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(54) **Gerotor Pump**

(57) A gerotor pump (56) comprises a rotor chamber having a longitudinally extending central axis, an outer rotor (70) rotatable in the rotor chamber with a radial clearance (78) between an outer periphery (80) of the outer rotor and the rotor chamber, an inner rotor (66) rotatable in the outer rotor and cooperably engageable therewith to define a plurality of pumping chambers (96) having respective volumes that vary when, in use, the inner rotor rotates relative to the outer rotor. The inner rotor (66) is rotatable about an axis of rotation spaced from the central axis and contained in a first plane that contains the central axis and the rotor chamber is configured such that the radial clearance (78) in at least one direction in the first plane is greater than at least one radial clearance (78) in a second plane that extends perpendicular to the first plane and contains the central axis.

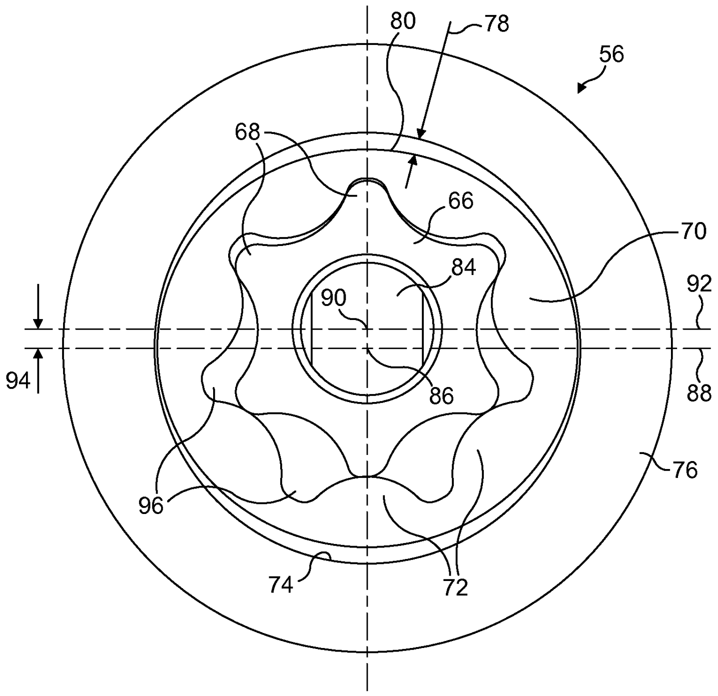

FIG. 3

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Description

Field of the Invention

[0001] The invention relates to gerotor pumps and particularly, but not exclusively, for gerotor pumps for use in diesel fuel injection systems.

Background to the Invention

[0002] The gerotor pump is a known type of positive displacement pump that can, for example, be used as a transfer pump in a diesel common rail fuel delivery system. In such systems, a gerotor pump can be used to suck fuel from the fuel tank and serves as a primary stage pump providing a fuel supply at a high enough pressure to fill a main high pressure fuel pump, which may be a plunger type pump.

[0003] Figure 1 is a schematic representation of a known gerotor pump configuration illustrating the pump geometry. The gerotor pump comprises an inner gear rotor 10 having n teeth 12 and an outer gear rotor 14 having *n+ 1* teeth 16. In the illustrated example, the inner gear rotor 10 has six teeth 12 and the outer gear rotor 14 has seven teeth 16. The outer gear rotor 14 is housed in a circular section rotor chamber defined by a bore 18 in a housing part 20. There is a constant radial clearance 22 between the circular outer periphery of the outer gear rotor 14 and the circular wall defining the bore 18. It will be appreciated that for ease of representation the clearance 22 is shown much exaggerated in the drawing.

[0004] A drive shaft 24 is secured to the inner gear rotor 10. The drive shaft 24 is supported for rotation by the housing 20 such that it can rotate the inner gear rotor 10 and, by engagement of the teeth 12, 16, the outer gear rotor 14 so that both the rotors are rotated in the bore 18 by the drive shaft. The axis of rotation of the inner gear rotor 10 is offset in the vertical direction (as viewed in Figure 1) with respect to the axis of rotation of the outer gear rotor 14 and the axis of the bore 18, which coincides with the axis of rotation of the outer gear rotor 14. The offset is indicated by reference numeral 26.

[0005] In use, as the rotors 10, 14 are rotated relative to one another by the drive shaft 24, pumping chambers 28 are formed between the respective sets of teeth 12, 16. The relative rotation of the inner and outer gear rotors 10, 14 causes the pumping chambers 28 to cyclically increase and then decrease in size. An inlet port (not shown) is provided in the housing 20 in the region of a rotational position of the rotors 10, 14 at which the pumping chambers 28 are relatively large and an outlet port (not shown) is provided in the housing 20 in the region of a rotational position at which the pumping chambers are relatively small. Typically, the ports are located approximately 180° apart and are kidney shaped.

[0006] As the size of a pumping chamber 28 increases, a vacuum is created so that as the pumping chamber sweeps past the inlet port, the fluid to be pumped is sucked into the pumping chamber. As the size of the pumping chamber decreases, the fluid is pumped (compressed if the fluid is a gas) and then swept out of the pumping chamber as the pumping chamber passes over the outlet port. The arrangement of the rotors 10, 14 and the inlet and outlet ports is such that a gerotor pump can provide a relatively pulseless output.

[0007] In gerotor pumps, it is necessary to control the position of the drive shaft 24 with respect to the bore 18 to ensure an adequate radial clearance 22 is maintained. Failure to maintain the radial clearance 22 results in loading of the rotors against the bore wall, which in turn causes rotor wear and may result in pump seizure. Providing the necessary positional control can be costly as all of the parts making up the tolerance stack must be accurately machined.

Summary of the Invention

[0008] The invention provides a gerotor pump comprising means defining a rotor chamber having a longitudinally extending central axis, outer rotor means rotatable in said rotor chamber with a radial clearance between an outer periphery of said outer rotor means and said rotor chamber, inner rotor means rotatable in said outer rotor means and cooperably engageable therewith to define a plurality of pumping chambers having respective volumes that vary when, in use, the inner rotor means rotates relative to the outer rotor means, said inner rotor means being rotatable about an axis of rotation spaced from said central axis and contained in a first plane that contains said central axis and said rotor chamber being configured such that the said radial clearance in at least one direction in said first plane is greater than at least one radial clearance in a second plane that extends substantially perpendicular to said first plane and contains said central axis.

[0009] The radial clearance has a minimum value and the or each said radial clearance in said second plane has said minimum value.

[0010] The invention also includes a gerotor pump comprising a housing defining a rotor chamber, an outer gear rotor received with radial clearance in said rotor chamber and rotatable in said rotor chamber, an inner gear rotor rotatable in said outer gear rotor and having toothing cooperably engaging toothing of said outer gear rotor to form a plurality of variable volume pumping chambers, said outer gear rotor being rotatable about an axis of rotation extending in a first plane, said inner gear rotor being rotatable about an axis of rotation extending in a second plane spaced from said first plane and said rotor chamber being configured such that at least one said radial clearance in said first plane is less than at least one radial clearance in a direction substantially perpendicular to said first plane.

[0011] The radial clearance has a minimum value and the or each said radial clearance in said first plane has said minimum value.

[0012] The invention also includes a gerotor pump having an outer gear rotor and an inner gear rotor rotatable in said outer gear rotor and a non-circular rotor chamber, the outer rotor being mounted for rotation in said rotor chamber with a radial clearance between an outer periphery of the outer rotor and opposed portions of a wall defining said rotor chamber and said rotor chamber being configured such that in the average direction in which forces generated by a fluid in the pumping chambers act when said pumping chambers are in flow communication with an outlet port the said radial clearance is less than the said radial clearance in at least one direction in a plane containing the axis of rotation of the inner gear rotor and a longitudinally extending central axis of said rotor chamber.

[0013] The invention also includes a gerotor pump having an outer gear rotor and an inner gear rotor rotatable in said outer gear rotor and a non-circular rotor chamber, the outer rotor being mounted for rotation in said rotor chamber with a radial clearance between an outer periphery of the outer rotor and opposed portions of a wall defining said rotor chamber and said rotor chamber being configured such that in the average direction in which forces generated by a fluid in the pumping chambers act when said pumping chambers are disposed on a high pressure side of the pump the said radial clearance is less than the said radial clearance in at least one direction in a plane containing the axis of rotation of the inner gear rotor and a longitudinally extending central axis of said rotor chamber.

[0014] The invention also includes a gerotor pump comprising means defining a rotor chamber having a longitudinally extending central axis, outer rotor means rotatable in said rotor chamber with a radial clearance between an outer periphery of said outer rotor means and said rotor chamber, inner rotor means rotatable in said outer rotor means and cooperably engageable therewith to define a plurality of pumping chambers having respective volumes that vary when, in use, the inner rotor means rotates relative to the outer rotor means, said inner rotor means being rotatable about a first axis of rotation, and said outer rotor means being rotatable about a second axis of rotation offset from said first axis of rotation in an offset direction, wherein the radial clearance between the outer periphery of the outer rotor means and the rotor chamber has a minimum value in a direction substantially perpendicular to the offset direction.

[0015] The invention also includes a gerotor pump comprising a housing defining a rotor chamber, an outer gear rotor received with radial clearance in said rotor chamber and rotatable in said rotor chamber, an inner gear rotor rotatable in said outer gear rotor and having toothing cooperably engaging toothing of said outer gear rotor to form a plurality of variable volume pumping chambers, said outer gear rotor being rotatable about an axis of rotation extending in a first plane, said inner gear rotor being rotatable about an axis of rotation extending in a second plane spaced from said first plane in an offset direction, and said rotor chamber being configured such that the radial clearance has a minimum value in a direction substantially perpendicular to the offset direction.

[0016] It will be appreciated that preferred and/or optional features described herein in relation to a particular embodiment, variant or aspect of the invention are equally applicable to the other embodiments, variants or aspects of the invention.

Brief Description of the Drawings

[0017] In order that the invention may be well understood, some embodiments thereof, which are given by way of example only, will now be described with reference to the drawings in which:

Figure 1 is a schematic representation of a prior art gerotor pump illustrating aspects of the pump geometry;

Figure 2 is a schematic illustration of a diesel fuel injection system comprising a gerotor pump according to the invention;

Figure 3 is a schematic representation of a part of a gerotor pump according to the invention illustrating aspects of the pump geometry;

Figure 4 is a schematic illustration of aspects of the geometry of the gerotor pump of Figure 3;

Figure 5 is a schematic illustration of a prior art gerotor pump having the configuration shown in Figure 1 and showing the effects of mispositioning of parts of the pump; and

Figure 6 is a schematic illustration of the gerotor pump of Figures 3 and 4 showing the effects of the same mispositioning of parts as in Figure 5.

Detailed Description of the Embodiments

[0018] Figure 2 shows a portion of a common rail diesel fuel injection system 50. The fuel injection system 50 comprises a fuel tank 52 containing a fuel strainer 54. The fuel tank 52 has an outlet connected to low pressure piping leading to a gerotor pump 56. The gerotor pump 56 feeds a high pressure plunger-type pump 58, which supplies high pressure diesel to a fuel rail 60 via a fuel filter 62. The fuel rail 60 is connected to a plurality of fuel injectors 64 arranged to deliver diesel into an engine (not shown). In addition to the components shown, the fuel injection system 50 comprises an electronic controller, transducers (such as pressure transducers) connected to the electronic controller and return lines for returning unused diesel fuel to the tank 52. Those features and other possible features will be familiar to those skilled in the art and since they do not form a part of the invention will not be described in any detail herein.

[0019] Figure 3 is a schematic representation of a part of the gerotor pump 56 illustrating aspects of the pump geometry. The gerotor pump 56 comprises an inner gear rotor 66 having n teeth 68 and an outer gear rotor 70 having *n + 1* teeth 72. In the illustrated embodiment, the inner gear rotor 66 has six teeth 68 and the outer gear rotor 70 has seven teeth 72. It is to be understood that these numbers are not to be taken as limiting and the number of teeth can be varied as desired.

[0020] The outer gear rotor 70 is housed in a generally elliptical section rotor chamber defined by a bore 74 in a member 76 of a pump housing. In the illustrated embodiment, the housing member 76 is a circular plate and the bore 74 extends between the major surfaces of the plate. There is a radial clearance 78 between the circular outer periphery 80 of the outer gear rotor 70 and the opposing wall defining the bore 74. It will be appreciated that for ease of representation the clearance 78 is shown much exaggerated in the drawing.

[0021] A drive shaft 84 is secured to the inner gear rotor 66 by any suitable means, for example by a key or splines (not shown). The drive shaft 84 is supported for rotation by the housing member 76 such that it can rotate the outer gear rotor 70 by engagement of the teeth 68, 72 of the rotors 66, 70 so that both rotors rotate in the bore 74.

[0022] Referring to Figures 3 and 4, the axis of rotation 86 of the outer gear rotor 70 extends in a first plane 88, which is a horizontal plane as viewed in Figures 3 and 4. The axis of rotation 86 of the outer gear rotor 70 coincides with the axis of the bore 74. The axis of rotation 90 of the inner gear rotor 66 is offset in the vertical direction (as viewed in Figures 3 and 4) with respect to the axis of rotation 86 of the outer gear rotor 70 and the axis of the bore 74. The axis 90 extends parallel to the axis 86 in a second plane 92 that extends parallel to the first plane 88. The perpendicular offset between the respective axes of rotation 86, 90 of the rotors (and thus between the first and second planes 88, 92) is the gerotor offset and is indicated in Figures 3 and 4 by reference numeral 94.

[0023] In use, as the rotors 66, 70 are rotated relative to one another and to the housing 76 by the drive shaft 84, pumping chambers 96 are formed between the respective sets of teeth 68, 72. The relative rotation of the inner and outer gear rotors 66, 70 causes the pumping chambers 96 to cyclically increase and then decrease in size. An inlet port (not shown) is provided in the pump housing 76 in a region of a rotational position of the rotors 66, 70 at which the pumping chambers 96 are increasing in volume (relatively large) and an outlet port (not shown) is provided in the housing 76 in a region of a rotational position at which the pumping chambers 96 are decreasing in volume (relatively small). Although not limited to this arrangement, the inlet and outlet ports can be located approximately 180° apart and be generally kidney shaped.

[0024] The configuration of the rotor chamber (in the illustrated embodiment the elliptical cross section of the bore 74) is such that the radial clearance 78 between the outer circular periphery 80 of the outer rotor 70 and the wall defining the bore 74 is not constant. As best seen in Figure 3 and marked in Figure 4, the radial clearance 78 in the first plane 88 (i.e. the plane containing the axis of rotation 86 of the outer gear rotor 70 and the axis of the bore 74) is less than the radial clearance 78(I) in directions perpendicular to the first plane 88. In the illustrated embodiment, the radial clearance has a minimum value in the first plane 88 and a maximum value in the radial directions perpendicular to the first plane (i.e. the direction of the plane 97 of the gerotor offset 94). Due to the generally elliptical cross section of the bore 74, the radial clearance 78 varies substantially continuously between its value in the first plane 88 and its value in the radial directions perpendicular to the first plane (i.e. in a plane 97, which is perpendicular to the first and second planes 88, 92, and contains the gerotor offset 94 as shown in Figure 4).

[0025] It will be understood that in all radial directions except those of the first plane 88 in which the axis of rotation 86 of the outer gear rotor 70 extends, the non-circular rotor chamber of the gerotor pump 56 has increased radial dimensions as compared with the rotor chamber of the prior art gerotor pump shown in Figure 1. This provides a greater radial clearance 78 in all directions except in the first plane 88, which allows the movement of the outer gear rotor 70 to be closely contained in the opposed radial directions perpendicular to the gerotor offset 94 while less restraint is provided in the other radial directions. This allows better control of the point of contact between the circular outer periphery 80 of the outer gear rotor 70 and the bore wall, which is important as the reaction force generated by that contact increases as the contact position moves away from the first plane 88. This allows the pump assembly to tolerate a significantly larger positional error between the drive shaft 84 and the rotor chamber than is possible with the prior art gerotor shown in Figure 1. These effects of the changed radial clearance characteristic of the gerotor pump 56 will be further appreciated from a consideration of Figures 5 and 6.

[0026] Figure 5 shows a prior art gerotor pump configuration corresponding to the gerotor pump shown in Figure 1. For ease of reference, the features of the gerotor pump shown in Figure 5 are indicated by reference numerals corresponding to those used in Figure 1. In the gerotor pump shown in Figure 5, the axis of rotation of the drive shaft 24, and so the inner gear rotor 10, is offset from its correct position due to tolerance stack up. This offset is indicated by the arrow 98. As a result, contact between the outer periphery of the outer gear rotor 14 and the wall of the bore 18 caused by the pressure in the chamber pockets 28 at their rotational position on the high pressure side of the pump (the forces generated by this pressure are indicated by arrows 100) is shifted out of the plane in which the axis of bore 18 extends towards the plane of the gerotor offset. The further the point of contact is from the plane in which the axis of rotation of the bore 18 extends, the greater is the reaction force indicated by arrow 102. As the reaction force 102 increases, the driving force indicated by arrow 104 also increases. Increased driving forces 104 lead to increased wear of the tips of the teeth 12 of the inner rotor 10.

[0027] Figure 6 illustrates what happens in a gerotor pump 56 according to the present invention when the drive shaft 84 is offset in the same way as the drive shaft 24 in Figure 5. In the gerotor pump 56, the increased radial clearance 78 away from the first plane 88 (Figure 3) which contains the axis 86 of the bore 74 results in the region of contact between the outer periphery of the outer rotor 80 and the bore 74 being kept closer to the first plane 88. As compared with the prior art pump geometry illustrated in Figures 1 and 5, this results in a lower reaction force 102 and driving force 104 for the same positional error.

[0028] It will be appreciated that although the gerotor pump 56 is shown having a rotor chamber with an elliptical cross-section, this is not essential. Other configurations are possible. What is required, is that the radial clearance 78 in a first plane 88 containing the rotor chamber axis 86 (i.e. the plane 88 that extends perpendicular to the plane 97 containing both the rotor chamber axis 86 and the axis of rotation 90 of the inner gear rotor 66) is kept relatively small, at least in one direction, and the radial clearance 78(l) in at least one direction in the plane 97 containing the rotor chamber axis 86 and axis of rotation 90 of the inner gear rotor 66 is relatively larger.

[0029] The embodiment provides a rotor chamber having non-circular cross section that is configured to provide an increased radial clearance between the outer periphery of the outer gear rotor and the facing wall of the rotor chamber in the direction of a plane 97 containing the central axis 86 of the rotor chamber and the axis of rotation 90 of the inner gear rotor. It is not essential that the rotor chamber is non-circular in order to obtain the increased radial clearance. In an alternative embodiment, the outer rotor has a circular outer periphery and the rotor chamber has a circular cross section. However, as compared with the configurations shown in Figures 1 and 5, the rotor chamber has a larger diameter providing a relatively larger radial clearance. In order to provide the necessary close clearance on the high pressure side of the pump, the drive shaft is shifted to the left (as viewed in Figures 1 and 5). In this embodiment, a close radial clearance is maintained on the high pressure side of the pump in a plane containing the axis of rotation of the inner gear rotor while a larger radial clearance is provided in the radial directions of a plane extending perpendicular to that plane and containing the axis of rotation of the inner gear rotor and the longitudinally extending central axis of the rotor chamber. However, this embodiment is non-symmetrical in that a relatively large radial clearance is provided in the radial direction of the plane containing the close clearance that this is on the low pressure side of the pump. As compared with the gerotor pump 56, this alternative configuration is not so desirable as it increases the pump capacity and the lack of symmetry limits the pump to rotation in just one direction. With the symmetrical configuration shown in Figure 3, the drive shaft can run in either direction.

[0030] It will be appreciated that while particularly suitable for such use, the embodiments of the gerotor pump are not limited to use in diesel fuel injection systems and have general applicability to the known uses of gerotor pumps such as, for example, in fuel injection systems generally and in motor vehicle engine lubrication systems.

Claims

1. A gerotor pump (56) comprising means defining a rotor chamber having a longitudinally extending central axis (86), outer rotor means (70) rotatable in said rotor chamber with a radial clearance (78) between an outer periphery (80) of said outer rotor means (70) and said rotor chamber, inner rotor means (66) rotatable in said outer rotor means (70) and cooperably engageable therewith to define a plurality of pumping chambers (96) having respective volumes that vary when, in use, the inner rotor means (66) rotates relative to the outer rotor means (70), said inner rotor means (66) being rotatable about an axis of rotation (90) spaced from said central axis (86) and contained in a first plane (97) that contains said central axis (86), and said rotor chamber being configured such that the said radial clearance (78(l)) in at least one direction in said first plane (97) is greater than at least one radial clearance (78) in a second plane (88) that extends substantially perpendicular to said first plane (97) and contains said central axis (86), wherein said radial clearance (78) has a minimum value and the or each said radial clearance in said second plane (88) has said minimum value.

2. A gerotor pump (56) as claimed in claim 1, wherein said outer rotor means (70) has an axis of rotation at least substantially coincident with said central axis (86).

3. A gerotor pump (56) as claimed in claim 1 or claim 2, wherein said radial clearance (78) has a maximum value and the or each said radial clearance in said first plane (97) has said maximum value.

4. A gerotor pump (56) as claimed in any one of the preceding claims, wherein between said first plane and said second plane (97, 88), said radial clearance (78) continuously decreases in size.

5. A gerotor pump (56) as claimed in any one of the preceding claims, wherein said rotor chamber has a

substantially elliptical cross-section.

6. A gerotor pump (56) comprising a housing defining a rotor chamber, an outer gear rotor (70) received with radial clearance (78) in said rotor chamber and rotatable in said rotor chamber, an inner gear rotor (66) rotatable in said outer gear rotor (70) and having toothing (68) cooperably engaging toothing (72) of said outer gear rotor (70) to form a plurality of variable volume pumping chambers (96), said outer gear rotor (70) being rotatable about an axis of rotation (86) extending in a first plane (88), said inner gear rotor (66) being rotatable about an axis of rotation (90) extending in a second plane (92) spaced from said first plane (88) and said rotor chamber being configured such that at least one said radial clearance (78) in said first plane (88) is less than at least one radial clearance (78(I)) in a direction substantially perpendicular to said first plane (88), wherein said radial clearance (78) has a minimum value and the or each said radial clearance (78) in said first plane (88) has said minimum value.

7. A gerotor pump (56) as claimed in claim 6, wherein said radial clearance (78) has a maximum value and the or each said radial clearance (78) in said direction perpendicular to said first plane (88) has said maximum value.

8. A gerotor pump (56) as claimed in claim 7, wherein said direction perpendicular to the first plane (88) is the direction in which said second plane (92) is spaced from said first plane (88).

9. A gerotor pump (56) as claimed in any one of claims 6 to 8, wherein said rotor chamber has a generally elliptical cross section.

10. A gerotor pump (56) as claimed in any one of claims 6 to 9, wherein said rotor chamber comprises a portion configured such that said radial clearance (78) increases substantially continuously between said first plane (88) and said direction perpendicular to said first plane (88).

11. A fuel injection system (50) comprising a gerotor pump (56) as claimed in any one of the preceding claims.

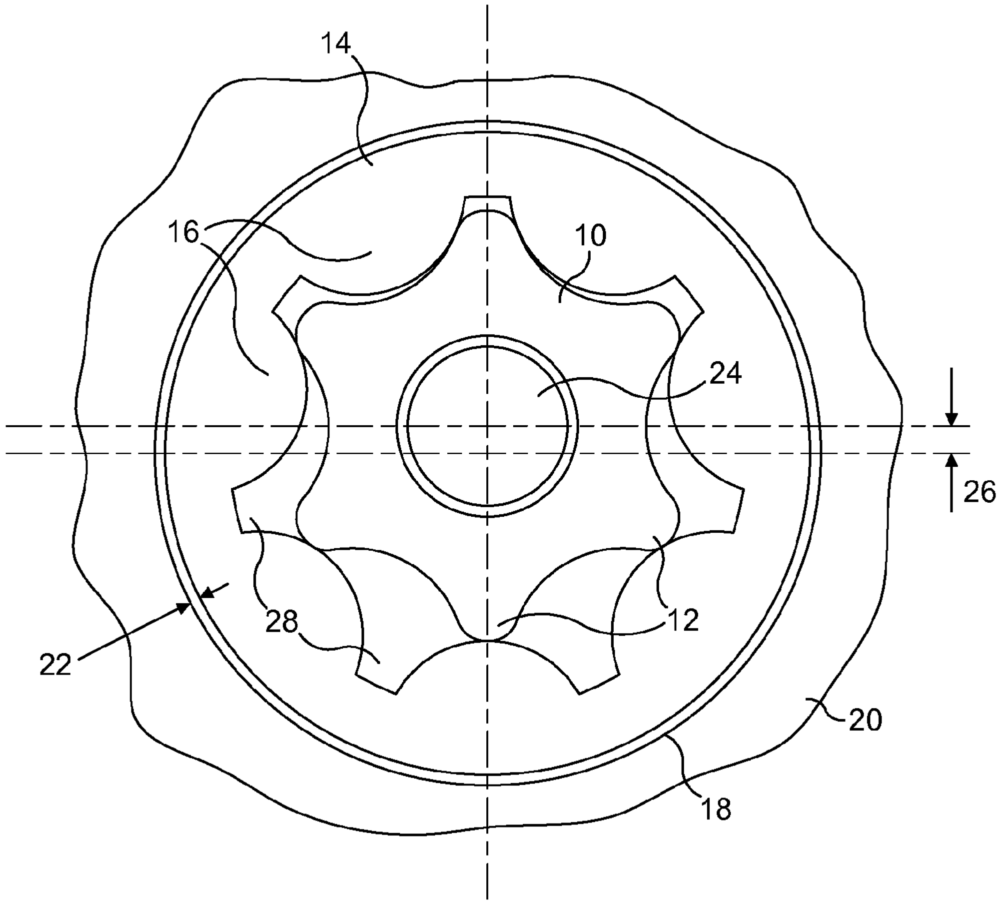


FIG. 1
PRIOR ART

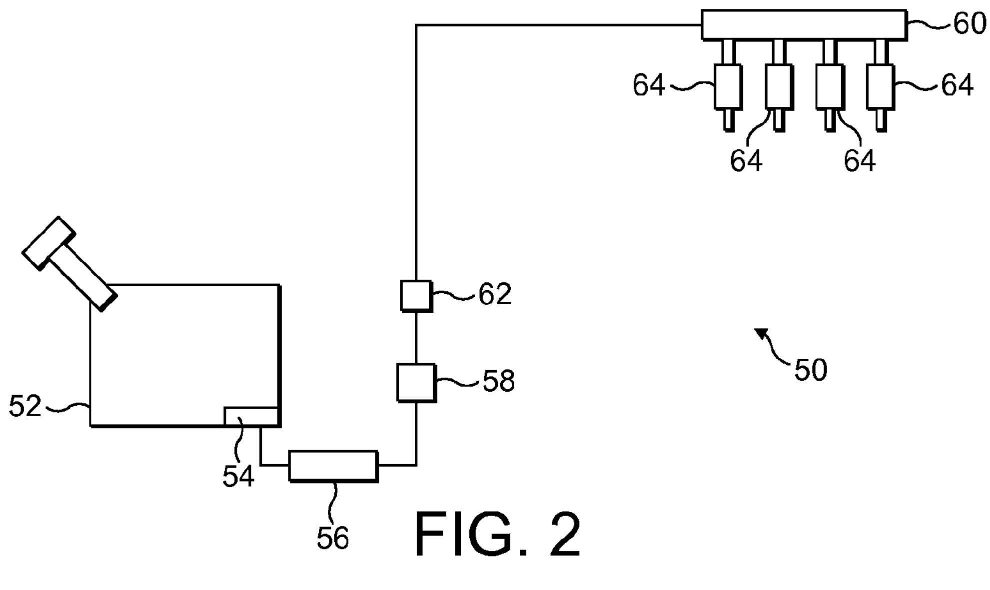
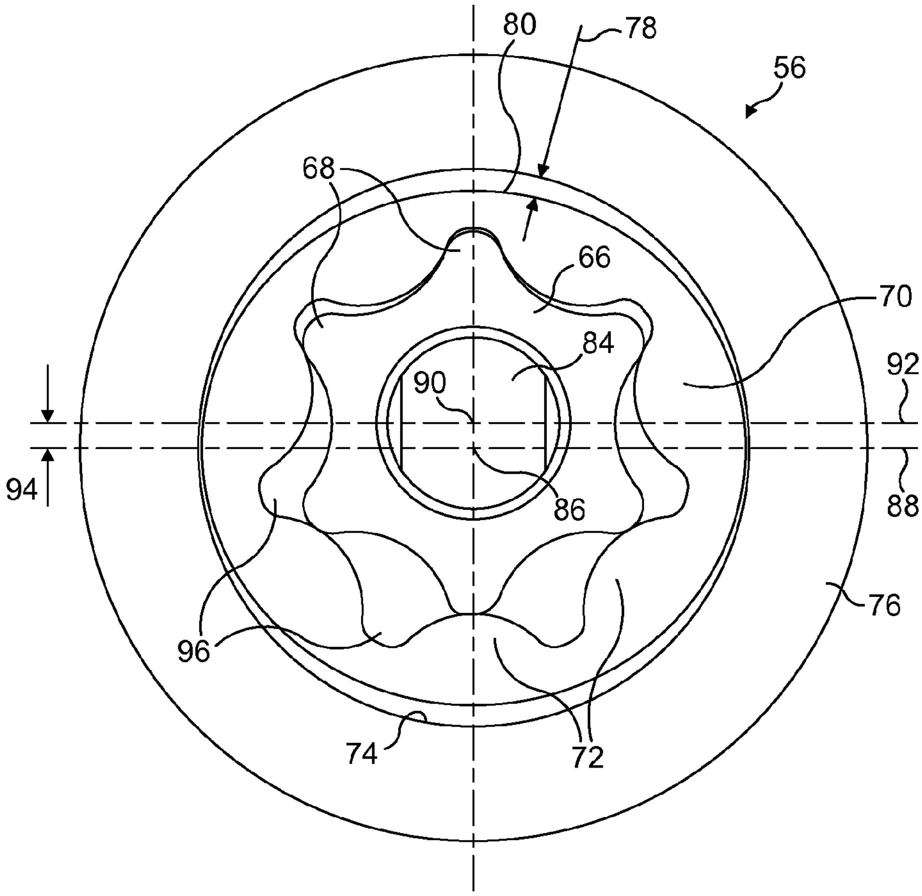


FIG. 2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70
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74
72

FIG. 3

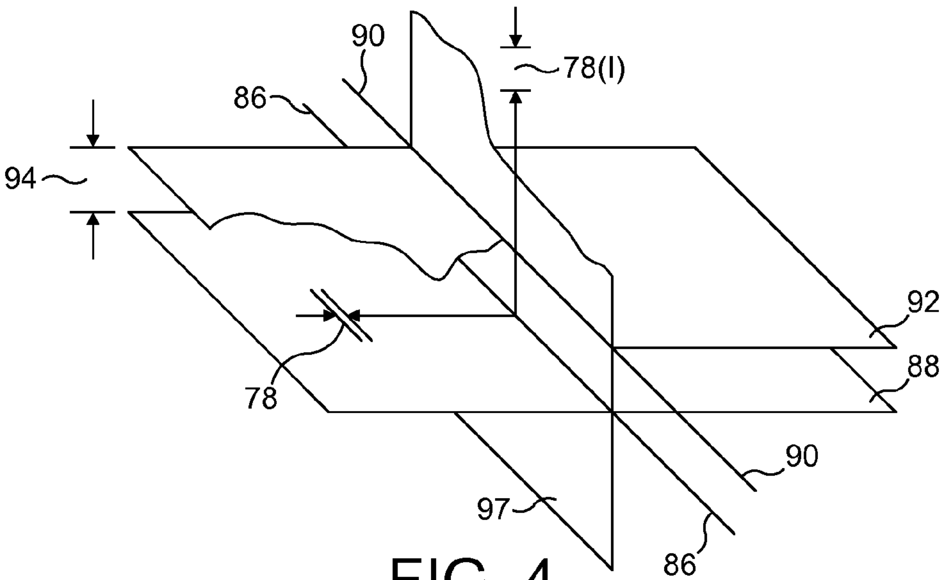
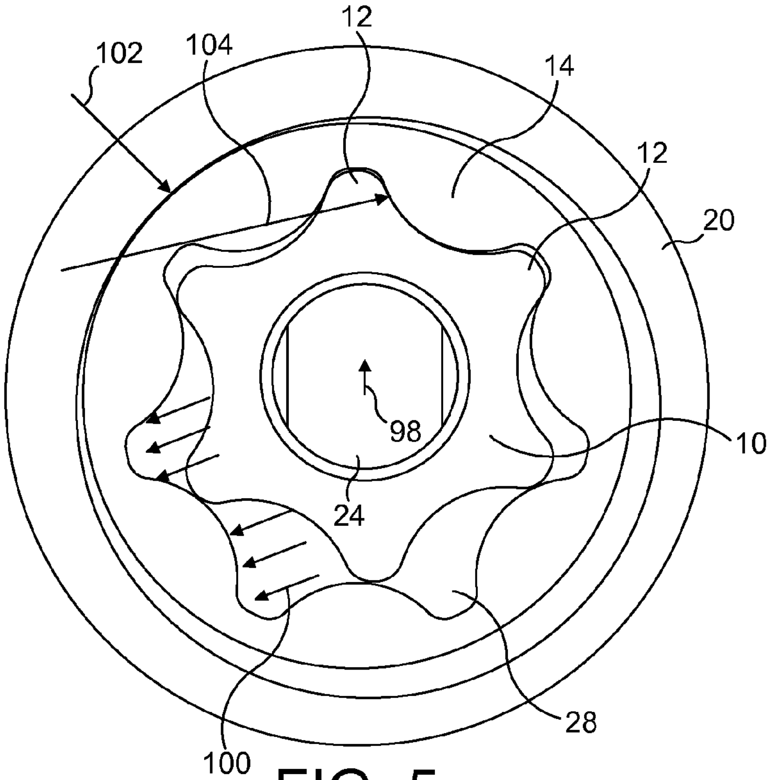
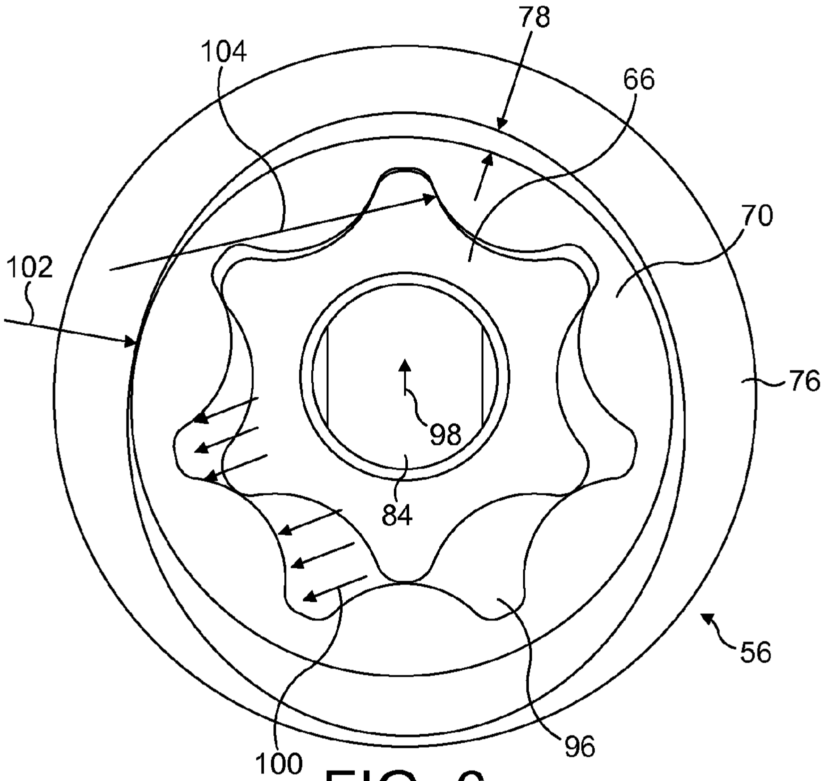

90
78(l)
86
94
92
78
88
90
97
86

FIG. 4


102
104
12
14
12
20
98
10
24
28
100
FIG. 5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104
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102
76
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84
56
100
96
FIG. 6