

[54] PLANETARY GEAR PUMP

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Related U.S. Application Data

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[52] U.S. Cl. **417/310, 418/153, 418/225**

[51] Int. Cl. **F01c 5/00, F03c 3/00, F04c 5/00**

[58] Field of Search **418/56, 156, 152, 153,
418/225, 227; 417/310**

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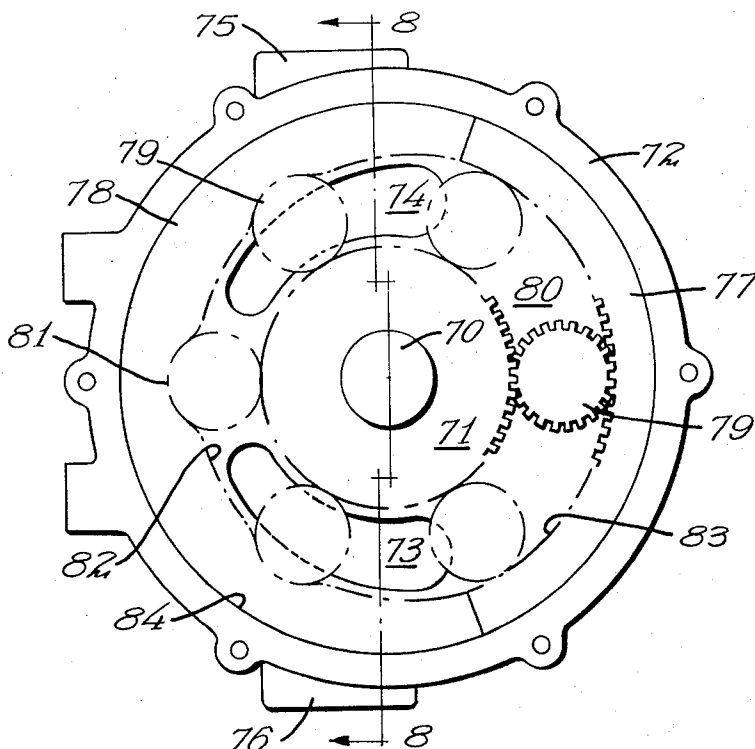
Assistant Examiner—Richard E. Gluck

[57]

ABSTRACT

A pump wherein a central rotating gear drives flexible planet gears about its circumference and inside a circumferential ring gear shaped outer housing. The space between the central rotating gear and the circumferential ring gear varies in cross sectional area to form a pumping chamber and communicates with inlet and outlet ports to permit pumping of fluid there-through. The variable shape of the pumping chamber is achieved through the use of non-concentric ring and sun gears, non-circular sun and ring gears, flexible segments in the ring gear, or a flexible sun gear.

7 Claims, 13 Drawing Figures



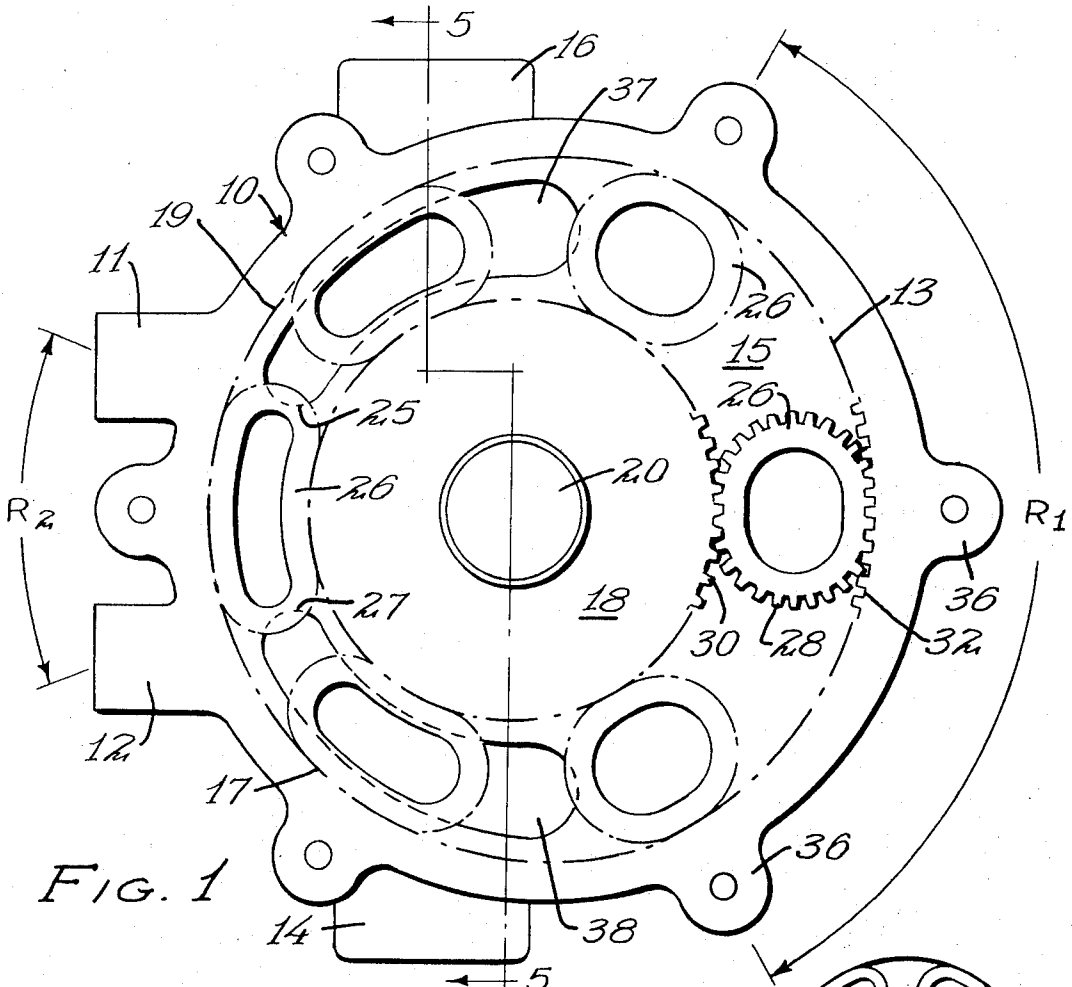


FIG. 1

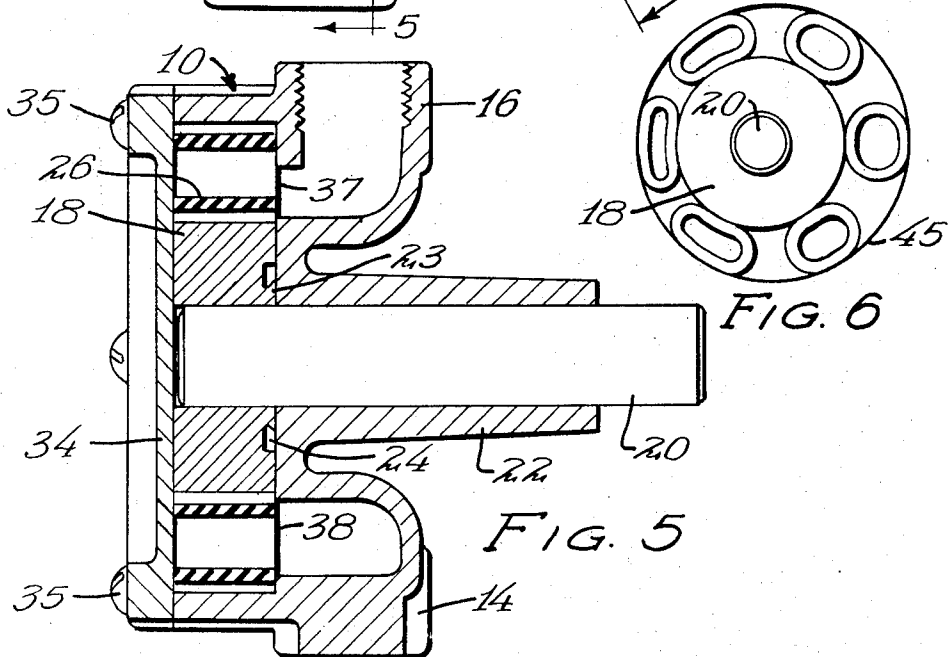


FIG. 5

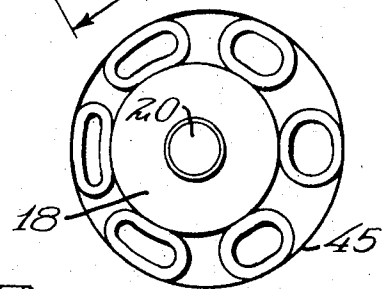


FIG. 6

SHEET 2 OF 4

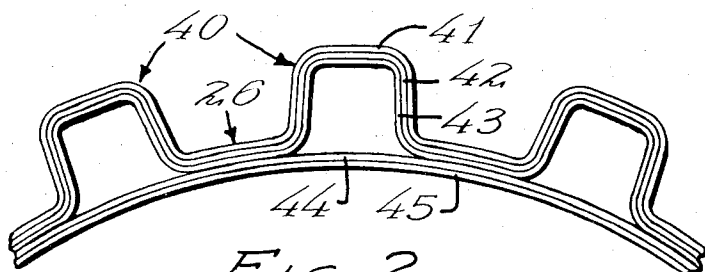


FIG. 2

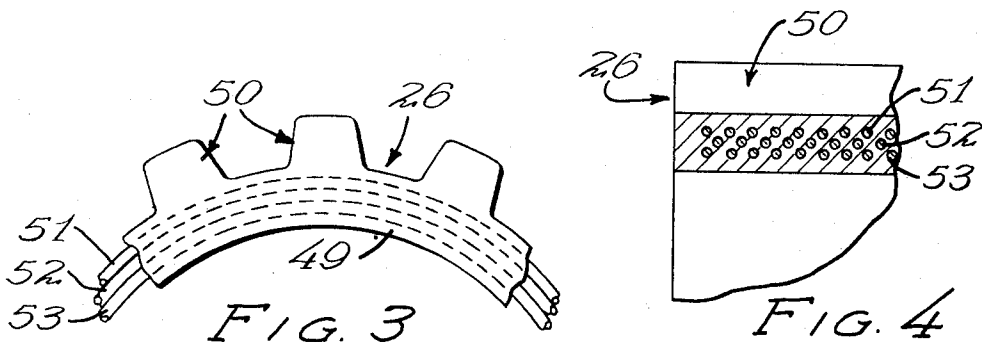


FIG. 3

FIG. 4

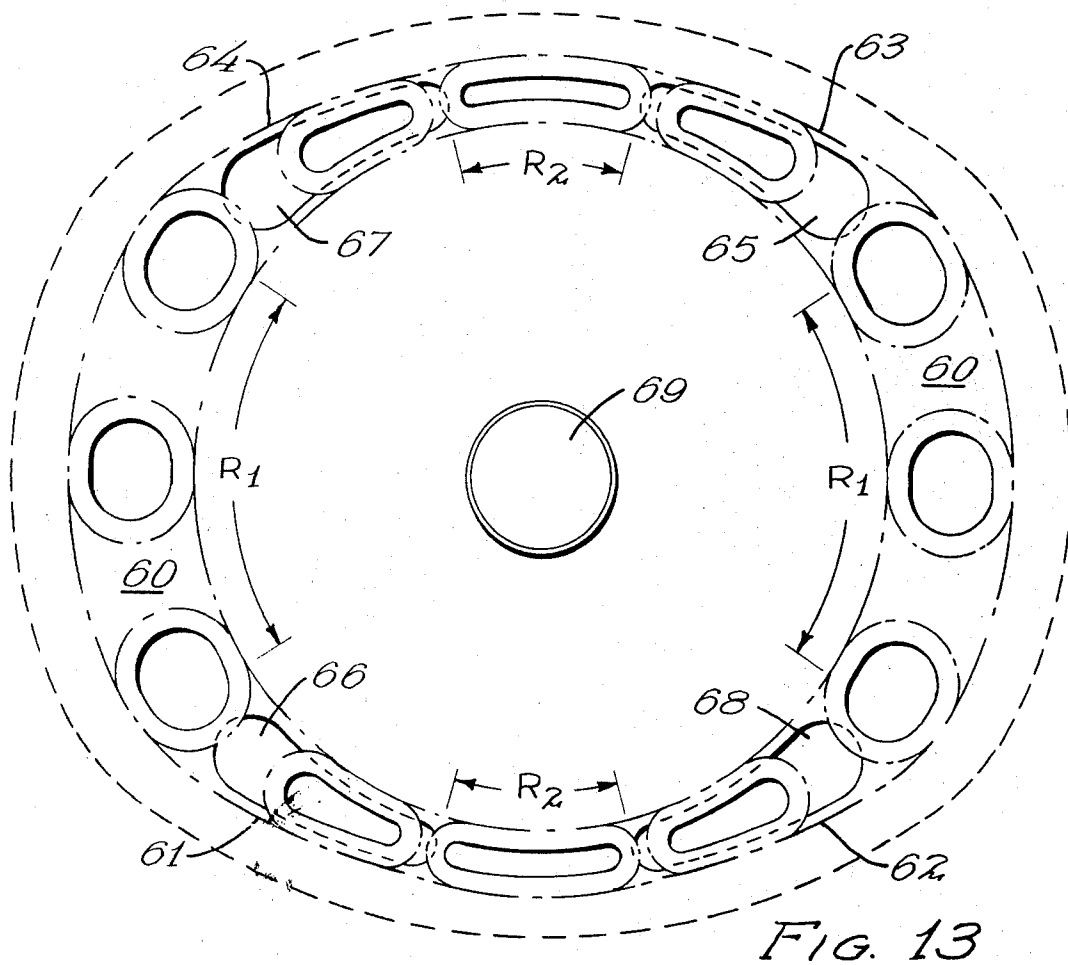


FIG. 13

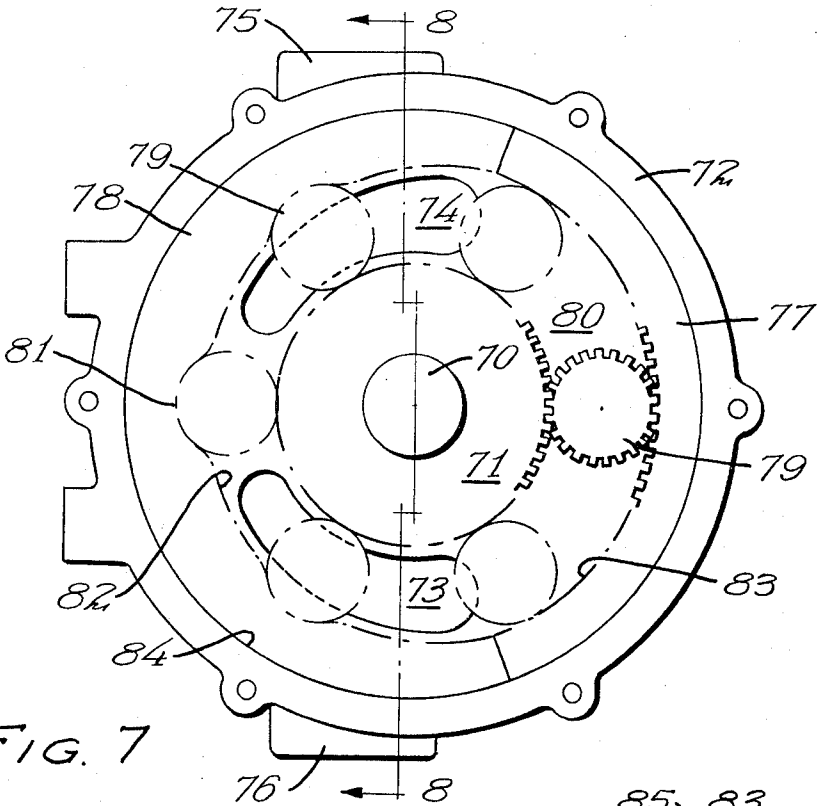


FIG. 7

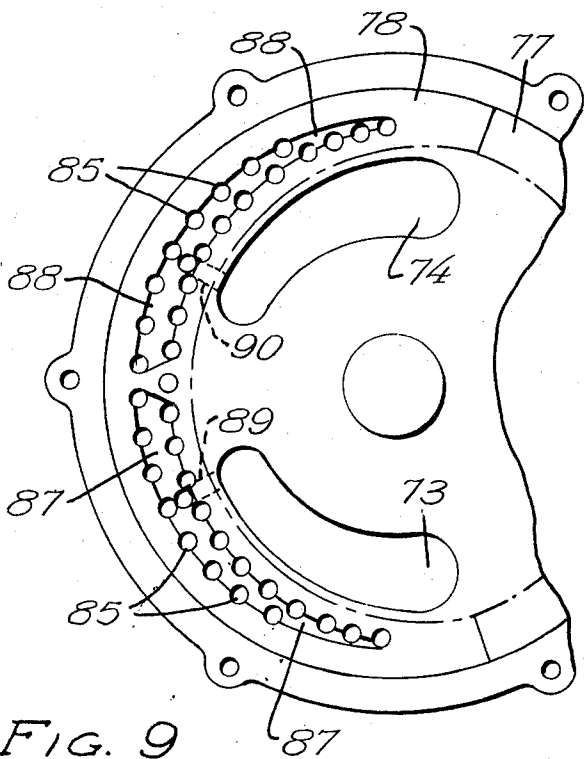


FIG. 9

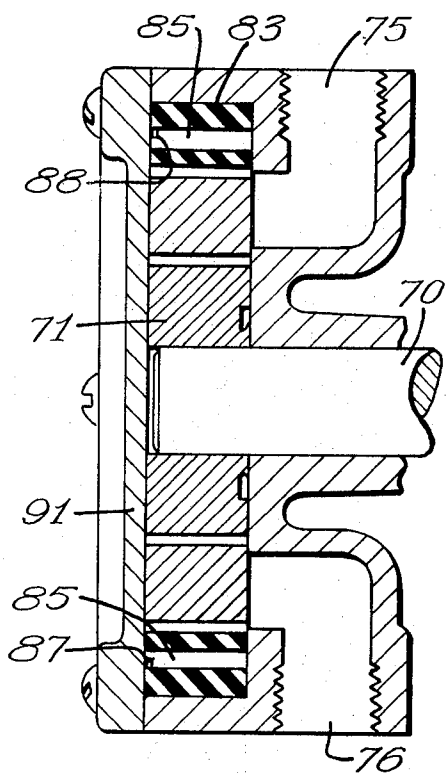
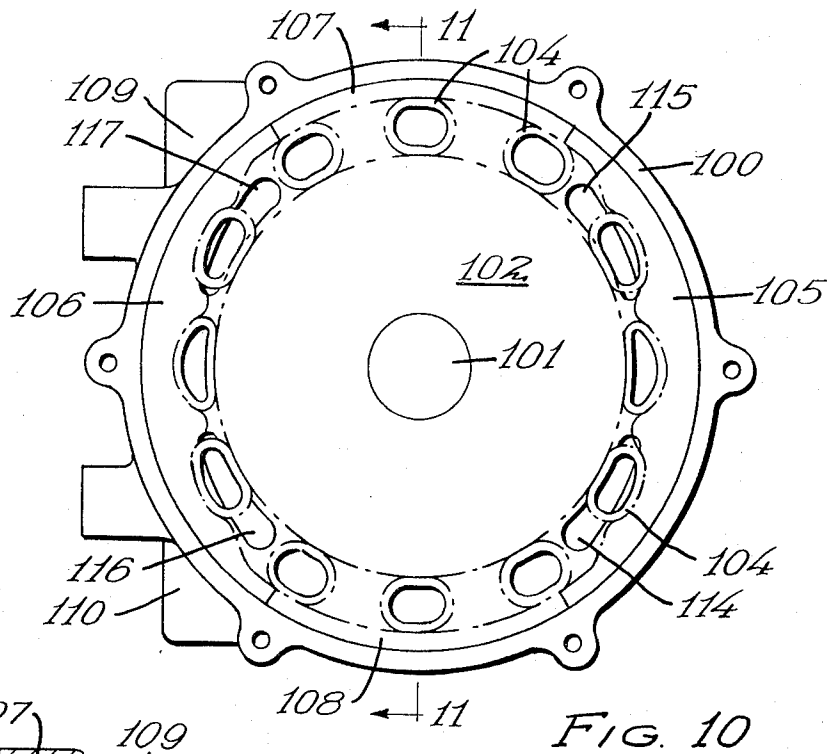
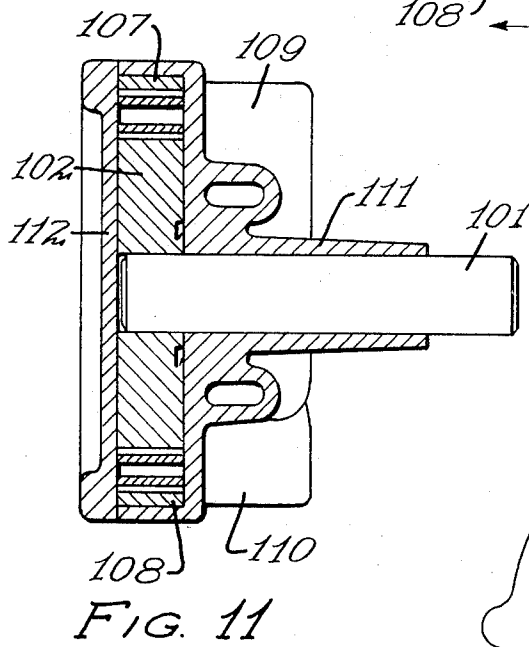
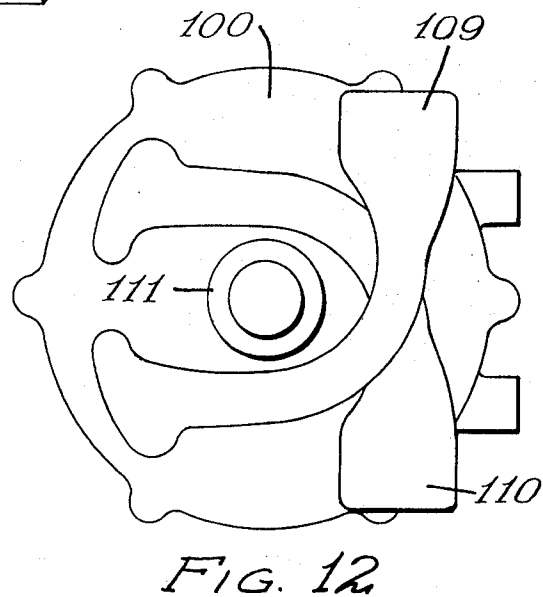


FIG. 8



PLANETARY GEAR PUMP

This is a division of application Ser. No. 267,560, filed June 29, 1972.

BACKGROUND OF THE INVENTION

Numerous types of pumps are known in the prior art. One class of pump which finds extensive utility in the fluid pumping art includes paddle pumps and sliding vane pumps. Paddle pumps generally employ a rotating member with a number of flexible paddles about the circumference. This paddle assembly is rotated within a generally circular housing which is non concentric with the paddle assembly so that the chamber between the rotating member and the housing varies in cross section. The springy flexible paddles adjust to this variance and operate to pump fluid between ports which are in communication with the chamber.

A number of difficulties are encountered with this type of pump. Since the paddles must be flexible to adjust to the varying width of the chamber they are easily deflected by higher pressure fluid so that the pumps must by limited to lower pressures. In addition, the continual rubbing of the paddles against the outside walls wears out the paddles and requires a large driving force to overcome the friction. This large driving force makes the pumps rather inefficient. Another difficulty stems from the fact that the paddles tend to wipe dirt particles around the outside of the chamber walls so that the chamber walls wear quickly and soon develop a bypass.

Another type of pump is known as the sliding vane pump. These pumps have the same offset central driving member positioned in a generally circular housing but instead of flexible paddles they utilize comparatively rigid vanes which slide in and out of radial slots in the central driving member. The vanes are held against the outside wall by either centrifugal forces or spring forces. These type of pumps suffer many of the same disadvantages as discussed earlier. The vanes tend to wipe dirt particles around the outside of the housing causing excessive wear. Also the vanes easily jam in the radial slots unless they are limited to use with fluids which are, in themselves, good lubricants such as oil and the like. The rubbing of the vanes against the outside walls requires a large driving force making the pump inefficient and highly susceptible to wear. The instant invention overcomes all of the above disadvantages in a new and novel way as indicated below.

SUMMARY OF THE INVENTION

Briefly, my invention contemplates using a central rotational driving member that is provided with teeth about its circumference. These teeth operate to rotate flexible planetary gears about the inside of a combination ring gear and housing. The central driving member can be thought of as a sun gear whereas the pumping gears are referred to herein as planetary gears. Ports are formed in the housing to communicate with the chamber between the sun gear and the ring gear so that fluid may be pumped therethrough by the rotational motion of the planetary gears. In one embodiment the chamber dimensions are caused to vary displacing the axis of the sun gear with respect to the axis of the ring gear. In another embodiment the ring gear is made with a changing radius and this radius can be varied repeatedly to provide several pumps in a single planetary gear arrangement. Other embodiments of the invention con-

template not only flexible planetary gears but flexible ring gears as well and also combinations of flexible planetary, sun and ring gears.

Since the planetary gears roll about the inside of the ring gear housing and about the outside of the central driving member or sun gear they tend to roll over dirt particles rather than dragging them along in an abrasive manner to wear parts of the pump. Obviously there is no dragging friction as with paddles or vanes but rather a rolling action. Accordingly much less force is necessary to drive the pump and it is therefore much more efficient than prior art designs. Still another advantage accrues from the fact that the planetary gears are held firmly in place by virtue of their being geared to both the inside and outside members so that relatively high fluid pressure can be generated in the pump. The more rigid the flexible gear is made the higher pressure that can be handled by the pump and several flexible gear designs are proposed herein which will achieve this end. Maintenance and repair of the pump are made easier since the flexible planetary gears may be simply slid in and out of the pump with very little effort. Prior art designs usually require that the entire central member which carries the paddles or vanes has to be removed to permit repair. It may therefore be seen that it is an object of my invention to provide a pump which is more efficient, less costly for the pressures involved, easily maintained, and less susceptible to wear. Further objects and advantages will become apparent upon consideration of the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view of one embodiment of the invention showing flexible planetary gears driven about the inside of a circumferential combination gear and housing by a sun gear.

FIGS. 2, 3 and 4 show various types of construction that may be employed to produce the flexible planetary gears.

FIG. 5 is a sectional view taken along line 5—5 in FIG. 1.

FIG. 6 is a schematic diagram showing a variation of the pump of FIG. 1 wherein the outer circumferential housing or ring gear may comprise a circular member.

FIG. 7 shows another embodiment of my invention wherein the planetary gears are comparatively rigid and the ring gear has flexible portions therein.

FIG. 8 is a sectional view taken on line 8—8 in FIG. 7.

FIG. 9 shows a modification that may be made to the flexible portion of FIG. 7 to provide improved flexibility.

FIG. 10 shows another embodiment of the present invention combining both flexible planetary gears and flexible ring gear portions.

FIG. 11 is a sectional view taken along line 11—11 in FIG. 10.

FIG. 12 is a view of the opposite side of the pump of FIG. 10 showing in particular the porting arrangement thereof.

FIG. 13 is a schematic diagram showing how the pump of FIG. 1 may be formed as a dual or balanced pump.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring simultaneously to FIG. 1 and FIG. 5 one embodiment of the present invention is shown. A housing 10 is shown which has a pair of mounting feet 11 and 12 formed thereon and an inside circumferential surface 13. Surface 13 is provided about its entire circumference with a series of teeth 32. Flexible planetary gears 26 are provided with a series of gear teeth 28 which engage teeth 32 to permit rotation about the inner surface 13 of housing 10. The flexible gears 26 are driven by a central driving member or sun gear 18 which is rotated by a shaft 20 about an axis which is displaced with respect to the nominal axis of housing 10. In the simplest configuration of my invention both the sun gear 18 and the housing 10 may be made circular as shown in FIG. 6. In FIG. 6 the surface 45 is a cylinder whose axis is displaced slightly to the right of the axis of sun gear 18. This embodiment is relatively inexpensive to produce since circular members are generally easy to machine. However, the embodiment of FIG. 1 is designed to be somewhat more sophisticated than that of FIG. 6.

In FIG. 1 the pumping chamber is designated by the numeral 15. Pumping chamber 15 has a cross sectional area dependent upon the radius of sun gear 18 and the radius of surface 13 in housing 10. These two radii are kept constant over the arc defined as arc R_1 in FIG. 1. Consequently, the size of chamber 15 throughout arc R_1 is constant in cross section. On the opposite side of the pump the chamber is also constant in cross section through the arc R_2 but the cross section is much smaller due to the fact that a lesser radius is used for surface 13. The two different radii surfaces 13 are smoothly connected together by ramp surfaces designated 17 and 19 which extend between the ends of arcs R_1 and R_2 .

My invention will pump fluids if rotated in either direction. The prior art pumps, of course, can only operate in one direction due to the slant of the vanes or paddles. For the purposes of explanation the operation of my pump is explained with respect to clockwise rotation of sun gear 18. This clockwise rotation is transferred through gear teeth 30 and gear teeth 28 to a plurality of flexible planetary gears 26 which are thereby caused to roll along surface 13 in a clockwise direction. The gears 26 themselves rotate in a counter clockwise fashion. With this direction of rotation a port 37 at the top of FIG. 1 operates as an intake port drawing fluid from a threaded intake opening 16 formed in housing 10. As each planetary gear 26 passes port 37 it is allowed to expand out due to the increasing cross sectional area of chamber 15 caused by ramp 19. Thus, the space inside the planetary gear 26 and between the various planetary gears 26 increases in volume allowing fluid to enter from intake port 37. This fluid is carried around the pump through the constant cross sectional area of chamber 15 defined by arc R_1 to outlet port 38 which is connected to outlet opening 14. As the planetary gears leave arc R_1 they encounter ramp 17 and are squeezed down to the dimensions prevalent through arc R_2 . The squeezing action forces fluid from within flexible planetary gears 26 into exit port 38. The space between the planetary gears is also decreased and fluid is forced from these spaces into exit port 38. Ports 37 and 38 are generally designed to be long enough so as

to be in communication with all of the spaces which are being squeezed in the ramp areas between arc R_1 and arc R_2 . The ends of the ports designated by numbers 25 and 27 are positioned so that they are slightly farther apart than the length of a squeezed down planetary gear 26. This is to insure that the inlet and exit ports cannot be in communication with either the space inside the planetary gear 26 or the space between two planetary gears 26 at the same instant of time. Such a situation would provide a by pass wherein fluid would be able to flow from the outlet port back to the inlet port.

In FIG. 5 it may be seen that shaft 20 is carried in a housing extension 22. Sun gear 18 is shown press fitted on the shaft 20 although key ways or any other type of mounting may be used. In the preferred embodiment it is contemplated that sun gear 18 would comprise a hard rubber material although metal and plastic would be equally suitable. The hard rubber sun gear 18 is molded with a small seal of softer material 23 which generally protrudes slightly from the rest of gear 18. When gear 18 is closed into housing 10 and sealed by means of a cover 34 the protruding sealing ring 23 is bent into a space 24 as shown in FIG. 5 so as to provide a good fluid seal. Other types of seals could be used as well. Cover 34 is anchored to housing by means of a series of screws 35. Cover 34 may be made from plastic or metal or any suitable material. In the preferred embodiment cover 34 is chosen to be of such a thickness as to have a slight flexibility. This flexibility operates as a safety valve. If the pressure becomes too great inside pumping chamber 15, cover 34 deflects slightly outward allowing the fluid to pass by the ends of the planetary gears 26 and return to the inlet ports. Consequently, no external or additional mechanism is required in the instant invention to provide an over pressure safety release. Many types of materials and forms of construction may be used for forming the flexible planetary gears 26. Two of these variations are shown in FIGS. 2, 3 and 4.

In FIG. 2 one embodiment of a flexible planetary gear 26 is shown in section. The gear teeth are shown as gear teeth 40 and they are formed by laminating layers of metal 41, 42 and 43 together which metal comprises any highly flexible metal such as spring steel. The teeth 40 are then supported underneath by additional layers of spring steel 44 and 45 which may comprise cylindrical members or portions of flat helical springs. Additional layers of springs or laminated material may be added to provide a more rigid and more springy planetary gear 26 so that higher pressures may be accommodated in the pumping chamber 15.

FIGS. 3 and 4 show another possible form of construction for flexible planetary gears 26. The teeth 50 and the main body of the gear 49 may be molded from a flexible hard rubber or plastic material. During the molding process several layers of reinforcing cords 51, 52 and 53 are molded therein. These cords may comprise plastic fibers such as nylon, glass or rayon. For stiffer springs they may comprise metal wires. In yet another arrangement reinforcing wires 51, 52 and 53 could comprise concentric coil springs alternately wound in opposite directions which coil springs could be manufactured from spring steel for example. A cross sectional view of this arrangement is shown in FIG. 4 wherein the successive layers of coil springs are more visible. The embodiments of FIGS. 2 and 3 are not the

only ways the flexible planetary gears could be made. For low pressure pumps solid rubber could be molded into the shapes shown. Other embodiments could use flexible gears which have no open space in the center at all but, on the contrary, are formed from solid rubber all the way to the core. Many other variations will occur to those skilled in the art and thus no limitation is intended by the showings of FIGS. 2, 3 and 4,

In the embodiment of FIG. 1 there will be high pressure in the area of exit port 38 on a rather continuous basis providing a one sided load on the bearing 22 carrying shaft 20. To alleviate this problem, which could become acute in higher pressure pumps, the design of FIG. 13 is contemplated wherein a dual pump is provided so that the high pressure loads are balanced thus, providing little or no sideways loading for the central shaft. FIG. 13 shows schematically only the geometry used in providing the pumping chamber designated by the numerals 60. In the embodiment of FIG. 13, pumping chamber 60 would be constant in cross section during both of the arcs designated by R_1 . Chamber 60 would also be constant in cross section but much smaller through the two arcs designated as R_2 . Ramp surfaces 61, 62, 63 and 64 would be used to connect these arcs and provide the gradual change in chamber dimensions. If the pump were to be rotated in a clockwise direction, as viewed in FIG. 13, intake ports 65 and 66 would be positioned as shown and outlet ports 67 and 68 would also be pictured as shown on opposite sides of the rotational axis 69 of the sun gear. Since the high pressure areas are on opposite sides of axis 69 no unbalanced load is produced. All of the embodiments shown and discussed so far have employed flexible planetary gears. Another embodiment of the invention however uses generally rigid planetary gears and incorporates flexible segments into the ring gear. Such an embodiment is disclosed in FIG. 7.

FIG. 7 shows schematically another embodiment of the invention with a layout similar to that of FIG. 1. As before, a shaft 70 rotates a sun gear 71 inside a housing 72. Inlet and outlet ports 74 and 73 communicate with inlet and outlet openings 75 and 76. Positioned within housing 72 is a ring gear comprising a generally rigid portion 77 and a flexible portion 78. The planetary gears 79 may be generally rigid in shape so as to compress into the soft portion 78 as shown on the left of FIG. 7. Since soft portion 78 squeezes inward between planetary gears 79 on the left, the cross sectional area of the pumping chamber 80 varies. Flexible portion 78 is thickest at point 81 and becomes progressively narrower in both directions until it abuts rigid portion 77 where the thickness is equal to the thickness of portion 77. It is contemplated that portion 78 will be molded originally so that the internal surface 82 would have the same radius as the internal surface 83 of rigid portion 77. However, the outside surface of soft portion 78 designated by the number 84 would extend outward to provide a thicker portion opposite point 81. As flexible portion 78 is inserted into housing 72 it would be squeezed into the shape shown in FIG. 7. This form of construction is used so that as planetary gears 79 rotate across the molded gear teeth on surface 82 surface 82 will more closely approximate the shape at which they were molded since surface 82 will be pushed to a radius generally corresponding to its original position when molded. In this way it is assured that the teeth on plane-

tary gears 79 will fit snugly with the teeth on the inside of both ring gear portions 78 and 77.

FIGS. 8 and 9 show more sophisticated versions of the pump of FIG. 7 wherein the soft portion 78 is provided with a series of holes 85 which extend through soft portion 78 so as to provide a multitude of voids or chambers therein. An arc shaped recess 87 is formed into the surface of soft portion 78 so as to connect together all of the holes 85 proximate to exit port 73. A second arc shaped recess 88 is similarly formed in the top half of soft portion 78 so as to connect together all of the holes 85 proximate the inlet port 74. These recesses 87 and 88 are then connected to their respective ports by means of a pair of passageways 89 and 90. These passageways 89 and 90 permit fluids to pass in and out of the chambers formed by recesses 87 and 88 and the top cover 91 as shown in FIG. 8. Fluid can thus travel from the recesses 87 and 88 into all of the holes 85. The fluid pressure thus introduced into the internal structure of soft portion 78 counter balances the fluid pressure in the pumping chamber 80. This permits the soft portion of the ring gear 78 to be constructed from a material of less rigidity than would be the case if solid flexible material were used such as shown in FIG. 7. In the embodiment of FIG. 9 the planetary gears and the central sun gear have been eliminated so as to better show the position of the inlet and exit ports and the recesses 87 and 88. However, upon assembly the geometry would be the same as that of FIG. 7 and it can be seen that as the generally rigid planetary gears 79 pass across flexible portion 78 they will squeeze down on the recesses 87 and 88 and on the voids or chambers 85 squeezing fluid out through ports 89 and 90. However, the continuous pressure of fluid inside soft portion 78 will quickly return it to its expanded position wherever possible as, for example, between the planetary gears. It should be noted that the soft portion of the ring gear in both the embodiments of FIG. 7 and FIG. 9 would probably be anchored to the outside casing by a suitable adhesive at the surface 84 (as shown in FIG. 7) and at the surface 93 (as shown in FIG. 8). Adhesive would not be applied along the surface contiguous to cover 91 or the surface on the side opposite the cover since this would hinder the in and out radial flexing of the soft portion.

FIGS. 10, 11 and 12 show another embodiment of the present invention using a different type of porting arrangement and employing a combination of many of the principles discussed hereinabove. A housing 100 contains a ring gear comprising two relatively rigid constant dimension portions 107 and 108 and two flexible portions 105 and 106 which could incorporate any of the design features already discussed such as fluid filled voids. Not only are portions of the ring gear flexible but also the planetary gears 104 are allowed to flex so that a double flexing action as indicated in FIG. 10. In this embodiment the side loads on the drive shaft 101 are reduced by making a dual or balanced pump arrangement. In addition maximum pumping is achieved by having both flexible planetary gears and flexible segments in the ring gear. For clockwise rotation of sun gear 102 the inlet ports would comprise ports 117 and 114 whereas the outlet ports would comprise ports 115 and 116. As is evident in FIG. 12 housing 100 is molded or cast to have two curved inlet and outlet tubes numbered 109 and 110 respectively. Tube 109 would be in direct communication with inlet port 117 and swing

across around shaft support 111 to be in communication with inlet port 114. By a similar design outlet port 116 would communicate with outlet tube 110 which swings around shaft support 111 and underneath inlet tube 109 so as to communicate with outlet port 115. It is clear that many other modifications may be made to the invention as disclosed without departing from its spirit and scope of the novel features. Thus, the following claims are presented to cover only these novel features.

We claim:

1. A fluid pump comprising:

a generally cylindrical drive member adapted for rotation about its axis and having gear teeth about its circumference to form a sun gear;

a housing surrounding and supporting said drive member and having a flexible inner circumferential surface disposed at a varying distance from said generally cylindrical drive member so as to form a pumping chamber therebetween said inner surface having gear teeth thereon to form a ring gear;

inlet and outlet passageways in communication with said pumping chamber;

a plurality of generally rigid rolling members held between said drive member and said inner circumferential surface adapted to be rolled by said drive member about said inner surface and carry fluid

through said pumping chamber from said inlet ports to said outlet ports said rolling members having gear teeth about their circumference to form planetary gears.

2. The apparatus of claim 1 in which said inner surface has portions of constant radius about axes coincident with the axis of rotation of said sun gear and ramp portions shaped to narrow said pumping chamber and connect together the constant radius portions.

3. The apparatus of claim 2 in which there are a plurality of constant radius portions and a plurality of ramp portions.

4. The apparatus of claim 3 in which said ring gear also has rigid portions interspersed in the flexible surface.

5. The apparatus of claim 4 including voids formed in the flexible portions of the ring gear, said voids being in communication with one of the inlet and outlet ports.

6. The apparatus of claim 5 in which said inlet and outlet passageways communicate with the pumping chamber proximate said ramp portions.

7. The apparatus of claim 6 in which said housing is closed on one side by a cover having just enough flexibility to permit fluid to pass beside said rolling members if the pressure exceeds a predetermined limit.

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