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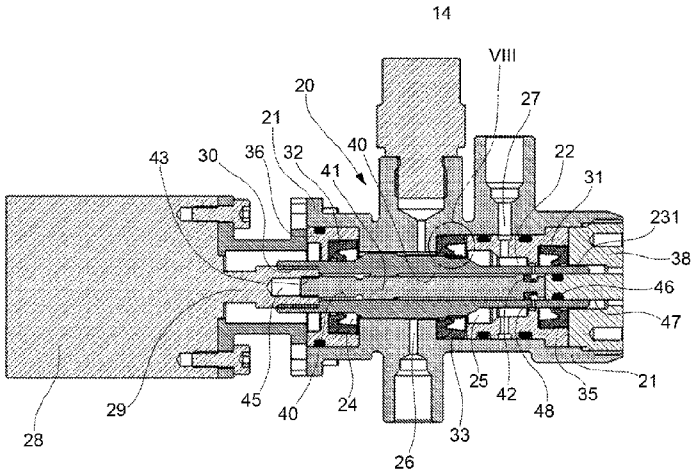

FIG. 2

(57) Abstract: A dual piston valve unit for an anti-lock braking system for bicycles The valve unit (20) comprises an outer valve body (21) with an axially elongated inner cavity (22) in which a main piston valve element (23) slides, separating an upstream chamber (25) from a downstream chamber (24). The main piston valve element (23) forms an inner axial channel (40) in which a secondary piston valve element (41) slides. An electric motor (28) causes simultaneous linear displacements of the main piston valve element (23) and the secondary piston valve element (41) in respective axially opposite directions. In use, the upstream chamber (25) is in fluidic communication with a driver-operated master cylinder. The volume available for the brake fluid within the upstream chamber (25) remains constant, whereby the rider's hand on the brake control lever does not feel the ABS system working.

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A dual piston valve unit for an anti-lock braking system for bicycles

Technical field

The present invention relates to a valve unit for a hydraulic braking system for controlling the anti-lock function of a wheel of a vehicle, particularly a bicycle or an e-bike.

Background art

Anti-Lock Braking Systems ("ABS") have been installed on vehicles with hydraulic brakes to prevent skidding, by reducing the effects of an abrupt stop. In an ABS braking system, all wheels of a vehicle are equipped with brake discs and associated phonic wheel sensors or equivalent elements, rotationally integral with the brake discs. The sensors detect the rotation speeds of the wheels to which they are associated and send signals indicative of the rotation speeds to an Electronic Control Unit (ECU) which processes the rotation signals received. Each brake disc is associated with a brake caliper. A master cylinder, actuated by a control (hand lever control in a bicycle) activates the brake calipers through respective hydraulic circuit, on each of which an ABS valve unit is installed. Each ABS valve unit controls the flow and pressure of the brake fluid towards the associated brake caliper, in response to electrical control signals from the electronic control unit. When the ECU detects a condition indicative of an imminent wheel locking, it operates the respective ABS valve to reduce the hydraulic pressure on the brake at the affected wheel, thus reducing the braking force on this wheel, so that the wheel remains braked but can rotate. This process is repeated continuously during braking, several times per second, preventing the vehicle from skidding.

WO 2021/205334 A1 discloses an ABS actuator device for a bicycle hydraulic braking system comprises a floating member, which carries a sealing ring that separates an upstream chamber, communicating with an inlet opening, from a downstream chamber, communicating with an outlet opening. The inlet opening is to be connected to a pumping device associated with the brake lever. The outlet opening is to be connected to the hydraulic cylinder actuator of a brake calliper. The position of the floating member is controlled by an electric motor. The floating member has a body with a passage for hydraulic communication

between the upstream chamber and the downstream chamber, and is provided with a coaxially inner valve member that cooperates with a valve seat formed in the body of the floating member, for controlling said hydraulic communication through the passage. The valve member is associated with a spring tending to keep the valve member engaged against the valve seat in a closed position in which hydraulic communication between the upstream chamber and the downstream chamber is interrupted. During normal operation of the brake, the electric motor is inactive and the floating member is in an end position towards the downstream chamber, in which the valve member of the floating member interacts with an abutment element of the actuator body, which holds the valve member in an open position, spaced apart from said valve seat, against the action of the spring, so that during normal brake operation, the fluid pumped by the pumping device can flow from said inlet opening to the outlet opening, in the direction of the hydraulic brake. In conditions that require the activation of the ABS, the electric motor is activated and causes a movement of the floating member in the direction of the upstream chamber and away from the end position, so that the valve member is brought into its closed position by the spring, interrupting the communication between the upstream chamber and the downstream chamber. The downstream chamber thereby increases in volume and generates a decrease in the pressure of the fluid supplied to the hydraulic brake.

With most ABS systems on bicycles, when the ABS function is activated, a drawback occurs in that the ABS valve increases the pressure in the brake fluid upstream of the valve, causing the brake control lever to rotate to some extent back towards a brake released position, opposing the action exerted by the driver's hand.

Summary of the invention

A primary object of the present invention is to provide an ABS valve unit capable of overcoming the above-mentioned drawback.

According to an aspect, the present invention provides a valve unit for a hydraulic braking system to control the anti-lock function of a bicycle wheel, as defined in claim 1. Preferred embodiments are defined in the dependent claims.

In summary, a valve unit comprises an outer valve body with an axially elongated inner cavity in which a main piston valve element slides, separating an upstream chamber from a downstream chamber. The main piston valve element forms an inner axial channel in which a secondary piston valve element slides. An electric motor causes simultaneous linear displacements of the main piston valve element and the secondary piston valve element in respective axially opposite directions. In use, the upstream chamber is in fluidic communication with a driver-operated master cylinder. The volume available for the brake fluid within the upstream chamber remains constant, whereby the rider's hand on the brake control lever does not feel the ABS system working.

Brief description of the drawings

In order that the present invention may be well understood there will now be described a few preferred embodiments thereof, given by way of example, reference being made to the accompanying drawings, in which:

figure 1 is a diagram schematically depicting the operation of an anti-lock braking system on a vehicle;

figures 2 to 4 are longitudinal cross-sectional views of a valve unit in different operating conditions;

figure 5 is a partial enlarged view of figure 4, showing further details;

figure 6 is an enlarged transversal cross-sectional view of a main piston valve member, taken along the line VI-VI in FIG. 5;

figure 7 is an enlarged transversal cross-sectional view of a components of the valve unit, taken along the line VII-VII in FIG. 5; and

figure 8 is an enlarged view of a detail encircled at VIII in figure 2.

Detailed description

Referring initially to figure 1, an Anti-Lock Braking System (ABS) comprises wheel rotation sensors 10 applied to the wheels of a vehicle, in this example an e-bike. The wheels are each equipped with brake discs (not shown) and associated brake calipers 11, which apply braking

force to brake pads on the caliper through a hydraulic brake circuit 15 and consequently generate a braking torque acting on the wheel. A hand lever 12 operates a hydraulic master cylinder 12 for generating and controlling pressure within the hydraulic brake circuit 15. A pressure sensor 14 detects the brake fluid pressure in the hydraulic circuit. The rotation sensors 10 detect the rotational speeds of the wheels to which they are associated and send signals indicative of the rotation speeds to a Brake Control Unit (BBCU) 16, which is an electronic unit that receives and processes signals from the rotation sensors 10 and the pressure sensor 14. Electric signals from the pressure sensor 14 are sent to the BBCU 16 through a line 9.

Each brake caliper is associated with an ABS valve unit 20. Each ABS valve unit controls the flow and pressure of the brake fluid towards the associated brake caliper, in response to electrical control signals from the Brake Control Unit 16. When the BBCU detects a condition indicative of an imminent wheel locking, it operates the respective ABS valve unit in order to reduce the hydraulic pressure on the brake at the affected wheel, thus reducing the braking force on this wheel, so that the wheel remains braked but can rotate. This process is repeated continuously during braking, several times per second, preventing the vehicle from skidding.

Referring to figure 2, each ABS valve unit 20 comprises an outer valve body 21 defining an inner cavity 22 having an axially elongate shape. A main piston valve member 23 is axially slidably accommodated within the inner cavity, separating an upstream chamber 25 from a downstream chamber 24. The outer valve body 21 forms an inlet port 27 establishing fluid communication between the upstream chamber 25 and the hydraulic master cylinder 13 operated by the brake lever 12. An outlet port 26 fluidically connects the downstream chamber 24 with one brake caliper 11 associated with the valve unit 20. The inlet port 27 and the outlet port 26 are axially spaced from one another along the inner cavity 22. In this context, the terms “upstream” and “downstream” are referred to the flow of brake fluid from the master cylinder to the brake caliper.

The main piston valve member 23 has a substantially tubular shape with an inner channel 40 axially extending through it. A secondary piston valve member 41 is axially slidingly

accommodated within the inner channel 40. The secondary piston valve member 41 has an upstream end portion fitted with a sealing gasket 42 slidingly and sealingly engaging the inner axial channel 40 of the main piston valve member 23.

An electric motor 28, secured to the outer valve body 21, simultaneously controls the axial positions of both the main piston valve member 23 and the secondary piston valve member 41 with respect to the outer valve body 21.

The electric motor 28 drives a rotating output shaft 29 coupled to the main piston valve member 23 through a first or outer rotary to linear motion conversion mechanism 30 that converts rotary motion of the rotating shaft 29 into linear displacement of the main piston valve member 23 within the inner cavity 22.

Through a second or inner rotary to linear motion conversion mechanism 43, the electric motor 28 simultaneously also controls the axial position of the secondary piston valve member 41. The second rotary to linear motion conversion mechanism 43 converts rotary motion of the rotating shaft 29 into linear displacement of the secondary piston valve member in an axial direction opposite to the axial direction in which the main piston valve member 23 is driven.

The rotary to linear motion conversion mechanisms 30 and 43 may include respective threaded couplings with helically opposite threads, whereby the rotation of the shaft 29 simultaneously causes an advancement of the main piston valve member 23 in a given axial direction, for example toward the downstream chamber 24, while the secondary piston valve member 41 is caused to withdraw in the opposite axial direction, in this example toward the upstream chamber 25.

According to the preferred embodiment shown in figures 2 to 5, the output shaft 29 has a tubular, axially extending end portion 44, with a radially outer cylindrical surface on which the first, outer rotary to linear motion conversion mechanism 30 is provided, and an axially extending end cavity 45 in which the inner rotary to linear motion conversion mechanism 43 is arranged.

The electric motor 28 is energized and controlled by the BBCU 16 through a line 8. The BBCU 16 receives power from a battery (not shown) through a line 7.

The electric motor may be provided with a position sensor for detecting the angular position of the output shaft 29, and consequently, detecting the axial position of the main piston valve member 23.

A first or upstream hollow tubular insert 35 is fitted within the inner cavity 22 and suitably shaped to fit two sealing gaskets within the outer valve body 21 and provide an axial passage for guiding an upstream end section 231 of the main piston valve member 23, as well as establishing fluid communication between the upstream chamber 25 and the inlet port 27.

Mounted within the inner cavity 22 are three stationary annular sealing gaskets 31-33, slidingly and sealingly engaging the main piston valve member 23: a first end (or upstream end) sealing gasket 31 and a second end (or downstream end) sealing gasket 32, which are arranged axially spaced from one another such that the inlet port 27 and the outlet port 26 are axially located between the upstream end and the downstream end sealing gaskets 31, 32. A third, intermediate sealing gasket 33 is mounted within the inner cavity between the inlet port 27 and the outlet port 26. No sealing gaskets are mounted on the main piston valve member 23.

The third, intermediate sealing gasket 33 can fluidically separate the downstream and upstream chambers 24, 25 and, depending on the axial position of the main piston valve member 23, can open and close a passage between the main piston valve member and the inner cavity, thereby establishing fluid communication between the downstream and upstream chambers 24, 25 or temporarily interrupting the fluid communication between the outlet and inlet ports 26, 27 by sealingly separating the upstream chamber from the downstream chamber.

Owing to the sealing gasket 42 on the secondary piston valve member 41, no flow of the brake fluid is allowed to flow directly between the downstream and upstream chambers

through the inner axial channel 40 of the main piston valve member 23.

A second or downstream hollow tubular insert 36 is fitted within the inner cavity 22 and suitably shaped to fit the downstream sealing gasket 32 within the outer valve body 21 and provide an axial passage for guiding a downstream end section 232 of the main piston valve member 23.

The downstream chamber 24, communicating with the outlet port 26, is delimited between the downstream end sealing gasket 32 and the intermediate sealing gasket 33.

The upstream chamber 25, communicating with the inlet port 27, is delimited between the upstream end sealing gasket 31 and the intermediate sealing gasket 33. At least one, and preferably a plurality of radial openings 48 are formed through the upstream end section 231 of main piston valve member 23, setting the upstream end portion of the axial inner channel 40 in fluid communication with the upstream chamber 25. As a result, the upstream chamber 25 also includes a variable volume, the amount of which depends on the relative axial position of the main and secondary piston valve members 23, 41, contained within the upstream end portion 231 of the main secondary piston valve member 41, between the sealing gasket 42 on the secondary piston valve member 41 and the upstream sealing gasket 31.

The upstream and downstream hollow tubular inserts 35, 36 are hermetically sealingly coupled to the outer valve body 21 by a number of static sealing rings such as O-rings 39 acting at the interfaces between each insert and the inner cavity 22.

The main piston valve member 23, on which the intermediate sealing gasket 33 can exert a sliding or dynamic sealing action, may be made in metal, for example an aluminum alloy, or another suitable rigid material, for example a thermosetting plastic material.

The outer valve body 21 has the task of steadily accommodating the sealing gaskets, but the wall of the inner cavity 22 does not also have the task of acting as a smooth sliding surface for a gasket, capable of withstanding high pressures without deforming noticeably.

Consequently, the outer valve body may be conveniently made of a relatively inexpensive thermoplastic material, such as, for example, PA 66 GF30 – PA 66 GF 50 – PA 6 – PA 66 CF30.

In accordance with the exemplary embodiment shown in figure 2, the outer valve body 21 is shaped as a substantially tubular body with axially opposite open ends and a central, radially thicker wall portion 211 in which the outlet port 26 is formed.

As shown in the embodiment of figure 2, the central, radially thicker wall portion 211 forms an upstream transversal surface 212 against which the intermediate sealing gasket can be steadily held in position between the central wall portion 211 and the upstream hollow tubular insert 35.

Preferably, the upstream sealing gasket 31 is steadily accommodated in an annular seat formed by the upstream end hollow tubular insert 35 and an upstream end plug 38 that may be used to close the upstream open end of the outer valve body 21 and slidingly accommodate the upstream end section 231 of main piston valve member 23.

The upstream end plug 38 may form a cylindrical protrusion 47 axially extending toward the upstream chamber 25 axially aligned with the inner axial channel 40 and protruding into the inner axial channel 40 at the upstream end section 231 of main piston valve member 23 to guide the linear motion thereof. The cylindrical protrusion 47 may provide a sealing ring 46 that seals the inner axial channel 40 at the upstream end section 231 of main piston valve member 23.

According to a preferred embodiment, the downstream sealing gasket 32 may be steadily accommodated in an annular seat formed by the downstream end hollow tubular insert 36 and a downstream transversal surface 213 formed by the central, radially thicker wall portion 211 opposite to the upstream transversal surface 212.

The three stationary annular sealing gaskets 31-33 are each preferably shaped with a respective conical lip designed for elastically radially engaging a respective surface of the

main piston valve member 23. The conical lip of the upstream end sealing gasket 31 tapers towards the upstream chamber 25, whereas the conical lip of the downstream end sealing gasket 32 tapers towards the downstream chamber 24.

Preferably, the conical lip of the intermediate sealing gasket 33 tapers towards the upstream chamber 25.

The main piston valve member 23 has a central section 233 with a smooth cylindrical surface 235 having a diameter D3 and one or more radially narrower surfaces 234 axially extending from the cylindrical surface 235 towards the upstream end of the main piston valve member. The one or more radially narrower surfaces 234 are configured to define one or more corresponding passages 236 between the main piston valve member 23 and the intermediate sealing gasket 33 in certain operational conditions of the valve unit.

According to an embodiment, as show in figure 8, the radially narrower surfaces 234 may be provided in the form of axially extending and circumferentially equally spaced grooves.

According to a preferred embodiment, the main piston valve member 23 provides the central section 233 in a substantially central position along its axial length.

The downstream end section 232 of the main piston valve member 23 has an external diameter D2 that is smaller than the external diameter D3 of the central section 233.

Preferably, the upstream end section 231 of the main piston valve member 23 has an external diameter D1 that is smaller than the external diameter D3 of the central section 233.

Still more preferably, the upstream end section 231 of the main piston valve member 23 has an external diameter D1 that is smaller than the external diameter D2 of the downstream end section 232.

According to an embodiment, as shown in figure 7, anti-rotation mechanisms, preferably in the form of key joints 49, 50 may be provided at the interface between the outer valve body

21 and the main piston valve member 23 and at the interface between the main and secondary piston valve members 23 and 41, to prevent relative rotation of the piston valve members, while allowing relative axial movement between the parts.

Optionally, the Brake Control Unit 16 (BBCU) may have an integrated Inertial Measurement Unit (IMU), designated at 6, which detects acceleration and orientation of the e-bike. Based on these measurements, the BBCU can energize the electric motor to control the positions of the main and secondary piston valve members 23, 41 activating the valve unit in order to prevent roll-over of the bike when the rider brakes excessively on high friction road surfaces, and prevents locking of the controlled wheel when the rider brakes on low friction surfaces.

In the following, exemplary operating modes of the ABS valve will be described: a normal braking operating mode, a fluidically insulated condition, and a pressure modulation operating mode.

During normal operation of the hydraulic bicycle brake, the ABS valve is in an idle condition (figure 2). The main piston valve member 23 is retracted in a start position, toward the downstream chamber 24, whereas the secondary piston valve member 41 is advanced in a start position toward the upstream chamber 25. The upstream end of the secondary piston member 4 may be in an end of stoke position, abutting against the upstream end plug 38, in this example against the cylindrical protrusion 47.

In all the positions that the secondary piston member 41 is able to reach in operation with respect to the main piston valve member 23, including the initial position of figure 2, the sealing gasket 42 on the secondary piston valve member 41 is always farther than the radial openings 48 from the upstream end sealing gasket.

In this position, the free end of the conical lip of the intermediate sealing gasket 33 is in an open position (figure 8), in which the smooth cylindrical surface 235 is axially shifted with respect to and is not engaged by the intermediate sealing gasket 33. In this open or normal operation position, the intermediate sealing gasket is transversally aligned with and radially separated from the one or more radially narrower surfaces 234. As a result, the one or more

corresponding passages 236 defined between the main piston valve member 23 and the intermediate sealing gasket 33 establish fluid communication between the downstream and upstream chambers 24, 25, and therefore between the master cylinder and the brake caliper.

During normal operation of the brake, the main piston valve member 23 remains in such a retracted, passive position and the brake fluid pumped by the brake lever 12 can flow from the inlet port 27 to the outlet port 26, through the passages or grooves 234, and then to the brake caliper 11 without any kind of interference by the ABS system. The secondary piston valve member 41 remains in an extended, passive position, close to or in abutment with the upstream end plug 38. The volume of brake fluid within the upstream end of the inner axial channel 40 is minimal.

In this normal operating mode, the BBCU control unit 16 constantly monitors the pressure in the hydraulic system, the angular speed of the wheels and, optionally, also information from the IMU. A control algorithm processes this information by deciding to switch to one of the remaining listed operating modes.

In locked wheel braking conditions, or when a condition of impending rollover or other loss of control during braking is perceived, the BBCU 16 energizes the control motor 28 of the wheel concerned, causing the relevant main piston valve member associated with that wheel to slide towards the upstream chamber 25 (figure 3), away from the initial inactive position of figure 2. At the same time, the rotation of the output shaft 29 causes the secondary piston valve member 41 associated with that wheel to slide within the inner axial channel 40 towards the downstream chamber 24 (figure 3), away from upstream end plug 38.

The main piston valve member 23 reaches an axially shifted position toward and the upstream chamber 25, in which the free end of the conical lip of the intermediate sealing gasket 33 is in a closed position, sealingly engaging the smooth cylindrical surface 235 of central section 233 of the main piston valve member 23. In this position of the main piston valve member (figure 3), the intermediate sealing gasket 33 fluidically insulates the downstream chamber 24 from the upstream chamber 25. As a result, fluid communication between the master cylinder and the brake calliper, is temporarily interrupted.

This fluidically insulated condition is a transient condition, because the electric motor 28 drives the main piston valve member further into the upstream chamber 25 (figure 4) and at the same time, the secondary piston valve member 41 is drawn farther into the axial inner channel 40 of the main piston n valve member 23. Since the downstream end section 232 of the main piston valve member 23 has a diameter D2 that is smaller than the diameter D3 of the central section 233 (figure 5), the movement of the main piston valve member 23 towards or further into the upstream chamber 25 causes the downstream chamber 24 to increase in volume, thereby instantaneously releasing the pressure of the brake fluid in communication with the brake calliper.

Conversely, the overall volume of the upstream chamber 25 remains substantially unchanged, because although the main piston valve member 23 is moving further into the upstream chamber 25, the reduction of volume available for the brake fluid in the upstream chamber 25 outside the main piston valve member is compensated by an increase of the volume available inside the upstream end portion of the axial inner channel 40.

More generally, depending on the directions in which the main and secondary piston valve members are linearly displaced, a variation (reduction or increase) of volume available for the brake fluid in the upstream chamber 25 outside the main piston valve member is compensated by a substantially equivalent or corresponding variation (increase or reduction, respectively) of the volume available inside the upstream end portion of the axial inner channel 40.

As a result, the pressure of the brake fluid in the hydraulic system between the valve unit 20 and the master cylinder 13 remains unchanged. Accordingly, the rider does not feel the hand lever 12 moving back toward a released brake position, opposing the brake operating force that the rider is exerting on the hand lever.

The volume compensation may be accomplished in different ways. According to an embodiment, the threaded couplings 30 and 43 may include helically opposite threads having equal pitches, and the cross-sectional area of the inner axial channel 40 may be equivalent

to the cross-sectional area of an annulus having an outer circumference with the D3 diameter of the central section 233 of the main piston valve member 33 and an inner circumference with the D1 diameter of the upstream end section 231 of the main piston valve member 33.

According to an alternative embodiment, considering that the inner axial channel 40 may be relatively narrow, the pitch of the second or inner threaded coupling 43 may be chosen to be longer than that of the first or outer threaded coupling 30. As a result, the linear speed of the secondary piston valve member 41 may be higher than that of the main piston valve member 23, moving in the opposite axial direction but leaving the volume of the upstream chamber 25 unchanged during activation of the valve unit.

According to a pressure modulation operating mode, the BBCU 16 controls the electric motor 28 so as to drive the main and secondary piston valve members 23, 41 back and forth repeatedly several times per second during braking, whereby the position of the main piston valve member 23 performs linear reciprocating motion between

- the fluid insulated condition of figure 3, in which the intermediate sealing gasket 33 seals the downstream chamber 24 from the upstream chamber 25, and
- the position of figure 4, in which the intermediate sealing gasket 33 still seals the downstream chamber 24 from the upstream chamber 25, but the main piston valve member 23 is farther into the upstream chamber, thereby increasing the volume and reducing the pressure in the downstream chamber 24.

As a result, the braking torque intermittently transmitted to the brake caliper prevents wheel locking, or rollover.

At the same time, the secondary piston valve member 41 is caused to reciprocate repeatedly back and forth within the axial inner channel 40. Owing to the compensated and constant volume and pressure of the upstream chamber 25, the hand of the rider does not feel the ABS valve unit working.

It will be observed that during the pressure modulation operating mode, the downstream chamber 24 remains fluidically separated or sealed from the upstream chamber 25, whereby

the master cylinder cannot exert any action on the brake caliper.

The BBCU unit controls the electric motor and the main piston valve member in the pressure modulation mode until the BBCU, through the hydraulic pressure sensor, detects that the pressure in the downstream chamber falls below a predetermined threshold, and sends a control signal to the electric motor 28, causing the main piston valve member 23 to return to its starting position (figure 2), switching back to the normal operating mode of the ABS valve.

Due to the design and position of the intermediate sealing gasket 33, fluidic insulation or sealing action performed by the intermediate sealing gasket 33 is maintained insofar as the pressure in the upstream chamber 25 is greater than or equal to the pressure in the downstream chamber 24. Conversely, when the pressure in the upstream chamber 25 becomes less than the pressure in the downstream chamber 24, which occurs when the rider releases the brake lever, the intermediate sealing gasket 33 allows the brake fluid to flow back from the downstream chamber 24 to the upstream chamber 25. This capability prevents braking torque from being applied to the brake calliper even when the rider releases the brake.

An algorithm manages the full axial movement of the piston up to reaching the fluidically insulated operating mode with the intermediate sealing gasket arranged as shown in figure 3, in which the brake calliper is fluidically insulated with respect to the master cylinder. If this condition is still not sufficient to effectively control braking, the algorithm acts to adjust the pressure within the downstream chamber in accordance with the above-described pressure modulation operating mode.

As an alternative to the above-described pressure modulation operating mode, the valve unit 20 may be controlled in a more conventional operating mode. According to the alternative operating mode, upon detecting a critical (skidding or rollover) braking condition, the BBCU energizes the electric motor 28 to drive the main and secondary piston valve members 23, 41 from the initial positions of figure 2 to the sealed or insulated position of figure 4, in which the pressure in the hydraulic circuit between the intermediate sealing gasket 33 and

the brake calliper is released. As soon as the BBCU, through the hydraulic pressure sensor, detects that the pressure in the downstream chamber falls below a predetermined threshold, it sends a control signal to the electric motor 28, causing the main and secondary piston valve members 23, 41 to return to their starting positions (figure 2), thereby reopening the flow of brake fluid through the passages or grooves 234, and temporarily re-establishing direct fluid communication between the master cylinder and the brake calliper. Upon detecting a persisting critical braking condition, the BBCU will immediately drive the main piston valve member 23 (and the secondary piston valve member 41) back to the sealed or insulated position of figure 4, and this process of opening and closing the passages 234 is repeated continuously during braking, several times per second, preventing the vehicle from skidding.

The arrangement of diameters D3 > D2 > D1 of sections 233, 232, and 231, respectively, of the main piston valve member 23 provides also an advantageous safe fail condition. In the event of a power failure of the electric motor 28 while the piston valve member 23 is in the position of figure 4, although the intermediate sealing gasket fluidically insulates the master cylinder from the brake calliper, the diameter D3 of the central section 233, being wider than the diameter D1 of the upstream end section 231, causes the main piston valve member 23 to move (to the left) toward the downstream chamber 24, until the passages 234 are reopened.

Preferably, the diameter D2 of the downstream end section 232 is greater than the diameter D1 of the upstream end section 231. As a result, as soon as the passages 234 are reopened, since the same hydraulic pressure will be present in the downstream chamber and the upstream chamber, the main piston valve member 23 will be effectively urged to move (to the left) toward the downstream chamber 24. This is because the area of an annulus delimited by the diameters D1 and D3 (on the upstream chamber side) is greater than the area of an annulus delimited by the diameters D2 and D3 (on the downstream chamber side). Consequently, the hydraulic forces acting on opposite sides of the main piston valve member 23 will provide an axial net force pushing it towards and further into the downstream chamber 24, reaching the position of figure 2. As a result, the valve unit always guarantees a sufficient braking torque to allow the vehicle to stop in a reasonable stopping distance, even in the event of an electric failure.

While specific embodiments of the invention have been disclosed, it is to be understood that such disclosure has been merely for the purpose of illustration and that the invention is not to be limited in any manner thereby. Various modifications will be apparent to those skilled in the art in view of the foregoing examples. The scope of the invention is to be limited only by the appended claims.

CLAIMS

1. A valve unit (20) for an anti-lock hydraulic braking system for a bicycle, the valve unit comprising:

an outer valve body (21) defining an inner cavity (22) having an axially elongate shape;

a main piston valve member (23) axially slidably accommodated within the inner cavity (22), and separating an upstream chamber (25) from a downstream chamber (24) within the inner cavity (22), the main piston valve member (23) having a substantially tubular shape with an inner channel (40) axially extending through it;

an inlet port (27) formed in the outer valve body (21), for establishing fluid communication between the upstream chamber (25) and a brake operating hydraulic master cylinder (13);

an outlet port (26) formed in the outer valve body (21), for establishing fluid communication between the downstream chamber (24) and a brake caliper (11) operatively associated with the valve unit (20), wherein the inlet port (27) and the outlet port (26) are axially spaced from one another along the inner cavity (22);

a secondary piston valve member (41) axially slidingly accommodated within the inner channel (40) and having an upstream end portion fitted with a sealing gasket (42) slidingly and sealingly engaging the inner axial channel (40) of the main piston valve member (23), wherein a volume inside an upstream end portion of the axial inner channel (40) is in fluid communication with the upstream chamber (25);

an electric motor (28) drivingly connected to the main piston valve member (23) for controlling the axial position of the main piston valve member (23) along the inner cavity (22), the electric motor (28) being drivingly connected also to the secondary piston valve member (41) for controlling the axial position of the secondary piston valve member along the inner axial channel (40), whereby the electric motor (28) causes simultaneous linear displacements of the main and the secondary piston valve members in respective axially opposite directions.

2. A valve unit according to claim 1, wherein

the main piston valve member (23) has a downstream end section (232) with a diameter (D2), an upstream end section (231) with a diameter (D1), and a central section

(233) with a smooth cylindrical surface having a diameter (D3), wherein the diameter (D3) of the central section (233) is greater than the diameter (D2) of the downstream end section (232), and wherein

the inner axial channel (40) has a fourth diameter (D4);

the said diameters (D1-D4) being so configured that, as a result of simultaneous linear displacements of the main and secondary piston valve members (23, 41) in opposite directions, a variation (reduction or increase) of volume available for the brake fluid in the upstream chamber (25) outside the main piston valve member (23) is compensated by a substantially equivalent or corresponding variation (increase or reduction, respectively) of volume available for the brake fluid inside the upstream end portion of the axial inner channel (40), whereby the pressure of the brake fluid in upstream chamber (25) remains substantially constant.

3. A valve unit according to claim 1, comprising a rotating output shaft (29) driven for rotation by the electric motor (28) and coupled to the main piston valve member (23) through a first rotary to linear motion conversion mechanism (30) that converts rotary motion of the rotating shaft (29) into linear displacement of the main piston valve member (23) within the inner cavity (22), the rotating output shaft (29) being also coupled to the secondary piston valve member (41) through a second rotary to linear motion conversion mechanism (43) that converts rotary motion of the rotating shaft (29) into linear displacement of the secondary piston valve member in an axial direction opposite to the axial direction in which the main piston valve member (23) is driven.

4. A valve unit according to claim 3, wherein the rotating output shaft (29) comprises

a tubular, axially extending end portion (44), with a radially outer cylindrical surface on which the first rotary to linear motion conversion mechanism (30) is provided, and

an axially extending end cavity (45), coaxially inner with respect to said radially outer cylindrical surface, in which cavity (45) the second rotary to linear motion conversion mechanism (43) is arranged.

5. A valve unit according to claim 3 or 4, wherein the rotary to linear motion conversion mechanisms (30, 43) include respective first and second threaded couplings with helically

opposite threads.

6. A valve unit according to claim 5, wherein the second threaded coupling (43) has threads with a pitch that is longer or shorter than a pitch of the first threaded coupling (30), and wherein the lengths of the pitches are chosen considering a cross-sectional area of the inner axial channel (40) and a cross-sectional area of an annulus having an outer circumference with the (D3) diameter of the central section (233) of the main piston valve member (33) and an inner circumference with the (D1) diameter of the upstream end section (231) of the main piston valve member (33), whereby during activation of the valve unit the linear speed of the secondary piston valve member (41) may be different than the linear speed of the main piston valve member (23) moving in the opposite axial direction but leaving the volume of the upstream chamber (25) unchanged.

7. A valve unit according to claim 5, wherein the threaded couplings (30, 43) include helically opposite threads having equal pitches, and wherein a cross-sectional area of the inner axial channel (40) is equivalent to a cross-sectional area of an annulus having an outer circumference with the (D3) diameter of the central section (233) of the main piston valve member (33) and an inner circumference with the (D1) diameter of the upstream end section (231) of the main piston valve member (33).

8. A valve unit according to claim 1, wherein anti-rotation mechanisms (49, 50) are provided at the interface between the outer valve body (21) and the main piston valve member (23) and at the interface between the main and secondary piston valve members (23, 41), to prevent rotation of the piston valve members while allowing them to perform linear axial movements.

9. A valve unit according to claim 1, wherein the anti-rotation mechanisms (49, 50) comprise key joints.

10. A valve unit according to claim 1, wherein

at least one radial opening (48) is formed through an upstream end section (231) of the main piston valve member (23), setting an upstream end portion of the axial inner channel

(40) is in fluid communication with the upstream chamber (25), and wherein

a cylindrical protrusion (47) integral with or secured to the outer valve body (21) axially extends toward into the upstream chamber (25) and is axially aligned with the inner axial channel (40) so as to protrude into the inner axial channel (40) at the upstream end section (231) of main piston valve member (23) to guide the linear motion thereof, and wherein

the cylindrical protrusion (47) provides a sealing ring (46) that seals the inner axial channel (40) at the upstream end section (231) of the main piston valve member (23).

11. A valve unit according to claim 2, wherein one or more radially narrower surfaces (234) axially extend from the smooth cylindrical surface (235) towards the upstream end section (231), and wherein the valve unit comprises three stationary annular sealing gaskets (31, 32, 33) mounted within the inner cavity (22) and slidingly sealingly engaging the main piston valve member (23):

(i) an upstream end sealing gasket (31) engaging the upstream end section (231);

(ii) a downstream end sealing gasket (32) engaging the downstream end section (232), wherein the upstream and downstream end sealing gaskets (31, 32) are arranged axially spaced from one another such that the inlet port (27) and the outlet port (26) are axially located between the upstream end and the downstream end sealing gaskets (31, 32);

(iii) an intermediate sealing gasket (33) mounted within the inner cavity (22) between the inlet port (27) and the outlet port (26),

wherein the main piston valve member (23) is axially drivable between

a normal braking position, in which the smooth cylindrical surface (235) is axially shifted with respect to and is not engaged by the intermediate sealing gasket (33), and the intermediate sealing gasket (33) is transversally aligned with and radially separated from the one or more radially narrower surfaces (234), whereby one or more corresponding passages (236) are defined between the main piston valve member (23) and the intermediate sealing gasket (33), thereby establishing fluid communication between the downstream and upstream chambers (24, 25); and

at least one fluidically insulating position, in which the main piston valve member (23) is axially shifted toward the upstream chamber (25), and the intermediate sealing gasket (33) engages the smooth cylindrical surface (235), thereby fluidically

insulating the downstream chamber (24) from the upstream chamber (25).

12. A valve unit according to claim 11, wherein the upstream end section (231) of the main piston valve member (23) has a diameter (D1) that is smaller than the diameter (D3) of the central section (233).

13. A valve unit according to claim 12, wherein the diameter (D2) of the downstream end section (232) is greater than the diameter (D1) of the upstream end section (231).

14. A valve unit according to any one of claims 11 to 13, wherein the intermediate sealing gasket (33) has a conical lip that tapers towards the upstream chamber (25).

15. A valve unit according to claim 11, wherein the one or more radially narrower surfaces (234) comprise axially extending and circumferentially spaced grooves.

16. A valve unit according to any one of claims 11 to 15, wherein the valve unit is configured so that the main piston valve member (23) can be driven, in accordance with a pressure modulation operational mode, to perform linear reciprocating motion and reach repeatedly and alternately two relatively axially displaced fluidically insulating positions:

a first fluidically insulating position, in which the main piston valve member (23) is axially shifted toward the upstream chamber (25), and the intermediate sealing gasket (33) engages the smooth cylindrical surface (235), thereby fluidically insulating the downstream chamber (24) from the upstream chamber (25); and

a second fluidically insulating position, in which the main piston valve member (23) is axially shifted farther toward and into the upstream chamber (25), and the intermediate sealing gasket (33) engages the smooth cylindrical surface (235), thereby fluidically insulating the downstream chamber (24) from the upstream chamber (25).

17. A valve unit according to any one of claims 1 to 15, wherein the valve unit is configured so that the main piston valve member (23) can be driven, in accordance with an operational mode, to perform linear reciprocating motion and reach repeatedly and alternately two axially displaced positions:

said normal braking position, in which the smooth cylindrical surface (235) is axially shifted with respect to and is not engaged by the intermediate sealing gasket (33), and the intermediate sealing gasket (33) is transversally aligned with and radially separated from the one or more radially narrower surfaces (234), whereby one or more corresponding passages (236) are defined between the main piston valve member (23) and the intermediate sealing gasket (33), thereby establishing fluid communication between the downstream and upstream chambers (24, 25); and

said at least one fluidically insulating position, in which the main piston valve member (23) is axially shifted toward the upstream chamber (25), and the intermediate sealing gasket (33) engages the smooth cylindrical surface (235), thereby fluidically insulating the downstream chamber (24) from the upstream chamber (25).

18. A valve unit according to claim 1, wherein the outer valve body (21) defining the inner cavity (22) is made of plastic material.

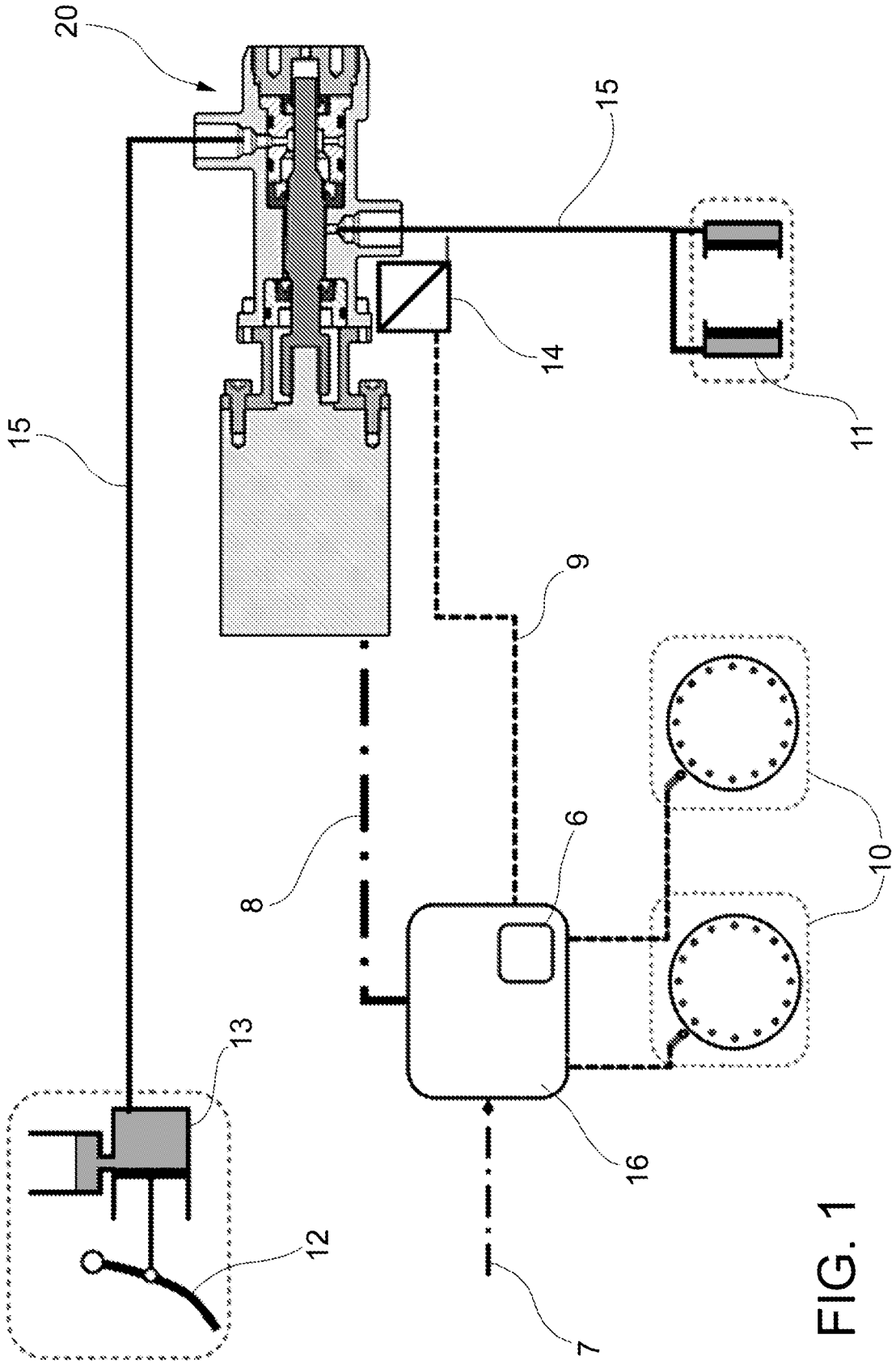
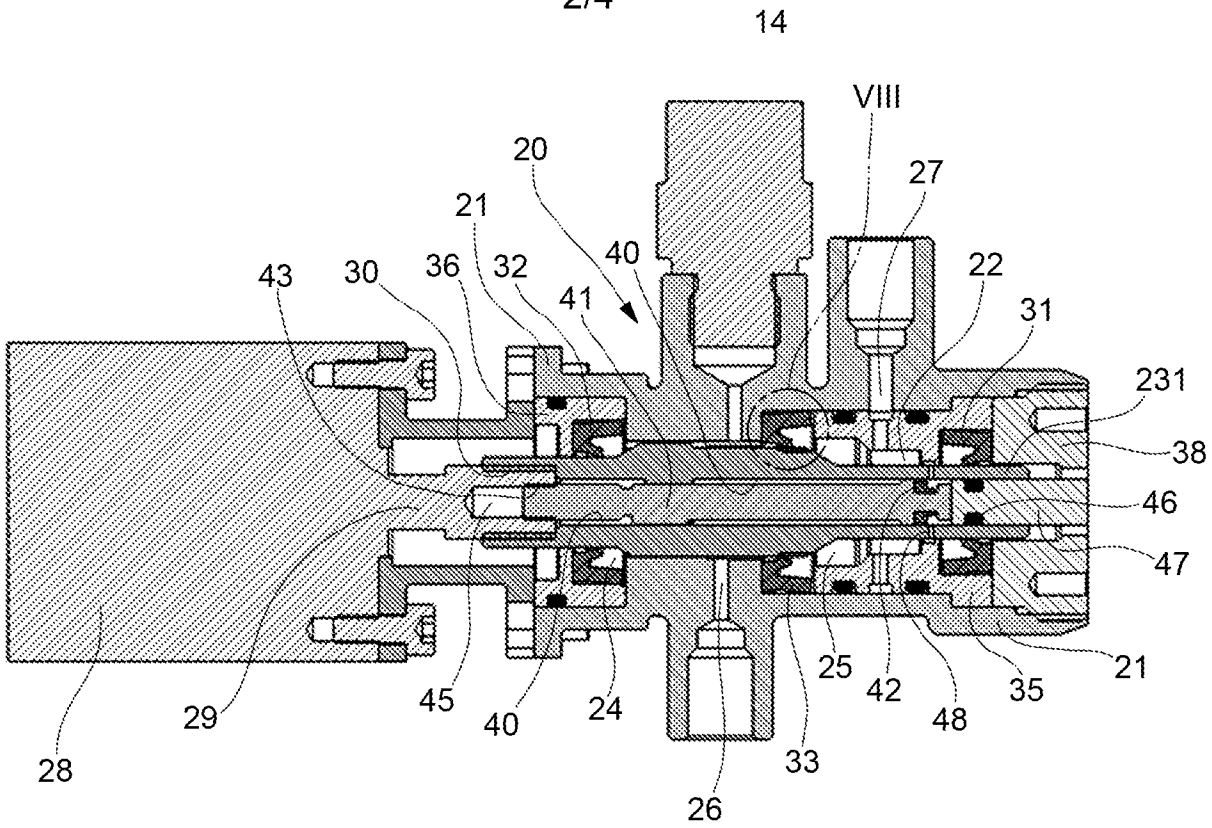


FIG. 1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VIII
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FIG. 2

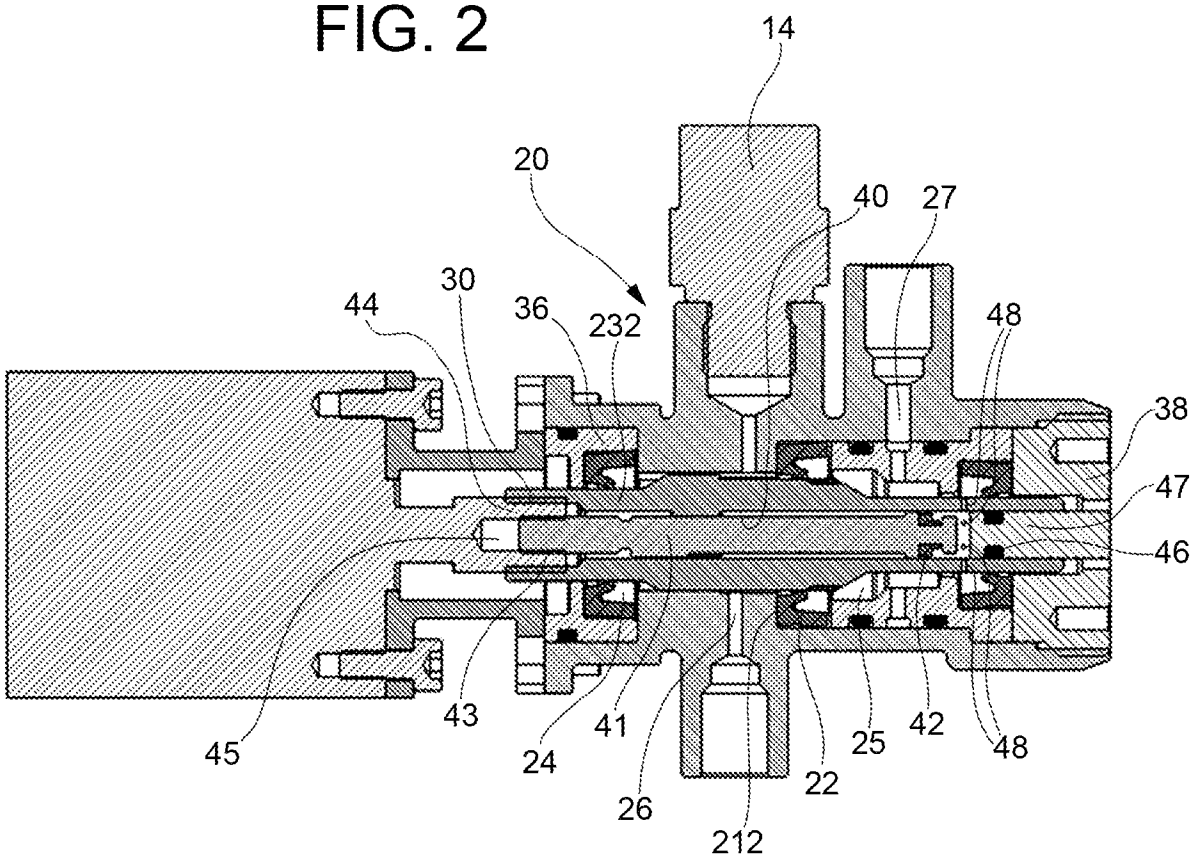
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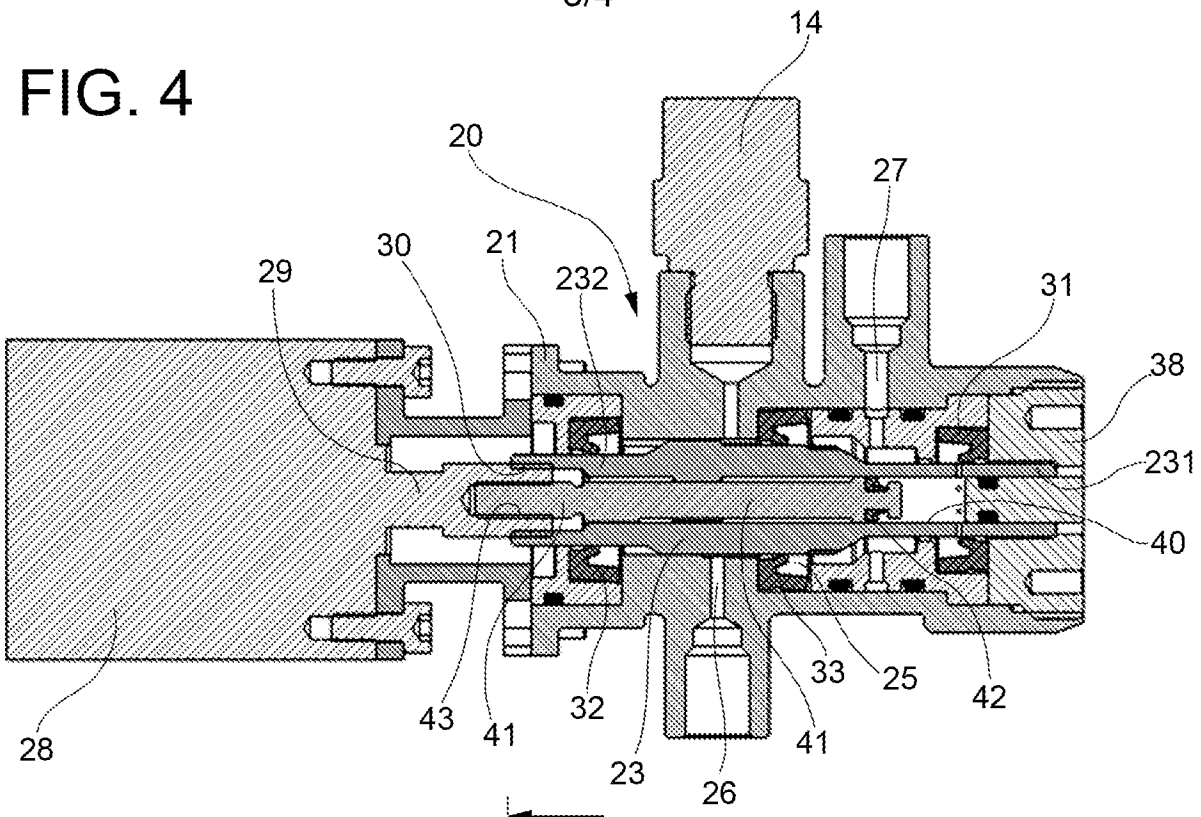
FIG. 3

FIG. 4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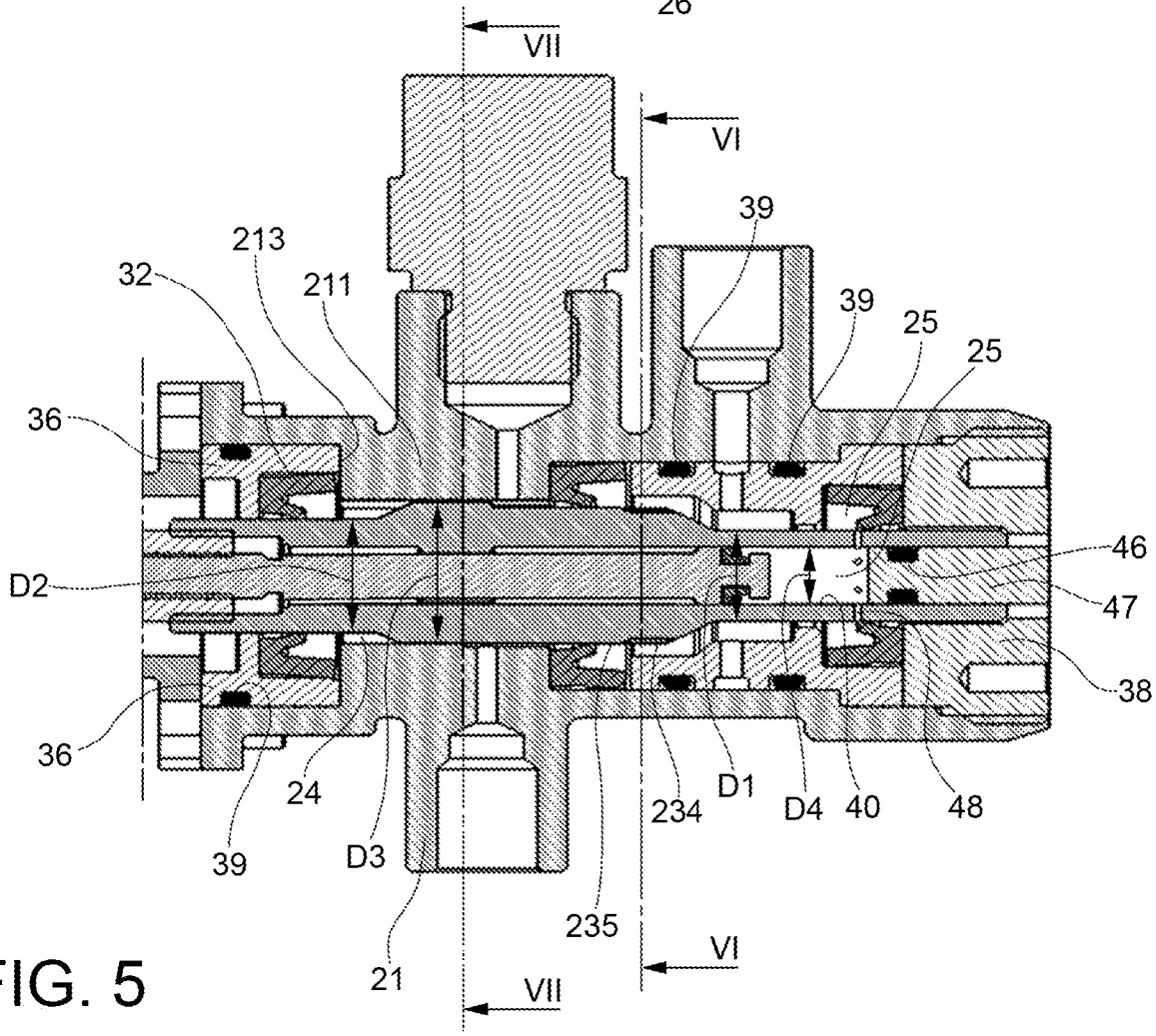
VII
VI
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213
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211
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36
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D2
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D3
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D1
D4
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48
235
21
VI
VII

FIG. 5

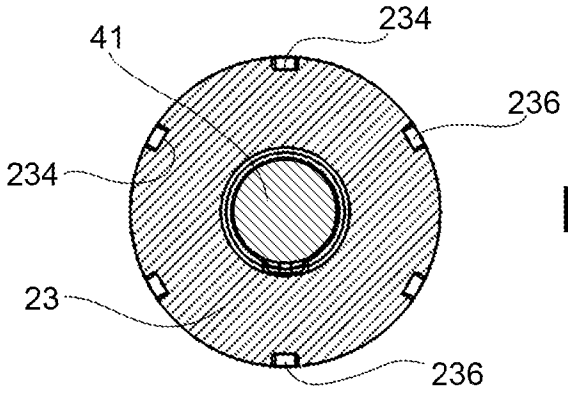

FIG. 6

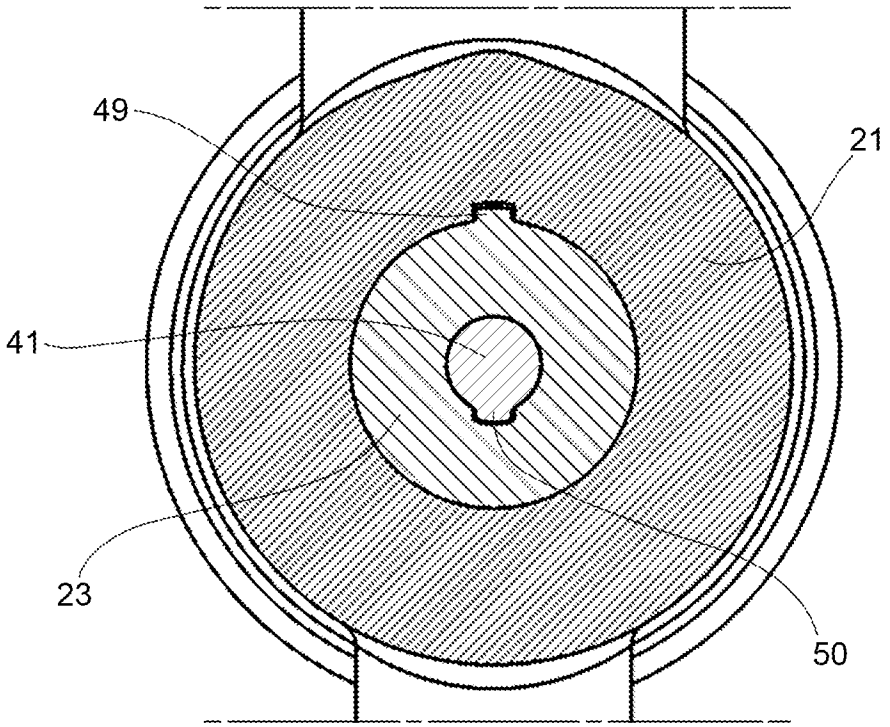

FIG. 7

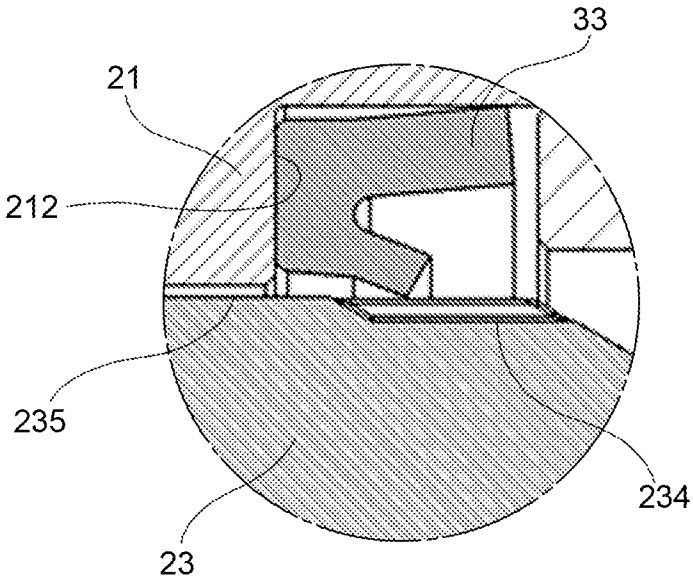

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/055693

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60T13/74 B60T8/17 B62L3/02
ADD. F16D121/24

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)

B60T B62M B62L F16D

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2021/205334 A1 (BLUBRAKE S R L [IT]) 14 October 2021 (2021-10-14) page 8, line 23 - page 13, line 23; figures 4, 5A, 5B	1-18
A	WO 2023/052909 A1 (BLUBRAKE S P A [IT]) 6 April 2023 (2023-04-06) page 10, line 12 - page 12, line 4; figures 7, 8	1-18
A	WO 2021/205337 A1 (BLUBRAKE S R L [IT]) 14 October 2021 (2021-10-14) figures 4, 4A, 4B, 4C	1-18
A	US 4 626 042 A (BURCKHARDT MANFRED [DE]) 2 December 1986 (1986-12-02) figure 1	1-18

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"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

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"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
29 July 2024	12/08/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lopez, Marco

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2024/055693

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