious to fluid as a consequence of which the
hydrodynamic oil film between the vanes 17 and the pocket walls 18 mentioned hereinabove is sustained. In FIGURE 2 the material of which the stator ring 20 is constructed is cast iron and the extremities of the pocket wall formed in the stator ring 20 and facing the metal vane 17 are indicated at reference numerals 18a. The liner material which covers the cast iron and which forms the bearing surface for the vane 17 is indicated at reference numeral 27.

In the embodiment of the invention illustrated in FIGURE 2 the liner material 27 is plastic fluorocarbon resin. Fluorocarbon resins are cleistomeric plastics, and are chemically analogous to the polyolefins, but with some or all of the hydrogen atoms replaced by fluorine atoms.

Fluorine substitution generally contributes to: (1) chemical inertness; (2) resistance to high and low temperature; (3) essentially zero moisture absorption; (4) low coefficient of friction; (5) non-flammability and (6) weather and oxidation resistance.

It is recognized that at least four classes of fluorocarbon resin are now commercially available. For example, polytetrafluoroethylene, whose basic unit consists of two carbons with four fluorine, is being substituted for hydrogen, represents one class of fluorocarbon resin which is supplied by E. I. du Pont de Nemours & Co., Inc., under the trade name "Teflon" and by Allied Chemical Corporation under the trade name "Halcon."

Polymeric fluorinated ethylene propylene, a copolymer of polytetrafluoroethylene and hexafluoropropylene, is also supplied by E. I. du Pont de Nemours & Co., Inc., under the trade name "Teflon FEP."

Polymeric chlorotrifluoroethylene is another resin which, in a strict sense, might be referred to as a chloro-fluorocarbon, however, typical of a material in this case is that supplied by Minnesota Mining and Manufacturing Co., under the trade name "KEL–F81." Copolymers of this type modified with small amounts of vinylidene fluoride and other fluorine containing monomers to improve processability are also available. Such resins include the materials supplied by Allied Chemical Corporation under the trade name "Plaskon" as well as "KEL–F82" supplied by Minnesota Mining and Manufacturing Co.

Lastly, polyvinylidene fluoride is another resin supplied by Pennsalt Chemical Corp. under the trade name "Kynar."

By using a plastic fluorocarbon resin such as "Teflon," machining of the cast iron (or sintered iron) walls of the pockets 18 is obviated since such plastic exhibits resiliency characteristics and is less hard than is the steel vane 18. Thus any irregularities in the liner material 27 and out-of-flatness spots or high points are flattened and smoothed by the vane 17 whereby the surface of the liner 27 assumes the contour of the vane 17.

Furthermore because of the low coefficient of friction of plastic fluorocarbon resin, wear on the liner as well as on the vane is reduced and the operating and performance characteristics of the hydrostatic device 10 are increased. Since the plastic is impenetrable by fluid the liner 27 is able to maintain the hydrodynamic oil film between the liner and the vane 17, even under high fluid pressures.

In FIGURE 3 the liner material is indicated at reference numeral 27a and in this embodiment is made of copper which has been plated to the stator ring 20. The material of which stator ring 20 is constructed in FIGURE 3 is sintered iron but the principles of the present invention also contemplate the application of copper plates to cast iron. In other words, the liner of plastic fluorocarbon resin indicated at reference numeral 27 in FIGURE 2 and the liner of copper plating indicated at reference 27a in FIGURE 3 can both be applied to either the cast iron stator ring indicated at 20a in FIGURE 3.

Since the hardness of the vane 17 is greater than the hardness of the copper plate 27a the surface of the copper will smooth under load to conform to the contour of the vane 17. In addition some of the surface characteristics of copper is its low coefficient of friction and it is, of course, impervious to fluids whereby the hydrodynamic oil film between the liner 27a and the vane 17 is maintained.

With respect to the hydrodynamic oil film, in the embodiment of the invention wherein the stator ring 20 is cast of cast iron, because of the imperviousness of cast iron the oil film is sustained between the walls of the vanes 17 and the pockets 18 since the oil cannot leak out of the chambers 21a–21g through the body of the stator ring 20.

On the other hand sintered iron, because of its porosity, is pervious to fluids and leakage of oil from the chambers 21a–21g can occur through the body of the stator ring 20. For that reason the present invention contemplates an impregnation of the sintered iron stator ring 20c with plastic, thereby rendering the ring 20c, including peripheral wall 19 which partially forms the chambers 21a–21g, impervious to the oil and ensuring the maintenance of oil in the chambers 21a–21g and of the hydrodynamic oil film between the vanes 17 and the pockets 18.

Although minor modifications might be suggested by those versed in the art it should be understood that I wish to embody within the scope of the patent warranted herein all such modifications as reasonably come within the scope of my contribution to the art.

I claim as my invention:

1. A fluid pressure device comprising a gear set having a pair of relatively movable internally and externally toothed members, said internally toothed member comprising a ring having an inner peripheral wall, a plurality of circumferentially spaced recesses in said ring opening to said inner peripheral wall, and a corresponding plurality of complementarily shaped vanes carried in said recesses and cooperating in gear relation with said externally toothed member, said vanes being slightly undersized with respect to said recesses for providing a hydrodynamic oil film between the walls thereof and being rotatable and slightly radially shiftable in said recesses for movement in response to operation of said gear set, the walls of said recesses being lined with bearing material having a lower coefficient of friction than said ring, having a hardness less than said vanes and being impervious to oil.

2. The fluid pressure device as defined in claim 1 wherein said ring is constructed of cast iron, the liner of the walls of the recesses comprises copper which is plated to the cast iron ring.

3. The fluid pressure device as defined in claim 1 wherein said ring is constructed of cast iron, the liner of the walls of the recesses comprises a coating of plastic fluorocarbon resin on the cast iron.

4. The fluid pressure device as defined in claim 3 wherein said fluorocarbon resin is selected from a class consisting of polytetrafluoroethylene, polymeric fluorinated ethylene propylene, polymeric chlorotrifluoroethylene and polyvinylidene fluoride.

5. A fluid pressure device comprising a gear set having a pair of relatively rotatably and orbitally movable internally and externally toothed members, said internally toothed member comprising a ring having an inner peripheral wall, a plurality of circumferentially spaced recesses in said ring opening to said inner peripheral wall, and a corresponding plurality of complementarily shaped vanes carried in said recesses and cooperating in gear relation with said externally toothed member,
said ring being constructed of plastic impregnated oil impervious sintered iron, the walls of said recesses being lined with bearing material having a lower coefficient of friction than said sintered iron ring.

6. The fluid pressure device as defined in claim 5 wherein the liner of the walls of the recesses comprises copper which is plated to the sintered iron ring.

7. The fluid pressure device as defined in claim 5 wherein the liner of the walls of the recesses comprises a plastic fluorocarbon resin.

8. The fluid pressure device as defined in claim 7 wherein said fluorocarbon resin is selected from a class consisting of polytetrafluoroethylene, polymeric fluoro-nated ethylene propylene, polymeric chlorotrifluoroethylene and polyvinylidene fluoride.