(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 012 010 A1

(12) # EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
07.01.2009 Bulletin 2009/02

(21) Application number: **07720394.1**

(22) Date of filing: **13.03.2007**

(51) Int Cl.:
F04B 39/00 *(2006.01)*

(86) International application number:
PCT/CN2007/000807

(87) International publication number:
WO 2007/119696 (25.10.2007 Gazette 2007/40)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR

(30) Priority: **14.03.2006 CN 200620007920 U**

(71) Applicant: **Zhu, Ronghui**
Anning village Haidian District
Beijing 100085 (CN)

(72) Inventor: **Zhu, Ronghui**
Anning village Haidian District
Beijing 100085 (CN)

(74) Representative: **Hellmich, Wolfgang**
European Patent and Trademark Attorney
Ernsbergerstrasse 14
81241 München (DE)

(54) **AN AXIAL PLUNGER PUMP OR MOTOR**

(57) An axial plunger pump or motor comprises a casing (1), a main shaft (2), a rotor cylinder (14), a rotary swash plate (9) and a plurality of plunger assemblies (10), wherein a constant velocity universal coupling (11) transmits torques between the rotary swash plate and the main shaft, such that the main shaft (14) and the rotary swash plate (9) rotate about the axes of the main shaft and the swash plate (41, 91), respectively, so as to realize energy transition between hydraulic energy and rotary mechanical energy.

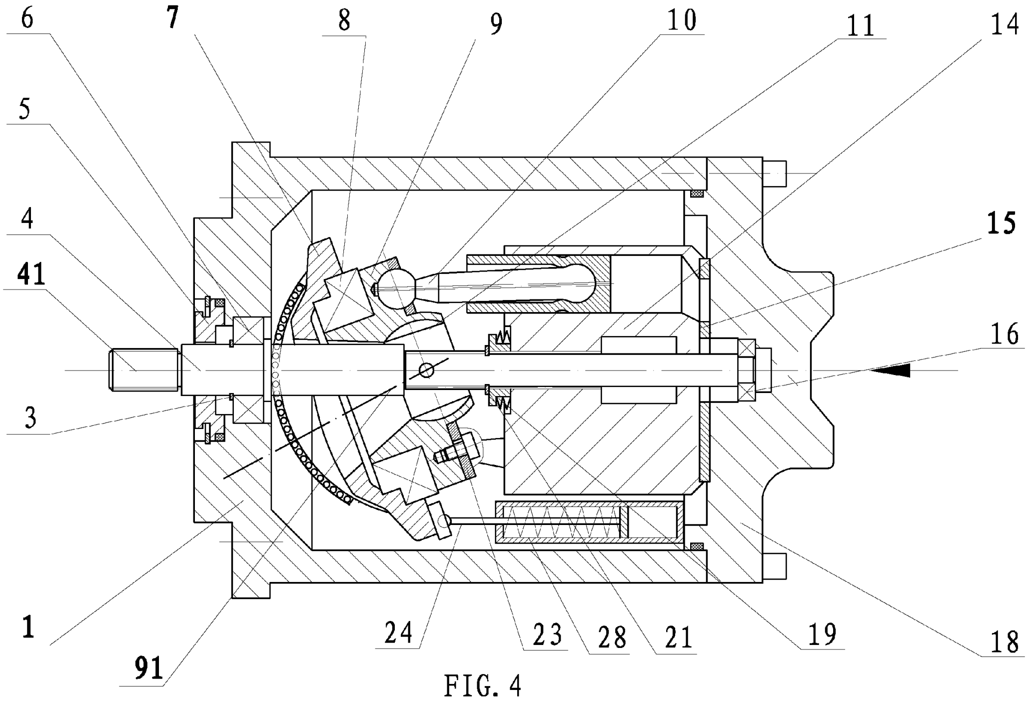


FIG. 4

EP 2 012 010 A1

Description

FIELD

[0001] The present invention relates to a hydraulic pump or motor device, particularly to an axial plunger pump or motor.

BACKGROUND

[0002] In hydraulic mechanisms, a hydraulic pump or motor is the heart of the hydraulic device. Theoretically, a hydraulic pump and a motor are switchable, except for some difference in some parts. Therefore, the description of the invention will only focus on the design of the pump, and the structure of a motor will be omitted in that it is similar to that of the pump. Plunger pumps have been increasingly widely employed in engineering mechanisms due to their high efficiency, adaptation to high pressure and aptness to carry out variable displacement adjustment.

[0003] The plunger pump can be classified into two categories according to the stroke direction of the plunger, that is, an axial plunger pump and an axial plunger pump. Furthermore, the axial plunger pump may be classified into a swash plate plunger pump and a bent axis plunger pump, according to the mechanism of motion transition. The structural characteristics of these two kinds of pumps are referred to Figs. 1 through 3, respectively.

[0004] Such an axial plunger pump of a swash plate type is a variable displacement pump of high pressure, high speed, high impact resistance and high integration degree. As shown in Figs. 1 and 2, a rotor is driven to rotate by the main shaft through involute splines. A plurality of plungers, which are uniformly distributed in the rotor, press the sliding tracks of the plunger assemblies against the plane of the frictional plate of the swash plate through a ball joint and a press plate. Since there forms an angle between the swash plate plane and the rotation axis, the plunger body not only rotates with the rotor, but also reciprocates along the plunger hole of the rotor. In this way, the plunger pump carries out oil intaking and supplying. The stroke of the plunger can be changed through adjusting the inclination angle of the swash plate, so as to perform variable displacement adjustments. Changing the inclination angle of the swash plate leads to variations of the flow direction of the pressurized oil, or the rotation direction of the rotor in case of serving as a hydraulic motor.

[0005] In such an axial plunger pump of a swash plate type, it is easy to perform variable displacement adjustments, and convenient to change the direction of the pressurized oil and the rotation direction of the rotor and to switch between the pump state and the motor state. Its cost is low, with relatively simple structure and small volume. However, an axial plunger pump of a swash plate type has three friction pairs, i.e., a pair between rotor and oil-distributing plate, a pair between plunger and plunger hole, and a pair between plunger sliding track and swash plate. In the friction pair between plunger and plunger hole, an individual plunger is not only subject to an axis force, but also to a tangential force and a torque. This is due to a normal force acted upon the sliding track of the plunger by the swash plate. The force and torque are balanced by the pressure applied on the plunger by the plunger hole. The sliding friction caused by such force and torque leads to component wearing and thus to a reduced mechanical efficiency. Therefore, the rotor needs to be balanced through a center axis supporting or an additional bearing since it is also acted upon by a rollover torque. Thus, such a pump has three disadvantages, (i) the overall efficiency is relatively low, wherein the volume efficiency of the oil pump is between 0.92 and 0.98 and the mechanical efficiency is between 0.90 and 0.95, and the overall efficiency is not higher than 0.95; (ii) it is susceptible to staining from oil and liquid, thus resulting in a short pump service life; (iii) the allowable rotation speed is not high.

[0006] As shown in Fig. 3, the working principle of a bent axis plunger pump is fairly similar to that of a swash plate pump. However, they have large differences in structure, and they also have different force profiles. In a bent axis pump, the method of articulating the ball head of the plunger is substituted for the approach of employing a sliding track and a swash plate in a swash plate pump, such that the structural strengthen and the impact resistance are improved. When the pump is operating, since the angle between the axis of the linking rod and the axis of the plunger is small, the lateral pressure between the plunger and the cylinder wall is much smaller than in the case of a swash plate pump. Therefore, wearing during operation is small, and the inclination angle βmay also be increased to 25 through 30 degrees (less than 20 degrees in case of a swash plate pump), such that the variation range of flow flux is enlarged. Furthermore, the drive shaft of a bent axis pump is small in dimension, or it does not penetrate through the oil-distributing disk, such that the rotor diameter of the cylinder is correspondingly reduced. Thus, leakage and loss due to friction are decreased, resulting in a higher overall efficiency than that of the swash disk pump, e.g., higher by 2-3% under the same technical level. The pump performance in oil-intaking is thus improved since the circumferential speed of the oil cylinder is decreased, and the rotation speed limit of the pump can therefore be increased. Furthermore, the requirement on the accuracy of oil-filtering in a bent axial pump is low, e.g., generally 25m, with comparison of 10 to 15m in a swash plate pump.

[0007] Due to above advantages, such bent axis pumps have been increasingly employed in the hydraulic mechanisms. However, such a pump carries out variable displacement through cylinder swinging, and the profile dimension is large. The inclination of the rotor and the power shaft makes the profile form a corner shape, which is not desirable in situations of narrow space or in case where coaxial assemble is required. In addition, structure and technical requirements are complicated, thus leading to a high cost.

SUMMARY

[0008] The object of the invention is to provide an axial plunger pump or motor, which increases the efficiency of the plunger pump or motor, has a simplified structure, a decreased volume, a lower cost, and a wide application range, and particularly is applicable to situations where special installation requirements should be meet, such as in transmissions of motor vehicles.

[0009] The above mentioned object of the invention may be achieved by the following technical solutions, i.e., an axial plunger pump or motor, comprising
a casing;
a main shaft rotatably supported on the casing;
a rotor cylinder with a plurality of plunger holes, which is coupled to the main shaft and is driven to rotate about the main shaft axis by the main shaft and which has an oil-distributing end surface;
an oil-distributing disk in cooperation with the oil-distributing end surface of the rotor cylinder;
a rotary swash plate whose end surface is disposed in a manner axially opposing the plurality of plunger holes of the rotor cylinder and which can rotate about the swash plate axis forming an angle with respect to the main shaft axis;
a plurality of plunger assemblies, an end of each being articulated to an end surface of the rotary swash plate and another end of each being slidably disposed in the plunger holes of the rotor cylinder;
a constant velocity universal coupling which is provided between the rotary swash plate and the main shaft and transmits torque therebetween, and which rotates the main shaft and the rotary swash plate about the main shaft axis and the swash plate axis forming an angle therebetween, respectively.

[0010] In the invention, said constant velocity universal coupling may be a Rzeppa constant velocity universal coupling, a half angular Rzeppa constant velocity universal coupling, a ball joint constant velocity universal coupling or a Weiss constant velocity university coupling.

[0011] The Rzeppa constant velocity universal coupling in the invention comprises an inner race ring with an outer raceway, an even number of steel balls, a holder and an outer race ring with an inner raceway, wherein said steel balls are arranged on the holder and are located in the inner raceway and the outer raceway, said inner race ring is coupled to the main shaft, said outer race ring is coupled to the rotary swash plate, such that the main shaft and the rotary swash plate are respectively rotated about the main shaft axis and the swash plate axis via the Rzeppa constant velocity universal coupling.

[0012] In the invention, as a particular example, said outer race ring may be integrally formed on the rotary swash plate.

[0013] In the invention, as an alternative example, said rotary swash plate may be supported on the casing via a swash plate bearing.

[0014] In the invention, as another alternative example, said rotary swash plate is supported on a pendulous disk via a swash plate bearing, the pendulous disk is supported on said casing via a pendulous disk bearing, and the rotation axis of the pendulous disk bearing is perpendicular to the main shaft axis and passes through the center of the constant velocity universal coupling.

[0015] In the above example, said pendulous disk may be connected with a variable displacement adjustment mechanism for adjusting the deflection angle of the pendulous disk, such that the angle between the swash plate axis of the pendulous disk supported thereon and the main shaft axis is adjusted through changing the deflection angle of the pendulous disk, and therefore the strokes of the plunger assemblies are changed so as to carry out variable displacement adjustments.

[0016] As an alternative example, said variable displacement adjustment mechanism in the invention is a variable displacement oil tank, the piston of which is connected to the pendulous disk so as to drive the pendulous disk to deflect through extending and retracting of the piston.

[0017] As another alternative example, the variable displacement adjustment mechanism is a variable displacement adjustment mechanism of a trunnion type, which includes a trunnion connected to the pendulous disk and a driving mechanism for driving the trunnion to rotate, the rotation axis of the trunnion is identical to the rotation axis of the pendulous disk so as to drive the pendulous disk to deflect through the trunnion.

[0018] In the invention, said rotor cylinder is in a conic shape, the diameter thereof at the end closer to the rotary swash plate is larger than that at the other end.

[0019] In the above-mentioned example, the plurality of plunger holes on said rotor cylinder are also distributed in a conic form, wherein the diameter of the circle in which the plunger hole center at the end in corporation with the plunger assemblies lies is larger than that at the other end.

[0020] In the invention, said plunger assembly may particularly be a plunger assembly of a ball joint type, which comprises a plunger and a ball-headed rod with both ends thereof being in a ball head shape, said rotary swash plate is provided with a socket, a ball-headed end of the ball-headed rod is located in the socket to form a ball-joint connection with the pendulous disk, and the other end thereof is located in the plunger to form a ball-joint connection with the plunger, and the plunger is slidably provided in the plunger hole. In the central portion of the ball-headed rod and the plunger is provided with a plunger port in communication with the plunger holes to introduce pressurized oil to lubricate the ball head at the both ends.

[0021] In the invention, the articulation centers of said plurality of plunger assemblies on the pendulous disk are located in a same plane, and the intersection point of the plane with the main shaft axis is identical to the center of the constant velocity universal coupling.

[0022] In the invention, said rotary swash plate is provided with an oil-distribution disk at the rear end thereof, the rotor cylinder is axially positioned along the main shaft through a pressure spring and a pressure spring stop collar, the end of the main shaft is provided with an oil port and a radial oil pathway, such that the pressure between the rotor cylinder and the oil-distribution disk is adjusted through introducing pressurized oil into the radial oil pathway.

[0023] In the invention, as an alternative embodiment, the oil-distribution end surface of said rotor cylinder may be a spheric surface, said oil-distribution disk forms a spheric corporation with the oil-distribution end surface.

[0024] In the invention, said swash plate bearing is a combination bearing of a needle bearing and a cylinder or a cone roller push bearing. The pendulous disk bearing is a needle bearing in a crescent form.

[0025] By employing the above-mentioned structure of the invention, the axial plunger pump or motor according to the invention may drive, via the constant velocity universal coupling, the rotary swash plate to rotate about the swash plate axis forming an angle with respect to the main shaft axis, while at the same the main shaft drive the rotary cylinder to rotate. In this way, the plunger assemblies reciprocate in the plunger holes of the rotor cylinder, causing volume variations in the cylinder, and communicates with the inlet port 13 and the outlet port 20 sequential via the cooperation with the oil-distributing disk. In this way, oil-intaking and oil-extruding are carried out, or in other words, transition between rotation mechanical energy and hydraulic energy is achieved. Wherein, since the constant velocity universal coupling transfers the rotating motion and the torque of the main shaft to the rotary swash plate which is rotating relative to the main shaft about a bent axis, the inclination angle of the rotary swash plate may be changed through driving the pendulous disk to swing by the variable displacement mechanism, so as to conveniently perform variable displacement adjustments.

[0026] As compared to a prior art axial plunger pump or motor of a swash plate type or a prior art axial plunger pump or motor of a bent axis type, the axial plunger pump or motor according to the present invention has the following effects.

(A) When compared with a variable displacement swash plate pump, the method of articulating the plunger assembly and the rotary swash plate is substituted for the sliding track and the swash plate in a swash plate pump, therefore structures corresponding to the main friction pairs are changed to a large extent. (i) Sliding friction between the sliding track of the plunger and the swash plate is changed to rolling friction, thus friction and leakage are decreased. Furthermore, the radial dimension of the swash plate is decreased, since the surface area of the ball head which forms a ball joint is larger than the area of the sliding track disk of the same diameter. (ii) As for the friction pair between the plunger and the rotor cylinder, the friction force is accordingly decreased since the lateral pressure is much less than in the case of the swash plate pump, the requirement on the accuracy of oil-filtering is largely relaxed, and the wearing is suppressed. (iii) As for the friction pair between the rotor cylinder and the oil-distribution disk, since the main shaft is free of the bent torque and only serves to support at the end, the diameter of the oil-distributing port of the rotor cylinder may accordingly decreased, such that the circumference of the oil port and the translation velocity of the relative motion is decreased and the power loss due to friction and leakage is suppressed. In addition, since the inclination angle of the rotary swash plate of the pump may be increased to 25 through 30 degrees (not larger than 20 degrees in case of a swash plate pump), the variation range of flow flux is enlarged, the dimension of the pump is decreased and the pump performance in oil-intaking is thus improved since the circumferential speed of the oil cylinder is decreased; at the same time, the hydraulic push acted upon the plunger is directly transferred to the casing through the ball head, the rotary swash plate, bearing and the pendulous disk support, such that motion components, such as the main shaft and the rotor cylinder, etc., are free of other additional forces and torques. In this way, the force profile of the motion components is improved, and friction and leakage are suppressed. The above effects have the following advantages:

(1) a higher overall efficiency than that of a swash plate pump, (2) an increased structural strength, a higher impact resistance, an increased resistance to staining from oil, a decreased wearing and an extended service life, (3) an increased rotation speed limit of such a pump or motor, (4) a further decreased dimension of such a pump or motor.

(B) When compared with a variable displacement bent axis pump, even in structural point of view, a constant velocity universal coupling is added, leading to a certain power loss (generally, 1-3%), four benefits can be obtained, that is,

(1) a decreased volume and a decreased weight. The means of deflecting and adjusting the pendulous disk is substituted for swinging the rotor body, so the radial dimension required by the same deflection angle is decreased. In the case of a bent axis pump, the power shaft is subject to a large bending torque while at the same time being acted upon by a torsion torque,

thus a sufficient axial length is necessary for the purpose of balancing, leading to a longer power shaft; in addition, the oil-distributing disk, the pendulous disk and the variable displacement adjustment mechanism located at the afterbody may occupy large space. These are not the case in the invention. With the same parameters, the radial length and the radial dimension of the inventive variable displacement plunger pump is decreased at lease 1/3 as compared to the conventional swash plate pump.

(2) coaxial transmission or transmission by a common shaft is achieved. It is suitable for applications of limited installation space which necessities coaxial transmission or transmission by a common shaft, such as the case in which a plurality of pumps are required to be connected in serials. This may simplify or optimize the mechanical systems in some application.

(3) an easy adjustment and switch. The output flow flux may be varied only by adjusting the inclination angle of the pendulous disk, and the flow direction and the switch between pump and motor may be carried out simply by changing the direction of inclination angle. However, in prior art bent axis plunger pump, sufficient stroke space and drive power are necessary to perform the same implementation.

(4) a further increased efficiency. Even the additional constant velocity universal coupling leads to a somewhat decrease in the efficiency, the prior art structure, which needs three heavy-duty bearings to bear the radial force, the axial force and the bending torque of the main shaft, is significantly simplified, i.e., only one heavy-duty bearing is needed. Thus the power loss due to friction is lowered, this is because the power shaft is free of a bending torque and the end surface bearing functions positioning only. The inventive structure dispenses with a sliding fit surface between the oil-distributing disk and the velocity adjusting disk as compared with the prior art velocity adjusting mechanism which carries out adjustment through swinging the rotor, thus corresponding leakage is suppressed and the volume efficiency is increased. In this way, the overall efficiency is higher than a conventional variable displacement bent axis pump.

DRAWINGS

[0027]

FIG. 1 is a schematic view of the structure of a prior art swash plate pump;

FIG. 2 is a sectional view taken along line A-A in FIG. 1;

FIG. 3 is a schematic view of the structure of a prior art bent axis pump;

FIG. 4 is a view showing the principles of the structure of the invention;

FIG. 5 is a schematic view showing the structure of the embodiment 1 of the invention in a front view;

FIG. 6 is a sectional view taken along line A-A in FIG. 5;

FIG. 7 is a sectional view taken along line B-B in FIG. 6;

FIG. 8 is a schematic view showing the structure of the embodiment 2 of the invention in a front view;

FIG. 9 is a schematic view showing the assembly structure of a Rzeppa constant velocity universal coupling;

FIG. 10 is a perspective view showing the exploded structure of a Rzeppa constant velocity universal coupling.

DETAILED DESCRIPTION OF EMBODIMENTS

[0028] See FIG. 4, an axial plunger pump or a motor mainly includes a casing 1, a main shaft 4 rotatably supported on the casing 1, a rotor cylinder 14 with a plurality of plunger holes which is coupled to the main shaft 4 and is driven to rotate about the main shaft axis 41 by the main shaft 4 and which has an oil-distributing end surface, an oil-distributing disk 15 in cooperation with the oil-distributing end surface of the rotor cylinder 14, a rotary swash plate 9 whose end surface is disposed in a manner axially opposing the plurality of plunger holes of the rotor cylinder 14 and which may rotate about the swash plate axis 91 forming an angle with respect to the main shaft axis, a plurality of plunger assemblies 10, an end of each articulated to an end surface of the rotary swash plate 9 and another end of each slidably disposed in the plunger holes of the rotor cylinder 14, a constant velocity universal coupling 11 which is provided between the rotary swash plate 9 and the main shaft 4 and transmits torque therebetween, and which rotates the main shaft 4 and the rotary swash plate 9 about the main shaft axis 41 and the swash plate axis 91 forming an angle therebetween, respectively. In this way, when the invention is employed as an axial plunger pump, the main shaft 4 is driven to rotate about the main shaft axis 41, and the rotary swash plate 9 is driven, by constant velocity universal coupling 11, to rotate about the swash plate axis 91 forming an angle with respect to the main shaft axis

41. Thus the plunger assemblies 10 reciprocate in the plunger holes of the rotor cylinder 14, causing volume variations in the rotor cylinder 14 to carry out oil-intaking and oil-extruding, or in other words, transition between rotation mechanical energy and hydraulic energy is achieved. When the invention is employed as an axial plunger motor, the rotary swash plate 9 rotates about the swash plate axis 91 by the hydraulic oil in the plunger holes so as to drive the main shaft 4 to rotate about the main shaft axis 41 via the constant velocity universal coupling 11 and to drive the rotor cylinder 14 coupled with the main shaft 4 to rotate. In this way, the plunger assemblies 10 reciprocate in the plunger holes, such that hydraulic energy is transited to rotary mechanical energy of the main shaft. In view of similarity in basic structures whether the inventive axial plunger pump is employed as a pump or as a hydraulic motor, the present invention will mainly describe in detail the situation where the inventive axial plunger or motor is employed as a pump.

[0029] In the present invention, as but one particular example, the casing 1 and a rear end cap 18 are connected to each via screws so as to form a closed box, and the main shaft 4 is supported in the box via a front bearing 6 and a rear bearing 16, as shown in Figs. 4 to 7. An inlet slot and an outlet slot in the oil-distributing disk 15 are communicated with an inlet port 13 and an outlet port 20, respectively. The main shaft 4 penetrates through the oil-distributing disk 15, the rotor cylinder 14, a pressure spring 19, the constant velocity universal coupling 11 and the rotary swash plate 9, in this order, and projects through an end seal cap 5 from a side of the box. The rotor cylinder 14 is circumferentially fixed to the main shaft 4 via a spline, and is pressed against the oil-distributing disk 15 by the pressure spring 19 surrounding the main shaft 4 so as to achieve an initial seal between the rotor cylinder 14 and the oil-distributing disk 15. The rotating main shaft 4 drives rotary swash plate 9 to rotate about the swash plate axis 91 via the constant velocity universal coupling 11, while at the same time driving the rotor cylinder 14 to rotate via the spline. In this way, the plunger assemblies 10 are driven to reciprocate in the plunger holes in the rotor cylinder 14, causing volume variations in the plunger holes. These plunger holes communicates with the inlet port 13 and the outlet port 20 sequential via the cooperation with the oil-distributing disk 15. In this way, oil-intaking and oil-extruding are conducted, i.e., transition between rotation mechanical energy and hydraulic energy is achieved.

[0030] In the invention, the constant velocity universal coupling 11 may be a Rzeppa constant velocity universal coupling, a half angular Rzeppa constant velocity universal coupling, a ball joint constant velocity universal coupling or a Weiss constant velocity university coupling. The invention takes a Rzeppa constant velocity universal joint as an example and gives a detailed explanation thereof. Other types of constant velocity universal joints, such as a half angular Rzeppa constant velocity universal coupling, a ball joint constant velocity universal coupling, a Weiss constant velocity university coupling, and the like, are also applicable if dimensions of space permit, even though their structures are relatively complicated as compared to the structure of a Rzeppa constant velocity universal joint . Therefore detailed explanations thereof are omitted. As shown in Figs. 5 through 10, in an example where the constant velocity universal coupling 11 is a Rzeppa constant velocity universal joint, it comprises an inner race ring 111 with an outer raceway, an even number of steel balls 112, a holder 113 and an outer race ring 114 with an inner raceway, wherein the outer race ring 114 is coupled to the rotary swash plate 9 and the inner race ring 111 is coupled to the main shaft 4, such that the main shaft 4 can drive the rotary swash plate 9 which is coupled to the outer race ring 114 to rotate about the swash plate axis 91 forming an angle with respect to the main shaft axis 41 while at the same time driving the inner race ring 111 (i.e., the rotation axis about which the outer race ring 114 rotates) to rotate about the main shaft axis 41. As a particular example, the inner holes of the outer race ring and the rotary swash plate 9 may be combined so as to integrate the outer race ring 114 with the rotary swash plate 9, thus space effectiveness in the radial direction is ensured. Even though the inner race ring 111 and the main shaft 4 may also be combined such that the inner race ring 111 is integrated with the main shaft 4, they are provided separately in consideration of manufacture process and installation feasibility, e.g., the inner race ring 111 is circumferentially fixedly coupled to the main shaft 4 via a spline and is restrained in the axial direction by a stop collar 21 on the shaft. As shown in Fig. 9, according the principles of a Rzeppa constant velocity universal joint, the sphere centers of both the inner race ring and the outer race ring should be arranged on the main shaft axis 41 and be located on each side of the center of the constant velocity universal joint coupling 11 with the distances thereto being equal. The holder 113 confines the even number of steel balls 112 in a same plane which also passes through the center of the coupling.

[0031] As an alternative example, the plurality of plunger assemblies 10 in the invention may be plunger assembles of a ball joint type, which comprises a plunger and a ball-headed rod with both ends thereof being in a ball head shape and which is provided with an oil port for introducing pressurized oil to lubricate the ball head at the both ends. The structure of the plunger assemblies 10 is the same as the structure of the plunger assemblies of the bent axis pump. Uniformly distributed on the right end of the rotary swash plate 9 are a plurality of sockets with their centers located in a same plane. The ends of ball heads of the plunger assemblies 10 are imbedded into the sockets of the rotary swash plate 9 and restrained therein by a retainer plate 23, and the plunger ends of the plunger assemblies 10 projects into the plunger holes of the rotor cylinder 14. The number of the plunger assemblies 10 is equal to the number of the sockets in the rotary swash plate 9 and the number of plunger holes in the rotor. The central point of the constant velocity universal coupling 11 is coincident with the intersection point of the central plane of the plurality of sockets in the rotary swash plate 9 with the main shaft axis.

[0032] In the invention, as shown in Fig. 4 through 8, the middle case of casing 1 and the front end cap may be an integral structure cast from cast iron or die-cast from aluminum alloy, while the rear end cap 18 is connected to the middle case via screws. Certainly, other structural forms may be employed, e.g., the middle case and the front end cap are not an integral structure and they are coupled with each other via screws. The integral structure presents strength, but it is more difficult to process, contrary to the latter case.

[0033] As shown in Figs. 4 through 7, as an alternative example of the invention, in embodiment 1, the axial plunger pump or motor according to the invention may carry out variable adjustments. The rotary swash plate 9 is embedded into a pendulous disk 7 via a swash plate bearing 8 which can receive a radial force, an axial force and a torque at the same time. The pendulous disk 7 is supported to the casing 1 via a pendulous disk bearing 2. The rotation axis of this pendulous disk bearing 2 is perpendicular to the main shaft axis 41 and passes through the center of constant velocity universal coupling 11. In other words, the pendulous disk 7 can only swing about the center of constant velocity universal coupling 11 in a plane parallel to the main shaft axis 41. In this way, the inclination angle of the rotary swash plate 9 (i.e., the inclination angle of the swash plate axis 91 with respect to the main shaft axis 41) may be adjusted through deflecting the pendulous disk 7 so as to carry out variable displacement adjustment. In embodiment 1, as shown in Figs. 4 through 7, the pendulous disk 7 may be connected with a variable displacement adjustment mechanism for adjusting the deflection angle of the pendulous disk 7. The constant velocity universal coupling 11 transfers the rotation motion of main shaft 4 and thus the moment to the rotary swash plate 9 rotating about the swash plate axis 91, therefore it is very convenient to carry out variable displacement adjustment of a pump or motor through driving, via the variable displacement adjustment mechanism, the pendulous disk 7 to swing so as to change the inclination angle of the rotary swash plate 9.

[0034] As shown in Fig. 4 through 6, in the embodiment 1, the pendulous disk 7 comprises an upper partial cylinder and a lower partial cylinder, and is supported to the casing 1 via the pendulous disk bearing 2, with its right end provided with an inner cylinder surface of a step shape for the swash plate bearing to be embedded. As shown in Fig. 6 and Fig. 7, as but one example of a variable displacement adjustment mechanism, the variable adjustment mechanism may be an adjustment mechanism of a trunnion type which conducts adjustment from outside. It includes a trunnion 24 connected to the pendulous disk 7 and a driving mechanism for driving the trunnion 24 to rotate. The rotation axis of the variable displacement trunnion 24 is identical to the swing axis. In this way, the variable displacement adjustment is achieved through the peripherally provided driving mechanism driving the trunnion 24 to rotate. In this example, at one side of the pendulous disk 7 may be provided with a seat 26 for the variable displacement trunnion via a threaded member 27. The variable displacement trunnion 24 is circumferentially fixedly connected to the trunnion seat 26 via a spline or a flat key so as to install the variable displacement trunnion 24 to the pendulous disk 7. Thus, structures are simple and mechanism is straightforward in that the pendulous disk 7 can be driven to swing only through rotating the trunnion 24. As another example of a variable displacement mechanism, the variable displacement mechanism may also includes a variable displacement oil tank 28, the piston of which is connected to the pendulous disk 7 so as to drive the pendulous disk 7 to deflect through extending and retracting the piston so as to carry out variable displacement adjustment. The variable displacement adjustment mechanism may certainly assume other forms, for example, they may take use of variable displacement mechanism of various swash plate pumps, only if the deflection angle of the pendulous disk 7 can be changed by means of the variable displacement mechanisms. Herein explanations thereof are omitted.

[0035] As shown in Fig. 5 and Fig. 6, the swash plate bearing 2 in the embodiment 1 may be two needle bearings in a crescent form which are longitudinally symmetrcial. The rotation axis of the bearing 2 is perpendicular to the main shaft axis 4 and passes through the center of the constant velocity universal coupling 11. The outer race ring of the bearing is fixed to the bearing seat of the casing 1, and the inner race ring thereof is fixed to the cylindrical surface of the pendulous disk 7 on the left side or is integral with the cylindrical surface. The function of the bearing is to transfer the push force acted upon the pendulous disk 7 to the casing 1 and to suppress the swinging resistance to the pendulous disk 7. The bearing may be other types of bearing, such as a sliding bearing.

[0036] In the embodiment 1, the rotary swash plate 9 may be provided with a flare-shaped inner hole at its left end. The main shaft 4 passes through this inner hole, and does not interfere with the rotary swash plate 9 when the rotary swash plate 9 is swinging with the pendulous disk 7. The rotary swash plate 9 is also provided with an outer cylinder surface at its left end so as to install the swash plate bearing 8. The rotary swash plate 9 has a plurality of sockets on its right end surface, the centers of which sockets are located in a same plane. Generally, the number of the sockets are odd, such as 5, 7, ..., 11. At the central portion of its right end, the rotary swash plate 9 is provided with a spherical hole, and there is engraved an inner raceway along the direction of the main shaft 4, as the out race ring of the constant velocity universal coupling 11.

[0037] As shown in Fig. 8, in the embodiment 2 which is another embodiment of the invention, the axial plunger pump or motor may be applicable to a constant displacement pump. Since no variable displacement adjustment is needed, the pendulous disk 7, the pendulous disk bearing 2 and the variable displacement mechanism can be dispensed with and the rotary swash plate 9 can be directly supported at the oblique surface of the casing 1, such that the whole structure is very simple and compact.

[0038] The important friction surface may be subject to plating or coating, for example, molybdenum disulfide plating so as to decrease friction loss and improve efficiency and service life.

[0039] The swash plate bearing 8 of the invention will receive an axial force, a radial force and a rolling torque from the swash plate. In consideration of this, a needle/cylinder (cone) roller push bearing may be employed as the bearing 8, and other types of bearings or combination bearings are also applicable if only they can perform the same functions.

[0040] In the present invention, as shown in Figs. 4 through 6 and Fig. 8, the main shaft 4 is provided with a spline or a flat key at its front end so as to be connected to other motive machines or working machines. On the middle of main shaft 4 are provided with splines to be circumferentially fixedly connected to the constant velocity universal coupling 11 and rotor cylinder 14, respectively, so as to drive the rotary swash plate 9 and the rotor cylinder 14 to rotate and to transfer torques. At the middle of the main shaft 4 is supported a disk pressure spring 19 with a stop collar 21 and a pressure spring seat. The pressure spring 19 may also be a cylinder-shaped coil spring. Generally, a residual pressure method is employed to calculate the pre-compression force, with the principle being to ensure reliable seal between the rotor cylinder 14 and the oil-distributing disk 15. The right end of the main shaft 4 is provided with an oil hole and a radial oil pathway, such that the pressurized oil introduced from the outside of the pump acts upon the right end surface of the rotor cylinder 14. Thus, the pressure between the rotor cylinder 14 and the oil-distributing disk 15 may be adjusted through adjusting the pressure of the pressurized oil from outside. In this way, the pressure between the rotor cylinder 14 and the oil-distributing disk 15 can be conveniently adjusted to ensure a higher efficiency of the pump under various working conditions.

[0041] As shown in Figs. 4 through 6 and Fig. 8, the rotor cylinder 14 in the invention is a cylinder with a plurality of plunger holes arranged uniformly in the circumferential direction. These plunger holes are in a close active corporation with the plungers of the plunger assemblies 10. As shown in Fig. 5 and Fig. 8, the oil-distribution end surface of the rotor cylinder 14 is a spheric surface, which is in a close corporation with the spheric oil-distributing disk 15, thus generating a spheric corporation therebetween and presenting a good self-centering characteristics. The rotor cylinder 14 may be made of such materials as copper, nodular cast iron, cast iron, forged steel, etc. The inner surface of the plunger holes and the spheric oil-distribution surface are subject to the treatment (such as embedding and plating) to decrease friction and enhance wear resistance. Since the constant velocity universal coupling 11 should be installed at the center of the rotary swash plate 9, the radial dimension thereof will consequentially be increased in case of the pump of small displacement. In this case, the rotor cylinder 14 may be formed in a conic shape, that is, its diameter on the left end is larger than its diameter on the right end. The plurality of plunger holes are shaped in a conic form, wherein, the diameter of the circle in which the plunger hole center at the end (in the left of the drawing) in corporation with the plunger assemblies 10 lies is larger than that at the other end (in the right of the drawing). In this way, it is not necessary to increase the diameter of the rotor cylinder 14 on the whole, and it is possible to decrease the diameter of the oil-distribution hole. As shown in Fig. 4, the oil-distribution end surface of the rotor cylinder 14 may be in a planar form, such that the process is easy.

[0042] In the sequel, the characteristics of the structure dimensions of the invention will be set forth through taking as an example the variable displacement pump as described in the embodiment 1 according to the invention, which has a displacement of 16 l/r and a rating pressure of 35MPa.

[0043] The number of the plungers of this pump is 7, thus each plunger has an effective volume of 2.3ml. The maximal stroke of the piston is 1.8cm to 2.0cm, and the diameter of the plunger is 12mm to 13mm. The diameter of the circle in which the plunger center lies is dependent on the swinging angle of the pendulous disk 7. The swinging angle is chosen to be 20 degrees according to experience, such that the diameter of said circle should be 56mm. The outer diameter of the rotor cylinder 14 is 75mm×40mm. The rating output torque of the pump is 89Nm, therefore, the diameter of the power shaft (main shaft 4) which employs simple steel is only between 15mm and 20mm. In consideration of the constrains on strength, dimension and angle of the constant velocity universal coupling 11 itself, and the strength and stiffness of the power shaft, the rotor cylinder 14 is formed in a conic shape, the rotor diameter at the larger end being 82mm and that at the smaller end being 72mm. The rotary swash plate 9 has a diameter of 85mm, and the diameter of pendulous disk 7 has a diameter of 100mm. Thus the dimension of the whole pump is 120mm×150mm (the extension length of the shaft end not included). Obviously, the dimension and the weight are smaller than those of the swash plate pump with the same displacement, and are even much smaller than those of the bent axis pump.

Claims

1. A axial plunger pump or motor, comprising
a casing;
a main shaft rotatably supported on the casing;
a rotor cylinder with a plurality of plunger holes, which

is coupled to the main shaft and is driven to rotate about the main shaft axis by the main shaft and which has an oil-distributing end surface;
an oil-distributing disk in cooperation with the oil-distributing end surface of the rotor cylinder;
a rotary swash plate whose end surface is disposed in a manner axially opposing the plurality of plunger holes of the rotor cylinder and which may rotate about the swash plate axis forming an angle with respect to the main shaft axis;
a plurality of plunger assemblies, an end of each being articulated to an end surface of the rotary swash plate and another end of each being slidably disposed in the plunger holes of the rotor cylinder;
a constant velocity universal coupling which is provided between the rotary swash plate and the main shaft and transmits torques therebetween, and which rotates the main shaft and the rotary swash plate about the main shaft axis and the swash plate axis forming an angle therebetween, respectively.

2. The axial plunger pump or motor according to claim 1, wherein, said constant velocity universal coupling is a Rzeppa constant velocity universal coupling, a half angular Rzeppa constant velocity universal coupling, a ball joint constant velocity universal coupling or a Weiss constant velocity university coupling.

3. The axial plunger pump or motor according to claim 1, wherein, said Rzeppa constant velocity universal coupling comprises an inner race ring with an outer raceway, an even number of steel balls, a holder and an outer race ring with an inner raceway, wherein said steel balls are arranged on the holder and are located in the inner raceway and the outer raceway, said inner race ring is coupled to the main shaft, said outer race ring is coupled to the rotary swash plate, such that the main shaft and the rotary swash plate are respectively rotated about the main shaft axis and the swash plate axis via the Rzeppa constant velocity universal coupling.

4. The axial plunger pump or motor according to claim 3, wherein, said outer race ring is integrally formed on the rotary swash plate.

5. The axial plunger pump or motor according to claim 1, wherein, said rotary swash plate is supported on the casing via a swash plate bearing.

6. The axial plunger pump or motor according to claim 1, wherein, said rotary swash plate is supported on a pendulous disk via a swash plate bearing, the pendulous disk is supported on said casing via a pendulous disk bearing, and the rotation axis of the pendulous disk bearing is perpendicular to the main shaft axis and passes through the center of the constant velocity universal coupling.

7. The axial plunger pump or motor according to claim 6, wherein, said pendulous disk is connected with a variable displacement adjustment mechanism for adjusting the deflection angle of the pendulous disk, such that the angle between the swash plate axis of the pendulous disk supported thereon and the main shaft axis is adjusted through changing the deflection angle of the pendulous disk.

8. The axial plunger pump or motor according to claim 7, wherein, said variable displacement adjustment mechanism is a variable displacement oil tank, the piston of which is connected to the pendulous disk so as to drive the pendulous disk to deflect through extending and retracting of the piston.

9. The axial plunger pump or motor according to claim 7, wherein, the variable displacement adjustment mechanism is a variable displacement adjustment mechanism of a trunnion type, which includes a trunnion connected to the pendulous disk and a driving mechanism for driving the trunnion to rotate, the rotation axis of the trunnion is identical to the rotation axis of the pendulous disk so as to drive the pendulous disk to deflect through the trunnion.

10. The axial plunger pump or motor according to claim 1, wherein, said rotor cylinder is in a conic shape, the diameter thereof at the end closer to the rotary swash plate is larger than that at the other end.

11. The axial plunger pump or motor according to claim 10, wherein, the plurality of plunger holes on said rotor cylinder are distributed in a conic form.

12. The axial plunger pump or motor according to claim 1, wherein, said plunger assembly is a plunger assembly of a ball joint type, which comprises a plunger and a ball-headed rod with both ends thereof being in a ball head shape, said rotary swash plate is provided with a socket, a ball-headed end of the ball-headed rod is located in the socket to form a ball-joint connection with the pendulous disk, and the other end thereof is located in the plunger to form a ball-joint connection with the plunger, and the plunger is slidably provided in the plunger hole.

13. The axial plunger pump or motor according to claim 12, wherein, in the central portion of the ball-headed rod and the plunger is provided with a plunger port in communication with the plunger holes to introduce pressurized oil to lubricate the ball head at the both ends.

14. The axial plunger pump or motor according to claim 1, wherein, the articulation centers of said plurality of plunger assemblies on the pendulous disk are located in a same plane, and the intersection point of the plane with the main shaft axis is identical to the center of the constant velocity universal coupling.

15. The axial plunger pump or motor according to claim 1, wherein, the rotor cylinder is axially positioned along the main shaft through a pressure spring and a pressure spring stop collar, the end of the main shaft is provided with an oil port and a radial oil pathway, such that the pressure between the rotor cylinder and the oil-distribution disk is adjusted through introducing pressurized oil into the radial oil pathway.

16. The axial plunger pump or motor according to claim 1, wherein, the oil-distribution end surface of said rotor cylinder is a spheric surface, said oil-distribution disk forms a spheric corporation with the oil-distribution end surface.

17. The axial plunger pump or motor according to claim 5, wherein, said swash plate bearing is a combination bearing needle bearing of a needle bearing and a cylinder or a cone roller push bearing.

18. The axial plunger pump or motor according to claim 6, wherein, said pendulous disk bearing is a needle bearing in a crescent form.

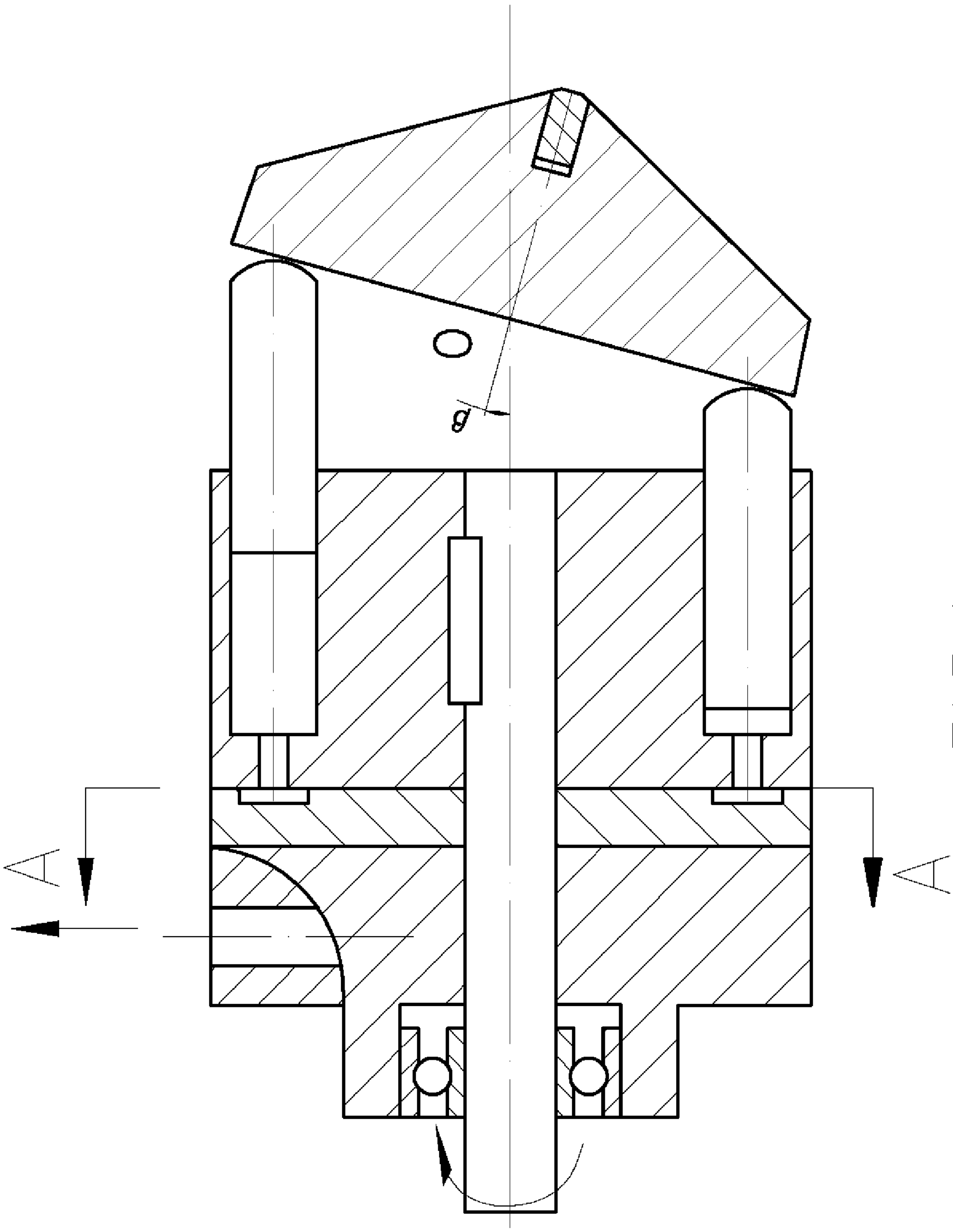
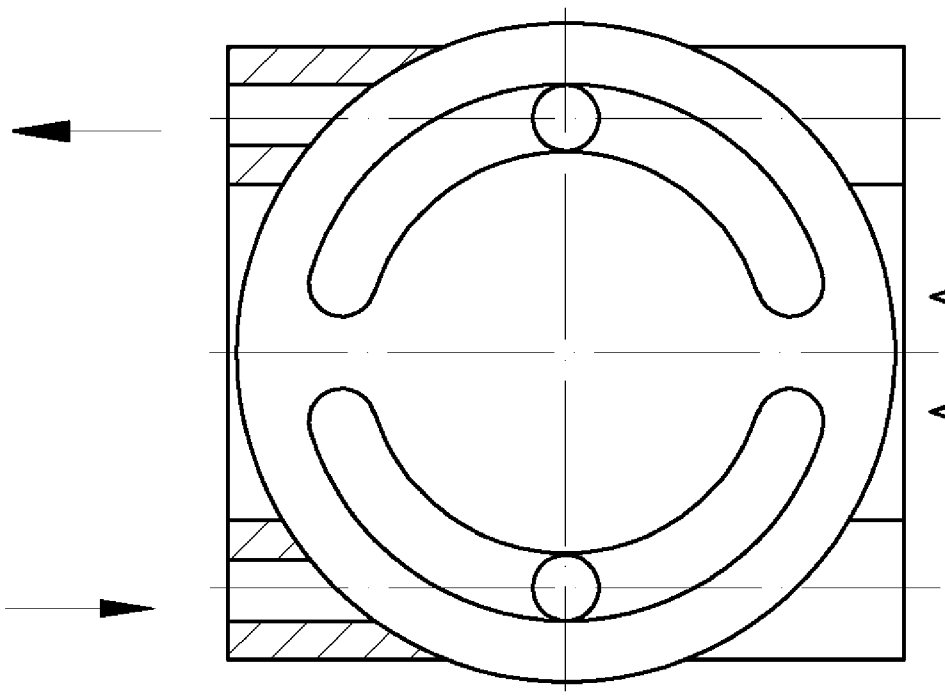


FIG.1



A–A

FIG. 2

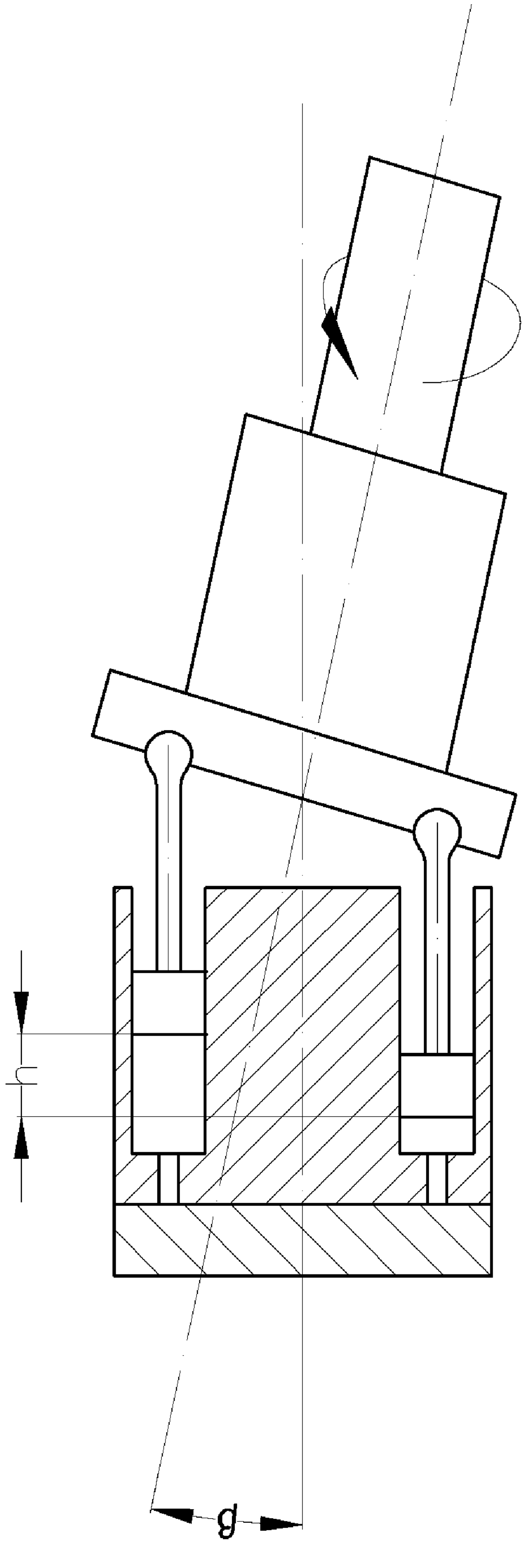


FIG.3

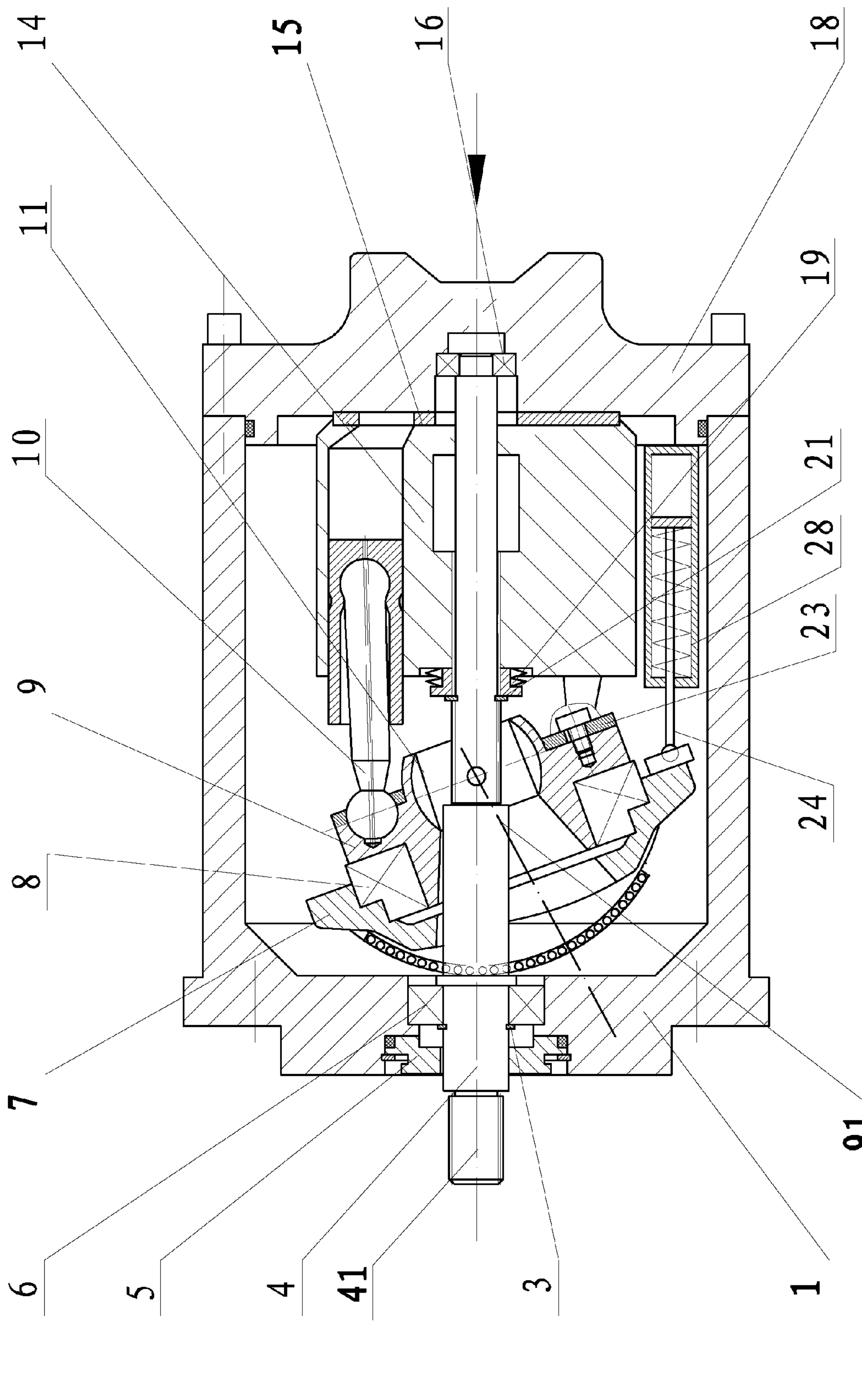


FIG. 4

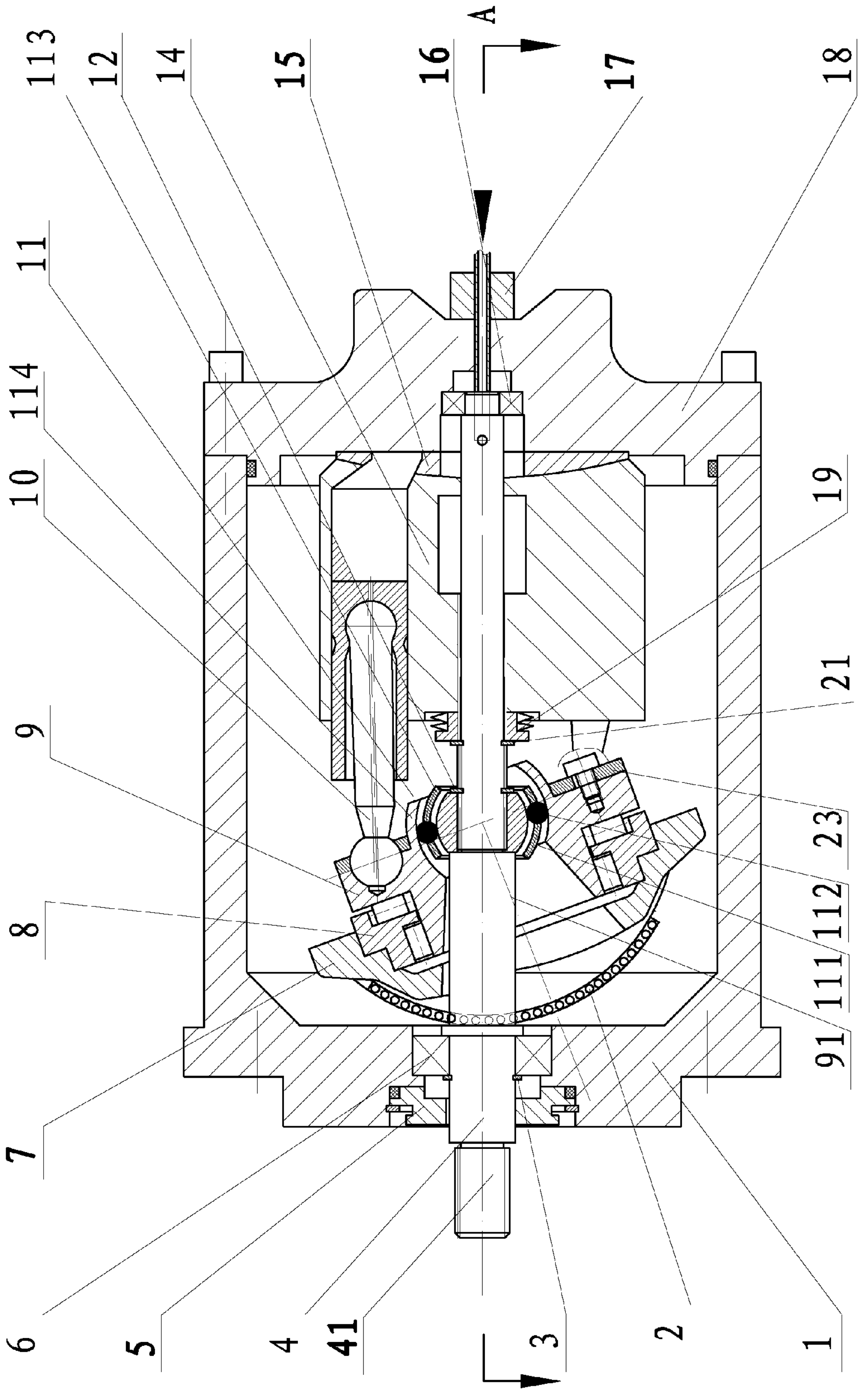


FIG. 5

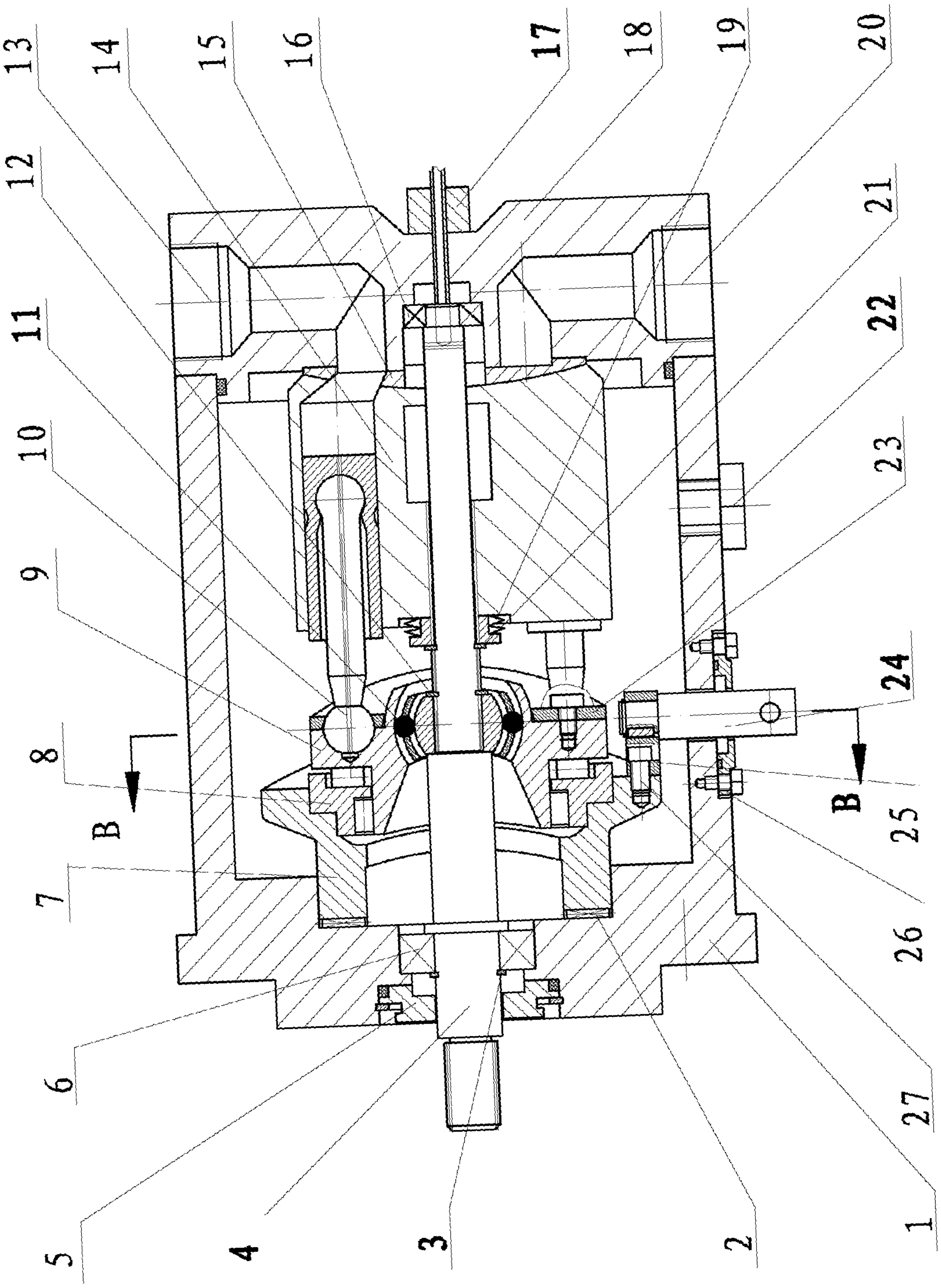


FIG. 6

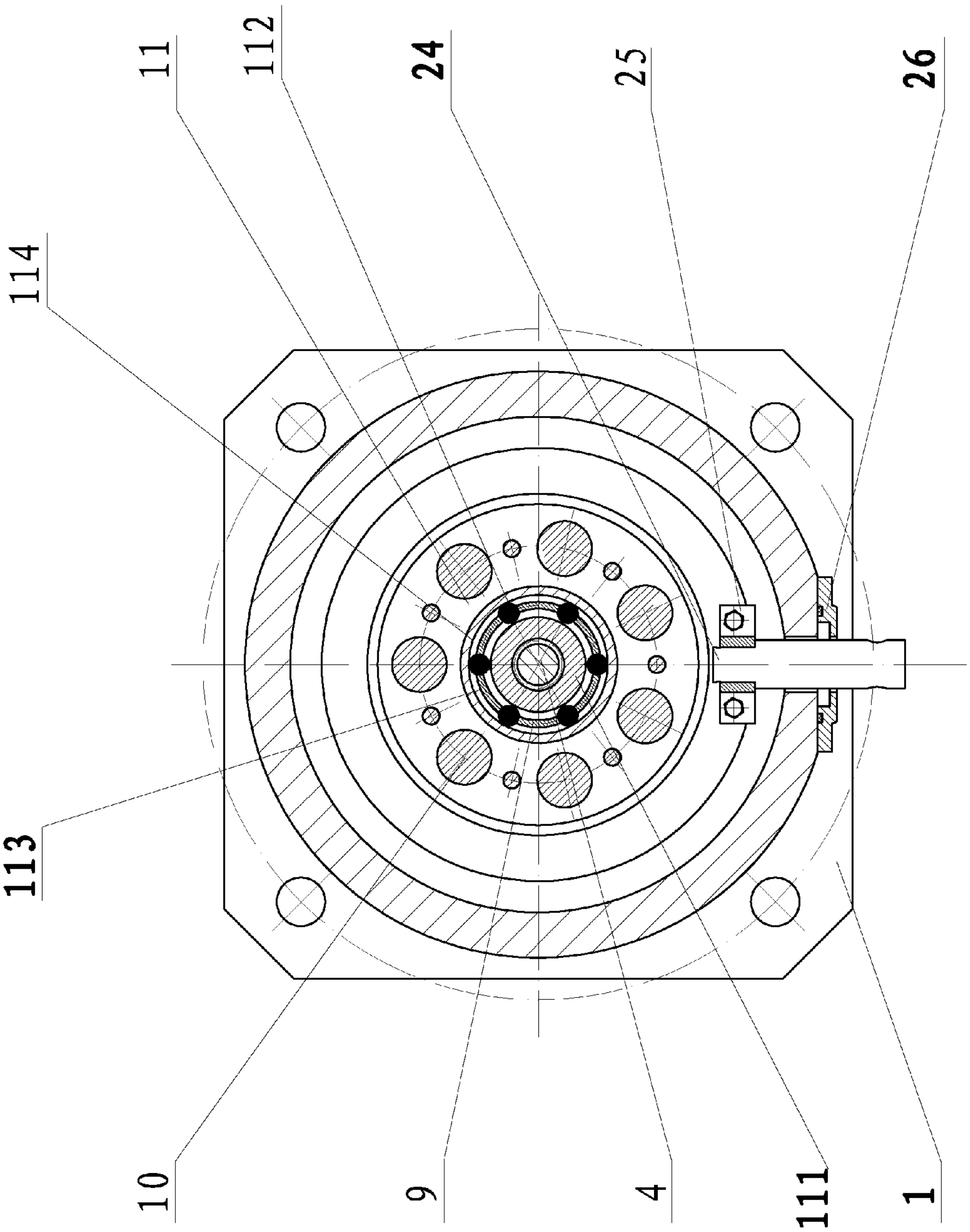


FIG. 7

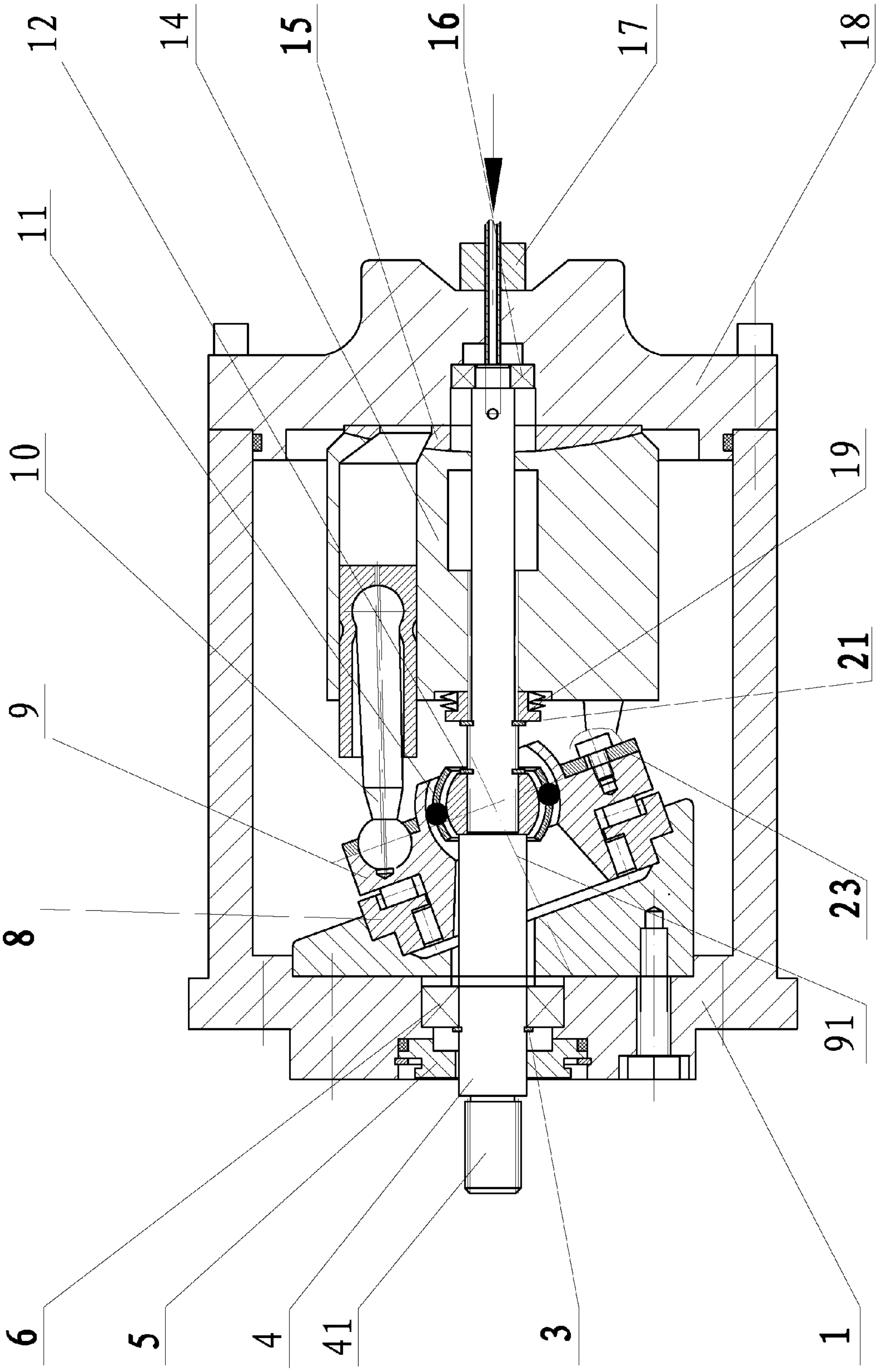
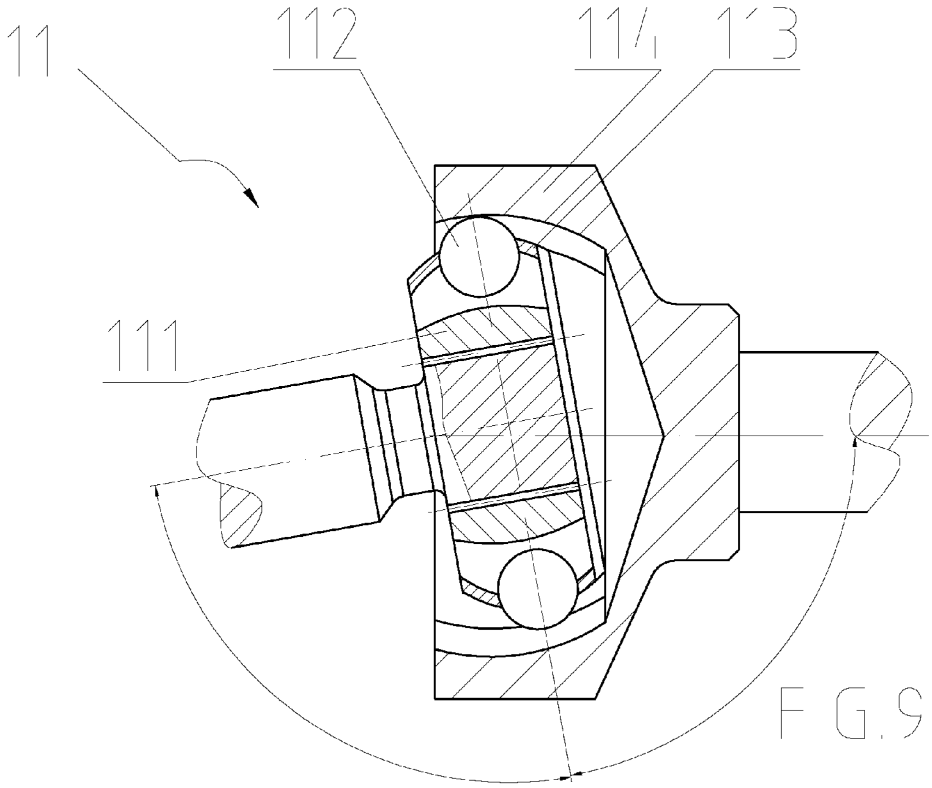


FIG. 8



F G.9

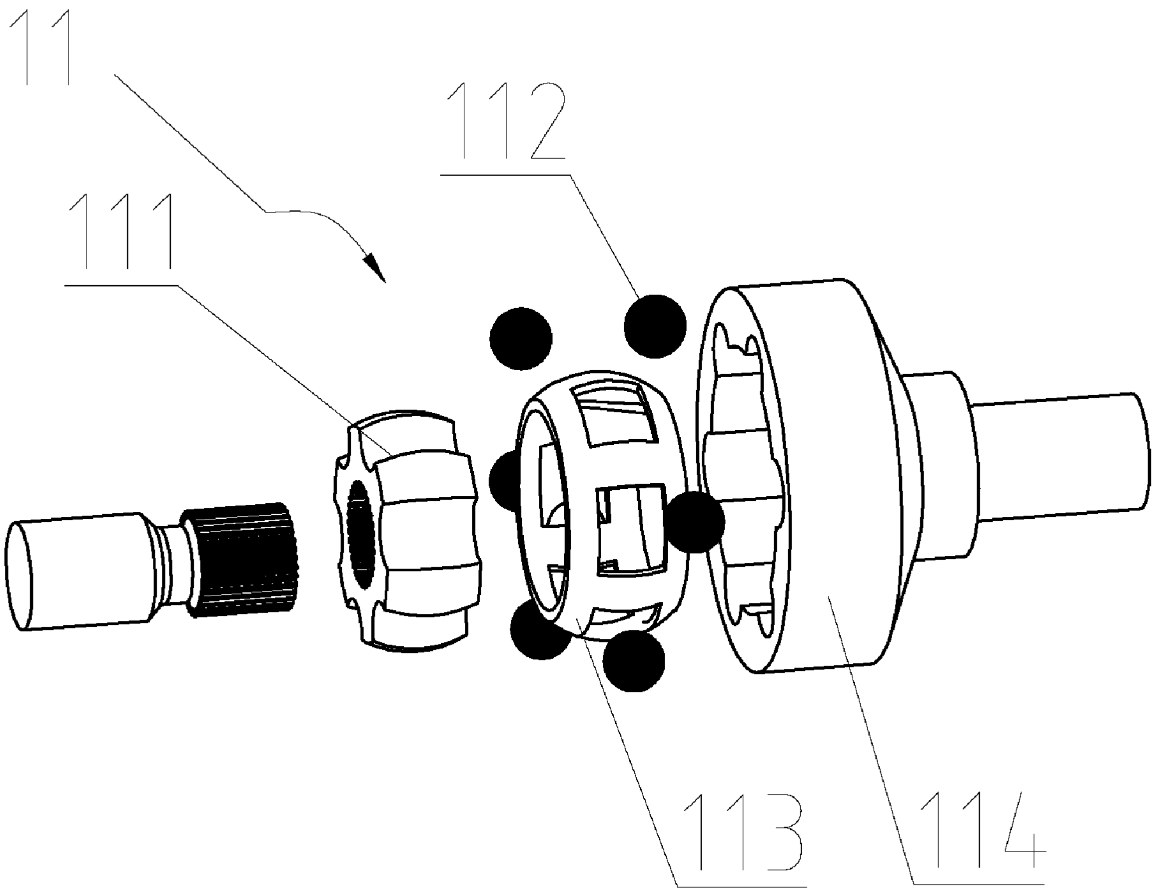


FIG.10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2007/000807

A. CLASSIFICATION OF SUBJECT MATTER

F04B39/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F04B39/00, 39/08, 39/10, 27/+, 1/+, F16D3/+

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC,WPI,PAJ,CNPAT, CNKI pump, motor, compressor, swash w plate, coupling, gimbal, universal w joint, piston,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 1138369A(MARTIN MARIETTA CORP) 18. Dec 1996(18.12.1996) see the claims, pages 5-7 and figures 1-2	1，15-18
Y		2-4，5，10-11，12-
Y	CN2126837Y(MA, Lianjiang) 10. Feb 1993（10.02.1993）see pages 1-3 and figure 1	2-4
Y	CN 2119511U(XI-AN MINING COLLEGE) 21. Oct 1992（21.10.1992）see page 3 and figure 1	10-11
Y	CN 2392928Y (ZHOU, Haiwei) 23. Aug 2000（23.08.2000）see pages 1-2 and figure1	5，12-14

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 May 2007 (22.05.2007)	07 Jun. 2007 (07.06.2007)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer SUN, Hongxia Telephone No. (86-10)62085457

Form PCT/ISA /210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2007/000807

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN1128325A(GONG, Wei) 07. Aug 1996 (07.08.1996) see the whole document	1-18
A	CN1250846A(LI, Shiliu) 19. Apr 2000 (19.04.2000) see the whole document	1-18
A	JP2003-129951A(DENSO CORP et al.)08. May 2003 (08.05.2003) see the whole document	1-18

Form PCT/ISA /210 (continuation of second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2007/000807

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 1138369A	18. 12.1996	US5493862A	27.02.1996
		CA2178480A	17. 05.1996
		WO9614523A	17. 05.1996
		AU4012195A	31. 05.1996
		EP0736152A1	09. 10.1996
		EP19950938913	10. 10.1995
		PL315748A	25. 11.1996
		DE69507595T	15. 07.1999
		BR9506444A	02. 09.1997
		JP9511818T	25. 11.1997
		AT176307T	15. 02.1999
		DE69507595D	11. 03.1999
CN2126837Y	10. 02.1993	none	
CN 2119511U	21. 10.1992	none	
CN 2392928Y	23. 08.2000	none	
CN1128325A	07. 08.1996	none	
CN1250846A	19. 04.2000	none	
JP2003-129951A	08. 05.2003	none	

Form PCT/ISA /210 (patent family annex) (April 2007)