United States Patent [19]

Ogasahara et al.

[11] 3,853,435

[45] Dec. 10, 1974

[54] **GEROTOR DEVICE WITH GEAR DRIVE FOR COMMUTATOR VALVE**

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[73] Assignee: **Kayabakogyokabushikikaisha**, Tokyo, Japan

[22] Filed: **Nov. 3, 1972**

[21] Appl. No.: **303,506**

[52] **U.S. Cl.** ...... **418/61 B**, 137/625.21, 180/79.2 R

[51] **Int. Cl.** **F01c 1/02**, F04c 1/02, B62d 5/00

[58] **Field of Search** .... 418/61; 137/625.21, 625.24; 180/79.2 R; 60/384

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Primary Examiner—John J. Vrablik

Attorney, Agent, or Firm—Saul Jecies

[57] **ABSTRACT**

Hydraulic apparatus comprising a rotor forming a gerotor portion, a commutator valve and a planetary gear mechanism having a speed-up function of the ratio of any times as many as the number of teeth of the rotor through which mechanism said gyrotor and the commutator valve are associated with each other, wherein the rotation of the commutator valve is speeded up any times as many as the number of the teeth of the rotor with respect to that of the rotor and at the same time the direction of the rotation is changed into the opposite direction thereof, whereby the change-over portion of the commutator valve may simply be divided into two high and low pressure portions in order to make simple the structure of the gerotor type pump or the commutator valve in a motor and smooth the operation thereof.

4 Claims, 14 Drawing Figures

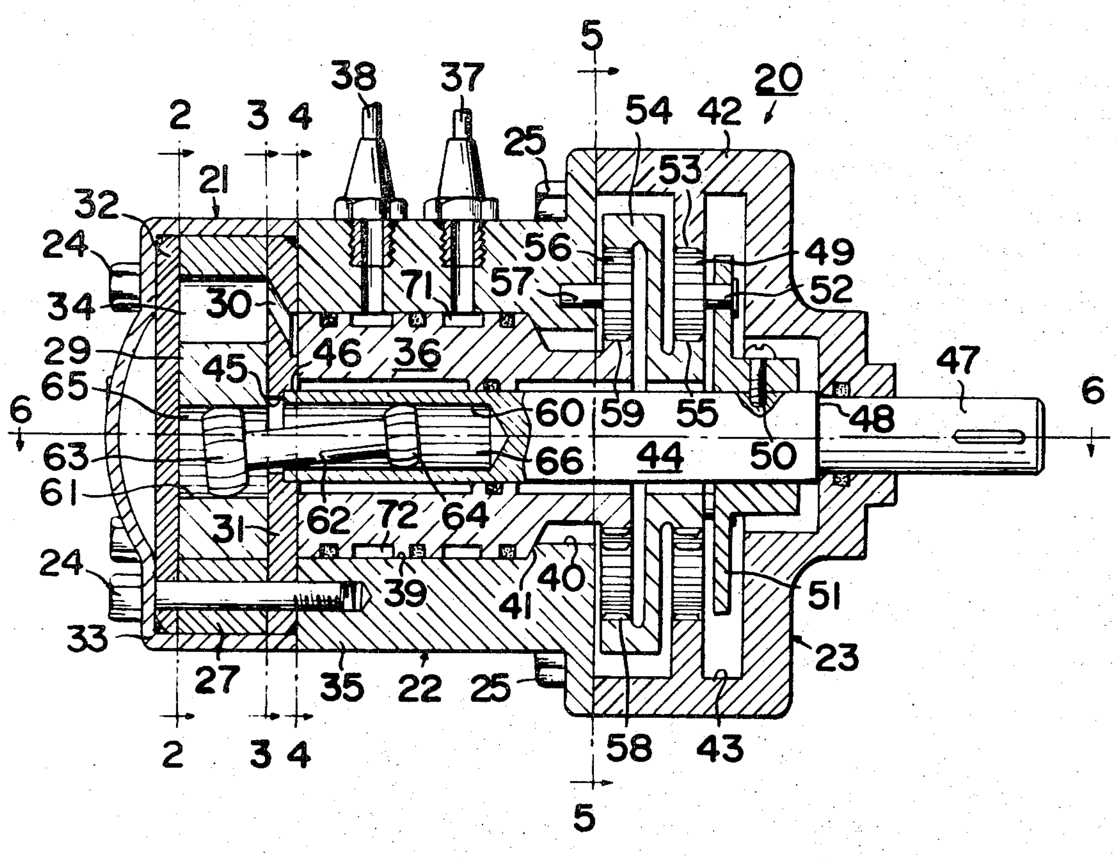

FIG. 1

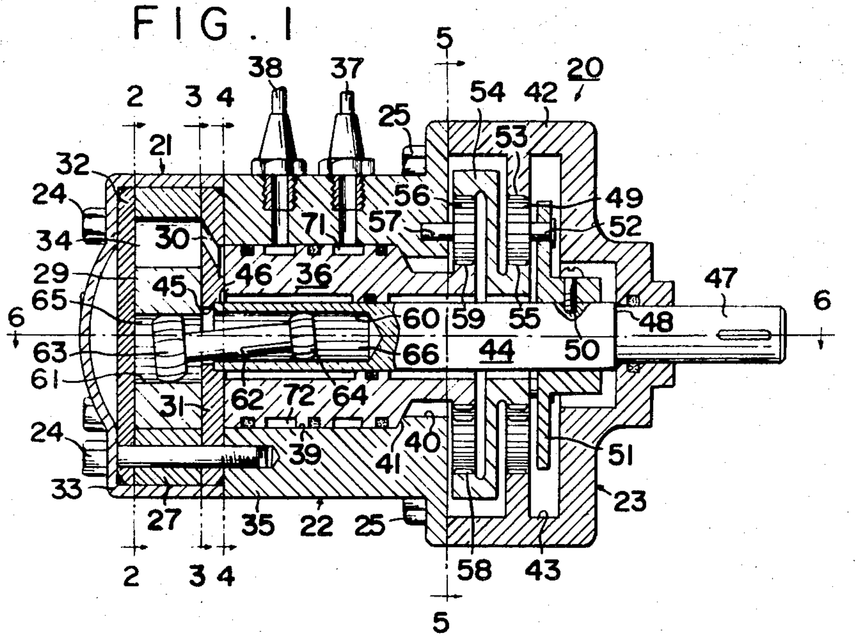
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FIG. 2

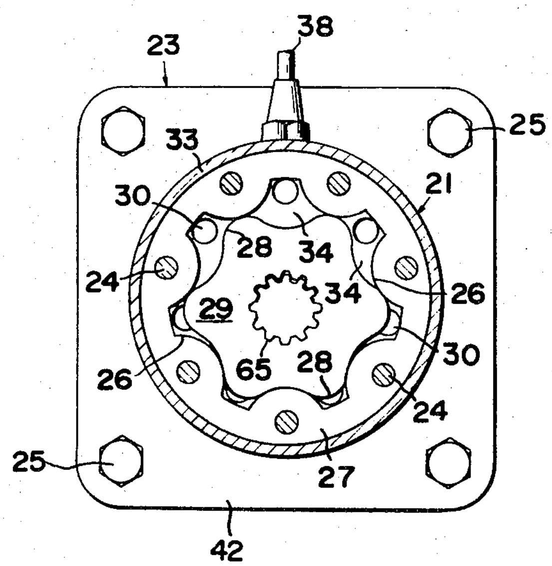
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FIG. 3

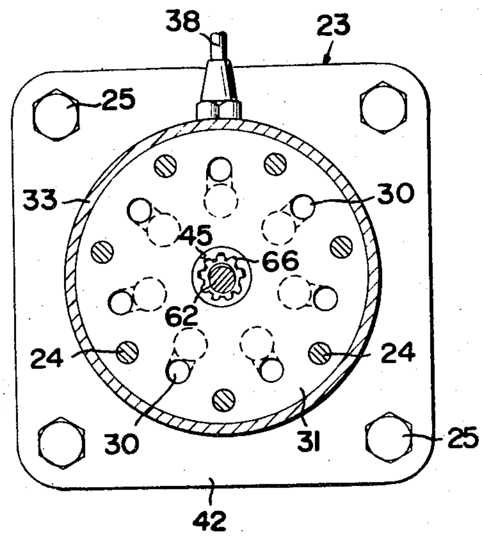
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FIG. 4

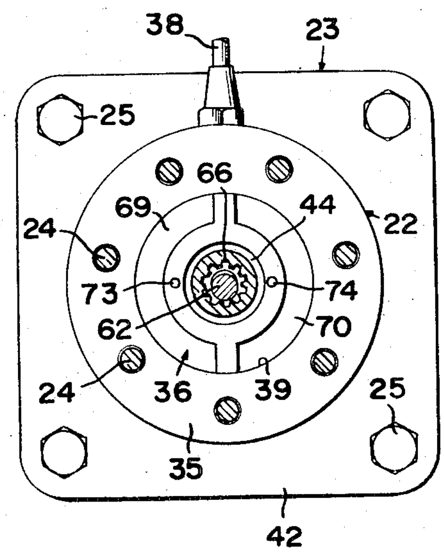
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FIG. 5

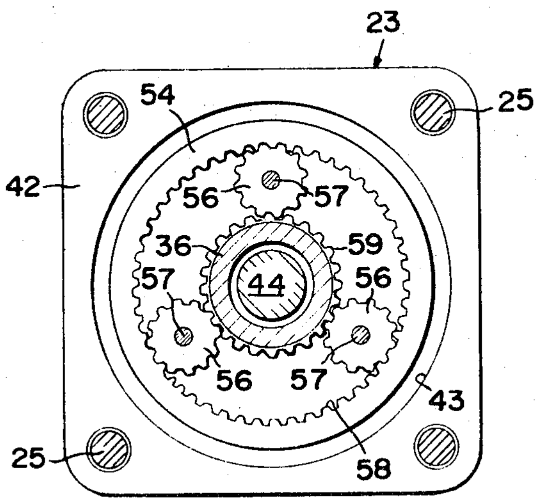
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FIG. 6

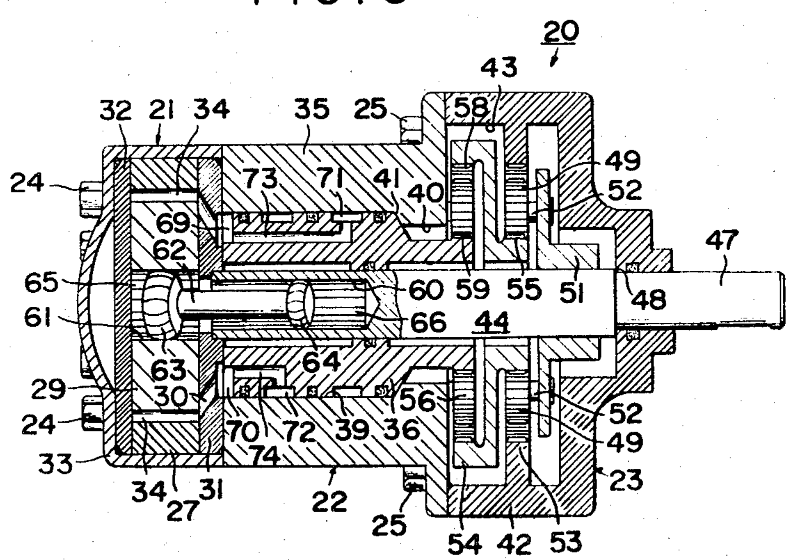
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FIG. 7A

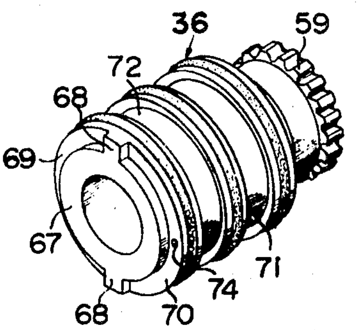


FIG. 7B

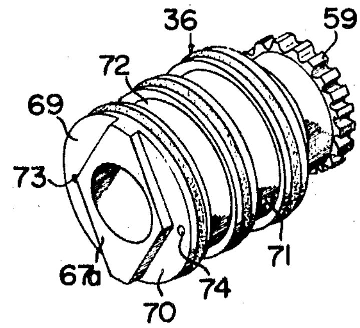


FIG. 10

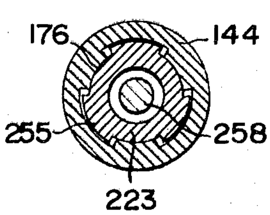
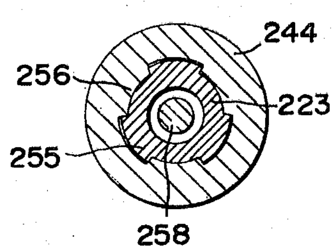


FIG. 11



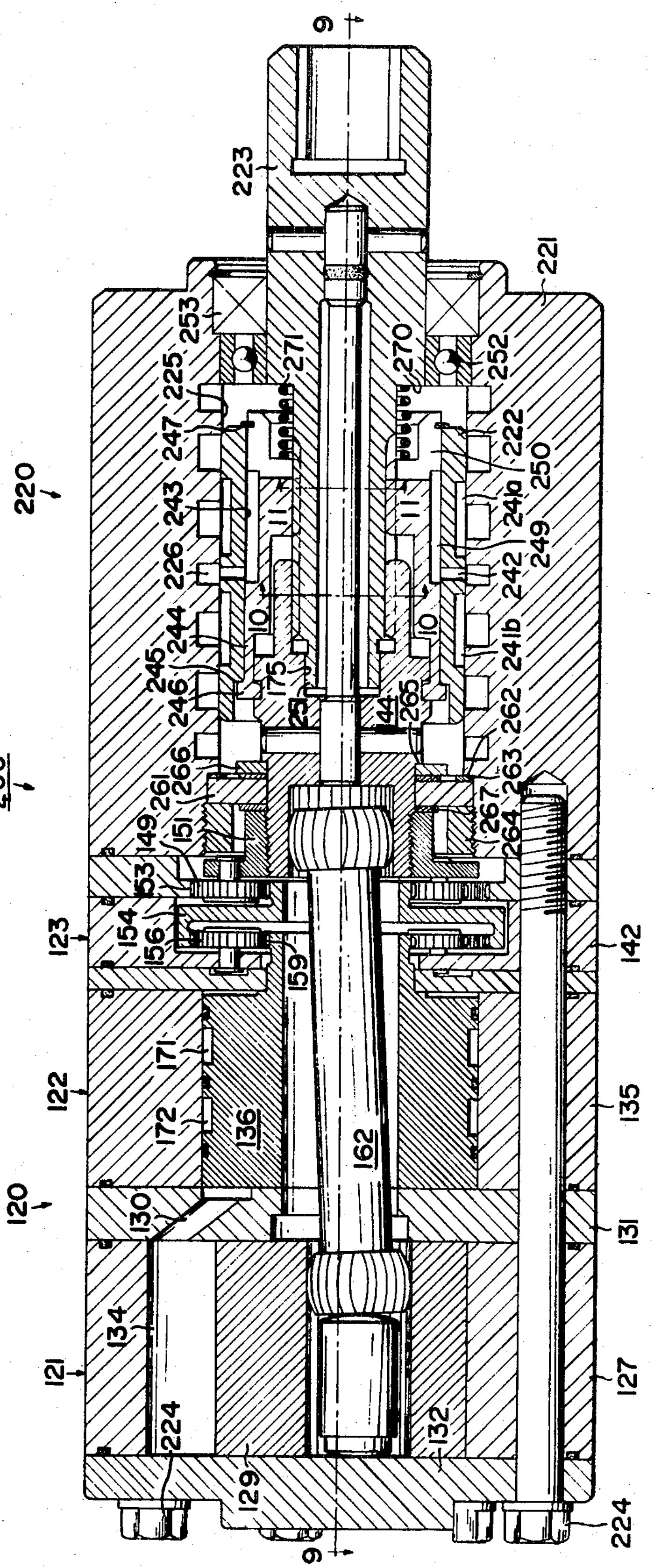

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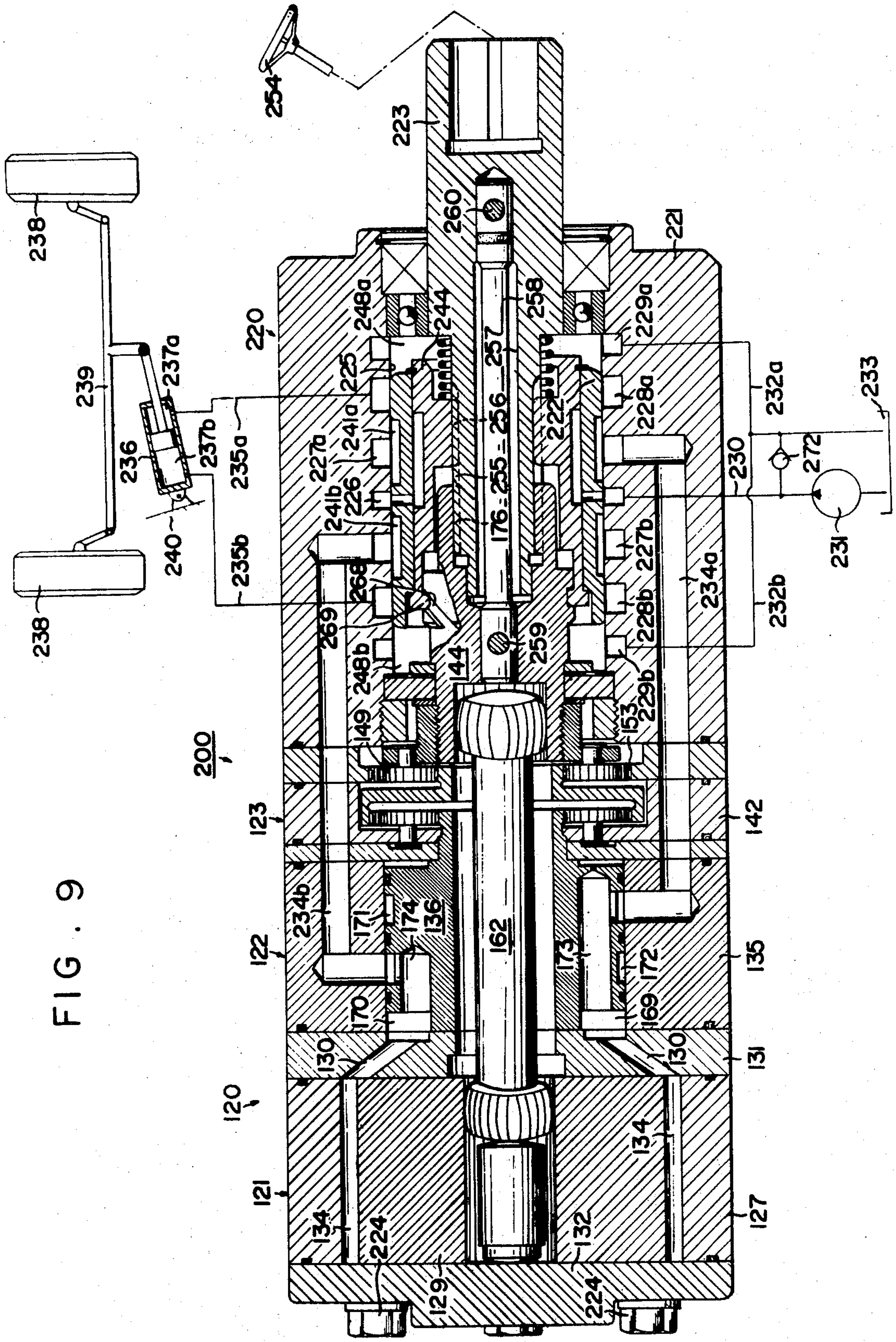
FIG. 8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232b
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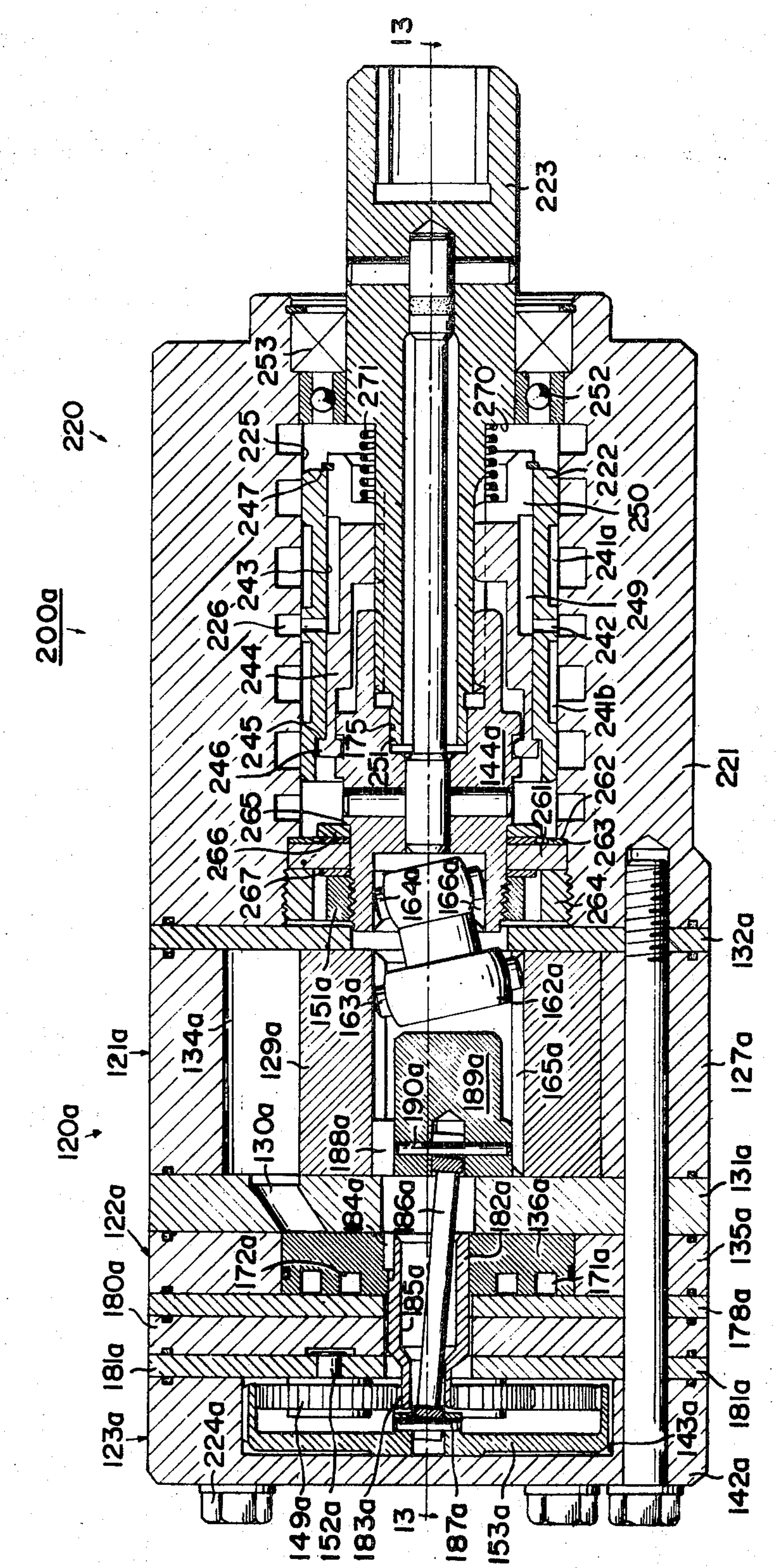
FIG. 9

FIG. 12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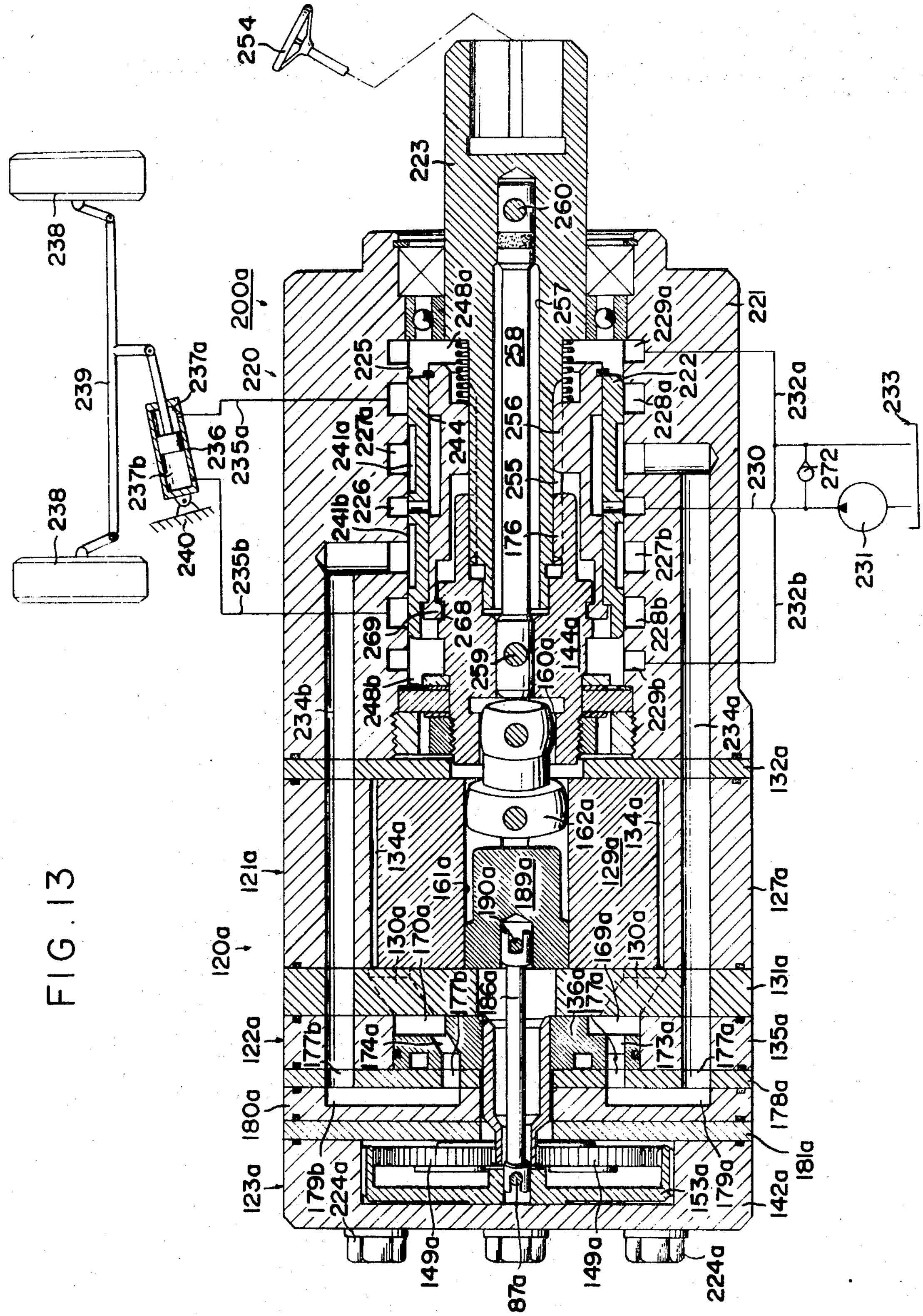
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FIG. 13

GEROTOR DEVICE WITH GEAR DRIVE FOR COMMUTATOR VALVE

BACKGROUND OF THE INVENTION

This invention relates to a so called gerotor type pump or a motor, or a hydraulic apparatus including it, in which a stator has one more tooth than the number of teeth of a rotor rotating therein and in which when the rotor rotates around the axis thereof, said axis rotates around the axis of another stator.

In such hydraulic apparatus, when the rotor rotates within this stator, a high pressure zone and a low pressure zone of each variable volume chamber formed therebetween move constantly and the moving direction of these high and low pressure zones becomes opposite to the rotational direction of the rotor. Therefore, during the operation of the rotor, in order to keep these high and low pressure zones communicating with respective predetermined or corresponding ports, a very complicated commutator type valve mechanism is usually provided in a shaft connecting with the rotor. By using said valve mechanism, the momentarily or continuously moving high pressure zone and low pressure zone are always communicated with their predetermined or corresponding ports. However, it necessarily requires much labor and time, and furthermore high cost to produce such commutator valves.

For the purpose of eliminating these disadvantages, there have been proposed a commutator valve in which the revolving movement of the rotor is directly transmitted to the commutator valve so as to rotate it, whereby the structure of said commutator valve may be made remarkably simple, since the moving direction and the cycle thereof of the high and the low pressure zones by accident often coincide with that of the axis of the rotor, or the direction of orbital movement and the cycle thereof of the rotor relative to the rotation axis of the stator. However, to rotate and drive the commutator valve directly by making good use of the revolution of the rotor inevitably causes a disadvantageous force to be exerted on a transmission mechanism portion thereof so that the transmission mechanism does not move smoothly, which is not only undesirable for a safe operation but also causes a partially applied force to act on the commutator valve, resulting in wearing it partially.

SUMMARY OF THE INVENTION

The object of the present invention is to improve such type of hydraulic apparatus, that is to say, to eliminate the above mentioned problems of the prior art and to provide an improved gerotor type hydraulic apparatus including a new valve transmission mechanism having a simple structure and being able to be produced at low cost. The special feature of the invention resides in that the shaft connected to the rotor side and the commutator valve are associated with each other through a planetary gear mechanism, by which mechanism the rotational movement of the rotor is speeded up as many times as many as the number of teeth thereof and at the same time the rotating direction thereof is inverted and it is transmitted to the commutator valve, whereby the rotating direction of the commutator valve and the cycle thereof may be coincided with the moving direction of the axis of the rotor and the cycle thereof with respect to the rotation axis of the stator, in other words, the moving direction of the axis of the rotor and the cycle thereof of the high and the low pressure zones, so as to facilitate the smooth transmission of the movement between the rotor and the commutator valve and make the structure of the commutator valve itself simple.

Other objects, and advantages of this invention will become apparent when reference is made to the following description considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal section front view illustrating an embodiment of a gerotor type hydraulic pump motor in accordance with the present invention;

FIGS. 2, 3, 4 and 5 show longitudinal side views respectively taken along line 2 — 2, line 3 — 3, line 4 — 4 and line 5 — 5 of FIG. 1;

FIG. 6 is a partially transversal plan view similarly taken along line 6 — 6 of FIG. 1;

FIGS. 7A and 7B show a commutator valve itself, FIG. 7A showing one example thereof and FIG. 7B showing the other one;

FIG. 8 is a longitudinal front view showing an example in which the present invention is applied to a valve mechanism portion for a hydraulic power steering apparatus including a gerotor type metering pump;

FIG. 9 is a transversal plan view taken along line 9 — 9 of FIG. 8;

FIGS. 10 and 11 are longitudinal side views similarly respectively taken along line 10 — 10 and line 11 — 11 of FIG. 8;

FIG. 12 is a longitudinal front view showing another example in which the present invention is applied to a valve mechanism portion for a hydraulic type power steering apparatus including a gerotor type metering pump similarly to FIG. 8; and

FIG. 13 is a transversal plan view taken along line 13 — 13 of FIG. 2.

DETAILED EXPLANATION OF THE PREFERRED EMBODIMENT

FIG. 1 shows a longitudinal elevation view of an embodiment of a gerotor type hydraulic pressure pump motor 20 in accordance with the present invention. This motor comprises a gyrotor part or portion 21 which is usually of cylindrical shape, a similarly cylindrical shaped valve mechanism 22, and a transmission mechanism part or portion 23. The gyrotor portion, the transmission mechanism part and the valve mechanism interposed therebetween are integrally assembled by axially aligning them with bolts 24 and 25.

The gerotor portion 21, as shown in FIG. 2, consists of a stator 27 having suitable number of inner teeth 26 and a rotor 29 having outer teeth 28 which are one less in number than the teeth 26 of the stator, the rotor 29 being eccentrically disposed in a center chamber or cavity of the stator 27. The stator 27 and the rotor 29 are supported respectively at one side thereof by a distributing board 31 having a through hole 30 for operating fluid supply and discharge and at the other side thereof by a partition board 33. After the stator 27, the distributing board 31 and the partition board 32 are covered with a cover 33, said three members and the cover 33 are secured against the valve mechanism portion 22. The rotor 29, as well known, moves on a predetermined orbit in the stator 27 by the engaging operation of the inner teeth **26** and the outer teeth **28** together with the rotating movement of the rotor **29.** When the rotor moves on the orbit, the outer teeth **28** thereof are sealingly engaged by the inner teeth **26** to form variable volume chambers **34** repeating expansion and contraction therebetween. Therefore, if the through hole **30** in the distributing board **31** is opened at the portion near to the bottom of these variable volume chambers **34,** that is to say, the portion near to the bottom of each inner tooth **26** in the stator **27,** the fluid can be supplied through hole **30** to, and can also be discharged, from the variable chamber.

FIG. **2** shows an eccentric axis of the rotor **29,** unexpectedly coinciding with a vertical center axis of the stator **27** but this condition is not limitative. When the rotor begins to rotate from any condition thereof including the above mentioned condition towards the direction of either right or left, the rotor **29** moves on the orbit opposite to that of the stator **27** while it rotates within the stator **27.** Now, in the position of FIG. **2,** assuming that the rotor **29** is rotating counterclockwise and moves on the orbit clockwise, the variable volume chamber **34** occupying the right side from the eccentric axis will expand, while on the other hand, the variable chamber **34** on the left side will contract.

Accordingly, if the apparatus in accordance with the present invention is employed as a pump, fluid is absorbed in the right side expanding variable volume chamber **34** and exhausted from the left side contracting variable volume chamber under pressure. When the apparatus mentioned above is used as a motor, fluid under pressure is supplied to the right side expanding variable volume chamber **34** and discharged from the left contracting variable volume chamber **34.**

As is apparent from these descriptions, the relation of a high pressure zone and a low pressure zone in each variable volume chamber **34** is interchanged between the case where the apparatus is used as a pump and where it is used as a motor. In any case, these high and low pressure zones respectively are always disposed on opposite sides of the eccentric axis which functions as the border thereof.

Apparently, this means that during the operation of the apparatus, the high and the low pressure zones of each variable volume chamber move towards the same direction and in the same cycle as the orbital motion of the rotor **29.**

The valve mechanism portion **22** is disposed in contact with the distributing board **31** of said gerotor portion **21.** This valve mechanism portion **22** comprises a casing **35** forming the exterior thereof and a commutator valve **36** rotatably accommodated therein. The casing **35** includes ports **37** and **38** for fluid supply and discharge and in the center is provided with a through hole **39** coaxial with the axis of the stator **27** in the gerotor portion **21,** one end of the through hole being formed to become a reduced diameter portion **40** so as to create a shoulder portion **41.** The axial movement of the commutator valve **36** is controlled by end faces of this shoulder portion **41** and disposed so as to slidably contact and rotate on these end faces and an inner surface of the through hole **39.** This commutator valve **36** permits successively changing over the communication of each variable volume chamber **34** in the gerotor portion **21,** via the through hole **30** formed in the distributing board **31,** with the ports **37** and **38** for fluid supply and discharge provided in the side of the casing **35,** under a fixed timing. Furthermore, the commutator valve **36** enables each of the momentarily changing high and the low pressure zones of the variable volume chamber **34** to keep communicating with the predetermined port **37** or **38,** whereby said operation of pump or motor may be continued. The detailed structure of this commutator valve **36** will be fully pointed out hereinbelow.

A casing **42** of a transmission mechanism part **23** which is located in contact with the valve mechanism portion **22** comprises a bored hole **43** which is coaxial with an axis of the stator **27** in the gyrotor portion **21,** namely the axis of the through hole **39** of the casing **35** in the valve mechanism portion **22.** A shaft **44** placed through the casing **42** and the commutator valve **36** in the valve mechanism **22** is rotatably disposed along the axis thereof, and one end of the shaft **44** is fitted into a large diameter portion **46** of a center hole **45** bored in the distributing board **31** in the gyrotor portion **21.**

The other end is formed with a small diameter portion **47,** and a shoulder portion **48** formed between the large and the small diameter portion is abutted against the casing **42** so that the axial movement of the shaft **44** can be prevented by these members. The small diameter portion **47** projects outward from the casing **42,** and to the portion **47** is applied input when the apparatus of the present invention is used as a pump, or from it is taken the output when the apparatus is used as a motor.

In the bored hole **43** of the casing **42** is contained a two-step planetary gear mechanism. The first-step planetary gear **49** has a shaft supported with respect to a supporting member **51** secured to the shaft **44** by a screw **50** and moves on a track around the shaft **44** in conjunction with the rotation thereof. This planetary gear **49** engages with an internal gear **53** provided in the side of the casing **42** while engaging with outer tooth portion **55** of an internal gear **54.**

The second planetary gear **56** has a shaft **57** supported with respect to the casing **35** of the valve mechanism portion **22** and also engages with an inner tooth portion **58** of said internal gear **54** while engaging with a gear part **59** formed in a base end of the commutator valve **36** whereby the rotation movement of the shaft **44** speeded up in a fixed ratio may be transferred to the commutator valve **36.**

In the rotor **29** of the shaft **44,** center holes **60** and **61** are provided. Over these center holes **60** and **61** and the center hole **45** of the distributing board **31** is placed a counter or intermediate shaft **62.** The ends of the intermediate or counter shaft have splines **63** and **64,** respectively, one of which splines (**63**) engaging with the same number of teeth of spline **65** bored in the center hole **61** adjacent the rotor **29** and the other of which **64** similarly mating or engaging with the same number of teeth or spline **66** bored or formed in the center hole **60** of the shaft **44.**

As pointed out earlier, the rotor **29** in the gyrotor **21** is disposed, eccentrically with respect to the stator **27,** on the other hand, the shaft **44** is located with respect to said stator **27.**

Thus, the intermediate shaft **62** situated within each center hole **60** and **61** ordinarily is inclined and the left end of the intermediate shaft **62** performs a rotational or orbital movement in common with that of the rotor **29** while the right end thereof carries out a simple rotational movement in common with that of the shaft **44.** For this reason, the spline joints between the intermediate shaft **62** and the rotor **29,** and the intermediate shaft, **62** and the shaft are universal joints, respectively, so as to make the above said movement possible.

Therefore, in the case where the apparatus of the present invention is utilized as a pump, an input applied to the shaft **44** is transmitted through the intermediate shaft **62** to the rotor **29** of the gerotor portion **21** or through the planetary mechanism to the commutator valve **36,** so that the rotor **29** performs a rotational movement in common with the shaft **44,** moving on the orbit along the stator while the commutator valve **36** performs a rotational movement in a direction opposite to that of the rotor, which rotational movement is being speeded up according to the fixed ratio relative to the rotation of the shaft **44.** When the apparatus is used as a motor, in contrast with the above case, the rotational movement of the rotor **29** only is transmitted through the intermediate shaft **62** towards the shaft **44** from which it is transmitted through the planetary gear mechanism, the direction of rotation of which is opposite to that of the rotor, which is speeded up under the fixed ratio with respect to the commutator valve **36.** The commutator valve **36** rotatably accommodated in the casing **35** of the valve mechanism portion, as well shown in FIG. **7,** is provided with an annular projection **67** on a plane of said valve adjacent the distributing board **31** with a diametrically outward extending projection **68** which is symmetrical to the projection **67,** and also with two diametrically and symmetrically disposed cavities **69** and **70** formed by these projections. A projection **67***a* which creates these cavities **69** and **70** may be shaped as illustrated in FIG. **7.** On the circumferential surface of the commutator valve **36** are bored two axially spaced annular grooves **71** and **72** which are opposed to and communicate with the ports for fluid supply and discharge **37** and **38** located adjacent the casing **35.**

Within the commutator valve **35** are bored two passages **73** and **74,** through one of which are communicated the port **37** and the annular groove **71** with the cavity **69,** and through the other of which are communicated the port **38** and the annular groove **72** with the cavity **70.**

As is well known every time the rotor **29** having n teeth rotates in the fixed stator **27** by $(360/n)$ degrees centering the axis of itself, the gyrotor portion **21** circulates around the orbit in the opposite direction to the rotor **29** centering the axis of the stator **27.** It is apparent from the above description that during the operations of said rotor the high and lower pressure zones of each variable volume chamber **34** created between said stator **27** and said rotor **29** move towards or in the same direction as the orbital movement of the rotor **29,** and in the same cycle as said rotor. This means that if the rotational movement of the rotor is speeded up by n times and the direction thereof is made opposite, which factors are transmitted to the commutator valve **36,** the rotational direction and the cycle of the commutator valve **36** coincides with the moving direction and the cycle of the high and low pressure zones of each variable volume chamber **34** in the gyrotor portion **21.** Therefore, in the case of the rotor **29** having six outer teeth **28,** as in the embodiments illustrated in FIGS. **1** through **7,** the movement of the shaft **44** rotating together with the rotor **29** is speeded up by six times by the planetary gear mechanism and the rotational direction thereof is reversed which factors are transmitted to the commutator valve **36,** whereby during the operation the cavities **69** and **70** can always be operated correspondingly to each of the high and low pressure zones.

Thus, it will be understood that the apparatus in question may operate as a pump by communicating one of the ports **37** or **38** with a fluid pressure source in order to rotate the shaft **44,** and as a motor by communicating one of the ports **37** or **38** with the fluid pressure source and the other port **38** or **37** with a fluid return side. Therefore, this apparatus according to the present invention permits obtaining the desired simple structure of the commutator valve **36** and the smooth operation thereof.

FIGS. **8** and **9** show a valve mechanism **200** for a hydraulic power steering apparatus combining the above mentioned gerotor type hydraulic metering pump **120** with a steering valve **220.**

Since said metering pump **120** has basically almost the same construction as the hydraulic pump motor **20** we have pointed out herein above, the structure and operation thereof can be easily understood with reference to the above explanation, so that similarly operating members are designated only by adding the prefix **100** to the original numerals and the detailed explanation of them is omitted and herein an explanation is directed only to the steering valve **220.**

The steering valve **220** comprises a casing **221,** a spool valve **222** and a stub shaft **223,** the casing **221** being attached axially and in alignment to the metering pump by a plurality of circumferentially arranged bolts **224.**

The casing **221** is provided with a valve hole **225** axially penetrating the center portion thereof. On the circumferential surface are provided an annular groove for fluid supply **226** and pairs of annular grooves **227***a* and **227***b*, **228***a* and **228***b*, **229***a* and **229***b*, each pair being symmetrically disposed centering said groove **226.** This center annular groove **226** is communicated with a hydraulic pump functioning as a source of fluid pressure through a passage for fluid supply, both annular grooves **229***a* and **229***b* being respectively communicated with a fluid storage tank through passages for fluid discharge **232***a* and **232***b*, and similarly the annular grooves **227***a* and **227***b* being communicated with annular grooves **171** and **172** disposed on a circumferential surface of the commutator valve **136** towards the metering pump **120** through pump passages **234***a* and **234***b*. The annular grooves **228***a* and **228***b* are communicated with operative chambers **237***a* and **237***b* disposed in both sides of a power cylinder **236** through cylinder passages **235***a* and **235***b*.

The power cylinder **236** is interposed between the tie rod **239** connected to the running wheels **238** and the structural portion **240** of the vehicle, so that when said power cylinder **236** is operated the running direction of the vehicle may be controlled.

The spool valve **222** is made of cylindrical stock and has two annular grooves **241***a*, **241***b* and through holes **242** situated between them. Within inner through holes **243** of of the spool valve **222,** a holder **244** is received. The spool valve **222** and the holder **244** are put one upon the other and connected integrally, owing to the engagement of a step portion **245** formed on the spool valve **222** with a projection **246** formed at an end of the holder **244**, and the engagement of a snap ring **247** fitted in the holder **244** with an end of spool valve **222**. The combination of the spool valve and the holder is positioned slidably within a valve hole **225** of said casing **221**, leaving spaces **248***a*, **248***b* at both ends of the combination.

The holder **244** has an annular groove **249** and a notch **250** on its outer surface, and a through hole **242** of said spool valve **222** is always communicated with the right space **248***a* through the annular groove **249** and the notch **250**. A stub shaft **223** is positioned within the casing **221** and the holder **244**. The reduced end **251** of the stub shaft is loosely fitted in a bored opening **175** of a shaft **144** situated at the side of the metering pump **120** and the portion adjacent to the base end of the stub shaft **223** is supported rotatably by a ball bearing **252** interposed between the shaft and the casing **221**. The space **248***a* is sealed by a sealing means **253** through the bearing **252**. The sealed portion of the stub shaft is extended and this extended portion is connected to the steering wheel **254**. On the circumference of the intermediate portion a spline **255** is formed, which spline **255** loosely engages with the spline **176** of the shaft **144** and on the other hand tightly engages with the spline **256** of the holder **244** ((see FIGS. **10** and **11**). Within the bored opening **257** formed along the axis of the stub shaft **223**, a torsion bar **258** is received and the ends of the torsion bar are connected by means of pins **259**, **260** respectively, to the shaft **144** and the stub shaft **223**, the axes of which coincide with the torsion bar **258**. Accordingly, the shaft **144** and the stub shaft **223** are connected with each other through the torsion bar **258**.

According to the embodiment of FIGS. **8** and **9**, the shaft **144** situated in the side of the metering pump **120** is supported by means of a ring member **261** placed securely within a valve bore **225** formed in the casing **221** of the steering valve **220**. The ring member **261** presses upon the step portion **262** of the valve bore **225** formed in the casing **221**, through a shim **263**, and is fixed securely by a ring nut **264** positioned in the rear of the ring member **261**. Furthermore, the ring member **261** is fixed rigidly by means of a collar **266** positioned in one side of the ring member and abutting a step portion **265** of the shaft **144** and a holding member **151** positioned in the other side of the ring member with a screw **150** through thrust bearings **267**. The shaft **144** has a feed screw portion **268** which engages with an internal thread **269** formed on an inner surface of a left end of a holder **244**. Accordingly, the spool valve **222** may be placed at a neutral position without any torsion generated in the torsion bar **258**, as shown, within the valve bore **225** of the casing **221**, by shifting the engaging position of the feed screw **268** and the inner thread **269** toward a direction owing to the force of the spring **271** interposed between a step portion **270** of the stub shaft **223** and the right end portion of the holder **244**.

As will be apparent from the above description, unless force is applied on the steering wheel **254**, the pressurized fluid delivered from a hydraulic pump **231** is returned to the tank **233** through a supply line **230**, the annular groove **226**, the through hole **242** of the spool valve **222**, an annular groove **249** and a notch **250** of the holder **244**, a right space or room **248***a*, an annular groove **229***a*, and discharging passage **232***a*.

When a steering force is applied to the steering wheel **254** so as to revolve the wheel clockwise or counterclockwise, the steering force will be transmitted from the stub shaft **223** to the shaft **144** through the torsion bar **258** and as a result of it a rotational force is applied to a rotor **129** of the gyrotor part **121** through an intermediate shaft **144**, so as to deliver the operating liquid into a space **237***a* or other space **237***b* of the power cylinder **236** according to the direction of revolution of the steering wheel **254** and to steer the running wheels **238**. Some resistance owing to the friction produced between the running wheels and the road is applied to the steering force of the wheels **238**, so that before the running wheels **238** are steered, the stub shaft **223** revolves and twists the torsion bar **258** with halting of the shaft **144** and the preceding members in order to generate some relative angular motion of the splines **176**, **255** within the scope of play or clearance of them. As the holder **244** revolves together with the revolution of the stub shaft **223** through the splines **255**, **256** and the inner thread **269** of the holder **244** engages with the feed screw **268** of the shaft **144**, the holder **244** moves axially together with the spool valve **222** to change over the valve.

It is assumed that the steering wheel or handle **254** is revolved counterclockwise in order to change over or shift the spool valve **222** to the left. Then, the flow direction of pressurized liquid delivered from the hydraulic pump **231** to the tank **233** is changed over to deliver the liquid into the expansion side of variable volume chamber **134** in the gyrotor part **121** through a delivery passage **230**, an annular groove **226**, the annular groove **241***a* of the spool valve **222**, the annular groove **227***a* of the casing **221**, a pumping passage **234***a*, the annular groove **171** of the commutator valve **136**, a passage **173**, a cavity **169**, and the through hole **130** of the distributing board **131**, respectively. As a result of it, a revolutional motion having revoluting direction of the stub shaft **223** is applied to the rotor **129** and the revolutional motion is fed back from the intermediate shaft **162** to the shaft **144** in order to control the volume of the pressurized liquid which is forced out of the contraction-side variable chamber **134** of the gerotor part **121**, according to the angular motion of the steering wheel **254** or, in other words, to meter the volume of the pressurized liquid passing through the gerotor part **121** corresponding to the angular motion of the steering wheel **254**. The pressurized liquid is simultaneously delivered to the space **237***b* of the base end side of the power cylinder **236** through the through hole **130** of the distributing board **131**, the cavity **170** of the commutator valve **136**, passage **174**, an annular groove **172**, the pumping passage **234***b*, an annular groove **227***b*, the annular groove **241***b* of the spool valve **222**, the annular groove **228***b* of the casing **221**, and the line **235***b*.

On the other hand, operating liquid within the opposite space **237***a* is pressed back to the tank **233** through the cylinder passage **235***a*, an annular groove **228***a*, a right space and room **248***a*, an annular groove **229***a*, and a discharging passage **232***a*. Therefore, the power cylinder **236** extends corresponding to the angular motion or position of the steering wheels **254** in order to steer the running wheel **238** to the left by means of the tierod **239**.

In case the steering handle **254** is turned to the right or clockwise and the spool valve **222** is changed over to the right, the pressurized liquid delivered from the hydraulic pump **231** is transmitted to the variable volume space **134** of the gyrotor part **121** through a feed passage **230**, annular grooves **226**, **241*b*** and **227*b***, a pumping passage **234*b***, an annular groove **172**, a passage **174**, a cavity **170**, and a passage **130**. Simultaneously, the rotor **129** turns in the direction opposite to the former one, that is to say, the rotor **129** turns along the same direction as the stub shaft **223** in order to meter the pressure fluid passing along the rotor according to the angular motion of the steering wheel, and the fluid is fed to the operating space **237*a*** at the forward end of the power cylinder **236** through a through hole **130**, a cavity **169**, a passage **173**, an annular groove **171**, a pumping passage **234*a***, annular grooves **227*a***, **241*a*** and **228*a***, and a cylinder passage **235*a***. Simultaneously the operating liquid within the operating space **237*b*** of the base end is pressed back into the tank **233** through the cylinder passage **235*b***, annular passage **228*b***, the left space **248*b***, an annular groove **229*b***, and a discharging passage **232*b***, to cause the shortening operation of the power cylinder **236** corresponding to the angular movement of the steering wheel **254** in order to steer or turn the running wheel toward the right by means of the tierod **239**.

In this way, if the steering wheel or handle **254** stops its rightward or leftward angular motion at a desirable angular position in each case, the delay in phase of the revolution movement of the shaft **144** to that of the stub shaft **223** will not be generated and the spool valve **222** will be returned to the neutral position shown by the cooperation of the feed screw **168** and the inner thread **269**, and the pressurized liquid delivered from the hydraulic pump **231** will be caused to flow back to the tank **233**, and at the same time both operating spaces **237*a*** and **237*b*** within the power cylinder **236** will be sealed or blocked from the position of the annular grooves **228*a*** and **228*b*** in order to sustain the running wheels **238** at the steered position at that moment.

According to the mechanism of this invention shown in FIGS. **8** and **9**, it will be apparent that the steering handle **254** can be steered or turned in a desired direction by using a pressurized liquid correspondingly to the angular position of the handle or wheel **254**.

The check valve **272** as shown is interposed between a feed passage **230** and the return line to the tank **233**; accordingly, in case the hydraulic pump **231** is not operative for some reason, the steering operation can be carried out manually.

This is because the operation of the handle causes the twisting motion of the torsion bar **258** owing to the stub shaft's operation, so that the spline **255** of the stub shaft **223** is abutted against a side wall of a tooth of the spline **176** in the side of the shaft **144**. Therefore, the position of the spool valve **222** is changed and subsequently the revolutional operation of the stub shaft **223** is transferred to the rotor **129** of the gerotor part **121** through the splines **255** and **176**, a shaft **144**, and an intermediate shaft **162**, so that the gyrotor part operates as a hand pump to absorb the operating liquid at the return side through said check valve **272** and to feed the pressurized liquid toward the power cylinder **236**.

In the embodiments described above, including that of FIG. **1**, a transmission mechanism part or portion **123** is positioned at the projecting side of the shaft **144** so that if a large speed-up ratio is is desired to be obtained by means of a one-step planetary gear mechanism, the outside diameter of the mechanism would become very large. Therefore, a two-step planetary gear mechanism is adopted in order to obtain a desired speed up ratio in the embodiments shown in FIGS. **1** through **11**. On the contrary, in the embodiments shown in FIGS. **12** and **13**, the desired speed-up ratio is obtained by replacing the transmission mechanism part **123*a*** with the gerotor part **121*a*** and using a one-step planetary gear without having to enlarge the outer diameter of the parts.

The embodiments shown in FIGS. **12** and **13** will now be described in more detail. In these embodiments, the gerotor part **121*a*** is situated at the right of a valve mechanism part **122*a*** and the transmission mechanism part **123*a*** is positioned at the left of the valve mechanism part, in order to form a metering pump **120*a*** which is placed or put on a steering valve **220** through the gerotor part **121*a*** and a partition board **132*a***. They are fastened or combined integrally to construct a valve mechanism **200*a*** of a hydraulic power steering apparatus. The steering valve **220** is identical with those of the embodiments shown in FIGS. **8** through **11** so that there is no necessity to explain about the steering valve **220** herein.

The gerotor part **121*a***, similarly to those of the embodiments described above, comprises a stator **127*a*** and a rotor **129*a*** the number of teeth of which is one smaller than that of the stator **127*a***, and the rotor **129*a*** is placed eccentrically in the stator **127*a***. An intermediate shaft **162*a*** is inserted through the center holes **160*a*** and **161*a*** of the rotor **129*a*** and the shaft **144*a***, and the rotational movement thereof can be transmitted between the rotor **129*a*** and the shaft **144*a*** by inserting the pins **163*a*** and **164*a*** attached to the ends of the intermediate shaft **162*a*** into axial grooves **165*a*** and **166*a*** formed on the center holes **160*a*** and **161*a*** of the rotor **129*a*** and the shaft **144*a***. In the embodiment shown in FIGS. **8** and **9**, a support member **151** supporting the primary planetary gear **149** situated within the transmission mechanism part **123** engages with a shaft **144*a*** in order to secure an annular member **261** into its proper place. On the contrary, according to the embodiment of FIGS. **12** and **13**, the annular member **261** is secured in the position between the shaft **144*a*** and a separate nut **151*a***.

The valve mechanism part **122*a*** of the embodiment shown in FIGS. **12** and **13** has two cavities **169*a*** and **170*a*** separated from each other and formed on a side of the part, and coaxial ring grooves **171*a*** and **172*a*** formed on the other side of the part, in order to make the valve mechanism part **122*a*** thin and to shorten the whole length of the apparatus. In the embodiment of FIGS. **12** and **13**, a commutator valve **136*a*** is constituted by communicating these annular grooves **171*a*** and **172*a*** with the cavities **169*a*** and **170*a***, respectively, through passages **173*a*** and **174*a***, and the commutator valve **136*a*** is received rotatably within a through hole **139*a*** of a casing **135*a***. A side of the commutator valve **136*a*** is applied to the gerotor part **121*a*** through a distributing board **131*a***. Variable volume chambers **134*a*** within the gerotor part **121*a*** are communicated with two cavities **169*a*** and **170*a*** through a through hole **130*a*** formed in the distributing board **131*a***. A partition board **178*a*** having through holes **177*a*** and **177*b*** and a spacer having two passages **179*a*** and **179*b*** are applied to the other side of the commutator valve **136*a***, and the annular grooves **171*a*** and **172*a*** which are arranged coaxially of the commutator valve **136*a*** are communicated to the pump passages **234**a and **234**b through the through holes **177**a and **177**b of the partition board **178**a and the passages **179**a and **179**b of the spacer **180**a.

The transmission mechanism part **123**a consists of a plurality of planetary gears **149**a supported on the fixed supporting member **181**a by a shaft **152**a, and rotatable inner gears **153**a engaging with the planetary gears **149**a. These planetary gears **149**a and the rotatable inner gears **153**a are received in a bored hole **143**a of the casing **142**a secured to the valve mechanism part **122**a through the fixed supporting member **181**a. The planetary gears **149**a engage with the geared portion **183**a formed on the end of a transmission member **182**a which is situated through the commutator valve **136**a, a partition board **178**a, a spacer **180**a and the fixed supporting member **181**a and, also, the base end of the transmission member **182**a is connected with the commutator valve **136**a by the key **184**a so as to transmit the revolutional motion of the planetary gear **149**a from the transmission member **182**a to the commutator valve **136**a through a key **184**a. Within the center hole **185**a of the transmission member **182**a, there is a second intermediate shaft **186**a the left end of which is connected to the inner gear **153**a through a pin **183**a and the right end thereof extends through the distributing board **131**a into the gyrotor part **121**a. The right end of the second intermediate shaft **186**a is connected to the connecting member **189**a through a pin **190**a, which connecting member **189**a is situated and secured in the central hole **161**a of the rotor **129**a by means of cutting groove **165**a and a key **188**a. In this way, the intermediate shaft **186**a is, together with the other intermediate shaft **162**a and a rotor **129**a of the gyrotor part **121**a, situated within the stator **127**a which is placed in an eccentric position, and the inner gear **153**a and the shaft **144**a are placed coaxially with the stator **127**a, so that the rotor **129**a, the inner gear **153**a and the shaft **144**a are respectively connected with the intermediate shafts **186**a and **162**a through universal joints.

Thus, the rotational motion of the shaft **144**a is transmitted to the rotor **129**a of the gerotor part **121**a through the intermediate shaft **162**a and also its speed is increased through the intermediate shaft **186**a, the inner gear **153**a, the planetary gear **149**a and a transmission member **182**a. Then, the direction of the rotational movement is reversed this is transmitted to the commutator valve **136**a. Accordingly, the diameter of the geared portion **183**a of the transmission member **182**a may be exceedingly reduced in comparison with the diameter of the inner gear **153**a, so that it is possible to revolve the commutator valve **136**a correspondingly to the moving direction and moving cycle of high and low pressure zones of each variable volume chamber **134**a in the gyrotor part **121**a. The operation of the embodiments shown in FIGS. **12** and **13** will be easily understood in view of the explanation of the embodiments of FIGS. **8** and **9**.

While the invention has been described in considerable detail, we do not wish to be limited to the particular embodiments shown and described, and it is our intention to cover hereby all novel adaptations, modifications, and arrangements thereof which come within the practice of those skilled in the art to which the invention relates.

What is claimed is:

1. In a hydraulic apparatus, a combination comprising a housing having a fluid supply port and a fluid discharge port;

a gerotor in said housing and including a stator, and a rotor which is rotatable relative to said stator and has a low-pressure zone and a high-pressure zone;

a commutator valve rotatably received in said housing and having two cavities indexed to face said high-pressure and low-pressure zone and being in communication with said fluid supply port and said fluid discharge port, respectively;

a main shaft extending through and defining an axis of rotation for said commutator valve;

an intermediate shaft having one end connected with said main shaft and another end connected with said rotor for rotation with the same in a first direction and at a first speed; and

gear means connected with said main shaft and said commutator valve and operative for rotating the latter in a direction opposite to said one direction and at a second speed which is greater than said first speed by a fixed ratio.

2. A combination as defined in claim **1**; and further comprising a steering valve for steering the wheels of a vehicle, said steering valve having a metering pump passage side and a stub shaft and said parts being communicated with said pump passage side; and further comprising a torsion bar connected with said stub shaft and with one of said main and intermediate shafts.

3. A combination as defined in claim **1**, wherein said stator has a first number of teeth, and said rotor has a second number of teeth which is smaller by one than said first number of teeth.

4. A combination as defined in claim **3**, wherein said gear means rotates said commutator valve at said second speed which is greater than said first speed by a number of times which corresponds to said second number of teeth on said rotor.

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