US009784107B2

(12) United States Patent
Gilbert

(10) Patent No.: US 9,784,107 B2
(45) Date of Patent: Oct. 10, 2017

(54) **HYDRAULIC MOTOR**

(71) Applicant: **Parker-Hannifin Corporation**, Cleveland, OH (US)

(72) Inventor: **Kenneth T. Gilbert**, Bristol, TN (US)

(73) Assignee: **PARKER-HANNIFIN CORPORATION**, Cleveland, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/060,363**

(22) Filed: **Oct. 22, 2013**

(65) **Prior Publication Data**

US 2014/0112813 A1 Apr. 24, 2014

Related U.S. Application Data

(60) Provisional application No. 61/716,873, filed on Oct. 22, 2012.

(51) **Int. Cl.**

F03C 2/00	(2006.01)
F03C 4/00	(2006.01)
F04C 2/00	(2006.01)
F04C 18/00	(2006.01)
F01C 1/10	(2006.01)
F01C 21/10	(2006.01)
F04C 2/10	(2006.01)
F04C 2/08	(2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***F01C 1/10*** (2013.01); ***F01C 21/108*** (2013.01); ***F03C 2/08*** (2013.01); ***F04C 2/086*** (2013.01); ***F04C 2/10*** (2013.01); ***F04C 2/103*** (2013.01); ***F04C 2/105*** (2013.01); ***F04C 15/06*** (2013.01)

(58) **Field of Classification Search**
CPC F04C 2/103; F04C 2/104; F04C 2/105; F04C 2/10; F04C 2/086; F04C 2/3446; F04C 15/06; F01C 1/10; F01C 1/104; F01C 21/108; F03C 2/08
USPC 418/61.3, 186–188, 1
See application file for complete search history.

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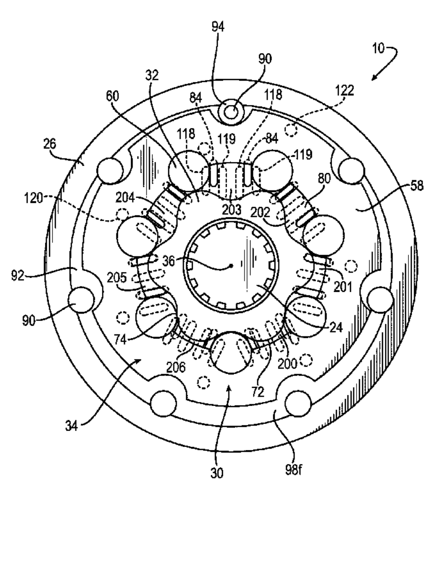
Primary Examiner — Theresa Trieu
(74) *Attorney, Agent, or Firm* — Renner, Otto, Biosselle & Sklar, LLP

(57) **ABSTRACT**

A hydraulic geroller (gerotor) motor, wherein an inner rotor of a revolving group has a plurality of lobes circumferentially spaced along an outer periphery of the inner rotor, and an orbiter of the revolving group includes an orbiting ring and rounded vane portions preferably formed by roller vanes contained in inner recesses of the orbiting ring for common orbiting with the orbiting ring about the fixed longitudinal axis. The orbiter also has fixed for orbiting therewith, fluid windows for directing fluid from the fluid ports to the revolving group. The windows may be formed in an integral portion of the orbiter or in a valve plate mounted for common orbiting with the orbiting orbiter. The valve plate cooperates with a stationary commutator plate or assembly to provide an efficient arrangement for the delivery and exhaust of hydraulic pressure fluid to and from the hydraulic motor.

19 Claims, 16 Drawing Sheets



(51) **Int. Cl.**
F03C 2/08 (2006.01)
F04C 15/06 (2006.01)

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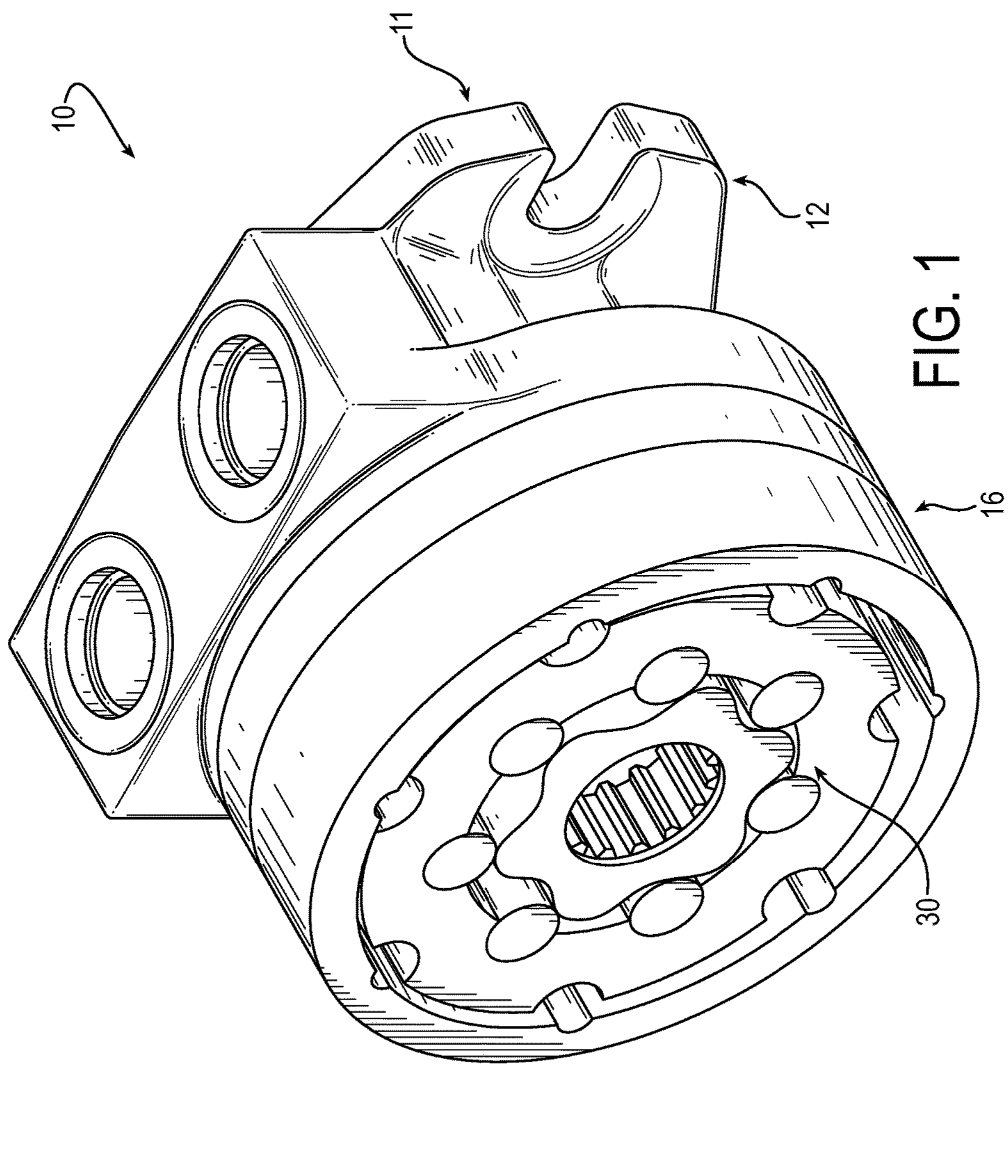

FIG. 1

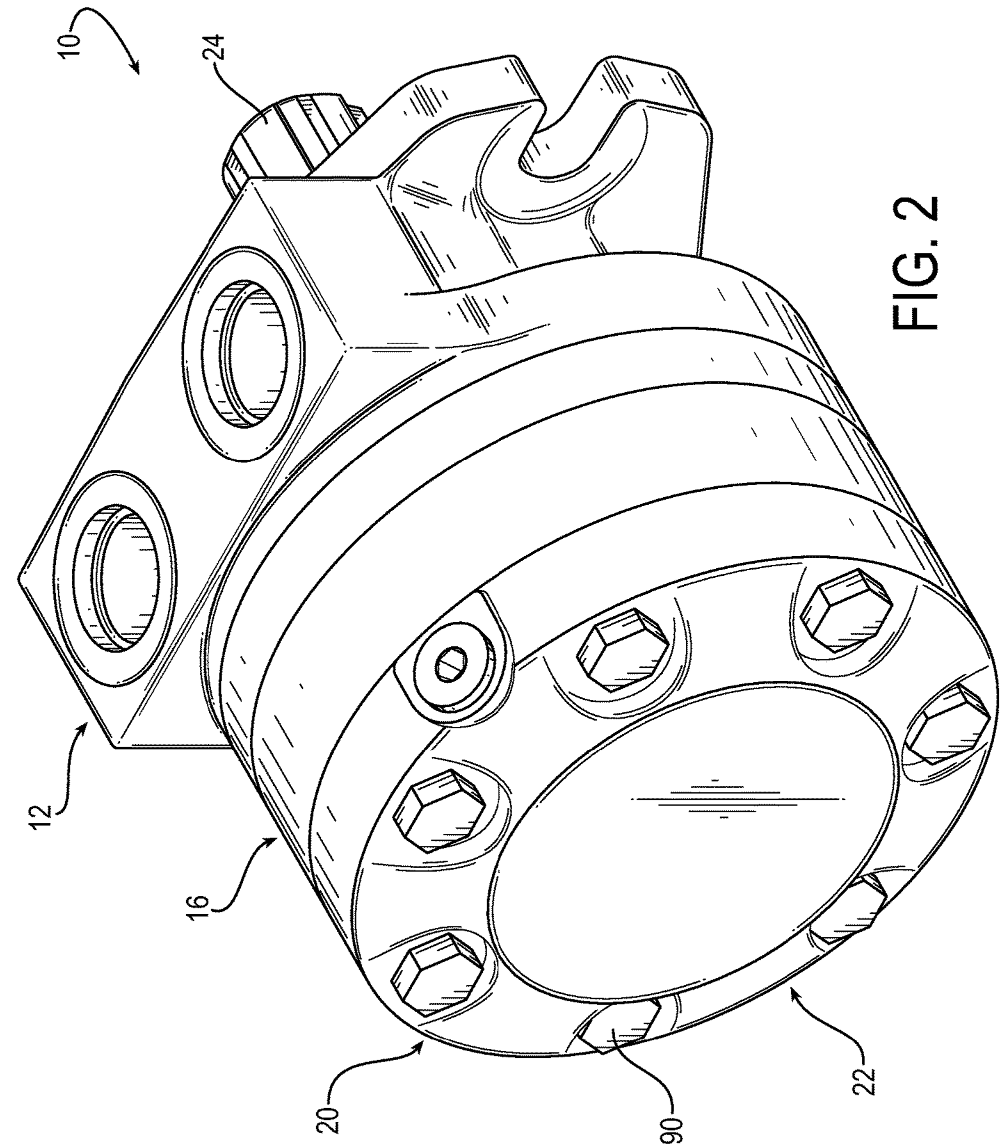

FIG. 2

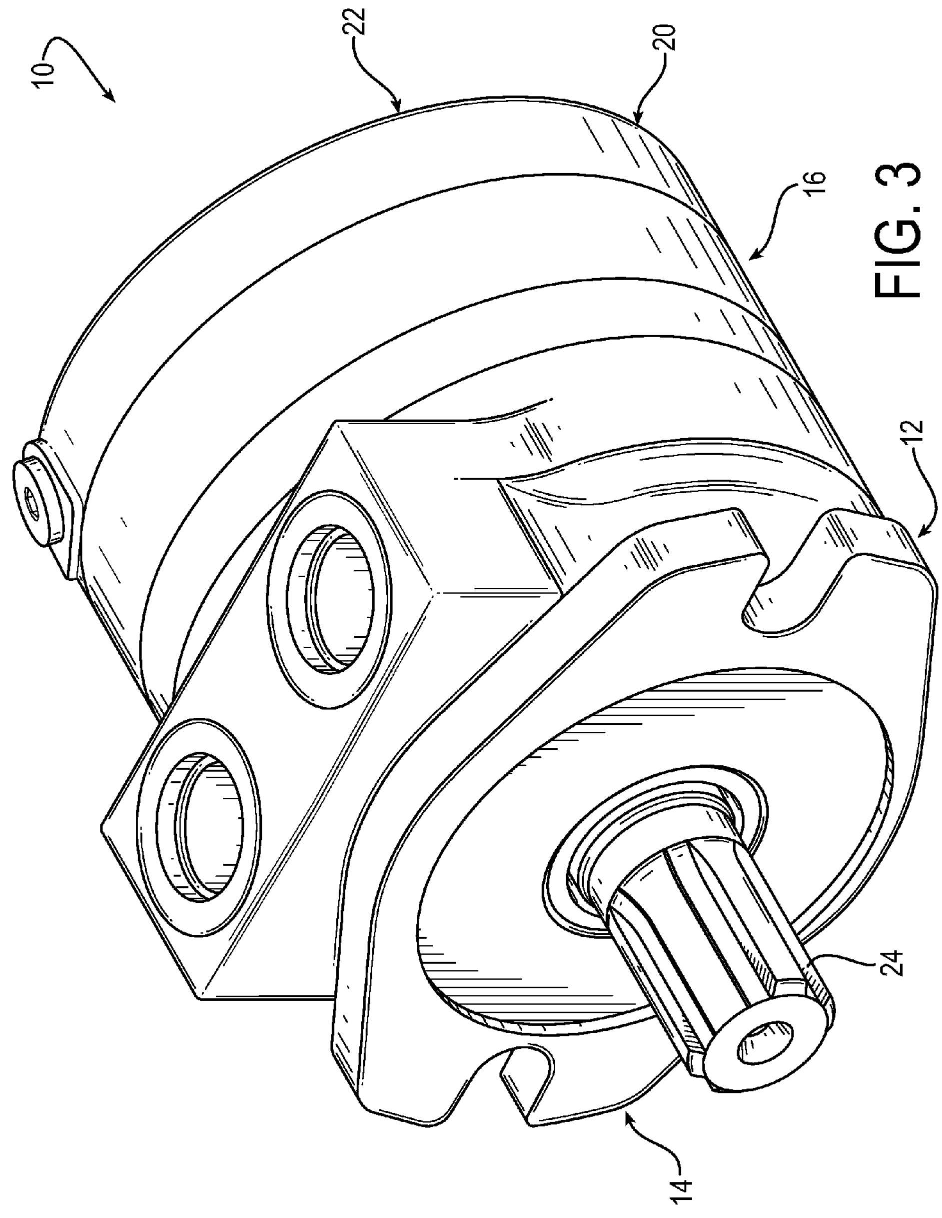

FIG. 3

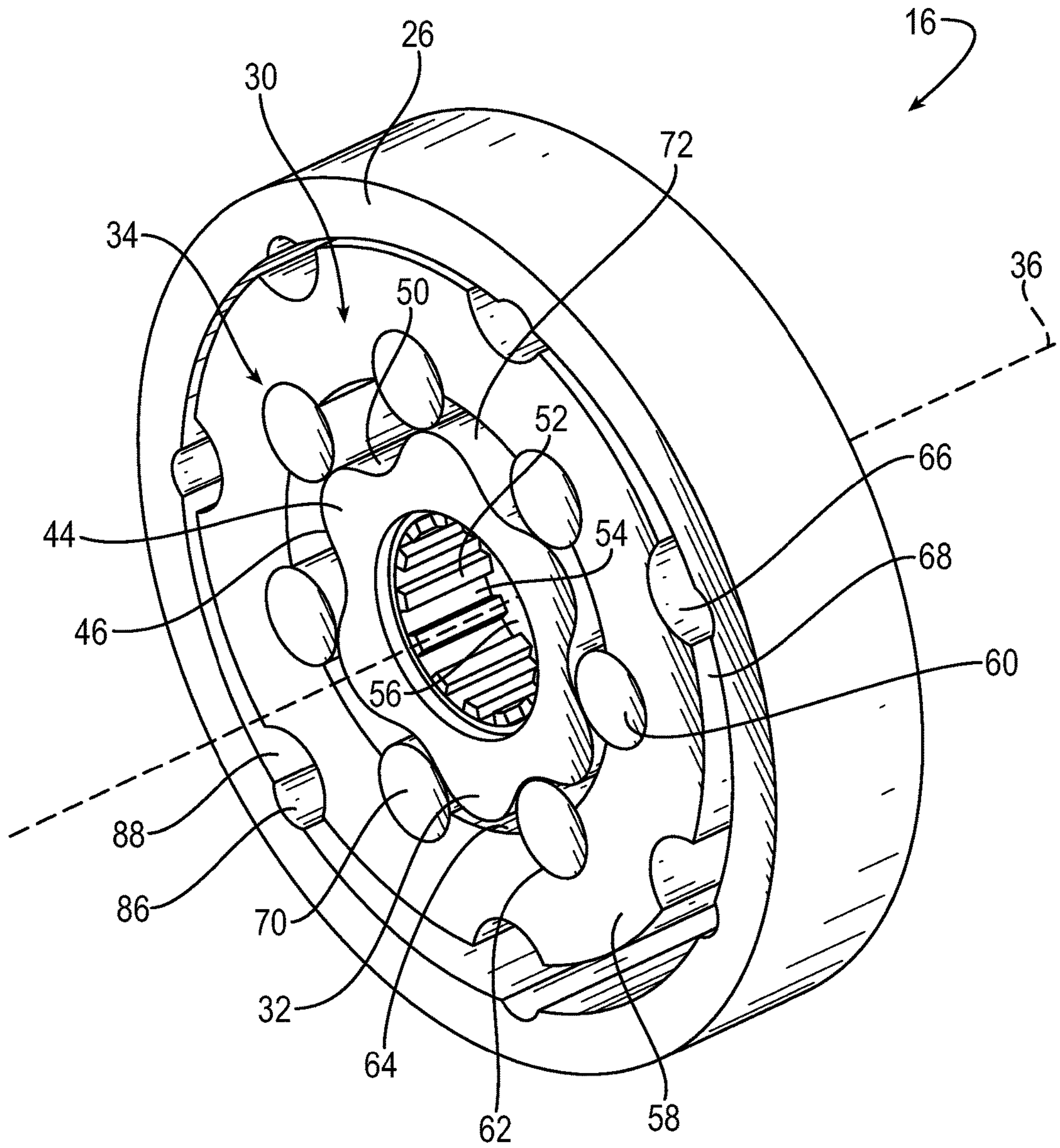

FIG. 4

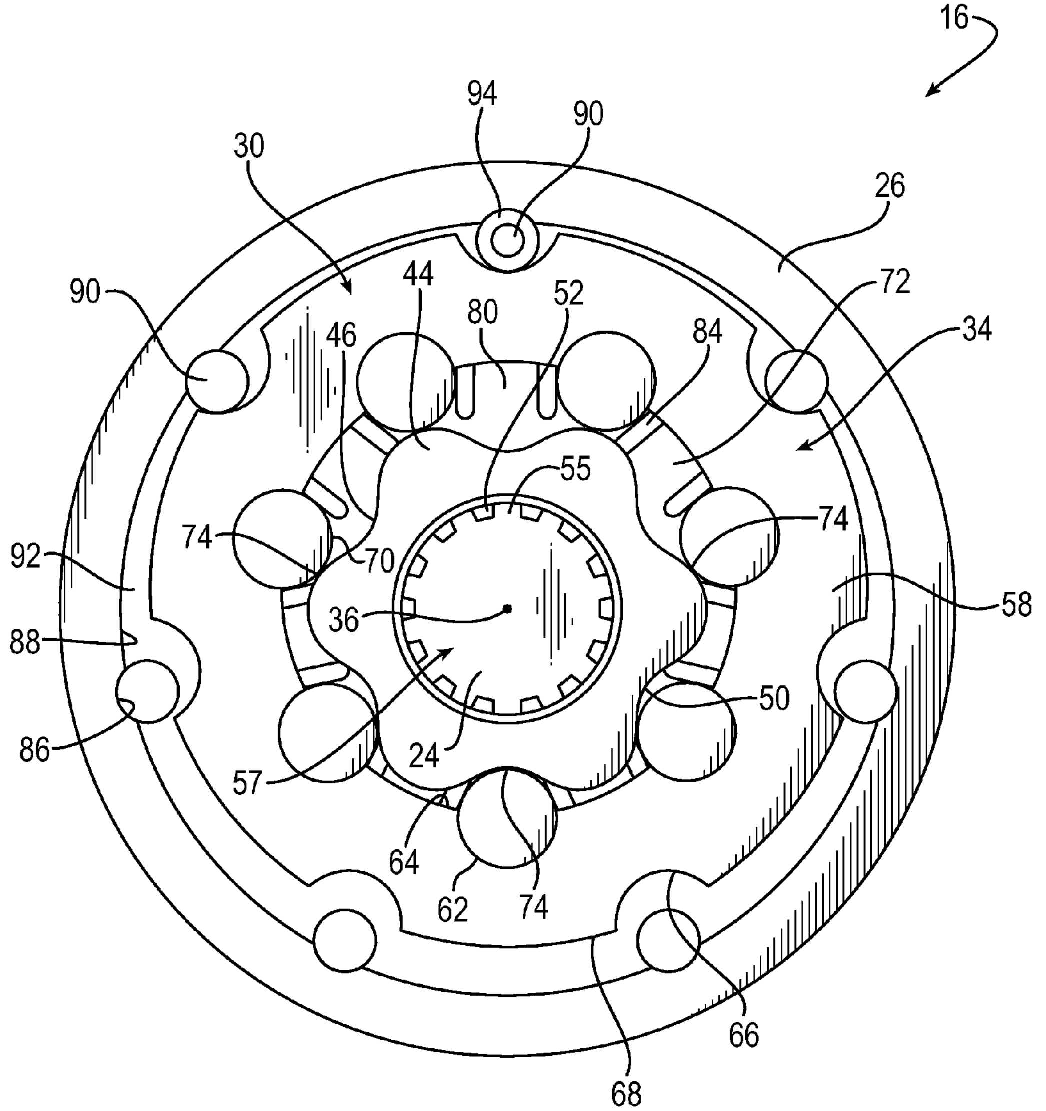
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FIG. 5

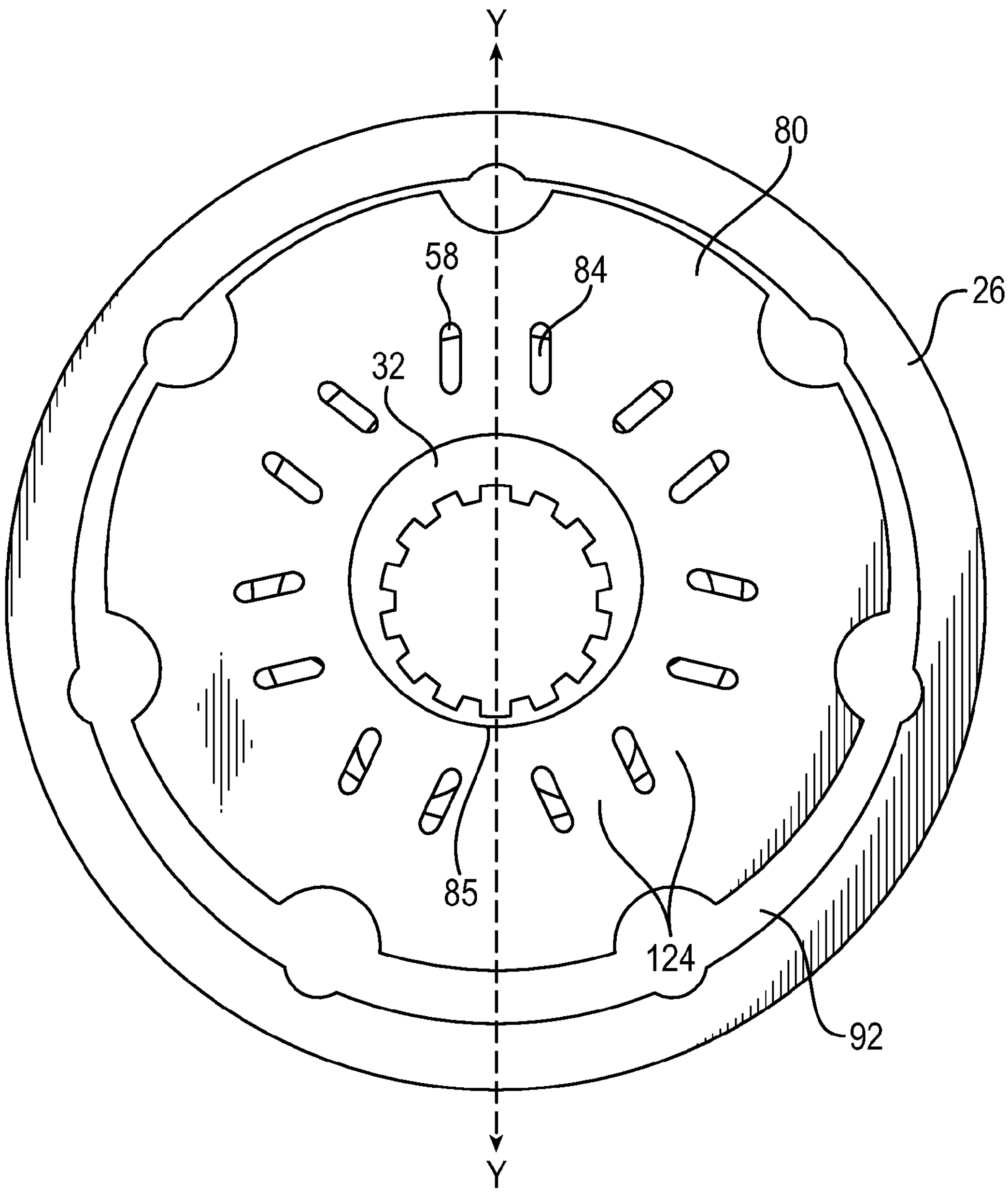
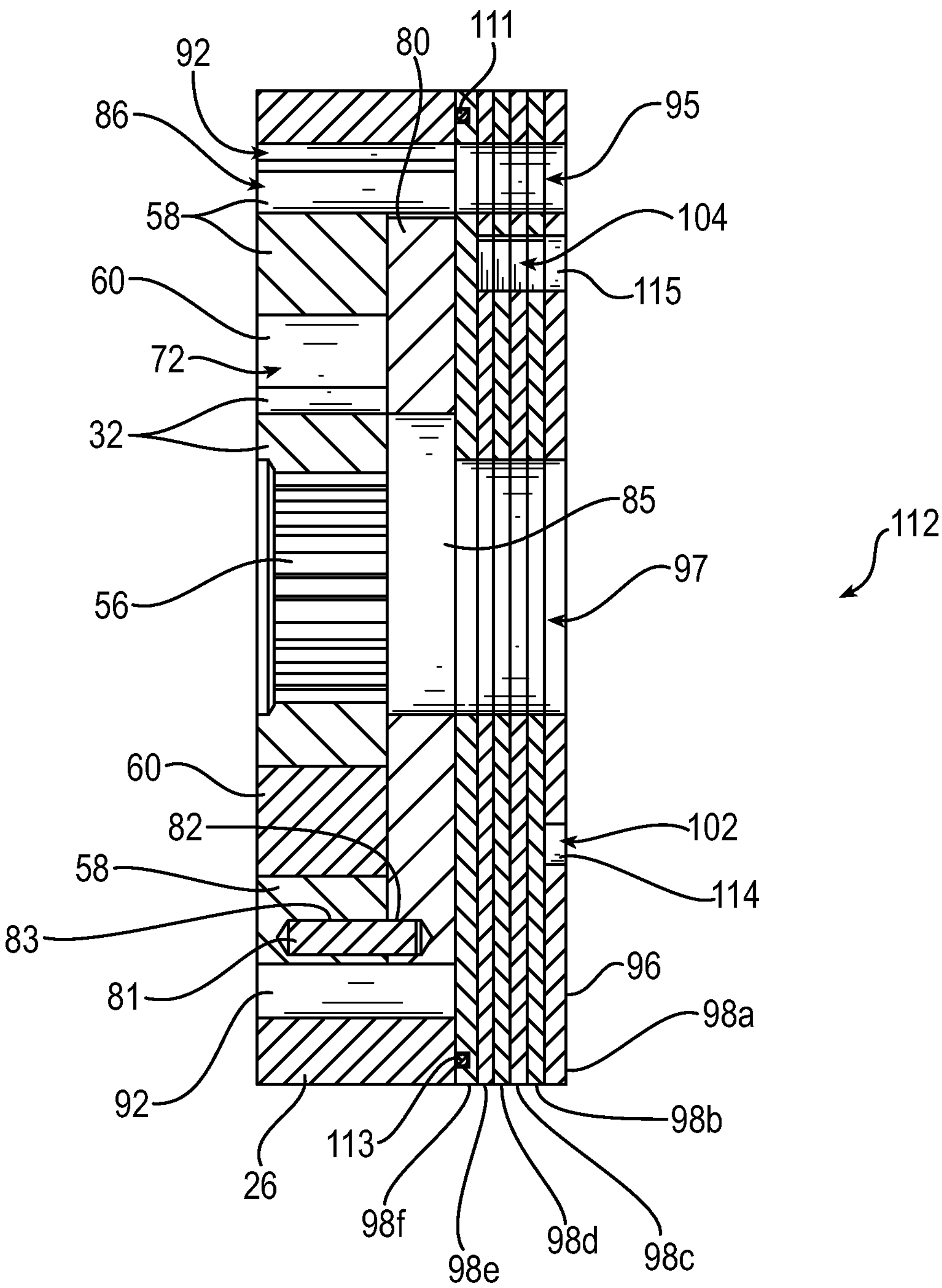


FIG. 6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98a
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98f
98e
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FIG. 7

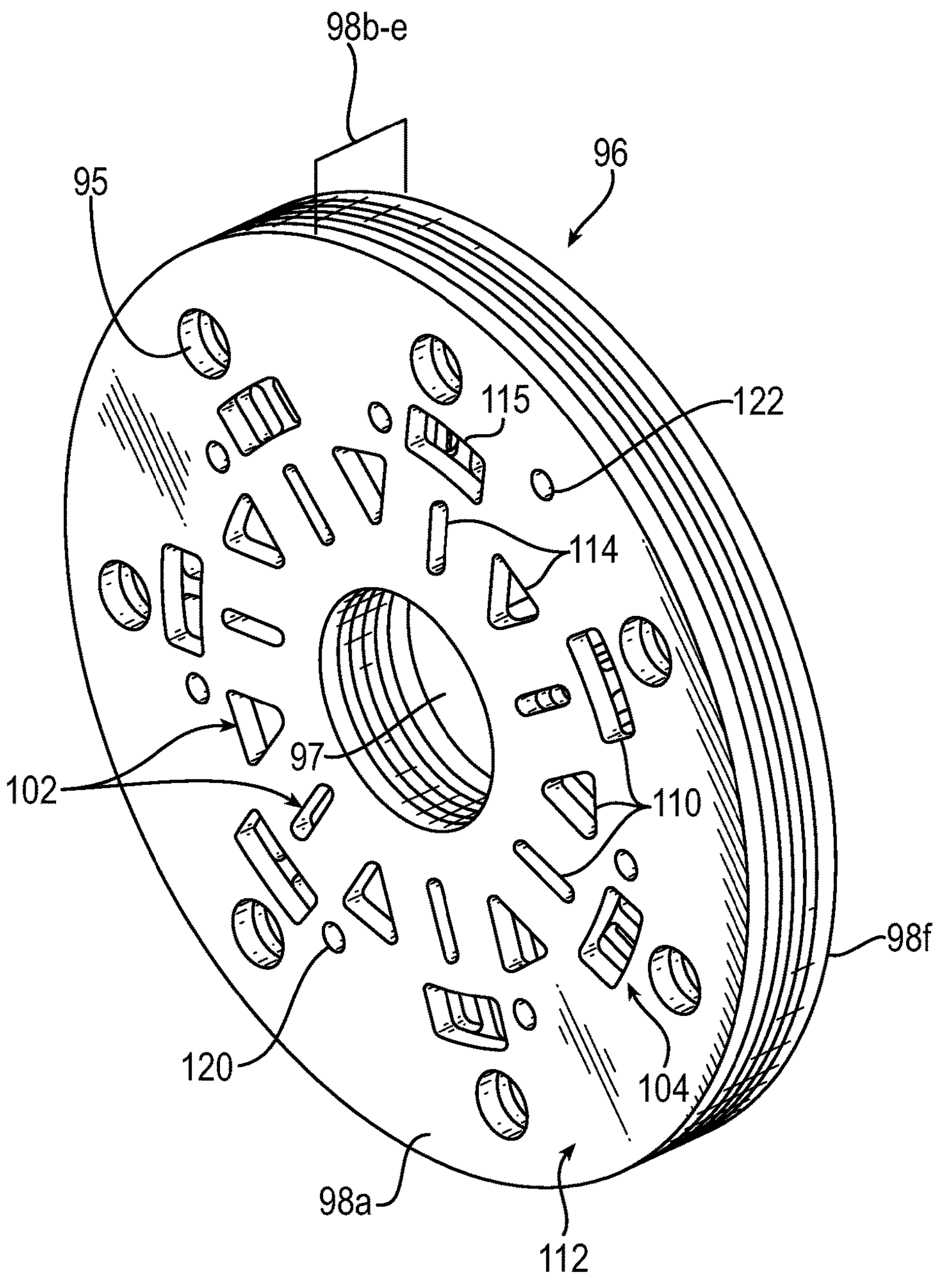


FIG. 8

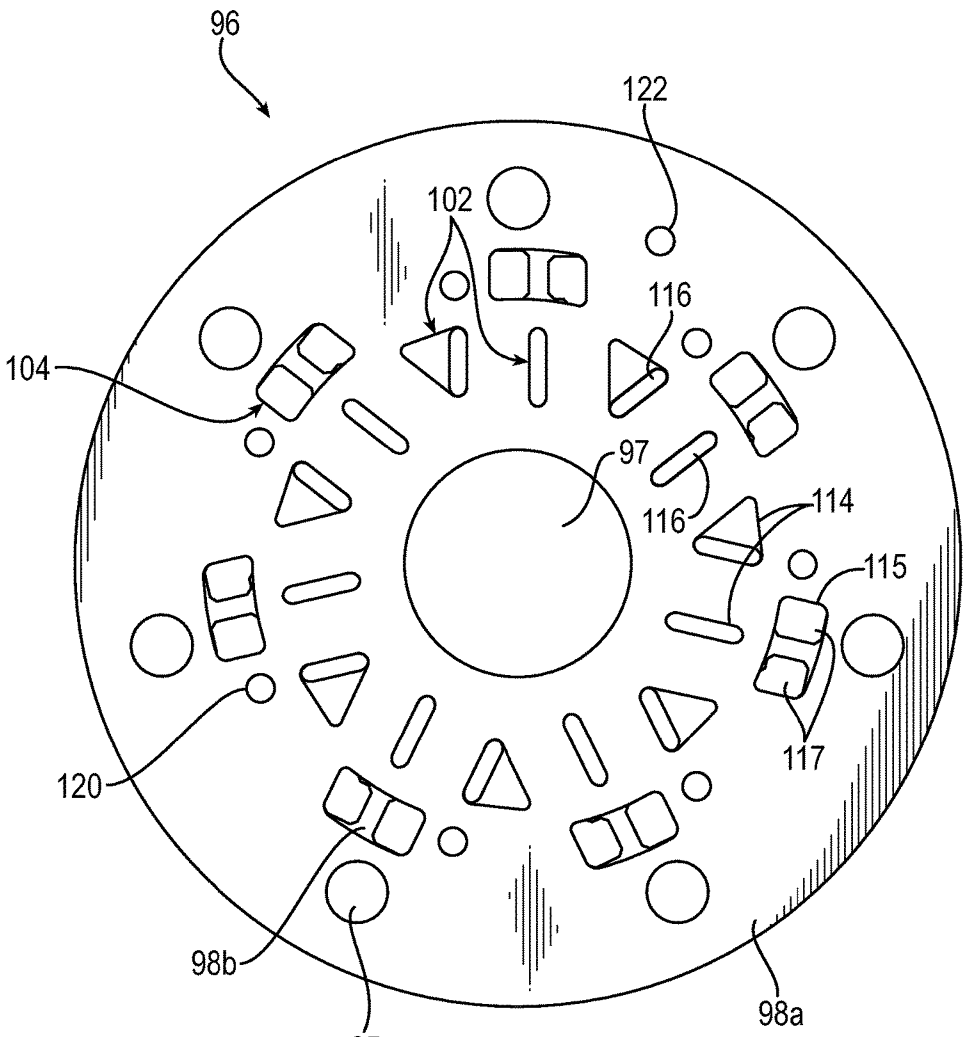


FIG. 9

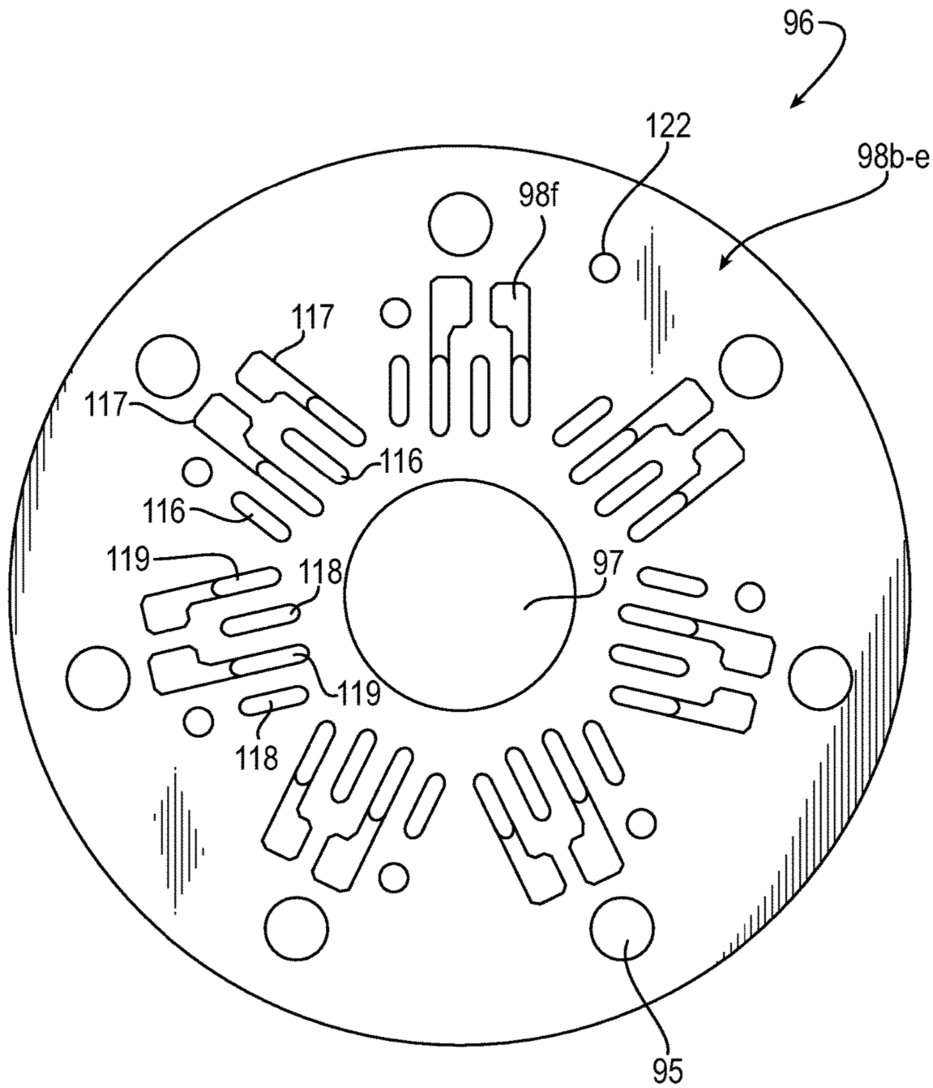


FIG. 10

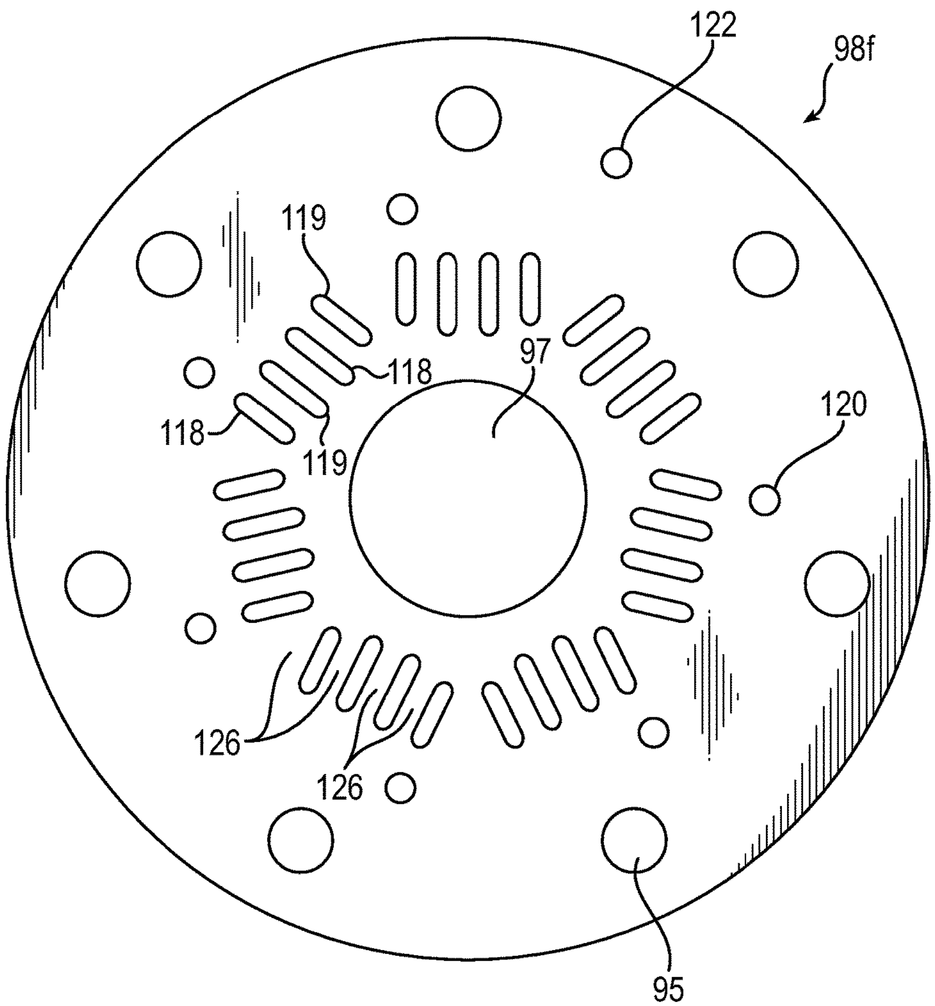


FIG. 11

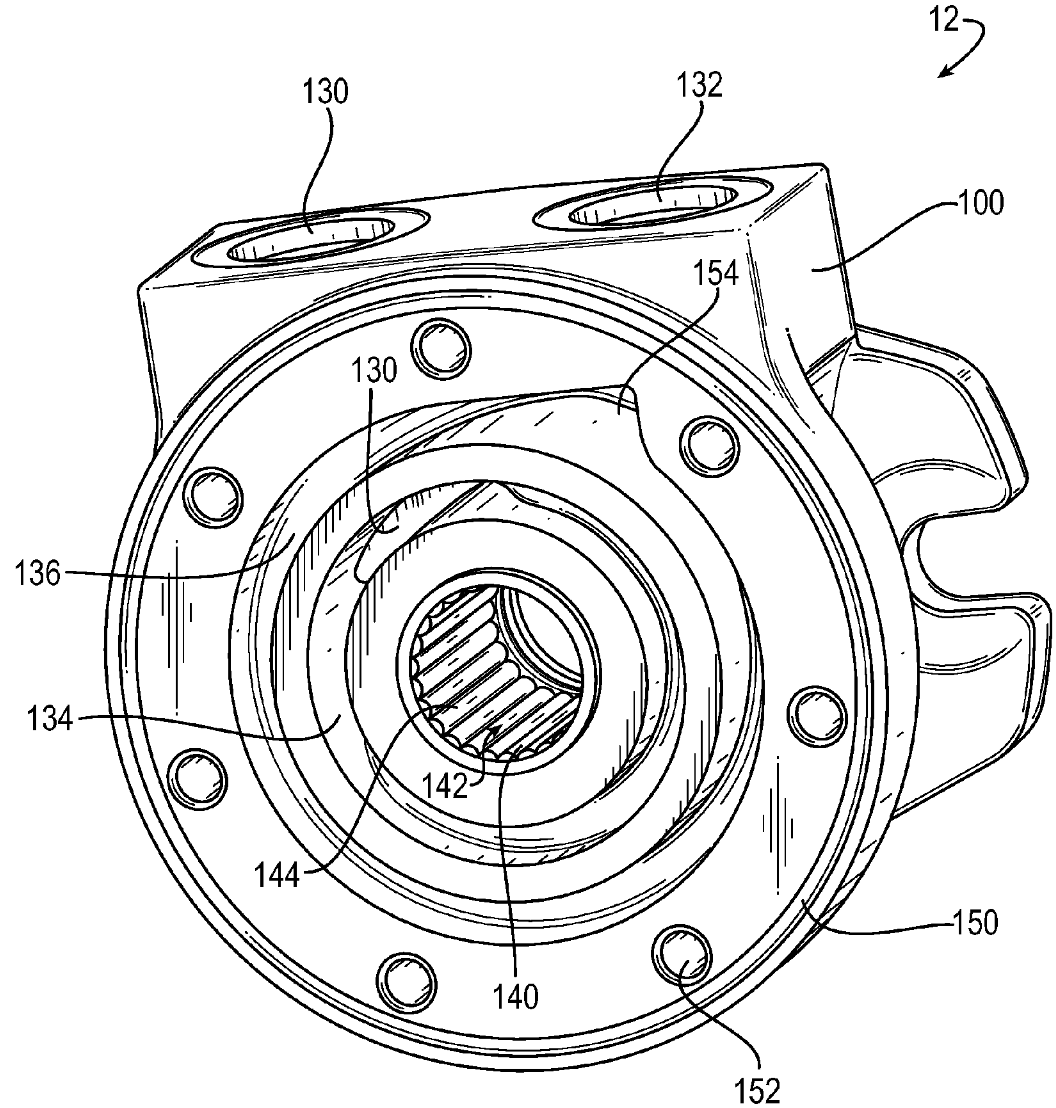


FIG. 12

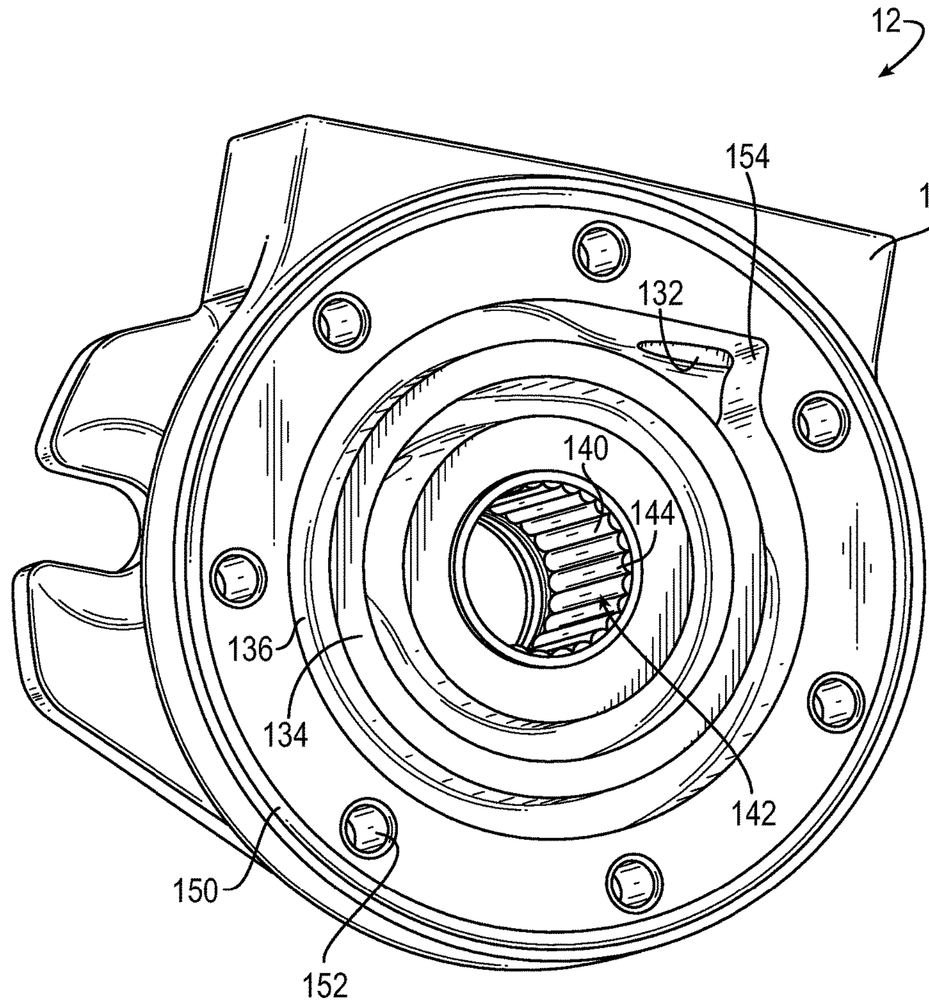


FIG. 13

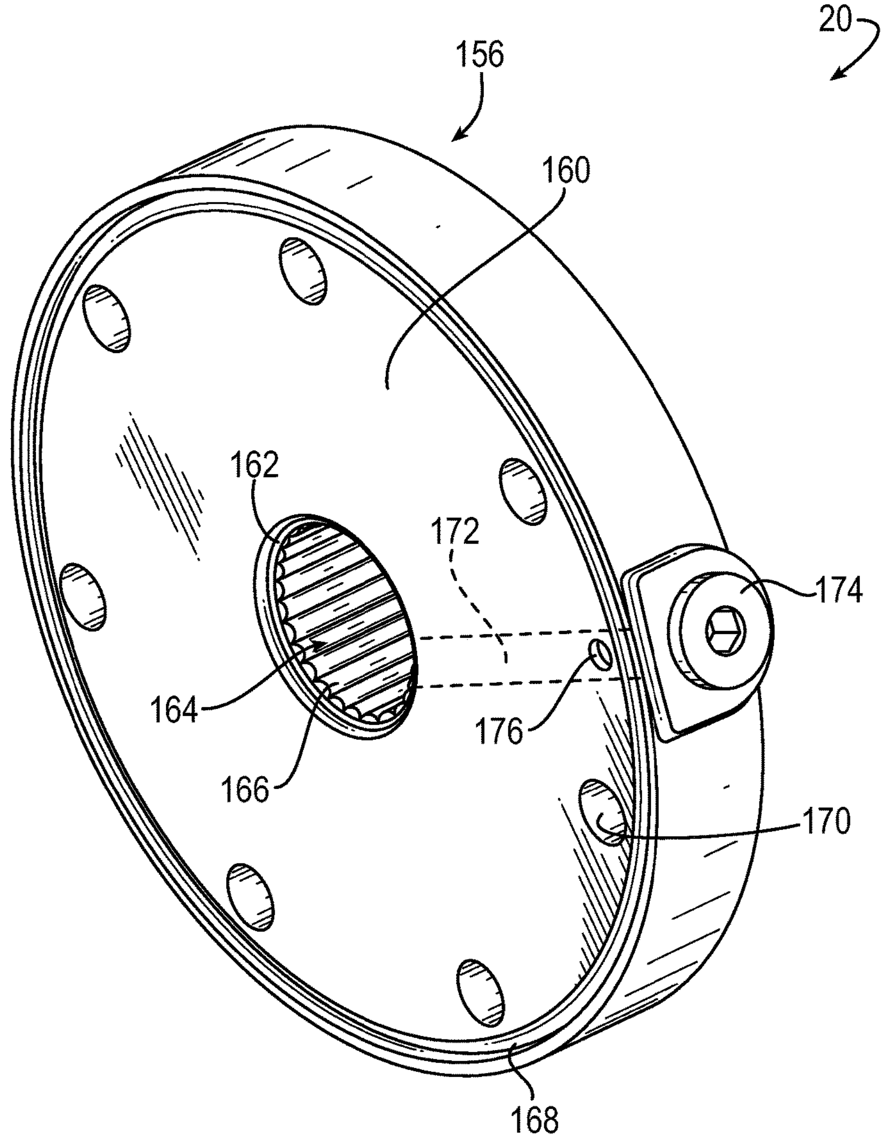


FIG. 14

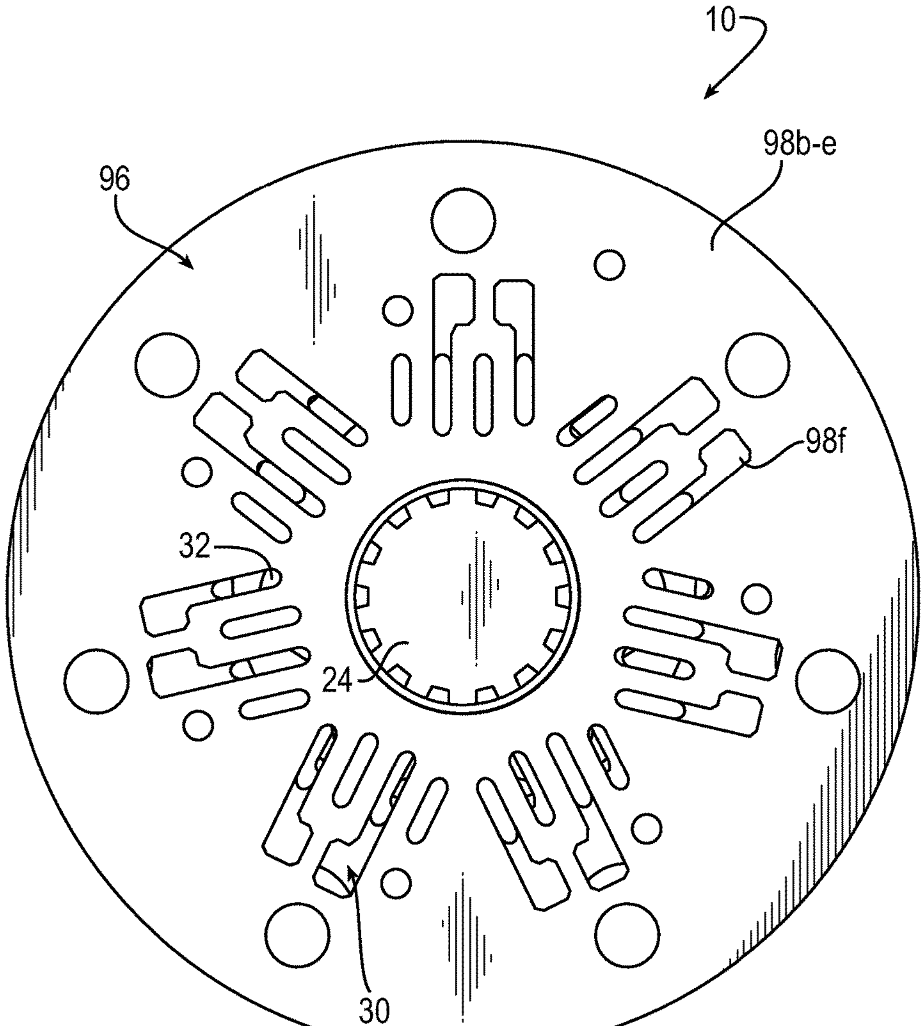
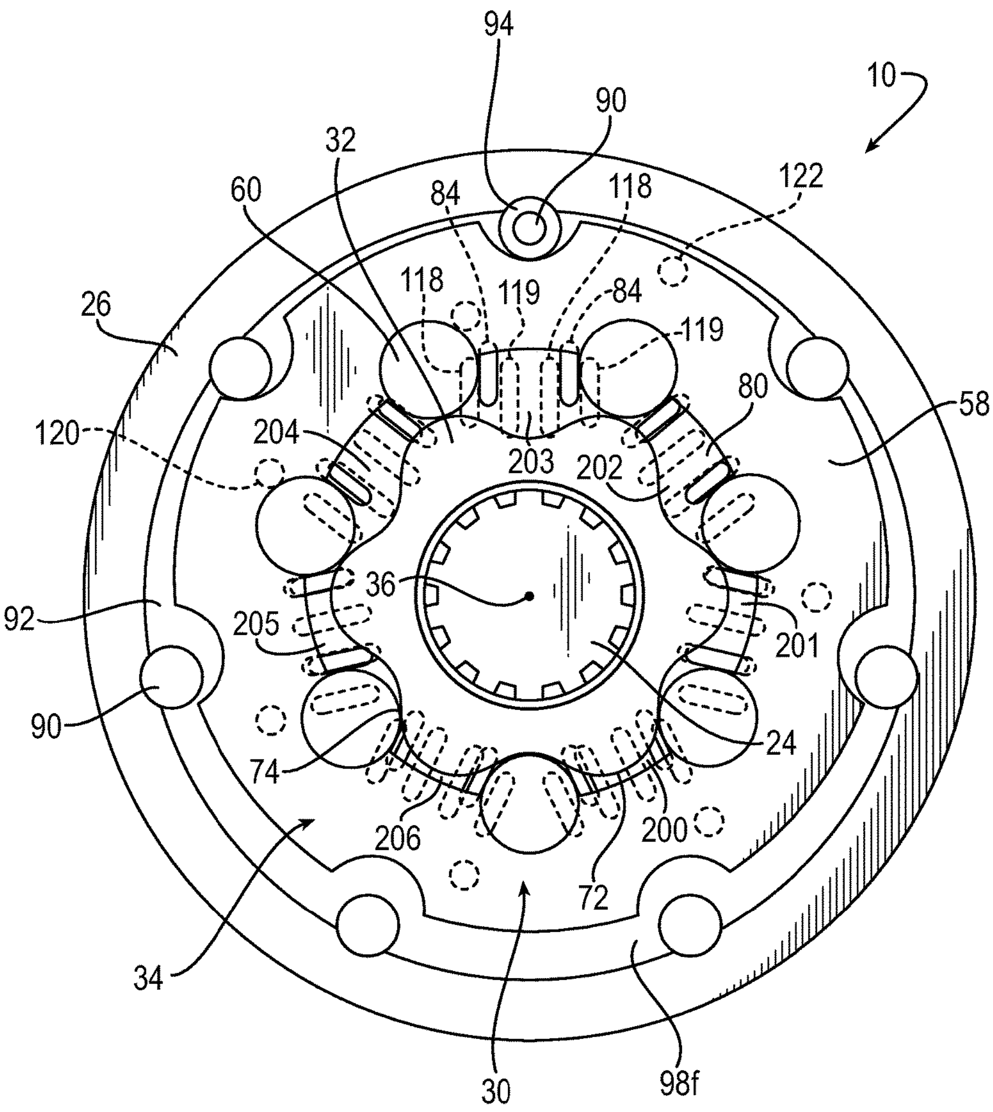


FIG. 15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205
201
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24
74
206
200
72
34
30
98f

FIG. 16

HYDRAULIC MOTOR

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/716,873 filed Oct. 22, 2012, which is hereby incorporated herein by reference.

FIELD OF INVENTION

The present invention relates generally to hydraulic motors, and more particularly to hydraulic motors having a rotating rotor and an orbiting ring and roller vanes.

BACKGROUND

Hydraulic systems include engines, hydraulic pumps, and hydraulic motors, and are used for consumer and commercial products, industrial processes, and systems for vehicles. One example of a hydraulic motor, used for example in the drive system of zero-turn-radius mowers, is a geroller motor. A geroller motor may be driven, for example, by a variable displacement piston pump to provide rotary motion for rotating a mower drive wheel.

Geroller motors typically have one of two types of shafts. A geroller motor having a flexible shaft that wobbles, such as a splined "dog-bone" shaft, typically has one moving member, such as an inner rotor, that both rotates and orbits with respect to a central longitudinal axis extending longitudinally through the geroller motor. Alternatively, a geroller motor having a straight-through shaft supported by bearings on both ends often includes two revolving members, an outer ring and an inner rotor. The outer ring is disposed about and interengages with the inner rotor. The members are received within a locating ring or casing. Movement of the members with respect to one another, and with respect to the casing, allows for full stationary contact between the shaft and the inner rotor. This contact allows the shaft to be extended through the hydraulic motor for mounting auxiliary devices, such as parking brakes, auxiliary drive functions, or encoders for speed readout or closed loop control.

Straight-through shaft geroller motors often operate at high temperatures and pressures where structural integrity is an important factor. The arrangement of the members and straight shaft allows for low internal pressure drop, high mechanical efficiency, high flow capability, and high torque output.

SUMMARY OF INVENTION

The present invention provides a hydraulic geroller (aka gerotor) motor, wherein an inner rotor of a revolving group has a plurality of lobes circumferentially spaced along an outer periphery of the inner rotor, and an orbiter of the revolving group includes an orbiting ring and rounded vane portions preferably formed by roller vanes contained in inner recesses of the orbiting ring for common orbiting with the orbiting ring about the fixed longitudinal axis. The orbiter also has fixed for orbiting therewith, fluid windows for directing fluid from the fluid ports to the revolving group. The windows may be formed in an integral portion of the orbiter or in a valve plate mounted for common orbiting with the orbiting orbiter. The valve plate cooperates with a stationary commutator plate or assembly to provide an efficient arrangement for the delivery and exhaust of hydraulic pressure fluid to and from the hydraulic motor.

According to one aspect of the invention, provided is a hydraulic motor including a motor housing having a fluid inlet and a fluid outlet, an output shaft mounted within the motor housing for rotation about a fixed longitudinal axis, and a revolving group for revolving in respect to the fixed longitudinal axis. The revolving group includes an inner rotor mounted on the output shaft, the inner rotor having a plurality of lobes circumferentially spaced along an outer periphery of the inner rotor, an orbiting ring surrounding the inner rotor, the orbiting ring having a plurality of inner recesses circumferentially spaced along an inner periphery of the orbiting ring, and a plurality of roller vanes disposed between the inner rotor and the orbiting ring, the roller vanes being received in the inner recesses for common orbiting with the orbiting ring about the longitudinal fixed axis. The orbiting ring and roller vanes orbit about the inner rotor and in respect to the fixed longitudinal axis.

The hydraulic motor may further include a valve plate integral with the orbiting ring, the valve plate having a plurality of fluid windows for enabling fluid communication between the fluid inlet and outlet and the revolving group. The hydraulic motor may further include a commutator assembly coupled to the motor housing, the commutator assembly including a plurality of commutator plates each having a plurality of apertures forming inlet and outlet ports for enabling fluid communication between the fluid inlet and outlet and the valve plate.

The lobes and the roller vanes may interengage to define a plurality of expanding and contracting volume chambers where rotation of the inner rotor may cause the volume chambers to change volume. The hydraulic motor may also include a commutator plate mounted to the housing, the commutator plate in fluid communication with the fluid inlet and outlet, and a valve plate configured to orbit with the orbiting ring, where the valve plate includes fluid windows that align with the inlet and outlet ports in the commutator plate to cause the volume chambers to expand and contract.

The inner rotor may have an internal bore having a plurality of rotor splines configured to engage shaft splines on the output shaft. The orbiting ring may have a plurality of outer recesses circumferentially spaced along an outer periphery of the orbiting ring. Each outer recess may interengage with a radially-extending protrusion spaced circumferentially about an inner periphery of the motor housing to constrain the orbiting ring from rotating. The radially-extending protrusion may be a motor bolt extending into the motor housing and located between an inner periphery of the motor housing and the outer periphery of the orbiting ring.

The inner periphery of the orbiting ring may be substantially cylindrical. The roller vanes may be substantially cylindrical, and the outer periphery of the inner rotor may be substantially trochoidal for maintaining contact with the substantially cylindrical roller vanes.

According to another aspect of the invention, provided is another hydraulic motor including a motor housing and a revolving group for revolving in respect to the motor housing. The revolving group includes an inner rotor for rotating in respect to the motor housing, the inner rotor having a plurality of lobes circumferentially spaced along an outer periphery of the inner rotor, and an orbiter surrounding the inner rotor, the orbiter having a plurality of radially-extending rounded portions circumferentially spaced along an inner periphery of the orbiter, and the orbiter also having a plurality of radially outwardly extending fluid windows. The orbiter orbits around the inner rotor in respect to the motor housing. The lobes glide against the radially-extending rounded portions to define a plurality of volume chambers. The orbiter has fixed for movement therewith a plurality of radially outwardly extending fluid windows aligned with the plurality of volume chambers. Spacing between the plurality of fluid windows and the plurality of radially-extending rounded portions remains constant during rotation of the inner rotor and orbiting of the orbiter, thereby preventing direct fluid communication between the volume chambers.

The hydraulic motor may further include a valve plate mounted to the orbiter and having the plurality of fluid windows, where a longitudinal center axis of each of the valve plate and the orbiter follow the same path in orbiting about a fixed longitudinal center axis of the inner rotor, thereby preventing alignment of each fluid window with more than one volume chamber at a time. The lobes and the radially-extending rounded portions glide against one another and interengage at shifting contact points between the lobes and the radially-extending rounded portions, where no shifting contact point passes over a fluid window in the valve plate.

The orbiter may include an orbiting ring surrounding the inner rotor, the orbiting ring having a plurality of inner recesses circumferentially spaced along an inner periphery of the orbiting ring, and a plurality of roller vanes disposed between the inner rotor and the orbiting ring, the roller vanes being received in the inner recesses and forming the radially-extending rounded portions of the orbiter. The hydraulic motor may further include a plurality of motor bolts located between an inner periphery of the motor housing and an outer periphery of the orbiter, where the motor bolts constrain the orbiter from rotating. The hydraulic motor may further include sleeves surrounding the motor bolts for interengaging with the orbiter. The radially-extending rounded portions circumferentially spaced along the inner periphery of the orbiter may be substantially semi-cylindrical portions, and the inner rotor may have a substantially trochoidal outer periphery for remaining in continuous contact with the substantially semi-cylindrical portions of the orbiter.

According to yet another aspect of the invention, a method is provided for utilizing pressurized fluid to produce rotary motion. The method includes the steps of injecting fluid into a motor housing and directing the fluid through a plurality of fluid ports in a commutator assembly coupled to the motor housing, selectively transmitting the fluid through fluid windows of a revolving valve, the revolving valve further including N rotor lobes on an inner rotor for rotating about a fixed longitudinal axis and for interengaging with N+1 radially-extending rounded portions of an orbiter surrounding the inner rotor to form N+1 sealed variable volume chambers therebetween, wherein the fluid windows orbit about the fixed longitudinal axis, selectively expanding some of the sealed volume chambers by providing a pressure differential between the sealed volume chambers to produce a rotary motion of the inner rotor, thereby driving an output shaft interengaged with the rotor, withdrawing through the fluid windows of the revolving valve means the fluid from the sealed volume chambers that have reached their maximum expansion, and exhausting the fluid from the motor housing.

The method may further include the steps of orbiting the orbiter about the fixed longitudinal axis during the rotation of the inner rotor, and preventing rotation of the orbiter about the fixed longitudinal axis via interengagement of the orbiter with a plurality of rods extending into the motor housing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front perspective view of an exemplary hydraulic motor according to the invention, with a forward section and output shaft removed.

FIG. **2** is a front perspective view of the exemplary hydraulic motor of FIG. **1** with the forward section and output shaft installed.

FIG. **3** is a rear perspective view of the exemplary hydraulic motor of FIG. **2**.

FIG. **4** is a front perspective view of an intermediate section of the exemplary hydraulic motor of FIG. **1** showing a revolving group.

FIG. **5** is a front view of the intermediate section.

FIG. **6** is a rear view of the intermediate section.

FIG. **7** is a cross-sectional view of the intermediate section and commutator assembly, shown at the y-plane of FIG. **6**.

FIGS. **8-11** are various views of exemplary commutator plates of the commutator assembly for use in the exemplary hydraulic motor of FIG. **1**.

FIGS. **12** and **13** are front perspective views of the rear casing of the hydraulic motor of FIG. **1**.

FIG. **14** is a rear perspective view of the forward housing of the hydraulic motor of FIG. **1**.

FIG. **15** is a rear view of the commutator assembly and revolving group.

FIG. **16** is a front view of the revolving group showing hidden fluid ports and fluid windows in broken lines.

DETAILED DESCRIPTION

The principles of the present application have general application to hydraulic motors, and particular application to a geroller motor and method of utilizing pressurized fluid to produce rotary motion, and thus will be described below chiefly in this context. The geroller motor may be suitable for use in driving systems such as in conveyors, winches, turrets, or hydraulic transmission systems of vehicles, such as zero-turn-radius mowers. It will of course be appreciated, and also understood, that the principles of the invention may be useful in other applications, in particular in pumps or compressor systems.

Referring now to the drawings in detail, and initially to FIGS. **1-3**, an exemplary hydraulic motor is illustrated at reference numeral **10**. The hydraulic motor **10** includes a plurality of axially aligned longitudinally adjacent sections. The sections include a rear commutator and bearing section **12** at the fluid delivery and exhaust end or rear end **14** of motor **10**, an intermediate geroller section **16** located axially adjacent the section **12**, a forward bearing section **20** located adjacent the work end or forward end **22** of the motor **10**, and a work or output shaft **24** that is coaxially received within the sections **12**, **16**, and **20**.

Turning to FIGS. **4-6**, the intermediate geroller section **16** includes a center housing **26** that receives a geroller set. The center housing **26** may be any suitable material such as ductile iron, gray iron, compressed powdered metal, etc. The geroller set, such as the revolving group **30**, receives and is acted upon by fluid, such as hydraulic fluid, directed into the hydraulic motor **10** from an outside source, such as a hydraulic pump. The revolving group **30** includes two revolving members, an inner rotor **32** and an orbiter **34**, which revolve in respect to one another within the center housing **26** and in respect to a fixed longitudinal axis **36**. As will herein be understood, revolving motion includes each of rotational and orbital motion. The inner rotor **32** is rotatable about the fixed longitudinal axis **36**, which extends longitudinally through the output shaft **24** and is coincident with respect to a center longitudinal axis of the motor **10**. The orbiter **34** surrounds the inner rotor **32** and orbits about the inner rotor **32** and in respect to the fixed longitudinal axis **36**.

The inner rotor **32**, which may be any suitable material such as steel, etc., includes a plurality of teeth, such as lobes **44**, circumferentially spaced along an outer periphery **46** of the inner rotor **32**. The lobes **44** define therebetween a plurality of radially inwardly directed outwardly open pockets **50** for receiving portions of the orbiter **34**. The inner rotor **32** also includes a plurality of radially inwardly extending rotor splines **52** circumferentially spaced along an inner periphery **54** of the inner rotor **32**. The inner periphery **54** defines an inner bore **56** extending through the inner rotor **32** for receiving the output shaft **24**. The rotor splines **52** are configured to engage with shaft splines **55** circumferentially spaced about a forward end **57** of the output shaft **24**. The shaft **24** may be any suitable material such as hardened machined steel, etc. It will be appreciated that in a situation where the motor **10** acts as a hydraulic pump, the output shaft **24** may act as an input or driving member in contrast to acting as an output or driven shaft in a motor.

The orbiter **34** includes an orbiting ring **58** surrounding and for orbiting about the inner rotor **32**. The orbiter **34** also includes a plurality of roller bearings, such as roller vanes **60**, received in the orbiting ring **58** for common orbiting with the orbiting ring about the longitudinal fixed axis. The orbiting ring **58**, which may be any suitable material such as steel, etc., includes a plurality of inner recesses **62** circumferentially spaced along an inner periphery **64** of the orbiting ring **58**. The orbiting ring **58** also includes a plurality of outer recesses **66** circumferentially spaced along an outer periphery **68** of the orbiting ring **58**.

Received in the inner recesses **62** are the plurality of roller vanes **60**, which may be any suitable material such as machined steel, etc. The roller vanes **60** seal fluid between themselves and the orbiting ring **58**. As shown, each inner recess **62** is substantially cylindrical and has a diameter greater than an external diameter of a roller vane **60**. Each inner recess **62** is configured to receive and retain a respective roller vane **60** via a circumferential extent greater than 180-degrees extending beyond an equator of the roller vane **60**, conforming to and securing the roller vane **60** in the inner recess **62**. The configuration allows each roller vane **60** to rotate within and in respect to each respective inner recess **62**. A semi-cylindrical portion **70** of each roller vane **60** extends radially outwardly from a substantially cylindrical inner periphery **64** of the orbiting ring **58**. It will be appreciated that the circumferential extent of the inner recesses **62** may instead be lesser than 180-degrees, and the vanes **60** may instead be retained in the recesses via dimensional tolerancing between the orbiter **34** and the inner rotor **32**.

As compared with other hydraulic motors, the arrangement of the lobes **44** and roller vanes **60** provides for increased manufacturing efficiency. Due to the generated nature of a lobed profile, a profile grind to form a lobed internal periphery of a part is significantly more difficult, expensive, and inefficient to perform than a profile grind to form a lobed outer periphery of a part. By including the lobes **44** on the outer periphery **46** of the inner rotor **32** rather than on the internal periphery **64** of the orbiting ring **58**, the difficult machining operations of an internal profile grind to form the generated lobed profile is eliminated.

As a result of the lobed profile of the outer periphery **46** of the inner rotor **32**, the roller vanes **60** and the lobes **44** of the inner rotor **32** interengage with one another to define a plurality of expanding and contracting volume chambers **72** therebetween. Generally, rotation of the inner rotor **32** and orbiting of the orbiter **34** with respect to one another causes the volume chambers **72** to change volume. More particularly, to form the volume chambers **72**, the inner rotor **32** includes N lobes **44**, such as the illustrated six lobes **44**. The lobes **44** define therebetween N pockets **50**, such as the illustrated six pockets **50**. The lobed outer periphery **46** of the inner rotor **32** is trochoidal in shape to provide a curve along which the lobes **44** may remain in continuous contact with the roller vanes **60**. The lobes **44** and roller vanes **60** may remain in contact at shifting contact points **74** as the inner rotor **32** and the orbiter **34** revolve with respect to one another and as the roller vanes **60** rotate within the inner recesses **62**.

The orbiter **34** may include N+1 inner recesses **62**, such as the illustrated seven inner recesses **62** on the orbital ring **58**, corresponding to N+1 roller vanes **60**, such as the illustrated seven roller vanes **60**, received therein. The roller vanes **60** may be spaced circumferentially about the inner periphery **64** of the orbiting ring **58** so as to provide the continuous contact, or continuous conjugate interaction, between the roller vanes **60** and the lobes **44** and pockets **50** of the inner rotor **32**. The interengagement of the inner rotor **32** with the orbiter **34** may define N+1 volume chambers **72**, such as the illustrated seven expanding and contracting volume chambers **72**. It will be appreciated that the orbiter **34** may instead include any suitable number of inner recesses **62** corresponding to a suitable number of lobes **44** of the inner rotor **32**.

With this arrangement, each lobe **44** may glide against the roller vanes **60** as the inner rotor **32** rotates and as the orbiting ring **58** orbits about the rotor **32**. Each roller vane **60** may roll successively from lobe **44**, to adjacent pocket **50**, to next adjacent lobe **44**, and so on around the outer periphery **46** of the inner rotor **32**. Hydraulic fluid directed into the revolving group **30** may be sealed between each pair of adjacent roller vanes **60**, a portion of the orbiting ring **58** extending therebetween, and the lobe or portions of lobes **44** gliding against the two adjacent roller vanes **60**.

The hydraulic fluid may be directed into and out of the continually expanding and contracting volume chambers **72** via radially outwardly extending fluid windows **84** fixed for movement with the orbiter **30**. A valve plate **80** including the fluid windows **84** may be integral with the orbiter **34**, and more particularly with the orbiting ring **58**. The valve plate **80** may be any suitable material such as compressed powdered metal, machined steel, etc. The valve plate **80** may be mounted to the orbiting ring **58** via attachment means, such as via engagement pins **81** or other suitable attachment means such as bolting, brazing, or soldering. As shown, the pins **81** are received in inwardly axially extending recesses **82** of the valve plate **80** and corresponding inwardly axially extending recesses **83** of the orbiting ring **58**. A longitudinal center axis of each of the valve plate **80** and the orbiter **34** may follow the same path in orbiting about the fixed longitudinal center axis **36**. A center bore **85** may extend axially through the plate **80** for receiving the output shaft **24**.

The radially outwardly extending fluid windows **84** extend through the valve plate **80** for directing the hydraulic fluid into the volume chambers **72**. As shown, a pair of fluid windows **84** aligns with each volume chamber **72**. Each respective pair of fluid windows **84** may remain aligned between a respective pair of roller vanes **60** due to the valve plate **80** being integral with the orbiting ring **58**. The spacing between the fluid windows **84** and roller vanes **60** prevents fluid communication between volume chambers **72**. Specifically, during the combination of rotating and orbiting of the members of the revolving group **30**, no fluid window **84** may be caused to align with more than one volume chamber **72** at a time. Further, no shifting contact point **74** between the lobes **44** and pockets **50** and the roller vanes **60** may be caused to align with a fluid window **84**, thereby also preventing fluid from moving between volume chambers **72**.

It should be noted that were the relationship between the fluid windows **84** and the roller vanes **60** not constant, each shifting contact point **74** would align with a fluid window **84** at some point in the revolution of the revolving members, i.e., the inner rotor **32** and the orbiter **34**. For instance, if the roller vanes **60** were received in the orbiting ring **58** and the valve plate **80** was integral with the rotating inner rotor **32**, rather than with the orbiting ring **58**, the combination of rotating of the inner rotor **32** and orbiting of the orbiting ring **58** would cause the contact points **74** to align with the fluid windows **84**. Alternatively, if the roller vanes **60** were received in the inner rotor **32** and the valve plate **80** was integral with the orbiting ring **58**, the contact points **74** would again be caused to align with the fluid windows **84**.

Turning now to the center motor housing **26**, constraint means are provided for constraining rotation of the orbiter **34**, and particularly for constraining rotation of the orbiting ring **58**, about the fixed longitudinal axis **36**. The center motor housing **26** may include a plurality of recesses **86** spaced circumferentially about an inner periphery **88** of the center housing **26**. Received in the recesses **86** may be pins, such as motor bolts **90**, which may be any suitable material such as steel, etc. As shown, the motor bolts **90** may extend axially through each of the forward and intermediate sections **12**, **16** and into the rear section **20** for affixing the sections **12**, **16**, **20** together. The inner recesses **86** may open radially inwardly to an outer chamber **92** defined by the outer periphery **68** of the orbiting ring **58** and the inner periphery **88** of the center housing **26**. The inner recesses **86** may be configured such that a portion of each of the motor bolts **90** extends radially inwardly beyond the inner periphery **88** of the center housing **26** to form radially inwardly extending protrusions. The motor bolts **90** may interengage with the outer recesses **66** of the orbiting ring **58**, which have diameters larger than the diameter of the motor bolts **90**. Accordingly, the interengagement between the outer recesses **66** and the motor bolts **90** may constrain the orbiting ring **58** from rotating, and thereby allow the orbiting ring **58** to orbit but not rotate about the center axis **36**. It will be appreciated that the motor bolts **90** may instead be received in other holes or recesses (not shown) of the center motor housing **26**, and additional vanes, similar to the roller vanes **60** may instead be received in the inner recesses **86** for interengaging with the orbiting ring **58**. It will also be appreciated that one or more of the housings, such as the center housing **26**, may be unitary with one or more of the other housings and collectively may be referred to as a housing.

The center motor housing **26** may include N+1 recesses **86**, such as the illustrated seven recesses **86**, corresponding to N+1 outer recesses **66** of the orbiting ring **58**, such as the illustrated seven recesses **66**. One of ordinary skill will realize that the orbiting ring **58** may have an increased structural strength where each outer recess **66** is circumferentially spaced between a pair of inner recesses **62**. It will be appreciated that the center motor housing **26** may instead include any suitable number of inner recesses **86** corresponding to a suitable number of outer recesses **66** of the orbiting ring **58**.

The motor bolts **90** may also include sleeves **94**, such as the sleeve **94** shown at the motor bolt **90** located at a twelve-o'clock location in FIG. **5**. The sleeves **94** may be any suitable material such as machined steel, etc. The sleeves **94** may surround at least a portion of one or more motor bolts **90** extending through the intermediate housing section **16** to engage with the outer recesses **66** of the orbiting ring **58**. The sleeves **94** may rotate about the bolts **90**, allowing for the orbiting ring **58** to glide against the sleeves **94**.

Referring now to FIGS. **7-13**, the rear commutator and bearing section **12** of FIGS. **1-3** includes a commutator assembly **96** and a rear motor housing **100**. The commutator assembly **96** may be coupled, such as mounted, to the rear motor housing **100**, and also to the center motor housing **26** via pins, such as the motor bolts **90**, extending through motor bolt holes **95** in the commutator assembly **96**. The commutator assembly **96** is held stationary in relation to the rotation and orbiting of the revolving group **30**. The motor bolt holes **95** are spaced circumferentially about a radially outward extent of the commutator assembly **96**. It will be appreciated that other suitable methods of mounting may be used, such as brazing or soldering. A center bore **97** extends axially through the commutator assembly **96** for receiving the shaft **24**.

The commutator assembly **96** includes a series of apertured individual plates **98***a-f*, which may be any suitable material such as steel, low to medium carbon steel, etc. The plates **98***a-f* are affixed together in order to form two separate sets of fluid ports **102**, **104** for aligning with the fluid windows **84** of the orbiting valving means or valve plate **80**. One of the sets of fluid ports is a set of high pressure fluid ports **102** for directing only high pressure hydraulic fluid through the motor **10**. The other of the sets of fluid ports is a set of low pressure fluid ports **104** for directing only low pressure hydraulic fluid through the motor **10**. The fluid ports **102**, **104** direct fluid to the fluid windows **84** as the valve plate **80** orbits integral with the orbiter **34**, thereby placing the fluid windows **84** into alignment with the fluid ports **102**, **104**. It will be appreciated that depending on the desired rotational direction of the output shaft **24**, the fluid ports **102** may direct low pressure and the fluid ports **104** may direct high pressure.

The commutator plates **98***a-f* of the commutator assembly **96** may be aligned together via peripherally-spaced pins (not shown) and then soldered to one another, although any other suitable method of affixation, such as brazing or bolting, may be utilized. The commutator assembly **96** specifically includes one rear plate **98***a*, affixed adjacent four identical intermediate plates **98***b-e*, affixed adjacent one forward plate **98***f*. The rear plate **98***a* is located adjacent the rear motor housing **100**. The forward plate **98***f* is located adjacent the valve plate **80** and the center housing **26** (FIG. **4**). A seal ring **111** may be disposed in an annular groove **113** of the forward plate **98***f*, and thus between the forward plate **98***f* and the center housing **26**, for preventing hydraulic fluid contained therein from leaking out of the motor **10**. As shown, each plate **98***a-f* has a plurality of fluid apertures **110** for aligning to form the fluid ports **102**, **104**. Note that each of FIGS. **9-11** illustrates views of the commutator assembly **96** from the assembly's forward side **112**. FIG. **9** shows a view of all of the plates **98***a-f*, FIG. **10** shows a view of only plates **98***b-f* with plate **98***a* removed, and FIG. **11** shows a view of only plate **98***f* with plates **98***a-e* removed.

Each commutator plate **98***a-f* may include N+1 separate sets of high pressure apertures and low pressure apertures, such as the illustrated seven sets of apertures **114** and **115**, **116** and **117**, **118** and **119**, for aligning in respect to the N+1 volume chambers **72**. The sets of apertures extend through each respective plate **98***a-f* for separating high pressure fluid being delivered to the motor **10** from low pressure fluid being exhausted from the motor **10**. The high pressure apertures **114**, **116**, **118** align to form the high pressure fluid ports **102**, and the low pressure apertures **115**, **117**, **119** align to form the low pressure fluid ports **104**. Each commutator plate **98***a-f* may also include pin apertures **120** for receiving the peripherally-spaced pins for aligning the plates **98***a-f* in respect to one another. An auxiliary aperture **122** may extend through each plate **98***a-f* and align with the outer chamber **92** located between the orbiting ring **58** and the center housing **26**. Alignment of the auxiliary apertures **122** may allow for the motor **10** to be configured as a two-chamber or a three-chamber motor, to be discussed in greater detail later.

The rear commutator plate **98***a* includes high pressure apertures **114**, arranged circumferentially about a radially inward extent of the rear commutator plate **98***a*, and low pressure apertures **115**, arranged circumferentially about a radially outward extent of the rear commutator plate **98***a*. The intermediate commutator plates **98***b-e* include circumferentially arranged alternating sets of four high and low pressure apertures **116**, **117**. As shown, the arrangement of each set of apertures **116**, **117** alternates from left to right in the order of high pressure aperture **116**, low pressure aperture **117**, high pressure aperture **116**, and low pressure aperture **117**. The low pressure apertures **117** of the intermediate commutator plates **98***b-e* extend farther radially outward than the pair of high pressure apertures **116** in order to align with the low pressure apertures **115** of the rear commutator plate **98***a* when stacked together. The apertures **118**, **119** extending through the forward commutator plate **98***f*, for aligning with the apertures **116**, **117**, are arranged in the same order as the apertures **116**, **117** of the intermediate plates **98***b-e*. It will be appreciated that the plates **98***b-f* could include any suitable number of apertures in each of the seven sets of apertures, or the plates **98***b-f* could include any suitable number of sets of apertures consistent with the number of volume chambers **72**.

During rotation of the inner rotor **32** and orbiting of the orbiter **34**, the fluid windows **84** are configured to orbit between the high pressure apertures **118** and the low pressure apertures **119** of the forward commutator plate **98***f*. The fluid windows **84** (FIG. **5**) of the valve plate **80** (FIG. **5**) and the apertures **118**, **119** may also be configured, such as sized large enough, to provide the least possible pressure loss across the system as is possible based on the eccentricity of the orbiter **34**. It should be noted that greater aperture area provided in a commutator plate corresponds to lesser pressure loss across the system, and thus more efficient driving of the inner rotor **32** and associated output shaft **24**.

It should also be noted that use of half the number of apertures **116-119** and half of the number of fluid windows **84** would result in a less efficient hydraulic motor. For example, a single high pressure aperture **116**, **118** and a single low pressure aperture **117**, **119** in each of the seven aperture sets of the commutator plates **98***b-f*, and correspondingly a single fluid window **84** for orbiting between the apertures, would result in a less efficient hydraulic motor **10**. This is because a lesser amount of hydraulic fluid would valve into and out of the intermediate geroller section **16**, resulting in pressure loss across the system.

In such a construction having half the number of apertures and fluid windows, were the areas of each of the fluid apertures and fluid windows increased as compared to the areas of each of the fluid apertures **116-119** and fluid windows **84** of the motor **10**, respectively,—to attempt to increase the motor efficiency—hydraulic fluid would leak between high and low pressure fluid ports **102**, **104**. For example, the valve plate **80** (FIG. **6**) includes valve plate portions **124** (FIG. **6**) spaced between the fluid windows **84**, and the forward commutator plate **98***f* includes commutator plate portions **126** spaced between the apertures **118**, **119**. Due to the orbiting nature of the orbiter **34** in respect to the stationary commutator assembly **96**, larger fluid apertures and larger fluid windows would result in lesser overlap of the plate portions **124**, **126**. Minimized overlap of plate portions **124**, **126** would therefore lead to leakage from the high pressure fluid ports **102** to the low pressure fluid ports **104**, resulting in an even less efficient hydraulic motor **10**. Accordingly, the sizing and location of the fluid apertures **118**, **119** and of the fluid windows **84** are configured as illustrated to provide for increased efficiency of the motor **10**, although suitable alternate configurations may be utilized.

Referring now to the rear motor housing **100** of the rear section **12**, hydraulic fluid is delivered to and from the commutator assembly **96** via passages through the rear motor housing **100**. The rear motor housing **100**, which may be any suitable material such as ductile iron, gray iron, or compressed powdered metal, etc., includes separate inlet and outlet ports **130**, **132** for coupling to an external hydraulic pump (not shown). Delivered high pressure fluid entering the inlet port **130** is directed to an annular inlet passage **134** in the rear housing **100**. The annular inlet passage **134** is disposed in a radially inward extent of the rear housing **100** for aligning with only the high pressure apertures **114** of the rear commutator plate **98***a*, and thus with only the high pressure fluid ports **102**. Exhausted low pressure fluid exits only the low pressure apertures **115** of the rear commutator plate **98***a*, and of the low pressure fluid ports **104**, and is directed to an annular outlet passage **136** in the rear housing **100**. The annular outlet passage **136** is disposed in a radially outward extent of the rear housing **100** and is fluidly connected to the outlet port **132**. As such, the commutator and bearing section **12** of the hydraulic motor **10** may provide for separate high and low pressure pathways between an external hydraulic pump and the fluid windows **84** of the valve plate **80**. It will be appreciated that in a situation where the motor **10** acts as a hydraulic pump, the inlet port **130** may be an outlet port and the outlet port **132** may be an inlet port.

The rear motor housing **100** also includes additional features. A center bore **140** for receiving the output shaft **24** extends axially through the rear housing **100**. A rear shaft chamber **142** is defined by the center bore **140** and surrounds the portion of the shaft **24** extending through the rear housing **100**. Bearings **144** for supporting the output shaft **24** may be located in the rear shaft chamber **142**. An annular seal groove **150** may be defined by a radially outward portion of the rear housing **100** for receiving a seal ring (not shown) for sealing between the rear housing **100** and the commutator assembly **96**. The rear housing **100** may also include N+1 motor bolt holes **152**, such as the illustrated seven motor bolt holes **152**, extending at least partially axially through a radially outward extent of the rear housing **100** located radially outward of the annular outlet passage **136**. The motor bolt holes **152** may be threaded to receive a threaded portion of the motor bolts **90**. The annular outlet passage **136** includes a radially outwardly protruding outlet portion **154** for aligning with the auxiliary aperture **122** extending through each of the commutator plates **98***a-f*. Alignment of each of the auxiliary apertures **122** with one another and with the outlet portion **154** may allow for fluid communication between the outer chamber **92** and the outlet port **132** of the rear housing **100**.

Turning now to FIG. **14**, a forward housing **156** of the forward bearing section **20** (FIGS. **1-3**) is illustrated. The forward housing **156** may be any suitable material such as ductile iron, gray iron, or compressed powdered metal. The forward housing **156** includes a mating surface **160** for mating against the revolving group **30**, thereby sealing a forward end of the volume chambers **72**. A center bore **162** extends partially axially through the forward housing **156** for receiving the forward end **57** (FIG. **5**) of the output shaft **24**. A forward shaft chamber **164** is defined by the center bore **162** and surrounds the portion of the shaft **24** extending into the forward housing **156**. Bearings **166** for supporting the output shaft **24** may be located in the forward shaft chamber **164**. An annular seal groove **168** may be defined by a radially outward portion of the forward housing **156** for receiving a seal ring (not shown) for sealing between the forward housing **156** and the center housing **26**.

The forward housing **156** may also include N+1 motor bolt holes **170**, such as the illustrated seven motor bolt holes **170**, extending axially through a radially outward extent of the forward housing **156** located radially outward of the mating surface **160**. The motor bolts **90** may extend axially rearwardly through the motor bolt holes **170** of the forward housing **156**, through the inner recesses **86** of the center housing **26**, through the motor bolt holes **95** of the commutator assembly **96**, and into the motor bolt holes **152** of the rear housing **100**. In this manner, the motor forward, intermediate, and rear sections **20**, **16**, **12** may be thereby coupled together. Also in this manner, the forward housing **156**, the center housing **26**, portions of the commutator assembly **96**, and the rear housing **100** may collectively be coupled together and referred to as a housing.

Further included in the forward housing **156** may be an axially extending outwardly open drain passage **172**, extending radially inward to the center bore **162**. A drain plug, such as a drain bolt **174**, may be received in, such as threaded into, the drain passage **172** for sealing the drain passage **172**. An auxiliary passage **176** may extend axially through the forward housing **156** for fluidly connecting the drain passage **172** to the outer chamber **92** (FIG. **5**) of the intermediate housing section **16**.

Accordingly, selective alignment of each of the auxiliary apertures **122** (FIG. **8**) with one another and with the outlet portion **154** (FIG. **12**) may allow for fluid communication between the outlet port **132** (FIG. **12**) and chambers surrounding the output shaft **24**, such as the rear shaft chamber **142** (FIG. **12**) and/or the forward shaft chamber **164**. In this way, selective alignment of the auxiliary apertures **122** in respect to the outlet portion **154** may allow for the hydraulic motor **10** to function as a two-chamber motor, with two pressure zones, or a three-chamber motor, with three pressure zones.

In a two-chamber hydraulic motor, the auxiliary apertures **122** may be aligned with the outlet portion **154**. Low pressure fluid may flow between the outlet port **132**, the annular outlet passage **136** (FIG. **12**), the outlet portion **154**, the aligned auxiliary apertures **122**, the outer chamber **92**, the auxiliary passage **176**, the forward shaft chamber **164**, an area between the rotor splines **52** and shaft splines **55**, and the rear shaft chamber **142**. Pressure may be equalized between the low pressure volume chambers **72**, the shaft chambers **142**, **164**, and the outer chamber **92**. Thus the shaft chambers **142**, **164** and the outer chamber **92** all may be at low pressure.

In a three-chamber hydraulic motor, the auxiliary apertures **122** may not be aligned with each other. Alternatively, if the auxiliary apertures **122** are aligned with one another, the apertures **122** may not be aligned with the outlet portion **154**. Thus the shaft chambers **142**, **164** and the outer chamber **92** may be pressurized at a pressure different than the high pressure fluid entering the inlet port **130** and the low pressure fluid exiting the outlet port **132**. The drain bolt **174** may be removed and a drain conduit (not shown) may be attached to the forward housing **156** for fluidly connecting the shaft chambers **142**, **164** to a hydraulic system reservoir (not shown). In this way, excess hydraulic fluid that has leaked into the shaft chambers **142**, **164** and the outer chamber **92** from the volume chambers **72** may be returned to the system reservoir.

Referring to FIGS. **14-16**, the hydraulic circuit and operation of the hydraulic motor **10** is illustrated. When high pressure pressurized hydraulic fluid flows into the motor **10**, through the inlet port **130**, the resistance of an external torsional load on the motor **10** may begin to build differential pressure between volume chambers **72**, thereby causing low pressure fluid to flow out of the motor **10** through the outlet port **132**. The differential pressure between the volume chambers **72** may cause the inner rotor **32** to rotate in the desired direction due to flow through the commutator assembly **96** and through the orbiting valve plate **80**, together serving as a timing valve means for the hydraulic motor **10**. As such, the force driving the revolving motion of the revolving group **30** may be due to a timed change in pressure of hydraulic fluid in the volume chambers **72**.

The timing may be at least partially accomplished by the valve plate **80** that orbits integral with the orbiting ring **58**, with the rigidity of the revolving group **30** enabling the inner rotor **32** and orbiting ring **58** to revolve in relation to one another. As the inner rotor **32** rotates in a first direction, the orbiter **34** may be caused to orbit in an opposite direction. Some of the chambers **72** may be caused to selectively expand while the other of the chambers **72** are caused to selectively contract, providing a continuous pressure differential between sealed volume chambers **72**.

More specifically, high pressure fluid may be delivered, such as injected, into the inlet port **130**, and subsequently into the high pressure fluid ports **102** extending through the commutator assembly **96**. The high pressure fluid may be exposed to different volume chambers **72** once the chambers **72** are exposed to the high pressure fluid ports **102** via orbiting of the valve windows **84**. Rotation of the inner rotor **32** in a first direction may be sustained as the orbiter **34** is orbited in the opposite direction about the fixed longitudinal axis **36**. The orbiter **34** may be constrained from rotating via the motor bolts **90**, thereby causing the volume chambers **72** to expand and contract. As the chambers **72** containing high pressure fluid expand and then reach maximum expansion, the high pressure fluid may lose pressure, becoming low pressure fluid. The low pressure fluid may be withdrawn from the volume chambers **72** that have reached their maximum expansion and have begun to contract. Particularly, the low pressure fluid may be withdrawn or exhausted out the outlet port **132** once the volume chambers **72** with low pressure fluid are exposed to the low pressure fluid ports **104** via continued orbiting of the valve windows **84**. As a result, the continued rotation of the inner rotor **32** may drive the rotation of the output shaft **24** interengaged with the inner rotor **32**.

For example, as shown in FIG. **16**, seven volume chambers **72** are defined by the revolving group **30** of FIG. **1**, and are separately referenced at **200-206**, in counter-clockwise order starting at the chamber **200** located approximately at a five-o'clock location. As viewed at the instant in revolution of the revolving group **30** illustrated in FIG. **16**, the inner rotor **32** is rotating in a counter-clockwise direction about the center axis **36**, while the orbiting ring **58** is orbiting in a clockwise direction about the center axis **36**. The chambers **200**, **201**, **202** are expanding due to high pressure fluid being injected into these volume chambers **72**. Chamber **202** has the greatest amount of high pressure fluid being injected therein due to the substantial alignment of the fluid windows **84** of the valve plate **80** with the high pressure apertures **118** of the forward commutator plate **98*f***. Chamber **203** is fully expanded and substantially no fluid is flowing into or out of this chamber. Chambers **204**, **205**, **206** are contracting as low pressure fluid is being exhausted out of these chambers **72**. Chamber **204** has the greatest amount of low pressure fluid being exhausted therefrom due to the substantial alignment of the fluid windows **84** with the low pressure apertures **119**.

Although the invention has been shown and described with respect to a certain embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

What is claimed is:

1. A hydraulic motor comprising:

a motor housing having a fluid inlet and a fluid outlet;

an output shaft mounted within the motor housing for rotation about a fixed longitudinal axis; and

a revolving group for revolving in respect to the fixed longitudinal axis, the revolving group including:

an inner rotor mounted on the output shaft, the inner rotor having a plurality of lobes circumferentially spaced along an outer periphery of the inner rotor;

an orbiting ring surrounding the inner rotor, the orbiting ring having a plurality of inner recesses circumferentially spaced along an inner periphery of the orbiting ring;

a plurality of roller vanes disposed between the inner rotor and the orbiting ring, the roller vanes being received in the inner recesses for common orbiting with the orbiting ring about the fixed longitudinal axis, wherein the orbiting ring and roller vanes orbit about the inner rotor and in respect to the fixed longitudinal axis; and

a valve plate integral with the orbiting ring, the valve plate having a plurality of fluid windows for enabling fluid communication between the fluid inlet and outlet and the revolving group.

2. The hydraulic motor according to claim **1**, further comprising a commutator assembly coupled to the motor housing, the commutator assembly including a plurality of commutator plates each having a plurality of apertures forming inlet and outlet ports for enabling fluid communication between the fluid inlet and outlet and the valve plate.

3. The hydraulic motor according to claim **1**, wherein the lobes and the roller vanes interengage to define a plurality of expanding and contracting volume chambers, and wherein rotation of the inner rotor causes the volume chambers to change volume.

4. The hydraulic motor according to claim **1**, further comprising:

a commutator plate mounted to the housing, the commutator plate in fluid communication with the fluid inlet and outlet; and

a valve plate configured to orbit with the orbiting ring,

wherein the valve plate includes fluid windows that align with the inlet and outlet ports in the commutator plate to cause the volume chambers to expand and contract.

5. The hydraulic motor according to claim **1**, wherein the orbiting ring has a plurality of outer recesses circumferentially spaced along an outer periphery of the orbiting ring, and wherein each outer recess interengages with a radially-extending protrusion spaced circumferentially about an inner periphery of the motor housing to constrain the orbiting ring from rotating.

6. The hydraulic motor of claim **5**, wherein the radially-extending protrusion is a motor bolt extending into the motor housing and located between an inner periphery of the motor housing and the outer periphery of the orbiting ring.

7. The hydraulic motor according to claim **1**, wherein the inner periphery of the orbiting ring is cylindrical.

8. The hydraulic motor according to claim **1**, wherein the roller vanes are cylindrical, and wherein the outer periphery of the inner rotor is trochoidal for maintaining contact with the cylindrical roller vanes.

9. The hydraulic motor according to claim **1**, wherein the inlet and outlet are disposed at the same axial side of the revolving group.

10. The hydraulic motor according to claim **1**, wherein each window of the plurality of fluid windows extends fully axially through the valve plate along the fixed longitudinal axis.

11. A hydraulic motor comprising:

a motor housing; and

a revolving group for revolving in respect to the motor housing, the revolving group including:

an inner rotor for rotating in respect to the motor housing, the inner rotor having a plurality of lobes circumferentially spaced along an outer periphery of the inner rotor; and

an orbiter surrounding the inner rotor, the orbiter having a plurality of radially-extending rounded portions circumferentially spaced along an inner periphery of the orbiter, and the orbiter having a plurality of radially outwardly extending fluid windows,

wherein the orbiter orbits around the inner rotor in respect to the motor housing, and the lobes glide against the radially-extending rounded portions to define a plurality of volume chambers,

wherein the orbiter has fixed for movement therewith the plurality of radially outwardly extending fluid windows aligned with the plurality of volume chambers, and

wherein spacing between the plurality of radially outwardly extending fluid windows and the plurality of radially-extending rounded portions remains constant during rotation of the inner rotor and orbiting of the orbiter, thereby preventing direct fluid communication between the volume chambers.

12. The hydraulic motor according to claim **11**, further comprising a valve plate mounted to the orbiter and having the plurality of fluid windows, wherein a longitudinal center axis of each of the valve plate and the orbiter follow the same path in orbiting about a fixed longitudinal center axis of the inner rotor, thereby preventing alignment of each fluid window with more than one volume chamber at a time.

13. The hydraulic motor according to claim **11**, wherein the lobes and the radially-extending rounded portions glide against one another and interengage at shifting contact points between the lobes and the radially-extending rounded portions, and wherein no shifting contact point passes over a fluid window in the valve plate.

14. The hydraulic motor according to claim **11**, wherein the orbiter includes:

an orbiting ring surrounding the inner rotor, the orbiting ring having a plurality of inner recesses circumferentially spaced along an inner periphery of the orbiting ring; and

a plurality of roller vanes disposed between the inner rotor and the orbiting ring, the roller vanes being received in the inner recesses and forming the radially-extending rounded portions of the orbiter.

15. The hydraulic motor according to claim **11**, further comprising a plurality of motor bolts located between an inner periphery of the motor housing and an outer periphery of the orbiter, wherein the motor bolts constrain the orbiter from rotating.

16. The hydraulic motor according to claim **11**, wherein the radially-extending rounded portions circumferentially spaced along the inner periphery of the orbiter are semi-cylindrical portions, and wherein the inner rotor has a trochoidal outer periphery for remaining in continuous contact with the semi-cylindrical portions of the orbiter.

17. The hydraulic motor according to claim **11**, wherein each window of the plurality of radially outwardly extending fluid windows communicates with each of an inlet and an outlet of the motor housing, and wherein the inlet and outlet are disposed at the same axial side of the orbiter.

18. The hydraulic motor according to claim **11**, wherein each window of the plurality of radially outwardly extending fluid windows in combination with a respective volume chamber defines a respective linear passage fully axially through the orbiter along a fixed longitudinal center axis of the motor housing about which the inner rotor rotates.

19. A method of utilizing pressurized fluid to produce rotary motion comprising the steps of:

injecting fluid into a motor housing and directing the fluid through a plurality of fluid ports in a commutator assembly coupled to the motor housing;

selectively transmitting the fluid through fluid windows of a revolving valve, the revolving valve further including N rotor lobes on an inner rotor for rotating about a fixed longitudinal axis and for interengaging with N+1 radially-extending rounded portions of an orbiter surrounding the inner rotor to form N+1 sealed variable volume chambers therebetween, wherein the fluid windows orbit about the fixed longitudinal axis;

selectively expanding some of the sealed volume chambers by providing a pressure differential between the sealed volume chambers to produce a rotary motion of the inner rotor, thereby driving an output shaft interengaged with the rotor;

withdrawing through the fluid windows of the revolving valve the fluid from the sealed volume chambers that have reached their maximum expansion; and

exhausting the fluid from the motor housing.

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