United States Patent

Zajac et al.

[15] **3,675,539**

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[54] HYDRAULIC MOTOR

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[52] **U.S. Cl.** **91/477**

[51] **Int. Cl.** **F04b 13/04**

[58] **Field of Search** 91/477; 74/60; 418/53

[56] **References Cited**

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[57] **ABSTRACT**

An axial piston hydraulic motor of the type wherein the motor drive shaft and cylinder block are coaxial characterized in that the pistons react against a nutating gear which progressively meshes with a gear having a different number of teeth, one gear being non-rotatable in the motor housing and the other gear being non-rotatable on the drive shaft whereby the drive shaft and housing are relatively rotated during each nutation of the nutating gear through an angle depending on the difference in the number of teeth of said gears. The motor herein is further characterized in that each piston as it reciprocates in its bore constitutes a three-way valve to alternately communicate an angularly displaced piston bore with the pressure inlet and return ports in the housing via passages in the cylinder block communicating with said ports and with such angularly displaced piston bore.

14 Claims, 7 Drawing Figures

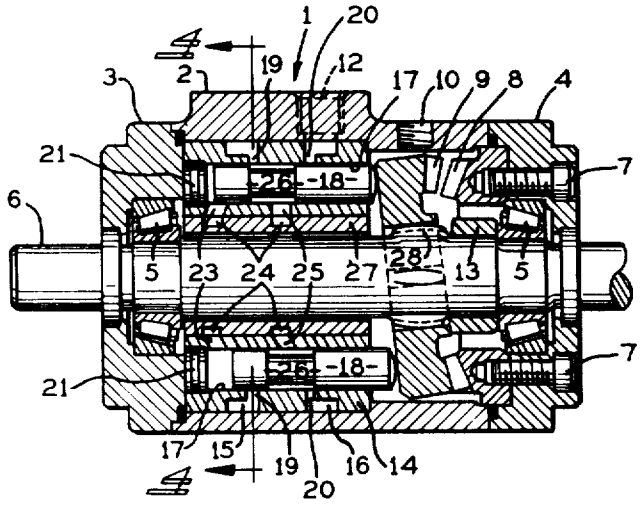


Fig. 1

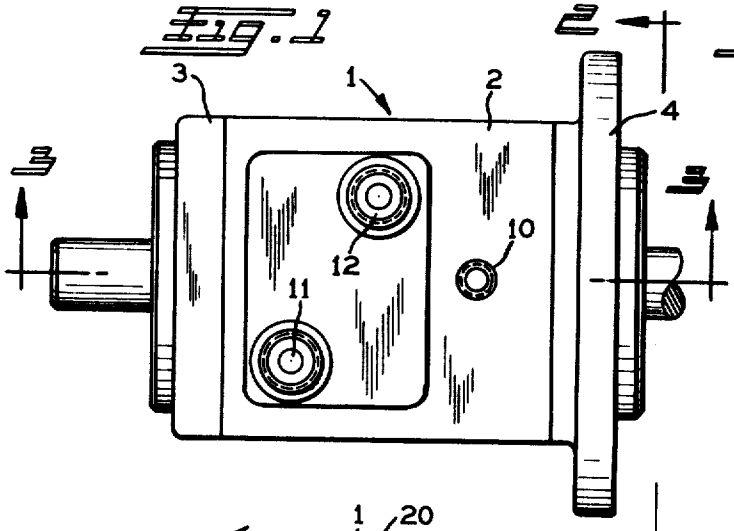


Fig. 2

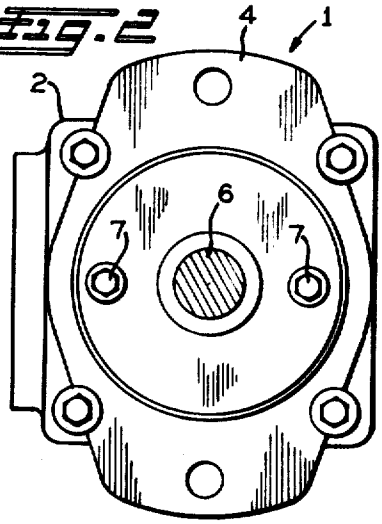


Fig. 3

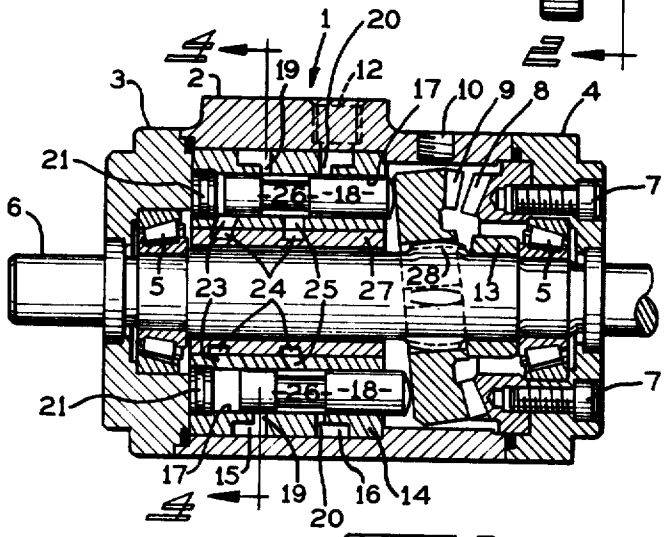


Fig. 4

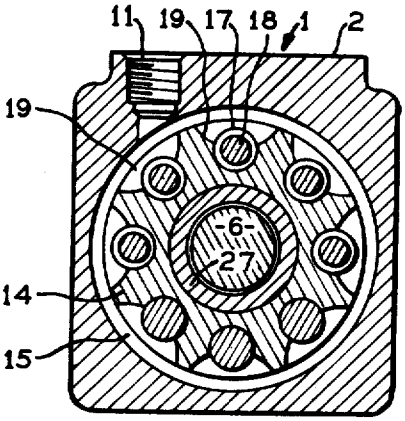


Fig. 5

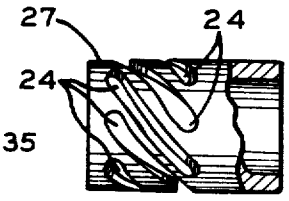


Fig. 6

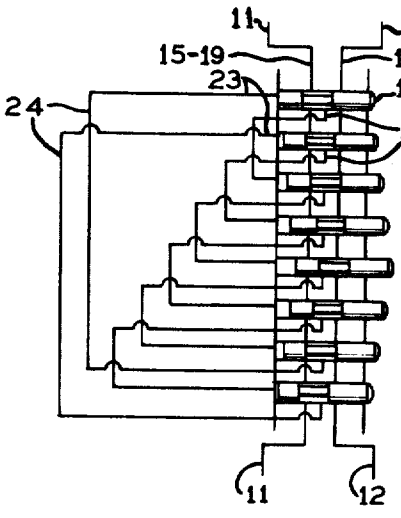
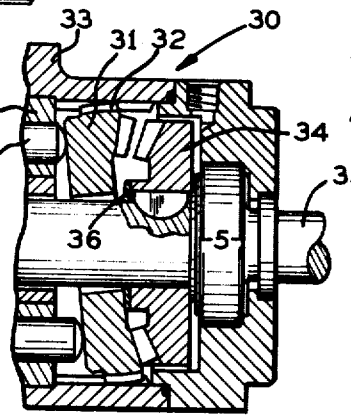


Fig. 7



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HYDRAULIC MOTOR

BACKGROUND OF THE INVENTION

In known inline piston motors, the cylinder block and drive shaft are coaxial and the hydraulic pressure on the pistons causes the latter to react against a canted swash plate thus to rotate the cylinder block and motor shaft. In this case, one end of the cylinder block constitutes a rotating valve member which cooperates with a slotted valve plate to alternately communicate the bores of the respective pistons with the pressure inlet and return ports of the motor housing.

Bent-axis piston motors are also well known and in this type of motor the cylinder block and the drive shaft are mounted at an angle with respect to each other so that the driving force causes a reaction against the flange of the drive shaft. Again, in this type of motor the end of the cylinder block constitutes a valving surface which cooperates with a valve plate in the housing to alternately communicate the piston bores with the pressure inlet and return ports of the motor housing.

SUMMARY OF THE INVENTION

Contrary to known piston type motors, the motor housing herein has a drive shaft journalled therein and a stationary cylinder block with pistons axially reciprocable therein. The pistons, when hydraulically actuated, cause nutation of a gear which has its teeth progressively meshing with the teeth of a gear having a different number of teeth, said gears being non-rotatable in the housing and on the drive shaft respectively, or vice versa, thus to cause a predetermined angle of relative rotation of the drive shaft and housing during each nutation cycle of the nutating gear.

Another object of this invention is to provide an axial piston hydraulic motor of the character indicated having a simplified valving and passage arrangement in which the pistons constitute three-way valves to alternately communicate angularly displaced pistons with the pressure inlet and return ports of the motor housing.

Other objects and advantages of the present invention will appear hereinafter.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a top plan view of a hydraulic motor embodying the present invention;

FIG. 2 is an end elevation view as viewed from line 2—2 on the right-hand side of FIG. 1;

FIG. 3 is a longitudinal cross-section view taken substantially along the line 3—3, FIG. 1;

FIG. 4 is a transverse cross-section view taken substantially along the line 4—4, FIG. 1;

FIG. 5 is a side elevation view of a distributor which communicates the pressure inlet and return ports of the respective piston valves with angularly displaced piston bores;

FIG. 6 is a developed view schematically showing how the pistons herein function as three-way valves; and

FIG. 7 is a fragmentary cross-section view of another embodiment of this invention.

DETAILED DESCRIPTION OF THE INVENTION

The hydraulic motor 1 as shown in FIGS. 1 to 6 comprises a housing 2 to which end caps 3 and 4 are secured as by bolts (not shown), said end caps 3 and 4 having anti-friction bearings 5 for the motor drive shaft 6 which extends through said end caps 3 and 4. The end cap 4 has secured therein, as by the screws 7, a stationary bevel gear 8 which, in the example herein shown, has 30 teeth. The drive shaft 6 has splined thereon for nutating movement a bevel gear 9 which has say, 31 teeth arranged so that as the gear 9 nutates about the pitch cone center of the gears 8 and 9 the teeth of gear 9 progressively mesh with the teeth of gear 8 to result in a one-tooth rotation of the drive shaft 6 for each nutation.

The housing 2 is provided with a drain port 10 to return internal leakage fluid to the reservoir (not shown) and the housing 2 is, in addition, provided with a pair of ports 11 and 12 either of which may be the inlet port for fluid under pressure while the other is the return port to the reservoir (not shown). In this way, the hydraulic motor 1 is rendered reversible to rotate the shaft 6 in either direction.

A spacer bearing 13 on shaft 6 has a conical bearing surface which is engaged by the nutating gear 9 to limit the degree of intermesh of the teeth of gears 8 and 9 as the gear 9 nutates.

Fixed in the housing 2 is a cylinder block 14 having peripheral grooves 15 and 16 communicating with the respective ports 11 and 12 and having a circular series of axial bores 17 (herein eight in number) in which the respective pistons 18 are reciprocable. Intersecting each bore 17 to communicate the same with the respective grooves 15 and 16 are arcuate slots 19 and 20. Adjacent the end cap 3 are plugs 21 in the respective bores 17 closing the same to form cylinders into which or from which fluid flows through the respective ports 23, helical passages 24, and ports 25 according to whether the ports 25 are communicated with the pressure inlet port 11 or 12 or with the return port 12 or 11, via the necks 26 of the respective pistons 18. As now evident each piston 18 constitutes a three-way valve to communicate the port 25 with port 19 or port 20. The passages 24 may be in the form of helical grooves in the outer surface of a distributor sleeve 27 (see FIG. 5) which is tightly fitted in cylinder block 14.

For convenience, the pistons and valves 18 are now referred as first through eighth consecutively in a clockwise direction as viewed in FIG. 4 or downwardly as viewed in FIG. 6 with the first piston 18 at the 12:00 o'clock position (FIG. 4) or at the top (FIG. 6).

When the nutating gear 9 is the FIG. 3 position, the first piston 18 (see FIG. 6) is just ready to receive fluid under pressure from inlet port 11 via the seventh piston valve which is then beginning to retract to the left from its mid-position; the second, third, and fourth pistons 18 are receiving fluid under pressure from inlet port 11 via the respective eighth, first, and second piston valves; the fifth piston 18 is just ready to conduct fluid to the return port 12 via the third piston valve which is then beginning to move outwardly to the right from its mid-position; and the sixth, seventh, and eighth pistons 18 are retracting and conducting fluid to the return port 12 via the respective fourth, fifth and sixth piston valves. As the gear 9 nutates each piston 18 will move outwardly and inwardly through these eight positions with flow of fluid into and from the end of its piston bore 17 being controlled by an angularly displaced piston valve 18.

By reason of the difference in the number of teeth in the nutating gear 9 and the fixed gear 8, each nutation will progressively turn the nutating gear 9 and drive shaft 6 according to the pitch times the number of teeth difference in the gears 9 and 8. As aforesaid, herein there is provided a one tooth difference in the gears 9 and 8 whereby during each nutation of the gear 9 the shaft 6 will be turned through an angle corresponding to the pitch of one tooth. The spline connection 28 between the shaft 6 and the nutating gear 9 is such that driving engagement is maintained while nutation is permitted.

In the three-way valve arrangement herein shown, the number of pistons 18 must be at least four or a multiple of four i.e. eight, 12, 16, 20, 24, etc. so that each piston valve 18 will control fluid flow to or from a piston bore 17 which is angularly displaced 90° therefrom. When the piston valves 18 are in mid-position, herein the third and seventh piston valves, communication of ports 25 with ports 19 and 20 is blocked. As the third piston 18 moves to the right from mid-position as viewed in FIG. 6 and thence to the left back to mid-position under the influence of pressure obtained through the first piston valve 18, the port 25 thereof is communicated with the return port 20 thus to vent the fifth piston 18 during its full stroke from right to left during 180° nutation of gear 9. Now, as the third piston 18 moves to the left from mid-position and thence to the right back to mid-position as permitted by venting through the first piston valve 18, the port 25 thereof is communicated with the pressure inlet port 19 thus to pres-

surize the fifth piston **18** during its full stroke from left to right during the next 180° nutation of gear **9**. Similarly, all of the piston valves **18** will move in opposite directions from mid-positions to control flow of fluid to and from pistons **18** which are spaced 90° therefrom.

In the motor **30** illustrated in FIG. **7**, the nutating gear **31** engaged by the pistons **18** is splined at **32** in the housing **33** for nutating motion. The gear **34**, with which the nutating gear **31** progressively meshes, is keyed on the drive shaft **35** and may have, for example, one tooth less than gear **31** to cause rotation of gear **34** and shaft **35** as the gear **31** is nutated by the reaction of pistons **18** thereagainst. A spacer bearing **36** having a conical surface engaged by gear **31** limits the extent of intermesh of the gears **31** and **34** as the gear **31** nutates. The end cap **37** may be provided with a drain port **38** to conduct leakage fluid in the housing **33** to a reservoir.

If it be desired to selectively operate the motor **1** or **30** in opposite directions, a four-way reversing valve may be connected to the ports **11** and **12**. Although it is intended herein to drive the shaft **6** or **35**, it is to be understood that the shaft may be fixed against rotation whereby the housing assembly will be driven by the nutation of the gear **9** or **31**. When the housing assembly rotates it may, for example, be the hub of a hydraulically driven wheel.

It can now be seen that the present motor is of the low speed-high torque type having a speed ratio of 31:1 (FIG. **3** wherein gears **9** and **8** have **31** and **30** teeth respectively) or 30:1 (FIG. **7** wherein gears **34** and **31** have **30** and **31** teeth respectively).

We therefore, particularly point out and distinctly claim as our invention:

1. A hydraulic motor comprising a housing having inlet and return ports; a drive shaft journalled in said housing; two bevel gears having at least a one tooth difference and respectively non-rotatably keyed to said housing and said shaft; one of said gears being thus keyed by axially disposed and radially interfitting key and groove means for nutation about its axis which is angularly disposed to the common axis of the other gear and said shaft to progressively mesh the teeth of said gears thus to relatively rotate said housing and shaft; a cylinder block in said housing having a circular array of cylinder bores coaxial with said shaft; pistons reciprocable in the respective cylinder bores and engageable with said one gear; and valve means effective to alternately communicate said cylinder bores with said inlet and return ports whereby said pistons are moved in one direction against said one gear by fluid under pressure from said inlet port thus to nutate said one gear and moved in the opposite direction by nutation of said one gear to return fluid to said return port.

2. The motor of claim **1** wherein said one gear is nutatably keyed on said shaft.

3. The motor of claim **1** wherein said one gear is nutatably keyed in said housing.

4. The motor of claim **1** wherein a spacer bearing on said shaft has a conical bearing surface progressively engaged by an annular end face of said one gear to limit the degree of gear tooth intermesh as said one gear is nutated.

5. The motor of claim **1** wherein said valve means comprises said pistons, each of which constitutes a three-way valve to alternately communicate said inlet port and return port with an angularly spaced cylinder bore via passages in said cylinder block.

6. The motor of claim **5** wherein said cylinder block has inlet, return, and cylinder passages therein communicating each cylinder bore respectively with said inlet and return ports and an angularly spaced cylinder bore adjacent the end of the piston in the latter; and wherein each piston has a neck portion between its end which, during reciprocation of said piston, alternately communicates said inlet and return passages with said cylinder passage, thus to actuate the piston in said angularly spaced cylinder bore.

7. The motor of claim **6** wherein said cylinder block has axially spaced apart peripheral grooves communicating the respective inlet and return passages with said inlet and return ports.

8. The motor of claim **6** wherein a distributor sleeve in said cylinder block has helical grooves in its periphery which define with said cylinder block helical passages communicating the cylinder passages with the respective angularly spaced cylinder bores.

9. A hydraulic motor comprising a housing means having inlet and return ports and axially spaced apart bearings; a drive shaft means journalled in said bearings; a cylinder block fixed in said housing means adjacent one of said bearings having a central bore through which said shaft extends, having a circular array of cylinder bores coaxial with said shaft and having inlet, return, and cylinder passages communicating an intermediate portion of each cylinder bore with said inlet and return ports and with an angularly spaced cylinder bore adjacent one end of said cylinder block; a nutating member in said housing means adjacent the other end of said cylinder block having an axially disposed and radially interfitting key and groove nutating connection with one of said means, having an end face which is tilted with respect to the axis of said shaft means; pistons reciprocable in the respective cylinder bores having one end exposed to fluid in the respective bores at such one end of said cylinder block and having the other end engageable with the tilted end face of said nutating member; the intermediate portion of each piston constituting a three-way valve to alternately communicate said cylinder passage with said inlet and return passages to cause nutation of said nutating member; and drive means adjacent the other of said bearings transforming nutation of said nutating member into rotation of said shaft means.

10. The motor of claim **9** wherein said cylinder block has at least four equally spaced cylinder bores with the respective cylinder passages extending helically from the intermediate portions thereof to the cylinder bores spaced 90° therefrom.

11. The motor of claim **10** wherein each piston has an intermediate neck portion which communicates the cylinder passage thereof with said inlet passage during movement in one direction from mid-position and back to mid-position and with said return passage during movement in the opposite direction from mid-position and back to mid-position.

12. The motor of claim **9** wherein a distributor sleeve in said cylinder block defines therewith said cylinder passages which extend helically from the intermediate portion of the cylinder bores to the respective angularly spaced cylinder bores.

13. The motor of claim **12** wherein said distributor sleeve has helical grooves in its periphery which define with the surrounding bore of said cylinder block said cylinder passages.

14. The motor of claim **12** wherein said cylinder block has axially spaced apart peripheral grooves through which the respective inlet and return passages are communicated with the inlet and return ports of said housing means.

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