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[54] **ROTARY FLUID PRESSURE DEVICE**

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[52] **U.S. Cl.** **418/61**
[51] **Int. Cl.** **F01c 1/02,** F03c 3/00, F04c 1/02
[58] **Field of Search** 418/61

[56] **References Cited**

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Assistant Examiner—John J. Vrablik
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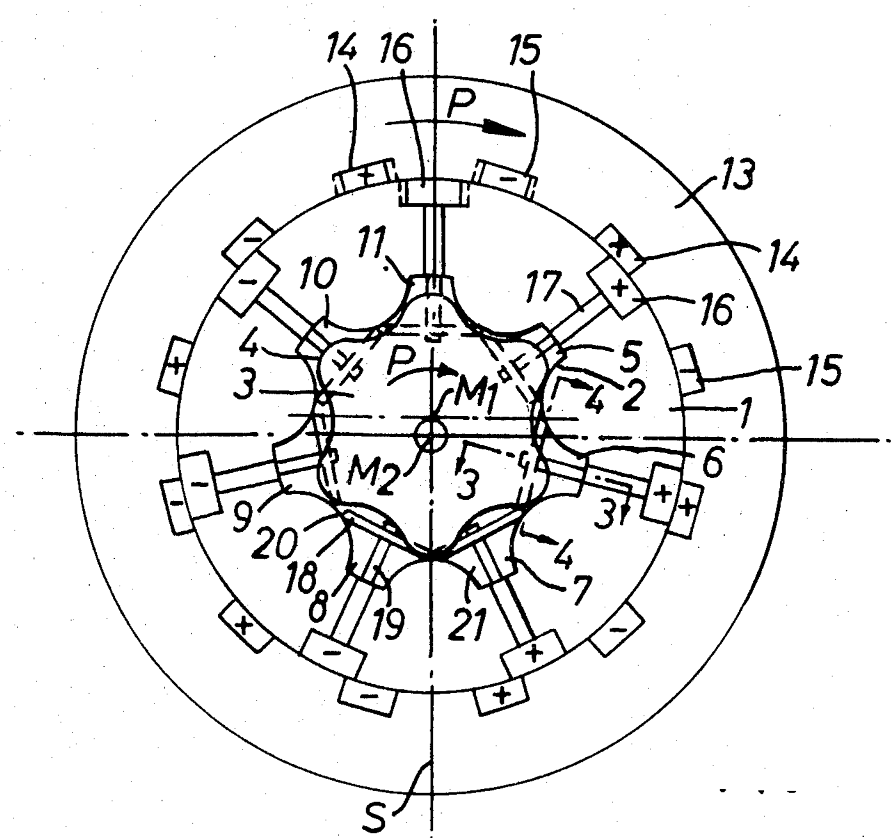
[57] **ABSTRACT**

The invention relates to fluid pressure motors and pumps of the type having a gerotor displacement mechanism. The rotary type valving for gerotor mechanisms has first and second sets of alternately arranged ports which have sequential fluid communication with ports of stationary passage which are connected to the displacement chambers. Optimum efficiency normally requires that these ports be formed and positioned with great precision. Auxiliary passages associated with the teeth of the gerotor mechanism itself, and which connect adjacent displacement chambers, effects a precise internal distribution of fluid so that only a gross of coarse fluid distribution is required of the valve ports and the fine or delicate distribution needed for optimum efficiency is performed by the auxiliary passages.

12 Claims, 7 Drawing Figures



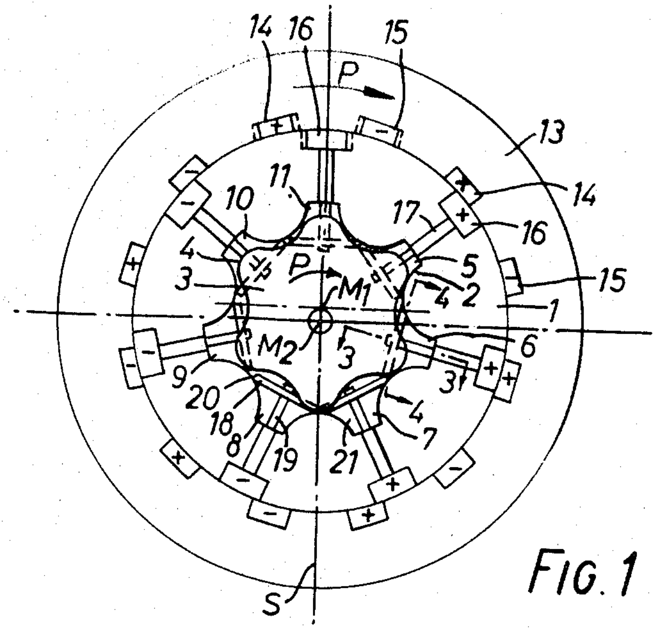


FIG. 1

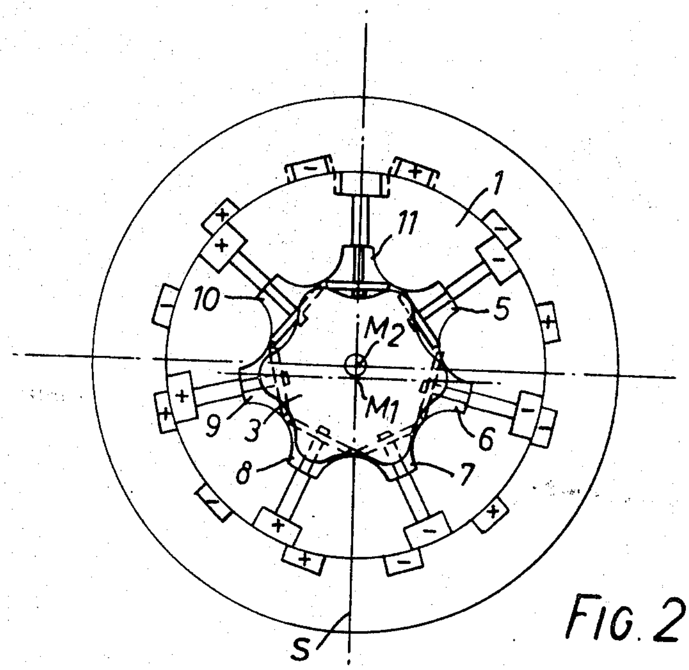


FIG. 2

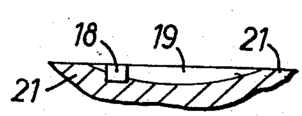


FIG. 3

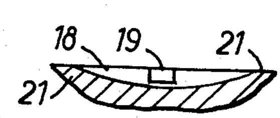


FIG. 4

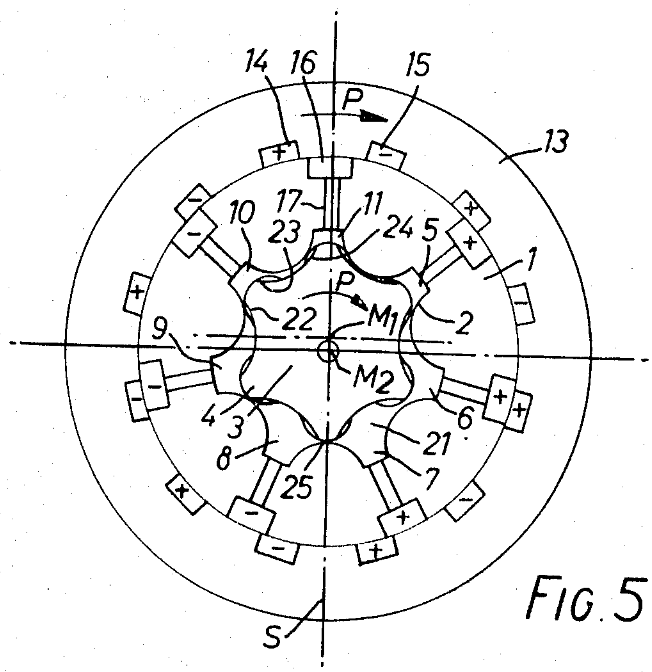


FIG.5

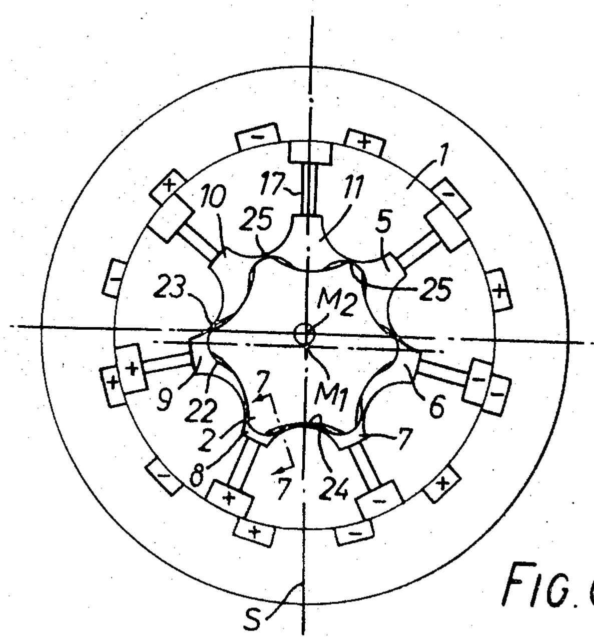


FIG.6

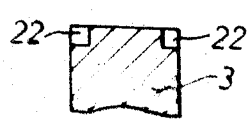


FIG.7

ROTARY FLUID PRESSURE DEVICE

The invention relates to a fluid-pressure machine such as a rotary hydraulic pump or motor comprising a toothed wheel and a toothed ring which surrounds the toothed wheel, has one more tooth than the wheel and forms displacement chambers therewith; a diversion valve consisting of two parts, one of which is coupled to the toothed elements and contains first control openings which override second control openings in the other valve part; and passages that lead from the second control openings to the displacement chambers.

In a machine of this kind and as disclosed, for example, in German Patent Specification No. 1,198,750, the speed at which a complete control cycle is carried out in considerably greater than the speed at which the toothed ring or toothed wheel revolves. Thus, a large torque is obtained when the system operates as a motor, and a large quantity of fluid is delivered when it is operated as a pump. The movable part of the diversion valve has the same low speed as the toothed wheel or toothed ring. This valve, therefore, requires to be of special form in order to distribute the incoming and outgoing medium to suit the more rapid control cycle. For this reason, numerous control openings are provided in both parts, the number of these openings corresponding to the number of teeth on the associated elements or to twice the number of teeth.

In order to impart optimum efficiency to the rotary-piston machine, the control openings in the diversion valve must be formed with greeat precision. The peripheral length of the control openings and the distances between them in the circumferential direction must be very precise, since otherwise the control cycle is interfered with. Furthermore one of the toothed elements moves orbitally and it is only able to drive the associated part of the diversion valve through one coupling, for example, a universal joint shaft. Of necessity, play occurs in such a coupling and this can be considerable, particularly in the case of machines which work in both rotary directions. Even if the diversion valve is precision made, this play adversely affects the efficiency of the machine.

The object of the invention is to provide a fluid-pressure machine in which the problems associated with the diversion valve are greatly reduced.

According to the present invention, this object is achieved by means of auxiliary passages which are associated with one of the toothed elements and which each connects adjacent displacement chambers on each side of the line of symmetry between inlet and outlet chambers, this connection, however, being substantially interrupted by the other toothed element in the zone of the line of symmetry.

Together with the other toothed element, these auxiliary passages form a secondary diversion valve. The primary diversion valve is, therefore, required to effect distribution on a rough basis, whereas precision distribution is carried out by the secondary diversion valve. This precision distribution can be achieved without any great difficulty since the auxiliary passages can be precisely shaped and the toothed elements are in any case precision components. The secondary diversion valve achieves balance between adjacent displacement chambers which are incompletely filled or emptied by the primary diversion valve. Such balance is impeded only in the zone of the line of symmetry, that is, between the delivery side and the low pressure or suction side. It is particularly important that the parts of the secondary diversion valve should be constituted by the toothed elements themselves or by control elements that are associated with the toothed elements. There is then no possibility of troublesome play caused by the coupling occurring in the secondary diversion valve.

Advantageously, the distance in a circumferential sense between adjacent first control openings in the (primary) diversion valve is greater than the circumferential length of the second control openings. The greater distance between the first control openings reduces the normal effect of the primary diversion valve; this, however, can be accepted because of the auxiliary passages located downstream. However, the greater peripheral distances permit play between the first and second part of the diversion vale without a second control opening moving into contact with a "false" first control opening.

Particular advantage accrues if the maxium possible lengths of the first as well as the second control openings are reduced. If this reduction in length is distributed over both valve parts, the smallest possible increase in resistance to flow is achieved.

In a preferred embodiment, the auxiliary passages are provided in a side wall connected to the toothed ring, and they are overridden by the lateraL surface of the toothed wheel. The form of the auxiliary passages and the contour of the toothed ring then determine the function of this secondary diversion valve.

In particular, the axuilary passages, the side wall, the toothed ring and the second control openings may be stationary. Furthermore, the toothed wheel may execute a rotary and orbital movement and the first control openings a rotary movement.

Manufacture can be rendered particularly simple if the auxiliary passages are formed by tangential grooves each of which is disposed symmetrically in relation to a trough between adjacent teeth of the ring, that is, if they extend along the line connecting the centre points of the crests of adjacent teeth and terminate at a small distance from these centre points. Such tangential grooves can be formed, for example, by milling with a side-milling cutter. If the grooves terminate at a small distance from the centre points of the crests of the teeth, then when the crest of a tooth or the base of a trough between the teeth of the toothed wheel bears against the crest of a tooth of the toothed ring, the grooves are covered in such a way that the connection between adjacent chambers is interrupted.

Expediently, the length of each tangential groove is so selected that when the colume of a given displacement chamber is at its mminimum, its associated groove is substantially completely covered by the tooth wheel. In this way separation of the inlet and outlet sides is achieved. Furthermore, the cross-section of the tangential grooves can be reduced at its ends. In particular, parts of each tangential groove which are of reduced cross-section are such that the groove projects into the two chambers adjacent a given chamber when that chamber is at its minimum volume. This minimum volume chamber undergoes a pressure reversal. Fluid is applied from the high pressure side through the flow-restricting point formed at the end of the tangential groove, only small quantities of fluid being necessary so that no sudden increase in pressure occurs when the said chamber is subsequently presented to the pressure side system.

Furthermore, a radial groove, extending approximately to the base of a trough between adjacent teeth and the ring, can be connected to each tangential groove. This ensures that a chamber of small volume can also be connected to the adjacent chamber by way of the tangential groove.

The auxiliary passages can, of course, be of some other shape, for example, they can be formed by a triangle, the base of which corresponds to the tangential groove and the height of which to the radial groove.

In another embodiment, the auxiliary passages are formed in the peripheral face of the toothed wheel and are overridden by the peripheral face of the toothed ring. In this arrangement it is only necessary to provide auxiliary passages in the toothed wheel; all the other components may remain unchanged.

In this arrangement, each auxiliary passage is expediently provided in a symetrical manner in the two flanks of each toothed of the wheel, sealing faces for cooperation with the toothed ring being left on the crest of the tooth and on the base of the trough between teeth. This auxiliary passages can be rendered ineffective by sealing off at the crest of the tooth and on the base of the gap between the teeth.

Each auxiliary passage preferably consists of two grooves at the peripheral edge of the toothed wheel.

Manufacture is simplified if the floor of each groove is located along an arc on the mutually facing flanks of adjacent teeth. Two of these grooves can then be formed in one milling operation.

The invention will now be described in greater detail, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic illustration of a first fluid pressure machine in the position in which the chamber volume is at a minimum;

FIG. 2 shows the arrangement of FIG. 1 in a position in which the chamber volume is at a maximum;

FIG. 3 is a partial section on the line 3—3 of FIG. 1;

FIG. 4 is a partial section on the line 4—4 of FIG. 1;

FIG. 5 is a schematic illustration of a second fluid pressure machine in a position in which the chamber volume is at a minimum;

FIG. 6 illustrates the embodiment of FIG. 5 in a position in which the chamber volume is at a maximum; and

FIG. 7 is a partial section on the line 7—7 of FIG. 6.

In all the figures, a stationary toothed ring 1 which has seven teeth 2 co-operates with a tooth wheel 3 which has six teeth 4. The centre point M_1 of the toothed wheel executes a circular movement about the centre point M_2 of the toothed ring. At the same time the toothed wheel rotates in the direction of the arrow P in the opposite rotary direction and moves through a distance equal to a tooth pitch during one complete circular movement of the centre point M_1. Seven displacement chambers 5, 6, 7, 8, 9, 10 and 11 are formed between the teeth of the toothed ring and the toothed wheel. If it is assumed that the machine of FIG. 1 is operating as a motor, the toothed chambers 5, 6 and 7 on one side of a line of symmetry S are subjected to the inlet pressure, the displacement chambers 8, 9 and 10 on the other side of the line of symmetry S are subjected to the lower outlet pressure, and the chamber 11 of minimum volume is a neutral chamber which, at the stage illustrated, is undergoing a reversal of pressure.

In order to illustrate the system more clearly, a diversion valve is shown on the outer circumference of the stationary toothed ring. In practice, these diversion valves are offset axially from the toothed elements 1 and 3. The diversion valve consists of a stationary part which is illustrated as being the ring 1 and a rotatable part 13. The part 13 rotates in the same direction and at the same speed as the toothed wheel 3, but its centre point coincides with M_2 and does not, therefore, rotate like the centre point M_1 of the toothed wheel. The coupling between the toothed wheel and the part 13 of the diversion valve can be achieved, for example, by means of a universal joint shaft not illustrated. The valve part 13 has first control openings 14 and 15 to which are alternately applied the higher inlet pressure and the lower outlet pressure and which are therefore marked in the drawings by the symbols + and –, respectively. The first control openings are equal in numer to twice the number of teeth on the toothed wheel 3. The other valve part 1 has second control openings 16 each of which is connected by way of a passage 17 to the trough formed between two adjacent teeth of the ring 1, that is, to a displacement chamber 5 to 11. As can be seen from the corresponding connections between the first and second control openings, the control openings 16, which lead to the displacement chambers 5, 6 and 7, are subjected to the higher pressure, and the second control openings 16, which lead to the displacement chambers 8, 9 and 10, are subjected to the lower pressure. The second control opening 16, connected to the displacement chamber 11, is not connected to any of the first control openings.

The rotary-piston machine thus far described is of the known type.

Tangential grooves 18 and radial grooves 19 are machined, for example, milled, in an end wall 21 arranged adjacent one face of the stationary toothed ring 1. These grooves form auxiliary channels which, together with the circumference of the toothed wheel 3, constitute a secondary diversion valve. Each tangential groove 18 extends symmetrically across a trough formed between adjacent teeth on the ring 1. Each extends along a straight line which interconnects the crests of adjacent teeth 2 and terminates shortly before the centre of each of these crests. The ends 20 are obliquely machined in such a way that the ends of the adjacent tangential grooves 18 run parallel with each other. Each radial groove 19 extends from a tangential groove 18 to the base of the trough formed between adjacent teeth of its associated displacement chamber.

As a result of this arrangement the chambers 5, 6 and 7 are interconnected through the auxiliary passages, that is, the tangential grooves 18 and the radial grooves 19, and the chambers 8, 9 and 10 are likewise interconnected by way of the auxiliary passages. As shown in FIG. 1, however, in the zone of the line of symmetry the toothed wheel 3 covers the entire tangential groove 18 in the zone of the smallest chamber 11, whereas on the opposite side of the surface between two adjacent tangential grooves 18 is covered. Here, therefore, connection between adjacent chambers is interrupted. Similar conditions exist in FIG. 2 where the line of symmetry has moved through 180° and the chamber 11 in which reversal of pressure is taking place now has the greatest volume. Here, the displacement chamber 5, 6 and 7 which are connected to the outlet side are interconnected through the tangential and radial grooves, and the chambers **8, 9** and **10,** which are connected to the inlet side, communicate with each other through the said grooves. However, the chamber **11** is blocked off from its two adjacent chambers, and on the opposite side the connection between the adjacent tangential grooves is shut off by the toothed wheel **3.** The result of this arrangement is that precise arrangement of the control openings **14, 15** and **16** is no longer important since the auxiliary passages **18** and **19** provide pressure balance between all the adjacent displacement chambers on the inlet side and the outlet side respectively, whereas communication between the outlet and inlet sides is restricted since auxiliary passages are interrupted near the line of symmetry. This results in a very precise mode of operation.

FIGS. **1** and **2** show in broken lines the peripheral lengths hitherto required in the upper control openings **14, 15** and **16.** Since during reversal of pressure in the displacement chamber **11,** the control opening **14** is required to become effective as soon as the control opening **15** has moved away from the control opening **16,** the peripheral length of the conventional control openings must be accurately predetermined. Thus, the distance between adjacent first control openings **14** and **15** should be equal to the peripheral length of the second control opening **16.** On account of the unavoidable play between the toothed wheel **3** and the valve part **13,** it often happened, however, that the valve part **13** lagged behind in the case of a motor, for example. The chamber **11** of minimum volume was then still subjected to the low outlet pressure whereas, for optimum operation, it should have been supplied with the higher inlet pressure. In the system in accordance with the present invention, on the other hand, the maximum possible length of all the control openings **14, 15** and **16** can be reduced as represented in solid lines. The reduction in length is distributed uniformly over the first control openings **14** and **15** and the second control openings **16.** If, as a result of play, lagging of the valve part **13** now occurs, It will have no important effect on the operation of the machine. Although the chamber **11** will not immediately be fed by the associated control openings **16,** a connection is established for this purpose between the chamber **5** and the chamber **11,** through the auxiliary passages **18** and **19,** as soon as the line of symmetry **8** has moved slightly from the illustrated position in the clockwise direction. Consequently, very accurate control is achieved. This effect takes place in both directions of rotation of the machine and it occurs when the machine is used as a motor as well as when it operates as a pump.

Because of the inclined ends of the tangential grooves **18,** there is no complete separation of the chamber **11** of the smallest volume from the two adjacent chambers **5** and **10** in the position illustrated in FIG. **1**; rather, connection is maintained through a flow-restricting zone of small cross-section. The result of this is that small changes in the volume of the chamber **11** which occur during separation of the associated second control opening **16** from the first control openings **14** and **15** are not accompanied by intolerable changes in pressure. Instead, excess pressure can be relaxed through one flow-restricting point in the adjacent chamber **10,** and a reduced pressure can be applied from the chamber **5** through the other flow-restricting point. Independently of a change in volume of this kind, the chamber **11** is gradually brought to the higher inlet pressure through the flow-restricting point of the chamber **5,** and very small quantities of fluid suffice for this purpose, so that when the first control opening **14** under higher pressure moves into contact with the second control opening **16** for the chamber **11,** no troublesome sudden rise in pressure occurs.

In the embodiment illustrated in FIGS. **5** and **6,** the same reference symbols are employed for like parts. In this embodiment, the auxiliary passages are not formed in the end wall **21,** but in the peripheral face of the toothed wheel **3,** and they are overridden by the peripheral face of the toothed ring **1.** An auxiliary passage **22** and **23** is provided, in a symmetrical arrangement, in each of the two flanks of each tooth **4,** a sealing surface **24** and **25** remaining on each of the sides of a passage, these surfaces co-operating with the toothed ring. Here again, it will be seen that the chambers **5, 6** and **7** are interconnected on one side of the line of symmetry by the auxiliary passages, and that the chambers **8, 9** and **10** are likewise interconnected by the auxiliary passages on the other side of the line of symmetry. In FIG. **5,** sealing faces **24** constitute means for closing the chamber **11,** whereas a sealing face **25** seals off the chambers **7** and **8** from each other. In FIG. **6** in which the line of symmetry has again moved through 180°, it can be seen that sealing faces **25** this time block off the chamber **11** on both sides, whereas a sealing face **24** separates the chambers **7** and **8** from each other. In this case too, the auxiliary passages **22** and **23** constitute connections between the chambers **5, 6** and **7** on the one hand, and between the chambers **8, 9** and **10** on the other.

FIG. **7** shows that the passages **22** only extend along the side edges of the toothed wheel **3.** The base of each of the passages **22** and **23** on the mutually facing flanks of adjacent teeth extends along an arcuate path, and the two passages can, therefore, be formed with a milling tool in one operation.

What we claim is:

1. A fluid pressure machine comprising an internally toothed ring gear having an axis, a cooperating externally toothed star gear having fewer teeth than said ring gear disposed eccentrically relative to said ring gear axis, said star gear having rotational movement about its own axis and orbital movement about the axis of said ring gear with the teeth of said gears intermeshing in sealing engagement to form expanding chambers on one side of a line of symmetry and contracting chambers on the other side of said line during relative movement between said gears, and end wall fixedly attached to said ring gear and forming fixed wall means for said chambers, valve means comprising a first valve part fixed relative to said ring gear and a second valve part which rotates in unison with said star gear, a first set of fluid ports in said valve first part having fluid connections with said chambers, said valve second part having a second set of ports cooperable with said first ports of said first valve part to continuously route fluid to said expanding chambers and away from said contracting chambers, articulated auxiliary passage means fixed relative to one of said gears and providing fluid communication between each one of said chambers and adjacent chambers on the opposite side thereof, said fluid communication for each said chambers being substantially blocked by the other of said gears at the instants when one of said chambers is in its maximum or minimum volume condition.

2. A fluid pressure machine according to claim 1 wherein the spaces between said second ports in the circumferential sense are greater than the spaces between said first ports.

3. A fluid pressure machine according to claim 2 wherein the circumferential dimensions of all of said ports are less than the maximum possible geometric dimensions.

4. A fluid pressure machine according to claim 1 wherein said auxiliary passage means are formed in said wall means and are overridden by one face of said star gear.

5. A fluid pressure machine according to claim 4 wherein said auxiliary passage means comprise tangentially extending grooves between adjacent teeth of said ring gear with each groove extending approximately along a line between the center points of the crests of adjacent teeth and terminating small distances from said center points.

6. A fluid pressure machine according to claim 5 wherein a radially extending fluid feeding and exhausting groove is connected to each of said tangentially extending grooves.

7. A fluid pressure machine according to claim 5 wherein one of said grooves is substantially covered by one face of said star gear when the associated one of said chambers has its minimum displacement volume.

8. A fluid pressure machine according to claim 5 wherein each of said grooves has reduced cross sections at its ends.

9. A fluid pressure machine according to claim 8 wherein each said groove extends into adjacent chambers on the opposite sides of one of said chambers which has its minimum displacement volume.

10. A fluid pressure machine according to claim 1 wherein said auxiliary passage means are formed in the teeth of said star gear and cooperate in a valving manner with the teeth of said ring gear.

11. A fluid pressure machine according to claim 10 wherein said auxiliary passages are grooves to opposite sides of each of said gear teeth with the separating surface area of the crests of the star gear teeth and the troughs therebetween being cooperable with said ring gear teeth.

12. A fluid pressure machine according to claim 11 wherein said grooves comprise a pair of grooves for the peripheral portion of each said star gear teeth.

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