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(54) **HYDRAULIC APPARATUS**

(57) The present application discloses a hydraulic device. The hydraulic device includes: a cylinder body; a piston arranged in the cylinder body, with an annular gap between the piston and the cylinder body, and a plurality of sealing grooves circumferentially configured and arranged on the piston at intervals along an axial direction, sequentially from bottom to top; a plurality of sealing rings, each arranged within a corresponding sealing groove, and movably connected in the sealing groove; and at least one pressure adjusting structure capable of driving the sealing ring to move in the sealing groove to adjust the gap between the sealing ring and the cylinder body. The present application discloses a hydraulic device to solve a problem of severe seal wear of existing pistons.

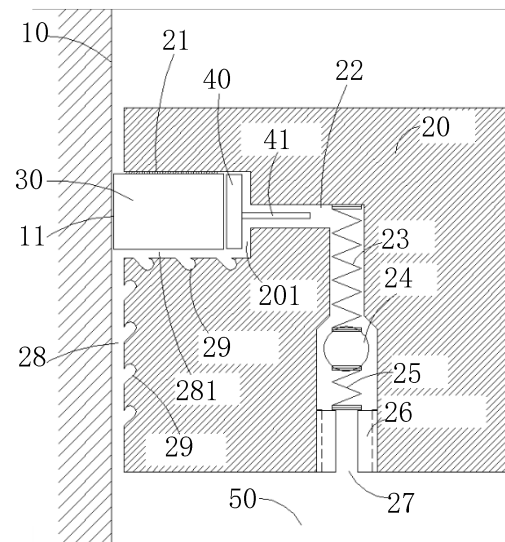


FIG. 1

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Description**TECHNICAL FIELD**

[0001] The present application relates to the field of hydraulic drive technologies, and more particularly, to a hydraulic device.

BACKGROUND OF THE INVENTION

[0002] A liquid hydrogen pump includes a hydraulic end (i.e., a cold end) and a drive end. The cold end is placed inside a liquid hydrogen storage tank and fully submerged in the liquid hydrogen. The drive end is placed outside the liquid hydrogen storage tank. A piston of the cold end is arranged in a hydraulic device and the piston drives a piston rod to move together in the hydraulic device, and the other end of the piston rod is linked to a working machine. A gap exists between the piston and an inner wall of the hydraulic device, which is sealed with multiple sealing rings provided in the gap to prevent excessive liquid hydrogen from sipping through the gap to the other side of the piston. This arrangement is also one of the measures employed to ensure high volumetric efficiency of the liquid hydrogen pump.

[0003] Among these multiple seals, the first seal (i.e., the lowermost sealing ring of the piston) typically experiences the greatest force, and thus wears out the fastest. Consequently, the first sealing ring often becomes severely worn while the remaining seals remain nearly intact. This leads to a critical issue that the liquid hydrogen pump has to be maintained by replacing a new sealing ring before the seal wears out to the point of failure. Such maintenance entails substantial costs.

[0004] Therefore, it is necessary to provide a hydraulic device to solve the above-mentioned problems.

SUMMARY OF THE INVENTION

[0005] In view of this, the present application aims at providing a hydraulic device to solve the problem of severe seal wear of existing pistons.

[0006] Based on the above objective, the present application provides a hydraulic device, including:

a cylinder body;

a piston arranged in the cylinder body, with an annular gap between the piston and the cylinder body, and a plurality of sealing grooves circumferentially configured and arranged on the piston at intervals along an axial direction, sequentially from bottom to top;

a plurality of sealing rings, each arranged within a corresponding sealing groove and movably connected in the sealing groove; and

at least one pressure adjusting structure capable of driving the sealing ring to move in the sealing groove to adjust the gap between the sealing ring and the

cylinder body.

[0007] Alternatively, when one pressure adjusting structure is provided, the pressure adjusting structure is used to drive the sealing ring in the lowermost sealing groove of the piston to move; and

when a plurality of pressure adjusting structures are provided, each of the pressure adjusting structures is arranged correspondingly to the sealing ring located below the upmost sealing groove of the piston respectively and used to drive the sealing rings in the sealing grooves of the piston from bottom to top in turn.

[0008] Alternatively, when a plurality of pressure adjusting structures are provided, adjusting forces provided by the plurality of pressure adjusting structures increase by an equal increment from bottom to top along the piston.

[0009] Alternatively, a surface of the sealing groove towards a lowermost side of the piston is configured as a roughened surface.

[0010] Alternatively, the roughened surface is a plurality of protrusions arranged at equal intervals along a radial direction.

[0011] Alternatively, the protrusions are inverted bosses or frustums.

[0012] Alternatively, an energizer is arranged in the sealing groove, and the energizer is disposed in the sealing groove and is in contact with the sealing ring; and the energizer is provided with a first cut-out, the sealing ring is provided with a second cut-out, and the first cut-out and the second cut-out are oppositely arranged along the axial direction of the piston.

[0013] Alternatively, the energizer is provided with a positioning rod, a positioning hole cooperating with the positioning rod extends from the sealing groove, and the positioning rod is capable of moving in the positioning hole; and when the positioning rod is in contact with the sealing ring, the positioning rod is used to limit a position of the second cut-out of the sealing ring and make the second cut-outs of adjacent sealing rings staggered.

[0014] Alternatively, an edge of the energizer is provided with at least two notches, and the at least two notches are symmetrically arranged on two opposite sides of the positioning rod.

[0015] Alternatively, at least one vortex groove is arranged on at least a local circumferential edge of the piston, and when a plurality of vortex grooves are provided, the plurality of vortex grooves are distributed at intervals along the axial direction of the piston; and/or, a surface of the sealing groove opposite to the roughened surface is provided with at least one vortex groove; and when a plurality of vortex grooves are provided, the plurality of vortex grooves are distributed at intervals along the axial direction of the piston.

[0016] Alternatively, the pressure adjusting structure includes a first adjusting channel, a first valve core and a first driving component, the first adjusting channel is arranged on the piston and includes a first inlet end

and at least one first outlet end, the first inlet end and the first outlet end are respectively communicated with the cylinder body and the sealing groove, the first valve core is arranged in the first adjusting channel; and the first driving component is capable of driving the first valve core to open and close the first adjusting channel.

[0017] Moreover, alternatively, the pressure adjusting structure includes a second adjusting channel, a second valve core and a second driving component, the second adjusting channel is arranged on the piston and includes a second inlet end and at least one second outlet end, the second inlet end is communicated with the cylinder body, and the second outlet end is communicated with a gap between two adjacent sealing grooves; and the second valve core is arranged in the second adjusting channel, and the second driving component is capable of driving the second valve core to open and close the second adjusting channel.

[0018] As can be seen from the above, compared with the prior art, the hydraulic device provided by the present application has the following advantages: by adopting the hydraulic device, the gap between the sealing ring in the sealing groove of the piston and the inner wall of the cylinder body is adjusted through the pressure adjusting structure according to a pressure change in the cylinder body, so as to provide functions of sealing, lubrication and pressure equalization respectively. The sealing ring of the piston realizes the sealing function. After the pressure born by a preceding seal of the piston (such as the first seal) reaches a specified pressure value, the pressure adjusting structure is switched from an opened state to a closed state, a pressure provided by the pressure adjusting structure acts on the sealing ring, and a part of liquid hydrogen may leak from the gap between the sealing ring and the inner wall of the cylinder body to the following seal (such as the second seal), but the leaked liquid hydrogen cannot push the preceding sealing ring to move to make the seal completely invalid, so the seal still works, but is not enough to seal the piston completely. When the liquid hydrogen acts on the piston, each sealing ring only seals a part of the pressure, and then the plurality of sealing rings seal parts of the pressure step by step to realize stepwise pressure reduction. Finally, the plurality of sealing rings collectively seal the entire liquid hydrogen pressures. Sealing is achieved while minimizing a backward slippage of the liquid hydrogen, and the uniform sealing pressure causes equal wear of the plurality of sealing rings. The leaked liquid hydrogen forms good self-lubrication on a surface of the sealing ring, which greatly reduces the wear of the sealing ring, prolongs the service life, extends the maintenance period and reduces costs.

DESCRIPTION OF THE DRAWINGS

[0019] The above features and technical advantages of the present application will become clearer and easier to understand by describing the embodiments thereof in conjunction with the accompanying drawings.

FIG. 1 is a partial sectional view of a hydraulic device adopted in a first embodiment of the present application.

FIGs. 2 to 5 are schematic diagrams of a roughened surface of a sealing groove of the hydraulic device adopted in the embodiment of the present application.

FIG. 6 is a schematic diagram of an energizer of the hydraulic device adopted in the embodiment of the present application.

FIG. 7 is a schematic diagram of another energizer of the hydraulic device adopted in the embodiment of the present application.

FIG. 8 is a partial sectional view of a hydraulic device adopted in a second embodiment of the present application.

FIG. 9 is a partial sectional view of a hydraulic device adopted in a third embodiment of the present application.

FIG. 10 is a partial sectional view of a hydraulic device adopted in a fourth embodiment of the present application.

FIG. 11 is a schematic diagram of a correlation between a pressure and a time during the use of the hydraulic device adopted in the embodiment of the present application.

Reference numerals:

[0020] 10 - inner wall; 11 - sealing surface; 20 - piston; 201 - second gap; 21 - roughened surface; 22 - adjusting channel; 23 - first spring; 24 - roll ball; 25 - second spring; 26 - lock nut; 27 - pressure-conducting through hole; 28 - annular gap; 281 - first gap; 29 - vortex groove; 30 - sealing ring; 40 - energizer; 41 - positioning rod; 42 - notch; 50 - high-pressure liquid hydrogen; 60 - valve core; 61 - third spring; and 70 - guide ring mounting groove.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0021] To make the objectives, technical solutions, and advantages of the present application more clear and understandable, the following further describes the present application in detail in combination with specific embodiments and with reference to drawings. Same parts are denoted by same reference numerals. It should be noted that the words "front", "rear", "left", "right", "upper" and "lower" used in the following description refer to the directions in the drawings. The words "inside" and "outside" are used to refer to a direction towards or away from a geometric center of a specific part respectively.

[0022] A hydraulic device is applied in a high-pressure liquid hydrogen pump. Liquid hydrogen is stored in a liquid hydrogen storage tank, which has an ultra-low temperature (approximately 20K). At such ultra-low temperature, steel becomes brittle and its strength weakens; furthermore, under a hydrogen-containing condition, there is a risk of hydrogen corrosion. Consequently,

maximum pressure-withstanding value of all liquid hydrogen storage tanks under the prior art remains relatively low. However, a hydrogen refueling station that stores liquid hydrogen requires high-pressure gaseous hydrogen to refuel vehicles loaded with compressed hydrogen. Therefore, a high-pressure liquid hydrogen pump is needed to compress the liquid hydrogen to a high pressure, and then vaporize the liquid hydrogen into high-pressure gaseous hydrogen for use by a hydrogen dispenser.

[0023] FIG. 1 is a partial sectional view of a hydraulic device adopted in a first embodiment of the present application. As shown in FIG. 1, the hydraulic device includes a cylinder body, a piston 20, a plurality of sealing rings 30 and at least one pressure adjusting structure.

[0024] The cylinder body includes, but is not limited to, a hydraulic cylinder, and the cylinder body is provided with an accommodating cavity.

[0025] The piston 20 is arranged in the cylinder body and there is an annular gap between the piston and the cylinder body; and a plurality of sealing grooves that are circumferentially configured are arranged on the piston 20 at intervals along an axial direction, sequentially from bottom to top. The piston 20 is movably arranged in the accommodating cavity, and a circumferential gap exists between a circumferential edge of the piston 20 and an inner wall 10 of the cylinder body.

[0026] Each sealing groove is respectively provided with the sealing ring 30, and the sealing ring 30 is movably connected in the sealing groove. The sealing ring 30 and the sealing groove cooperate with each other to provide a seal for the piston 20, and the piston 20 is provided with a plurality of seals at intervals from bottom to top. A lower seal of the piston 20 is referred to as a preceding seal, and an upper seal of the piston 20 is referred to as a following seal. The sealing ring 30 may move left and right and up and down in the sealing groove. The closer the sealing ring 30 is to the sealing groove, the larger the gap between the sealing ring 30 and the cylinder body, while the farther the sealing ring 30 is from the sealing groove, the smaller the gap between the sealing ring 30 and the cylinder body.

[0027] The pressure adjusting structure is capable of driving the sealing ring 30 to move in the sealing groove to adjust the gap between the sealing ring 30 and the cylinder body. When the pressure adjusting structure is opened (that is, high-pressure liquid hydrogen 50 can pass through), the pressure adjusting structure can drive the sealing ring 30 to move in the sealing groove, such as close to the sealing groove or close to the inner wall 10 of the cylinder body, so as to adjust the gap between the piston 20 and the cylinder body to increase or decrease. When the pressure adjusting structure is closed, the sealing ring 30 can be driven to remain stationary in the sealing groove.

[0028] The sealing groove and the sealing ring 30 cooperate with each other to provide a sealing function for the cylinder body. When the piston 20 reciprocates

along the accommodating cavity of the cylinder body, a pressure borne by the piston 20 changes gradually, and a position of the sealing ring 30 changes accordingly, thus providing lubrication and pressure equalization functions. When the pressure starts to increase, the pressure adjusting structure is opened, and the pressure adjusting structure drives the sealing ring 30 to move to one side far away from the sealing groove, such as pushing the sealing ring 30 from right to left to provide a sealing effect. At this time, the gap between the sealing ring 30 and the inner wall 10 of the cylinder body is minimum. As the high-pressure liquid hydrogen 50 enters the gap between the cylinder body and the piston 20, both sides of the sealing ring 30 are subjected to driving forces, wherein one the first side, the pressure adjusting structure pushes the sealing ring 30 close to the cylinder body, and on the second side, the gap between the piston 20 and the inner wall 10 of the cylinder body is communicated with the sealing groove, and after the high-pressure liquid hydrogen 50 enters the gap, it pushes the sealing ring 30 away from the cylinder body, for example, pushing the sealing ring 30 from left to right. Under the driving force on the both sides, the gap between the sealing ring 30 and the inner wall 10 of the cylinder body is slightly increased, so that the high-pressure liquid hydrogen 50 can pass through the seal from the gap and provide lubrication function for the seal. When the pressure continues to increase to a predetermined value, the pressure adjusting structure is switched from an opened state to a closed state, and the pressure provided by the pressure adjusting structure acts on the sealing ring 30, so that the sealing ring 30 remains motionless in the sealing groove, and the gap between the sealing ring 30 and the inner wall 10 of the cylinder body remains unchanged, so that the high-pressure liquid hydrogen 50 can pass through the seal from the gap and enter the following seal, thereby realizing the pressure equalization function.

[0029] By adopting the hydraulic device above, the gap between the sealing ring 30 in the sealing groove of the piston 20 and the inner wall 10 of the cylinder body is adjusted through the pressure adjusting structure according to a pressure change in the cylinder body, so as to provide functions of sealing, lubrication and pressure equalization respectively. The sealing ring 30 of the piston 20 realizes the sealing function. After the pressure borne by the preceding seal (such as the first seal) of the piston 20 reaches a specified pressure value, the pressure adjusting structure is switched from the opened state to the closed state, a pressure provided by the pressure adjusting structure acts on the sealing ring 30, and a part of high-pressure liquid hydrogen 50 may leak from the gap between the sealing ring 30 and the inner wall of the cylinder body to following seal (such as the second seal), but the leaked high-pressure liquid hydrogen 50 cannot push the preceding sealing ring 30 to move to make the seal completely invalid, so the seal still works, but is not enough to seal the piston completely. When the liquid hydrogen acts on the piston

20, each sealing ring only 30 seals a part of the pressure, and then the plurality of sealing rings 30 seal a part of the pressure step by step to realize stepwise pressure reduction. Finally, the plurality of sealing rings 30 collectively seal the entire liquid hydrogen pressures. Sealing is achieved while minimizing a backward slippage of the liquid hydrogen, and the uniform sealing pressure causes equal wear of the plurality of sealing rings 30. The leaked liquid hydrogen forms good self-lubrication on a surface of the sealing ring 30, which greatly reduces the wear of the sealing ring 30, prolongs the service life, extends the maintenance period and reduces costs.

[0030] In one embodiment of the present application, a surface of the sealing ring 30 towards the inner wall 10 of the cylinder body is a sealing surface 11, an annular gap 28 is formed between the piston 20 and the inner wall 10 of the cylinder body, and a gap is formed between the sealing surface 11 and the inner wall 10 of the cylinder body, and the gap between the sealing surface 11 and the inner wall 10 of the cylinder body changes continuously with the movement of the sealing ring 30.

[0031] Generally, the lowermost seal of the piston 20 is worn first. In order to prolong the service life of the piston 20, alternatively, when only one pressure adjusting structure is provided, the pressure adjusting structure is used to drive the sealing ring 30 in the lowermost sealing groove of the piston 20 to move. When a plurality of pressure adjusting structures are provided, each pressure adjusting structure is arranged correspondingly to the sealing ring 30 below the upmost sealing groove of the piston 20 respectively and used to drive the sealing rings 30 in the sealing grooves of the piston 20 from bottom to top in turn. If the piston 20 is provided with ten seals, the tenth seal is used to provide a sealing function, and the remaining nine or less seals may be provided with pressure adjusting structures. That is, the pressure adjusting structures may be provided for nine or less seals from bottom to top (for example, if the pressure adjusting structures are provided for five seals, they are provided for the five seals arranged from bottom to top), so that the ten or less seals can be worn to the same extent. When the pressure adjusting structure is opened, the high-pressure liquid hydrogen 50 can pass through the sealing ring 30 of the piston 20 to achieve the sealing or pressure equalization function. When the pressure adjusting structure is switched from the opened state to the closed state, a part of high-pressure liquid hydrogen 50 may leak along the sealing surface 11 of the first (or each) sealing ring 30 to the following one, but the leaked high-pressure liquid hydrogen 50 cannot push the sealing ring 30 to move to make the seal completely invalid, so the seal still works, but is not enough to seal the piston completely. The leaked liquid hydrogen forms good self-lubrication on the sealing surface 11, which greatly reduces the wear of the sealing ring 30.

[0032] Alternatively, when a plurality of pressure adjusting structures are provided, adjusting forces provided by the plurality of pressure adjusting structures increase

by an equal increment from bottom to top along the piston 20. The piston 20 is sequentially provided with a plurality of seals from bottom to top, and each seal includes a sealing groove and a sealing ring 30. Except for the topmost, last seal, the sealing groove of each seal is connected with a pressure adjusting structure, and each seal can only seal a certain amount of pressure to equalize the pressure, so that a pressure drop of each sealing ring 30 is the same, and finally the wear is the same, further prolonging the service life, extending the maintenance period and reducing costs.

[0033] In one embodiment of the present application, the piston 20 is sequentially provided with ten seals from bottom to top, and the sealing grooves of the first to ninth seals are all communicated with a pressure adjusting structure. The pressure adjusting structure includes, but is not limited to a relief valve, and relief pressures set by spring forces in the relief valves are 5 MPa, 10 MPa, 15 MPa, 20 MPa, 25 MPa, 30 MPa, 35 MPa, 40 MPa and 45 MPa from the first to the ninth respectively. That is, when a pressure of the high-pressure liquid hydrogen 50 is 5 Mpa, the pressure adjusting structure of the first seal is closed. The high-pressure liquid hydrogen 50 continues to move to the second seal, and when the pressure of the high-pressure liquid hydrogen 50 is 10 Mpa, the pressure adjusting structure of the second seal is closed. The high-pressure liquid hydrogen 50 continues to move to the following seal.

[0034] The sealing groove includes an upper surface, a lower surface and an inner surface. The upper surface is a surface towards a lowermost side of the piston 20, and the lower surface is a surface towards an uppermost side of the piston 20. The upper surface and the lower surface are oppositely arranged. The sealing ring 30 can move back and forth between the upper surface and the lower surface. The inner surface is oppositely arranged with the inner wall 10 of the cylinder body. The sealing ring 30 can move back and forth between the inner surface and the inner wall 10 of the cylinder body. In order to better position the sealing ring 30, alternatively, the surface of the sealing groove towards the lowermost side of the piston 20 (i.e., the upper surface or an upper bearing surface) is configured as a roughened surface 21. The sealing ring 30 cannot move when contacting with the roughened surface 21, and has a positioning function. The sealing ring can move freely after being separated from the roughened surface 21.

[0035] The upper bearing surfaces (i.e., the surface towards a bottom surface of the piston 20) of the multiple sealing grooves on the piston 20 are roughened. When the sealing ring 30 abuts against the roughened surface 21, a static friction force is great, so that the sealing ring 30 cannot move left and right. When the piston 20 moves downward, the pressure of the high-pressure liquid hydrogen is transmitted to the sealing ring 30, pushing the sealing ring 30 upward, forming a great static friction force, which makes the sealing ring 30 unable to move. Especially, when the pressure adjusting structure is

closed, the static friction force and an acting force provided by the pressure adjusting structure jointly ensure the position of the sealing ring 30 to be unchanged. The lateral immobility ensures that a sealing pressure between the sealing ring 30 and the inner wall 10 remains unchanged. When the piston 20 moves upward, the sealing ring 30 is separated from the roughened surface 21 and can move freely.

[0036] FIGs. 2 to 5 are schematic diagrams of the roughened surface 21 of the sealing groove of the hydraulic device adopted in the embodiment of the present application. FIGs. 2 to 5 show different structural forms of the roughened surface 21. The roughened surface 21 has a strong blocking effect on the movement of the sealing ring 30 away from the cylinder body, but has a relatively small blocking effect on the movement of the sealing ring 30 toward the cylinder body.

[0037] Alternatively, the roughened surface 21 is a plurality of protrusions arranged at equal intervals along a radial direction. The protrusions are evenly distributed on the sealing groove to provide uniform friction force. In addition, according to specific requirements, the protrusions may be provided at unequal intervals.

[0038] There are a plurality of ways to realize the roughened surface 21. As shown in FIG. 2, a plurality of triangular protrusions are arranged on the surface of the sealing groove towards the lowermost side of the piston 20, and right sides of the triangular protrusions are inclined surfaces, forming a structure similar to barbs, so that the protrusions have a strong blocking effect on the right movement of the sealing ring 30, and have a small blocking effect on the left movement of the sealing ring 30.

[0039] As shown in FIG. 3, a plurality of symmetrical triangular protrusions are arranged on the surface of the sealing groove towards the lowermost side of the piston 20, forming a structure similar to cross barbs, so that the protrusions have a strong blocking effect on the right movement of the sealing ring 30, and have a small blocking effect on the left movement of the sealing ring 30.

[0040] As shown in FIG. 4, a plurality of battlement-shaped protrusions are arranged on the surface of the sealing groove towards the lowermost side of the piston 20. The battlement-shaped protrusions can position the sealing ring 30 in contact with them and prevent relative displacement of the sealing ring 30.

[0041] Alternatively, the protrusions are inverted bosses or frustums. The boss or the frustum includes a connecting surface and a contact surface which are oppositely arranged. The connecting surface is used for connecting with the sealing groove, and the contact surface is used for contacting with the sealing ring. A diameter of the connecting surface is larger than that of the contact surface, and a diameter of the boss or the frustum is gradually changed, that is, the closer the diameter is to the connecting surface, the larger the diameter is, while the closer the diameter is to the con-

necting surface, the smaller the diameter is. The connecting surface of the frustum or the boss has a certain contact area, which can provide a required friction force for the sealing ring.

[0042] As shown in FIG. 5, a plurality of bosses or frustums are arranged on the surface of the sealing groove towards the lowermost side of the piston 20. Trapezoidal protrusions can position the sealing ring 30 in contact with them and prevent relative displacement of the sealing ring 30.

[0043] In one embodiment of the present application, a height of the roughened surface 21, that is, a height of the protrusion, ranges from 0.01 mm to 1 mm, and the plurality of protrusions are evenly distributed on the contact surface, with a distribution density of 1 to 100 per square centimeter. Alternatively, the protrusions are arranged in a row, and protrude out in a prismatic shape on the sealing groove of the piston 20 to position the sealing ring 30.

[0044] In order to better achieve the expansion of the sealing ring 30, alternatively, an energizer 40 is arranged in the sealing groove, and the energizer 40 is disposed in the sealing groove and is in contact with the sealing ring 30. The energizer 40 is provided with a first cut-out (not labeled), and the sealing ring 30 is provided with a second cut-out (not shown). The first cut-out and the second cut-out are oppositely arranged along the axial direction of the piston 20. By setting positions of the first cut-out and the second cut-out, a sealing performance of the sealing ring 30 can be improved. The energizer 40 concentrates a force on one side surface of the sealing ring 30 for pushing the sealing ring 30 to move. This reduces the driving difficulty, and facilitates the timely response of the sealing ring 30.

[0045] In one embodiment of the present application, the energizer 40 is C-shaped, that is, the energizer 40 is provided with a first cut-out, which is a non-closed ring. For example, the driving force provided by the pressure adjusting structure acts on the energizer 40 and the sealing ring 30, so that the sealing ring 30 generates a leftward thrust and generates a sealing pressure on the inner wall 10 of the cylinder body, which is equal to or slightly higher than a set pressure of the corresponding pressure adjusting structure, thereby realizing the pressure equalization function.

[0046] After the sealing groove receives the sealing ring 30, it is necessary to install an energizer 40, and a certain distance is reserved between the energizer 40 and the sealing groove, so that the high-pressure liquid hydrogen 50 can act on the energizer 40 conveniently. By appropriately reducing a volume of a space behind the energizer 40 (i.e., a second gap 201), pressure transmission of a fluid leaking from the pressure adjusting structure is faster, so as to apply a pressure to the sealing ring 30.

[0047] FIG. 6 is a schematic diagram of an energizer 40 of the hydraulic device adopted in the embodiment of the present application. As shown in FIG. 6, the energizer 40

is provided with a positioning rod 41.

[0048] In order to make the position of the energizer 40 more stable, alternatively, the energizer 40 is provided with a positioning rod 41, a positioning hole cooperated with the positioning rod 41 extends from the sealing groove, and the positioning rod 41 is capable of moving in the positioning hole. When the positioning rod 41 is in contact with the sealing ring 30, the positioning rod is used to limit a position of the second cut-out of the sealing ring 30 and make the second cut-outs of adjacent sealing rings 30 staggered. The positioning hole is communicated with the sealing groove, or the positioning hole is simultaneously communicated with the sealing groove and the pressure adjusting structure. The energizer 40 includes an inner surface and an outer surface, and the positioning rod 41 is arranged on the outer surface, located in a middle part or an upper-middle part of the energizer 40, and extends away from the energizer 40, usually in the form of a circular rod. The positioning rod 41 and the first notch are respectively arranged at two opposite sides of the energizer 40. The positioning rod 41 moves in the positioning hole to limit a position and a moving range of the energizer 40 and the sealing ring 30 in the sealing groove. At the same time, due to the limited moving range of the energizer 40, the energizer 40 responds to the relief pressure more favorably and quickly.

[0049] Further, when the sealing ring 30 is C-shaped, that is, the sealing ring 30 is provided with the second cut-out, which is a non-closed ring, after the energizer 40 is positioned by the positioning rod 41, the cut-out on the energizer 40 may position the sealing ring 30 again by the positioning rod 41, so that the gaps of the sealing ring 30 are staggered and a sealing performance is optimized. A plurality of adjusting channels 22 and positioning holes may be arranged, each adjusting channel 22 communicates with one positioning hole, and then the plurality of communicating adjusting channels 22 and positioning holes are evenly distributed in a circumference of the piston 20, so as to position openings of the sealing rings 30 and avoid a large volume of uncontrollable leaks caused by the openings of the sealing rings 30 converging at the same angle during operation.

[0050] FIG. 7 is a schematic diagram of another energizer 40 of the hydraulic device adopted in the embodiment of the present application. As shown in FIG. 7, the energizer 40 is provided with a notch 42.

[0051] In order to make an energizing effect of the energizer 40 better, alternatively, an edge of the energizer 40 is provided with at least two notches 42, and the at least two notches 42 are symmetrically arranged on two opposite sides of the positioning rod 41. One or more notches 42 are respectively arranged on both sides near the positioning rod 41, and the notches 42 may be semi-circular or other shapes, so that the strength of this part is slightly weaker than that of other parts, and the sealing ring 30 can be expanded outward with better roundness during deformation, thereby increasing a better energiz-

ing effect.

[0052] In order to reduce the action of the fluid between the piston 20 and the inner wall 10 acting on the sealing ring 30 and the energizer 40, the sealing ring 30 may be widened or the sealing groove may be narrowed, to appropriately narrow a first gap 281 between the sealing ring 30 and the sealing groove, so that an amount and a speed of the high-pressure liquid hydrogen 50 leaking through the annular gap 28 flowing to the second gap 201 on the side of the energizer 40 can be limited. Alternatively, at least local circumferential edge of the piston 20 is provided with at least one vortex groove 29. When a plurality of vortex grooves 29 are provided, the plurality of vortex grooves 29 are distributed at intervals along the axial direction of the piston 20; and/or, one surface of the sealing groove opposite to the roughened surface 21 is provided with at least one vortex groove 29. When a plurality of vortex grooves 29 are provided, the plurality of vortex grooves 29 are distributed at intervals along the axial direction of the piston 20. The vortex groove 29 is a groove-shaped structure extending along a flowing direction of the fluid. When the fluid flows through the position of the vortex groove 29, the fluid may be diverted to form a backflow and a vortex. The backflow is opposite to a direction of an original fluid, which hinders the flow of the original fluid and slows down a flow rate, thus hindering a source flow, thereby reducing a speed and a pressure of this part of fluid acting on the sealing ring 30 and the energizer 40.

[0053] Referring to FIG. 1, alternatively, the pressure adjusting structure includes a first adjusting channel 22, a first valve core and a first driving component. The first adjusting channel 22 is arranged on the piston 20, and the first adjusting channel 22 includes a first inlet end and at least one first outlet end. The first inlet end and the first outlet end are respectively communicated with the cylinder body and the sealing groove. The first valve core is arranged in the first adjusting channel 22 and the first driving component is connected with the first valve core and capable of driving the first valve core to open and close the first adjusting channel 22. When the pressure does not reach a predetermined value, the first adjusting channel 22 remains open. When the high-pressure liquid hydrogen 50 enters the first adjusting channel 22, the pressure gradually increases, and the first driving component starts to drive the first valve core to move. When the pressure reaches the predetermined value, the first valve core and the first driving component closes the first adjusting channel 22. When the pressure is lower than the predetermined value again, the first driving component starts to drive the first valve core to move again.

[0054] In one embodiment of the present application, the pressure adjusting structure includes, but is not limited to, a relief valve. The first adjusting channel 22 uses a relief hole with a variable diameter, and the first valve core uses a roll ball 24. The roll ball 24 moves within a certain range. When the roll ball 24 moves to the smallest diameter, the first adjusting channel 22 is closed, and when

the ball 24 leaves the smallest diameter, the first adjusting channel 22 is opened. The first driving component adopts two springs, which are a first spring 23 and a second spring 25 respectively. The first spring 23 is longer than the second spring 25, and the first spring 23 and the second spring 25 are respectively arranged on two opposite sides of the roll ball 24. The other end of the first spring 23 is arranged at a top end of the first adjusting channel 22, a bottom end of the first adjusting channel 22 passes through the piston 20, and a lock nut 26 is arranged inside. A center of the lock nut 26 is provided with a pressure-conducting through hole 27. Two opposite ends of the pressure-conducting through hole 27 are respectively communicated with the first adjusting channel 22 and the cylinder body. The other end of the second spring 25 is arranged on the lock nut 26. When the pressure does not reach a predetermined value, the first adjusting channel 22 remains open. When the high-pressure liquid hydrogen 50 enters the first adjusting channel 22, with the pressure gradually increasing, the first spring 23 is compressed and the second spring 25 is stretched, so that the roll ball 24 moves. When the pressure reaches the predetermined value, the roll ball 24 moves to the smallest diameter, and the first adjusting channel 22 is switched from the opened state to the closed state. When the pressure is lower than the predetermined value again, both the first spring 23 and the second spring 25 are reset to drive the roll ball 24 away from the smallest diameter, and the first adjusting channel 22 is switched from the closed state to the opened state.

[0055] There are a plurality of relief valves, and set closing pressures of the relief valves may be selected by controlling elastic forces of the first spring 23 and the second spring 25. For example, the closing pressures of the nine relief valves of the piston 20 from bottom to top are set to 5 MPa, 10 MPa, 15 MPa, 20 MPa, 25 MPa, 30 MPa, 35 MPa, 40 MPa and 45 MPa respectively. The pressure of the high-pressure liquid hydrogen 50 transmitted to the back of each sealing ring 30 is gradually increased, and the pressure on the sealing surface 11 of each seal is uniformly increased. A pressure difference between the seals is equal, so that the high-pressure liquid hydrogen 50 is sealed step by step under control.

[0056] FIG. 8 is a partial sectional view of a hydraulic device adopted in a second embodiment of the present application. The main difference between FIG. 8 and FIG. 1 is that structures of the valve cores and the driving components are different, and there is a guide ring mounting groove 70. The first valve core is a T-shaped valve core 60, the first driving component is a third spring 61, the third spring 61 is sleeved on the valve core 60, the valve core 60 can move close to the lock nut 26, and the third spring 61 can abut against a variable-diameter section of the first channel. When the pressure does not reach the predetermined value, the third spring 61 pushes the valve core 60 close to the lock nut 26, and the first adjusting channel 22 remains open. When the high-

pressure liquid hydrogen 50 enters the first adjusting channel 22, the pressure gradually increases, pushing the valve core 60 to move upward and starting to compress the third spring 61. When the pressure reaches the predetermined value, the third spring 61 is further compressed, the valve core 60 moves to the smallest diameter, and the first adjusting channel 22 is switched from an opened state to a closed state. When the pressure is lower than the predetermined value again, the third spring 61 returns, driving the valve core 60 away from the smallest diameter, and the first adjusting channel 22 is switched from the closed state to the opened state. The guide ring mounting groove 70 is arranged on the piston 20 for installing a guide ring, and a movement accuracy of the piston 20 is ensured by the guide ring, so as to avoid an influence of excessive deviation on the sealing performance of the piston 20.

[0057] In addition to the above implementation, the pressure adjusting structure may also be realized in another way. FIG. 9 is a partial sectional view of the hydraulic device e adopted in a third embodiment of the present application. As shown in FIG. 9, the pressure adjusting structure includes a second adjusting channel 22, a second valve core and a second driving component.

[0058] The structural difference between the second adjusting channel 22 shown in FIG. 9 and the first adjusting channel 22 shown in FIG. 1 is that the first adjusting channel 22 communicates directly with the sealing groove, and the second adjusting channel 22 communicates with the annular gap 28 between the piston 20 and the inner wall 10 of the cylinder body, and then communicates with the sealing groove through the annular gap 28.

[0059] Alternatively, the pressure adjusting structure includes a second adjusting channel 22, a second valve core and a second driving component, and the second adjusting channel 22 is arranged on the piston 20. The second adjusting channel 22 includes a second inlet end and at least one second outlet end. The second inlet end is communicated with the cylinder body, and the second outlet end is communicated with a gap between two adjacent sealing grooves. The second valve core is arranged in the second adjusting channel 22, and the second driving component is capable of driving the second valve core to open and close the second adjusting channel 22. The second outlet end of the second adjusting channel 22 of the pressure adjusting structure is arranged between two adjacent sealing grooves, that is, the second outlet end of the second adjusting channel 22 is arranged in the annular gap 28 between two sealing rings 30. When the pressure does not reach a predetermined value, the second adjusting channel 22 remains open. When the high-pressure liquid hydrogen 50 enters the second adjusting channel 22, the pressure gradually increases, and the second driving component starts to drive the second valve core to move. When the pressure reaches the predetermined value, the second valve core and the second driving component closes the second

adjusting channel 22. When the pressure is lower than the predetermined value again, the second driving component starts to drive the second valve core to move again.

[0060] A relief fluid with a predetermined pressure directly relieves the annular gap 28 between two adjacent sealing rings 30, so that the pressure at the annular gap 28 between each sealing ring 30 is a set pressure, and the pressure difference between upper and lower sides of each sealing ring 30 is a set pressure difference. During the movement of the piston 20, a pressure distribution between two adjacent sealing rings 30 is distributed according to a set value, which is balanced with a pressure of the fluid flowing from the annular gap 28 between the piston 20 and the inner wall 10, and the balanced residual pressure is the final sealing pressure. The residual pressure is a smaller value resulting from a lower side pressure offsetting an upper side pressure. For example, the pressure difference of each seal may be set to 5 MPa.

[0061] FIG. 10 is a partial sectional view of a hydraulic device adopted in a fourth embodiment of the present application. As shown in FIG. 10, the main difference between FIG. 10 and FIG. 9 is that the piston 20 is provided with a vortex groove 29.

[0062] In order to better achieve a desired sealing pressure, in this way, a flow rate of the fluid flowing from the gap between the piston 20 and the inner wall 10 of the cylinder body (i.e., the first gap 28) may also be limited, so that the relief pressure may take effect first. Alternatively, a plurality of vortex grooves 29 distributed at intervals along the axial direction are arranged on a circumferential edge of the piston 20; and/or, a plurality of vortex grooves 29 distributed at intervals along the radial direction are arranged on one surface of the sealing groove facing away from the lowermost side of the piston 20. The vortex grooves 29 limit the flow rate of the fluid flowing from the first gap 28, so that a fluid flowing from a pressure relief channel works first, that is, the relief pressure works first, which may push the sealing ring 30 downward and leftward. After the pressure of the high-pressure liquid hydrogen flowing from the first gap 28 at the lower side is transferred to the sealing ring 30, the pressure on the upper side is offset, and the sealing ring 30 is positioned and sealed according to the residual pressure. In this case, the sealing pressure is the pressure difference of the two fluids in upper and lower. Once positioned, the sealing ring 30 can no longer move, and can only work under the sealing pressure during positioning, so as to achieve a desired sealing pressure.

[0063] The following further introduces a use process of the hydraulic device.

[0064] FIG. 11 is a schematic diagram of a correlation between a pressure and a time during the use of the hydraulic device adopted in the embodiment of the present application. P1 is an equalizing pressure; t1 is an equalizing time; P2 is a positioning pressure; t2 is a positioning time; P3 is a sealing pressure; and t3 is a

sealing time.

[0065] As shown in FIG. 11, the piston 20 may be summarized as "first equalizing, then positioning and then sealing" in a compressed liquid hydrogen stroke.

[0066] The piston 20 is provided with ten seals. The sealing groove and the sealing ring 30 cooperate with each other to provide a sealing effect for the cylinder body. When the piston 20 reciprocates along the accommodating cavity of the cylinder body, a pressure borne by the piston 20 changes gradually, and a position of the sealing ring 30 changes accordingly, thus providing lubrication and pressure equalization functions. There are pressure adjusting structures, which are relief valves, in the first nine sealing grooves from bottom to top. Relief pressures set by spring forces in the relief valves corresponding to the first nine seals are 5 MPa, 10 MPa, 15 MPa, 20 MPa, 25 MPa, 30 MPa, 35 MPa, 40 MPa and 45 MPa respectively.

[0067] During the compressed liquid hydrogen stroke, the pressure adjusting structure undergoes a switch from being opened to closed. The liquid hydrogen pressure squeezes the roll ball 24 through the relief hole, compressing the first spring 23 and stretching the second spring 25. When the pressure reaches the set pressure, the relief valve closes, and the set pressure acts on the energizer 40 and the sealing ring 30, causing the sealing ring 30 to generate a leftward thrust and a sealing pressure, which is equivalent to or slightly higher than the set pressure of the corresponding relief valve. Therefore, the function of pressure equalization is realized.

[0068] In the compressed liquid hydrogen stroke, the high pressure of the high-pressure liquid hydrogen flowing from the annular gap 28 first acts on the sealing ring 30, causing the sealing ring 30 to generate upward pressure, to push the sealing ring 30 tightly against the roughened surface 21 of the sealing groove, and the roughened surface 21 provides a great static friction force, so that the sealing ring 30 cannot move. Therefore, the function of positioning is realized.

[0069] In the compressed liquid hydrogen stroke, an amount and a speed of the sealing ring 30 flowing from the annular gap 28 to the first gap 281 and the second gap 201 are limited due to the decrease of the first gap 281 and the obstruction provided by the vortex groove 29. Moreover, the pressure leaked from the relief valve is transmitted more quickly due to the decrease of a volume of the second gap 201, and a sealing thrust of the sealing ring 30 to the left is mainly driven by the pressure of the high-pressure liquid hydrogen 50 leaked from the relief valve. After the high-pressure liquid hydrogen 50 flowing from the annular gap 28 flows to the second gap 201, the high pressure in the second gap 201 cannot push the sealing ring 30 further toward the wall of the cylinder due to the positioning function of the roughened surface 21, but the high pressure in the second gap 201 can offset a reaction force exerted on the sealing ring 30 by the high-pressure liquid hydrogen 50 leaking from the sealing surface 11, thus ensuring that the sealing ring 30 cannot

move away from the wall of the cylinder, and ensuring that the seal will not fail completely.

[0070] Because the sealing pressure on the preceding sealing surface 11 is lower than that of the high-pressure liquid hydrogen 50, a part of the high-pressure liquid hydrogen 50 may leak (upward) along the sealing surface 11. However, the leaked high-pressure liquid hydrogen 50 cannot push the sealing ring 30 to move to the right to make the seal completely invalid. The high-pressure liquid hydrogen can only be leak upward from the gap in the sealing surface 11, so the seal still works, but is not enough to seal the position completely. The leaked high-pressure liquid hydrogen 50 forms good self-lubrication on the sealing surface 11, which greatly reduces the wear of the sealing ring 30. Through the quantitative leakage on the nine seals in the above leakage process, good self-lubrication is realized, and at the same time, the wear of all the sealing rings 30 is close to the same.

[0071] The sealing ring 30 relies on the high-pressure liquid hydrogen 50 for self-lubrication and therefore requires continuous wetting by the high-pressure liquid hydrogen 50. At the same time, a slippage volume of the high-pressure liquid hydrogen 50 cannot be excessive. The aforementioned hydraulic device achieve a slippage volume of the high-pressure liquid hydrogen 50 of 1% by arranging ten sealing rings. As a result, a liquid hydrogen pump equipped with the hydraulic device above achieves a high volumetric efficiency.

[0072] As can be seen from the above description and practice, compared with the prior art, the hydraulic device provided by the present application has the following advantages: by adopting the hydraulic device, the gap between the sealing ring 30 in the sealing groove of the piston and the inner wall of the cylinder body is adjusted through the pressure adjusting structure according to a pressure change in the cylinder body, so as to provide functions of sealing, lubrication and pressure equalization respectively. The sealing ring 30 of the piston realizes the sealing function. After a pressure born by a preceding seal of the piston (such as the first seal) reaches a specified pressure value, the pressure adjusting structure is switched from an opened state to a closed state, a pressure provided by the pressure adjusting structure acts on the sealing ring 30, and a part of high-pressure liquid hydrogen 50 may leak from the gap between the sealing ring 30 and the inner wall of the cylinder body to the following seal (such as the second seal), but the leaked high-pressure liquid hydrogen 50 cannot push the preceding sealing ring 30 to move to make the seal completely invalid, so the seal still works, but is not enough to seal the piston completely. When the liquid hydrogen acts on the piston 20, each sealing ring 30 only seals a part of the pressure, and then the plurality of sealing rings 30 seal parts of the pressure step by step to realize stepwise pressure reduction. Finally, the plurality of sealing rings 30 collectively seal the entire liquid hydrogen pressures. Sealing is achieved while minimizing a backward slippage of the liquid hydrogen, and the uni-

form sealing pressure causes equal wear of the plurality of sealing rings 30. The leaked liquid hydrogen forms good self-lubrication on a surface of the sealing ring 30, which greatly reduces the wear of the sealing ring 30, prolongs the service life, extends the maintenance period and reduces costs.

[0073] Those of ordinary skills in the art should understand that those described above are merely specific embodiment of the present application, but are not intended to limit the present application. Any modifications, equivalent replacements, improvements, and the like made without departing from the principle of the present application shall all fall in the scope of protection of the present application.

Claims

1. A hydraulic device, comprising:

a cylinder body;
a piston arranged in the cylinder body, with an annular gap between the piston and the cylinder body, and a plurality of sealing grooves circumferentially configured and arranged on the piston at intervals along an axial direction, sequentially from bottom to top;
a plurality of sealing rings, each arranged within a corresponding sealing groove, and movably connected in the sealing groove; and
at least one pressure adjusting structure capable of driving the sealing ring to move in the sealing groove to adjust the gap between the sealing ring and the cylinder body.

2. The hydraulic device according to claim 1, wherein,

when one pressure adjusting structure is provided, the pressure adjusting structure is used to drive the sealing ring in the lowermost sealing groove of the piston to move; and
when a plurality of pressure adjusting structures are provided, each of the pressure adjusting structures is arranged correspondingly to the sealing ring located below the upmost sealing groove of the piston respectively and used to drive the sealing rings in the sealing grooves of the piston from bottom to top in turn.

3. The hydraulic device according to claim 2, wherein, when a plurality of pressure adjusting structures are provided, adjusting forces provided by the plurality of pressure adjusting structures increase by an equal increment from bottom to top along the piston.

4. The hydraulic device according to any one of claims 1 to 3, wherein, a surface of the sealing groove towards a lowermost

side of the piston is configured as a roughened surface.

5. The hydraulic device according to claim 4, wherein, the roughened surface is a plurality of protrusions arranged at equal intervals along a radial direction. 5
6. The hydraulic device according to claim 5, wherein, the protrusions are inverted bosses or frustums. 10
7. The hydraulic device according to claim 4, wherein, an energizer is arranged in the sealing groove, and the energizer is disposed in the sealing groove and is in contact with the sealing ring; and the energizer is provided with a first cut-out, the sealing ring is provided with a second cut-out, and the first cut-out and the second cut-out are oppositely arranged along the axial direction of the piston. 15
8. The hydraulic device according to claim 7, wherein, the energizer is provided with a positioning rod, a positioning hole cooperating with the positioning rod extends from the sealing groove, and the positioning rod is capable of moving in the positioning hole; and when the positioning rod is in contact with the sealing ring, the positioning rod is used to limit a position of the second cut-out of the sealing ring and make the second cut-outs of adjacent sealing rings staggered. 20 25
9. The hydraulic device according to claim 8, wherein, an edge of the energizer is provided with at least two notches, and the at least two notches are symmetrically arranged on two opposite sides of the positioning rod. 30 35
10. The hydraulic device according to claim 4, wherein, at least one vortex groove is arranged on at least a local circumferential edge of the piston, and when a plurality of vortex grooves are provided, the plurality of vortex grooves are distributed at intervals along the axial direction of the piston; and/or, a surface of the sealing groove opposite to the roughened surface is provided with at least one vortex groove; and when a plurality of vortex grooves are provided, the plurality of vortex grooves are distributed at intervals along the axial direction of the piston. 40 45
11. The hydraulic device according to any one of claims 1 to 3, wherein, the pressure adjusting structure comprises a first adjusting channel, a first valve core and a first driving component, the first adjusting channel is arranged on the piston and comprises a first inlet end and at least one first outlet end, the first inlet end and the first outlet end are respectively communicated with the cylinder body and the sealing groove, the first valve core is arranged in the first adjusting channel; and the first driving component is capable of driving the 50 55

first valve core to open and close the first adjusting channel.

12. The hydraulic device according to any one of claims 1 to 3, wherein, the pressure adjusting structure comprises a second adjusting channel, a second valve core and a second driving component, the second adjusting channel is arranged on the piston and comprises a second inlet end and at least one second outlet end, the second inlet end is communicated with the cylinder body, and the second outlet end is communicated with a gap between two adjacent sealing grooves; and the second valve core is arranged in the second adjusting channel, and the second driving component is capable of driving the second valve core to open and close the second adjusting channel.

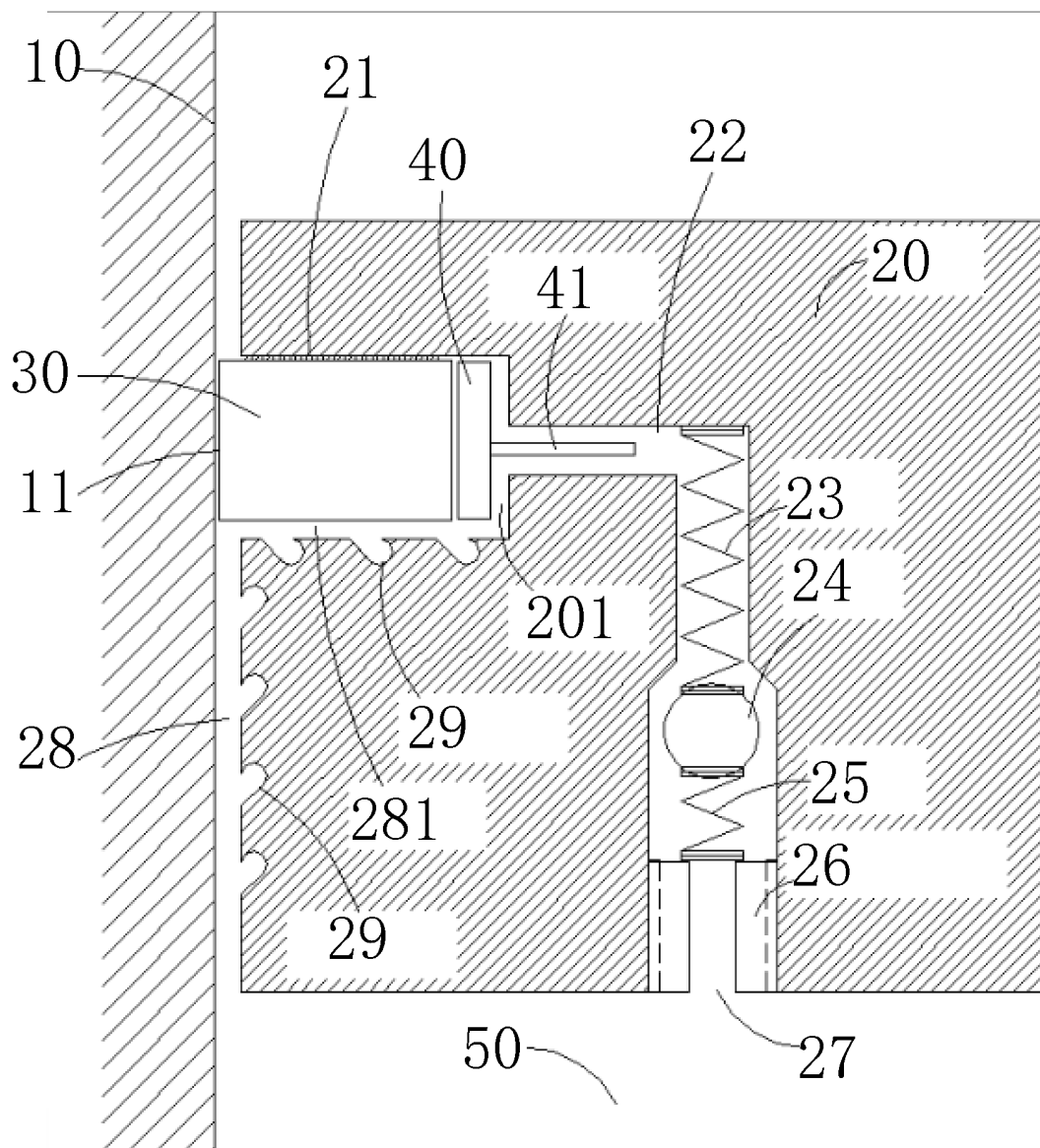


FIG. 1

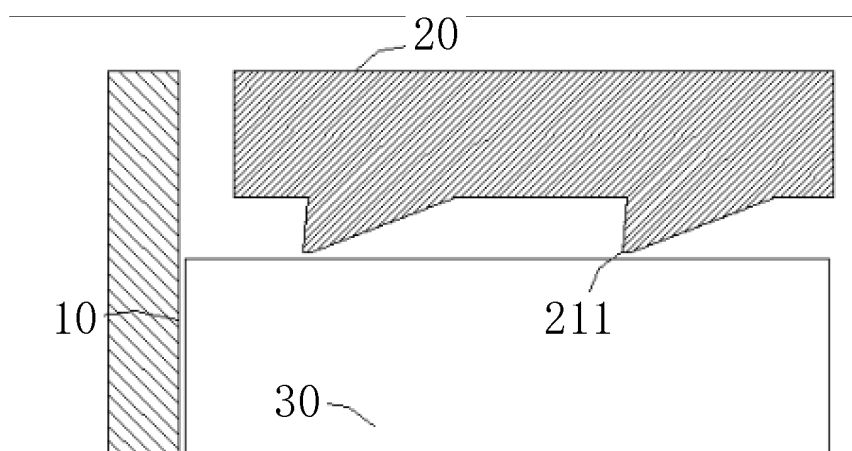


FIG.2

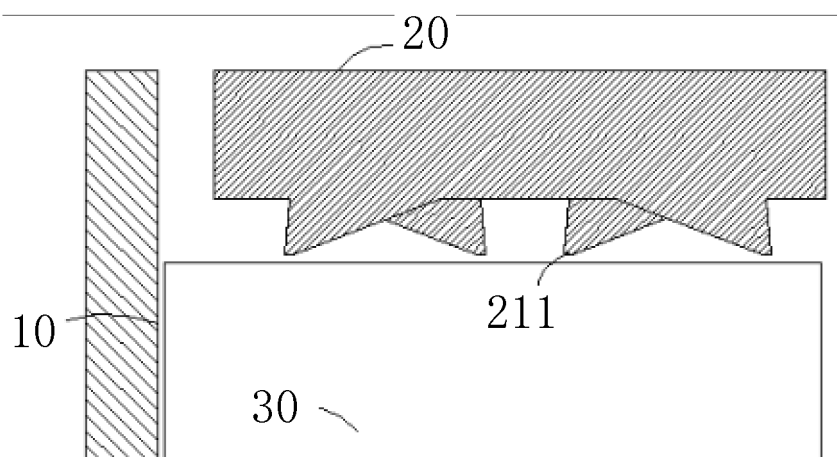


FIG. 3

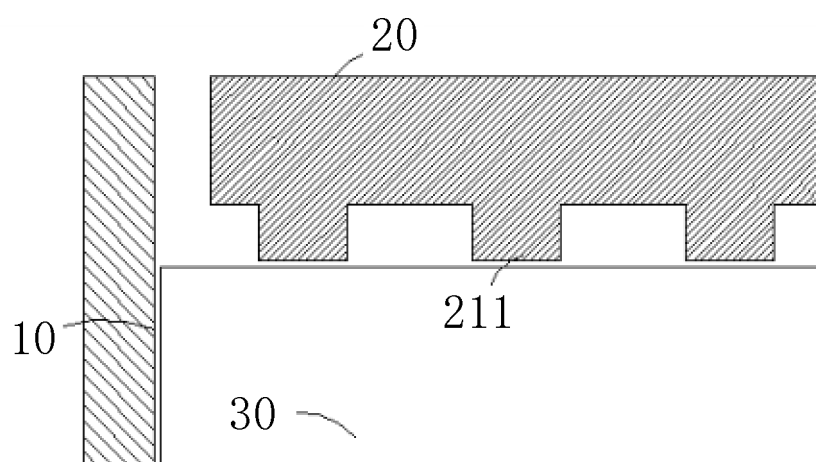


FIG. 4

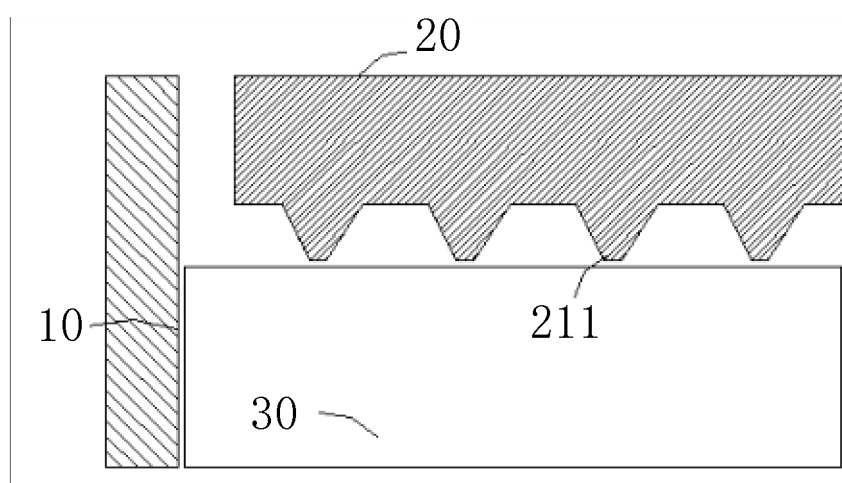


FIG. 5

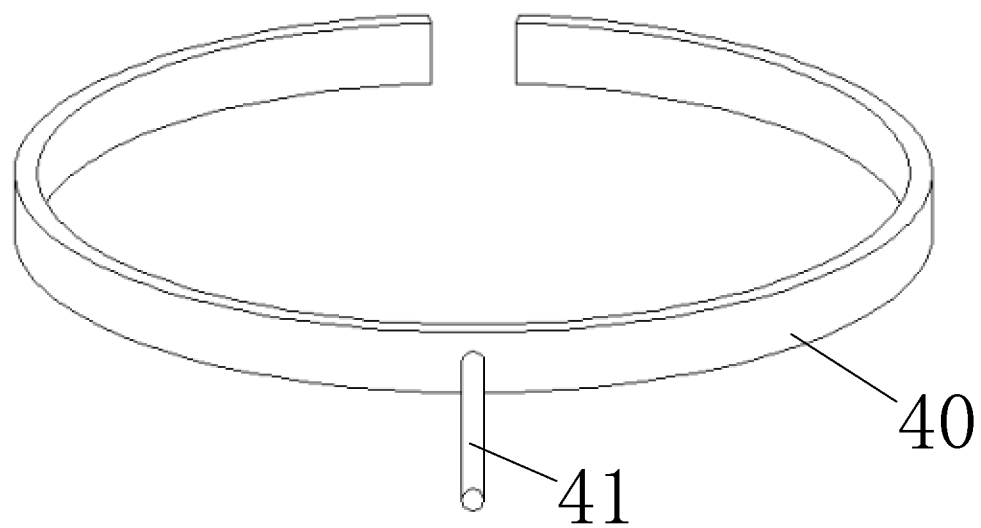


FIG. 6

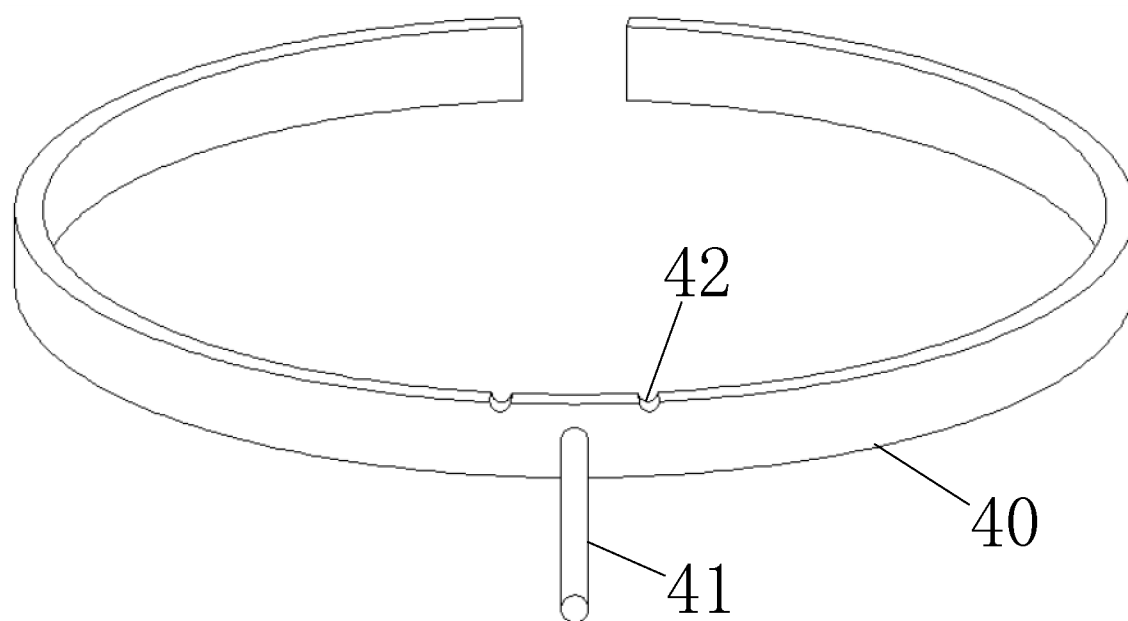


FIG. 7

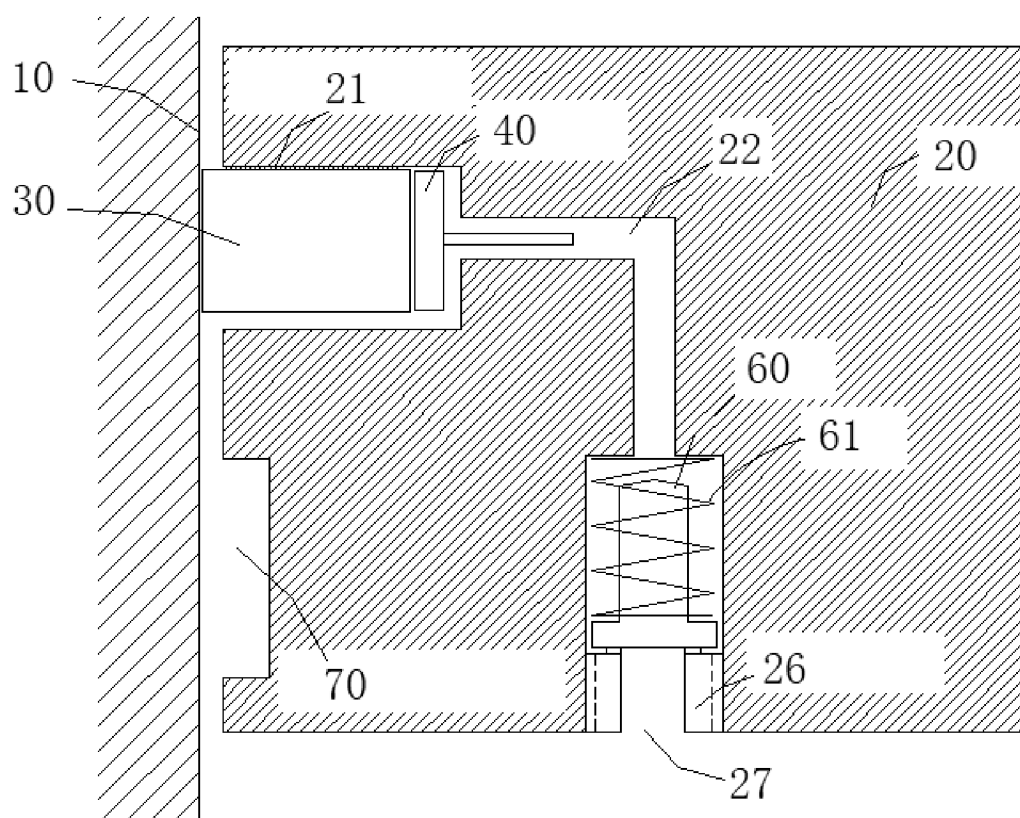


FIG.8

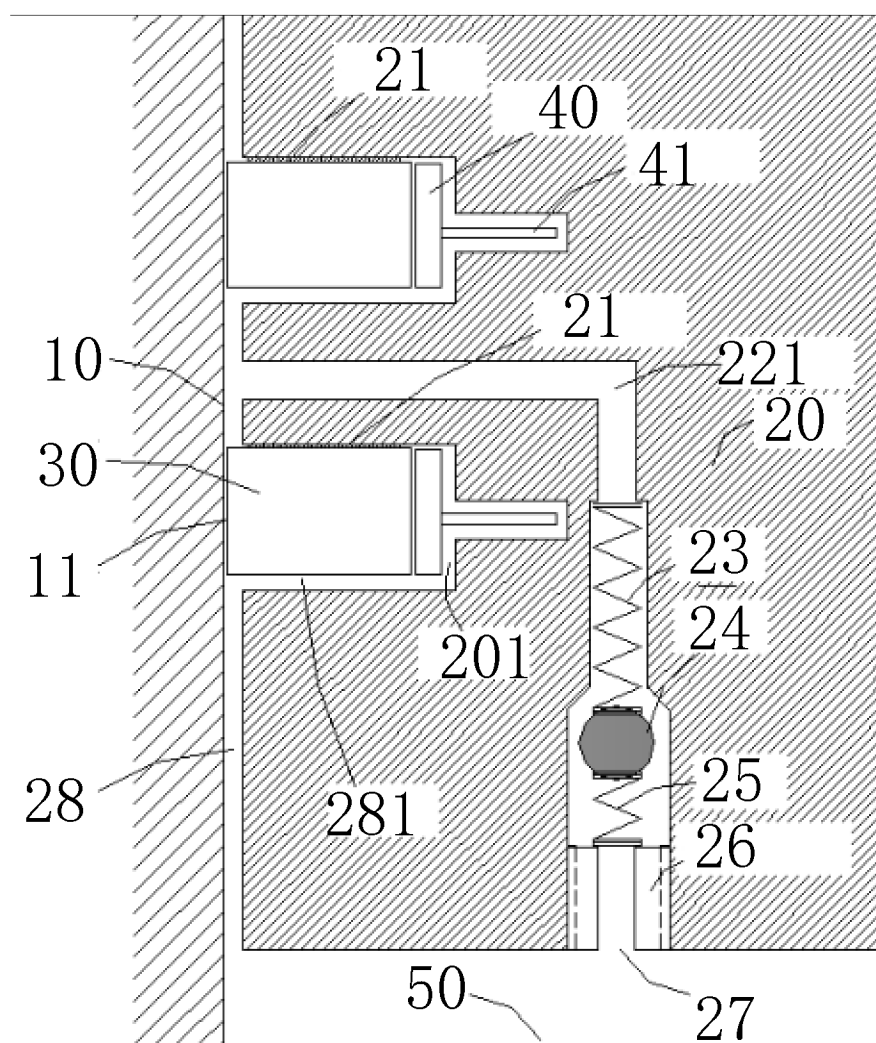


FIG.9

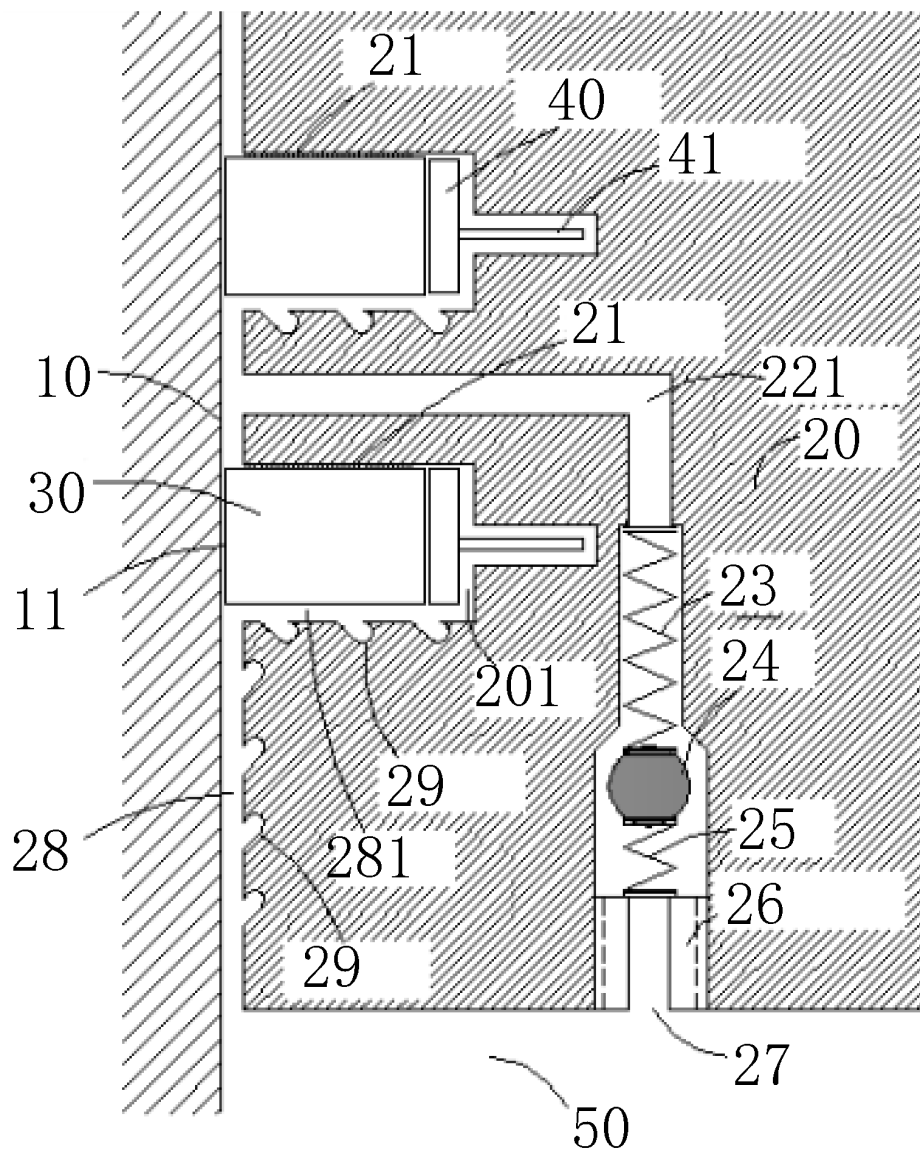


FIG. 10

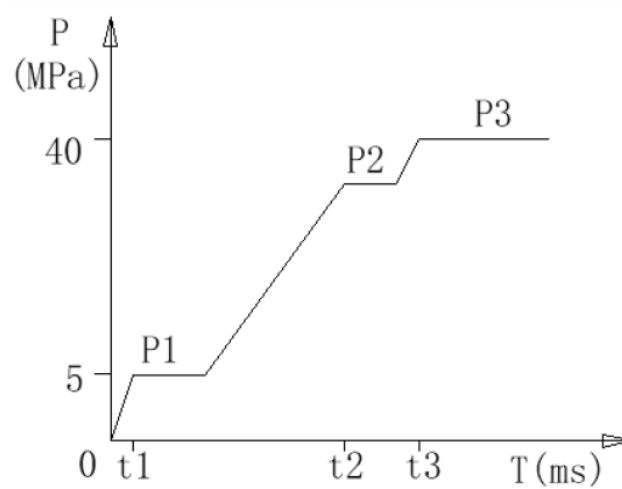


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/135563

A. CLASSIFICATION OF SUBJECT MATTER

F04B15/08(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:F04B

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)

CNABS, CNTXT, ENTXTC, WPABSC, CNKI: 缸, 活塞, 活塞环, 密封环, 压力, 调节, 可调, 移动, 磨损, 粗糙, 涡流槽; VEN, ENTXT, USTXT, EPTXT, WOTXT: cylinder, piston, piston ring, seal ring, pressure, regulation, adjust, moving, wear, rough, vortex.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2004339976 A (TOYOTA MOTOR CORP.) 02 December 2004 (2004-12-02) description, paragraphs 16-40, and figures 1-5	1, 2
Y	JP 2004339976 A (TOYOTA MOTOR CORP.) 02 December 2004 (2004-12-02) description, paragraphs 16-40, and figures 1-5	11, 12
Y	CN 201080934 Y (FESTO AG & CO.) 02 July 2008 (2008-07-02) description, page 4 line 23-page 11 line 24, and figures 1-3	11
Y	DE 9301925 U1 (DIEHL GMBH & CO.) 16 June 1994 (1994-06-16) description, page 3 line 17-page 5 line 17, and figures 1-2	12
X	JP 2009156179 A (TOYOTA MOTOR CORP.) 16 July 2009 (2009-07-16) description, paragraphs 21-44, and figures 1-4	1-2
Y	JP 2009156179 A (TOYOTA MOTOR CORP.) 16 July 2009 (2009-07-16) description, paragraphs 21-44, and figures 1-4	11, 12

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

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"D" document cited by the applicant in the international application	"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
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"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	

Date of the actual completion of the international search

13 May 2024

Date of mailing of the international search report

16 May 2024

Name and mailing address of the ISA/CN

China National Intellectual Property Administration (ISA/
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Beijing 100088

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/135563

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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				DE	102006011482	B4	15 July 2010
DE	9301925	U1	16 June 1994	None			
JP	2009156179	A	16 July 2009	None			
CN	108167263	A	15 June 2018	CN	108167263	B	22 October 2019

Form PCT/ISA/210 (patent family annex) (July 2022)