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(54) **Title**: ENERGY EFFICIENT HYDROSTATIC TRANSMISSION CIRCUIT FOR AN ASYMMETRIC ACTUATOR UTILIZING A SINGLE 4 - QUADRANT PUMP

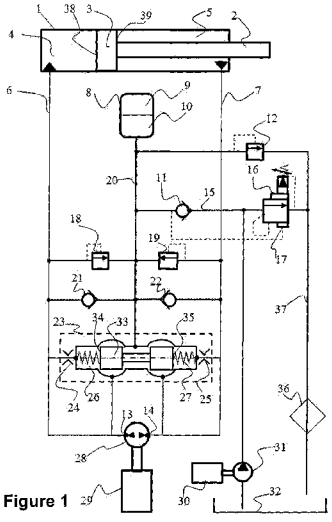

Figure 1

(57) **Abstract**: The invention relates closed hydraulic transmission circuit in order to drive an asymmetric actuator (1) by utilizing a single flow adjustable pump (28) by means of changing drive speed or displacement or both. The unequal flow rate generated in the closed hydraulic circuit due to the inherent asymmetric geometry of the hydraulic actuator (1) is compensated by utilizing a hydraulic accumulator (8) and flow compensation valve (23). The flow compensation valve (23) connects the non-working chamber of the hydraulic actuator (1) to the accumulator line (20) in order to compensate the unequal flow rates. The proposed hydraulic circuit is capable of carrying static load via accumulator (8) without creating resistive torque on pump drive shaft. The hydraulic accumulator (8) capable of storing hydraulic energy and furthermore the flow adjustable pump (28) and motor unit (29) which are capable of operating in 4-quadrants provide energy recovery.

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PATENT

ENERGY EFFICIENT HYDROSTATIC TRANSMISSION CIRCUIT FOR AN ASYMMETRIC ACTUATOR UTILIZING A SINGLE 4 - QUADRANT PUMP

Technical Field of the Invention

The invention is related with a hydrostatic transmission circuit utilizing a single pump which is capable of working in pumping or motoring mode by changing its displacement or drive speed in order to drive an asymmetric hydraulic actuator (Ex: a dual acting single rod hydraulic cylinder).

The subjects of the invention are increasing the energy efficiency, providing energy regeneration, compensation of the unequal flow rate created in the closed hydraulic circuit due to the geometrical structure of the asymmetric actuator and compensation of the static load acting on the actuator.

Background

The hydrostatic transmission systems are generally used in mobile applications. In conventional hydrostatic transmission systems a variable displacement pump driven by a constant speed power source and capable of reversing the direction of the flow is directly connected to a fixed displacement hydraulic motor. Hence the motor speed and the rotation direction is controlled by the pump stroke. In this circuit the actuator is symmetric hence the inflow and out-flow of the driven motor is the same. In order to compensate for the leakage losses a check valve bridge is utilized.

In case of the asymmetrical actuators for example double acting single rod cylinders which are commonly used in industry, due to their geometrical structures the inflow and outflow rates of the actuator are different. For example, in case of extending a single rod hydraulic cylinder, flow rate going out rod side is smaller than flow rate that entering cap side. This unequal flow rate arising from area difference makes impossible of applying conventional hydrostatic circuitry together with this actuators. The state of art in the hydrostatic transmission systems driving asymmetric actuator a second variable displacement pump is

utilized so as to provide flow equalization and overcome flow rate deficiency or redundancy arising from geometry ıf the actuator. Using a second pump increases expenditure of the system.

Exemplary application of the prior art Patent No. US7430860b2, has a title "Hydrostatic Transmission Circuit". In this system, a modified hot oil shuttle valve is utilized and the previously required charge pump and relief valve are eliminated. When the modified hot oil shuttle valve is in neutral position, it contributes to solution of heat problem of hydraulic motor. Improvement just provided in the shuttle valve with hot oil and this provides addition cooling to hydraulic motor and pump. In this circuitry the aim of the hot oil shuttle valve is to extract oil from closed loop hydrostatic circuitry continuously. By means of making the improvement of neutral position of hot oil shuttle valve whole oil provided by the charge pump to the circuitry is able to discharge to the tank line at low pressure drop.

One of the exemplary patent that belongs to prior art is an application with Patent No. US2004/0006981A1 has a title as 'Hydraulic Devices for Smooth Operations of Hydrostatic Transmission'. The invention utilizes a hydraulic valve assembly consisting of shuttle valve with integrated by pass orifices and check valves, in order to provide energy efficiency, cooler operation and smoother start up. In this circuit solution energy regeneration is not considers and since the actuator is symmetric the flow compensation due to the geometry of the asymmetric actuator is out of scope.

One of the prior art with patent No. US8033107B2 to Tikkanen considers flow equalization of the asymmetric actuator utilized in a hydrostatic drive. In order to compensate the flow difference due to the area ratio of the single rod hydraulic cylinder three tandem-connected pumps are utilized. Two of them are variable displacement pumps, and the last is a constant displacement pump. The first variable displacement pump is connected between the two chambers of the actuator and controls the motion of the actuator. The second variable displacement pump is connected between a hydraulic reservoir or accumulator and the cap side of the actuator. This pump compensates the efficient/deficient flow rate due to the area difference of the actuator piston. The displacement regulations of the two pumps are dependent and determined by the area ratio of the actuator. A third tandem connected constant displacement pump serves as a charge pump, it continuously delivers flow to the hydraulic circuit, in order to prevent cavitation and compensate for leakage flows. The excess flow rate

in the closed circuit is directed to the hydraulic reservoir or accumulator over the valve named as tapping valve which is in fact a shuttle valve, by this way volumetric flow equalization is completed. The invention is varied by utilizing hydraulic accumulators in order to store hydraulic energy. However since the variable displacement pumps are not capable of operating in motoring mode energy cannot be recovered pump drive units.

A second prior art considering flow equalization of the asymmetric actuator is US0079609a1 numbered patent application. This patent focuses on the work machine application where at least one single rod actuator is utilized. Its circuit solution scheme is similar to the prior art with patent No US8033107B2. The invention utilized there variable displacement pumps. Different from the prior one the displacements of the pumps can be adjusted independently and the two main pump are capable of working in motoring mode. Similar to the prior art numbered US8033107B2 one variable displacement pump determines the motion of the actuator while a second one compensates the unequal flow rate due to the area ratio, and the third pump charges flow rate to the closed loop circuit. The excess flow rate in the closed circuit is directed to the accumulator by utilizing a shuttle valve assembly. Utilizing an accumulator provides energy regeneration furthermore since the pumps are capable of working in pumping mode, the hydraulic energy stored in the accumulator can be transmitted to the load over the pumps.

Another exemplary application on literature is Patent No.US6263670B1. This invention utilizes a three position three port pilot pressure operated loop flushing valve in a tradition hydrostatic transmission system where symmetric actuators are utilized. The main purpose of the proposed valve solution is to provide flushing in neutral mode and under all operating conditions of the hydrostatic transmission system. Since no asymmetric actuator is utilized flow equalization is not considered in this patent and furthermore no energy regeneration is possible.

The prior art DE patent no 1601732 is the oldest one that proposes solution to hydrostatic transmission systems of single rod hydraulic cylinder. The circuit solution utilizes two variable displacement pumps, the first pump connected between the two chambers of the hydraulic actuator is use to control the direction and motion of the actuator. The second pump which is connected between a reservoir and cap side of the hydraulic cylinder is used to compensate for leakage flow rates and flow deficiency or excess flow due to the area

difference of the single rod cylinder. In order to guarantee the cavitation problems completely a third pump and a shuttle valve is added to the system. The third pump continuously delivers flow rate to the system, and the shuttle valve directs the resulting excess flow to the hydraulic reservoir. The shuttle valve always connects the low pressure chamber of the actuator to the hydraulic reservoir over a pressure relief valve, thus limiting the chamber pressure at a constant value.

Another exemplary patent driving an asymmetric actuator is JP58102806. The purpose of the invention is to prevent an occurrence of energy loss and cavitation in the closed loop hydraulic circuit. A single variable displacement pump determines the motion of the asymmetric actuator. A charge pump is utilized to overcome the flow deficiencies that might arise in the circuit, for example the extension situation of the actuator. The deficient flow rate due to rod area will be compensated by the charge pump. The excess flow rate that might arise in the closed loop circuit is directed to the tank line over a shuttle valve and relief valve holding the chamber pressure at a constant value. As a summary the shuttle valve is utilized only for discharging the excess flow rate and the deficient flow rate is compensated by a second charge pump. Because no flow rate is delivered to the system over the shuttle valve and no accumulator is utilized in order to store hydraulic energy, no energy regeneration is possible with this circuit solution.

The circuit solutions presented above can be classified in two main groups, one group of prior arts relate with symmetric actuators, and they utilize modified shuttle valve or tapping valve assemblies for improved motion control objectives. The second groups of prior arts are related with asymmetric actuators; commonly they utilize two pumps for the motion control and a third pump for charging purposes. One variable displacement pump controls the motion of the actuator, and a second variable displacement pump compensates for unequal flow rate due to inherent asymmetric geometry of the double acting single rod actuator. The displacements of the two pumps are changed synchronously and proportionally determined by the area ratio of the actuator. In order to solve cavitation problems and compensate for leakages, excess flow rate is delivered to the closed loop systems via a charge pump and by using valve assemblies named as tapping valve or shuttle valve, excess flow in the closed circuit is oriented to the tank or accumulator line. One other purpose of these tapping or shuttle valves is to receive the oil from the closed loop hydraulic circuit and transmit it to the tank line, hence providing cooling and filtration.

The main drawback of the presented prior arts is the usage of multiple pump units in order to control the motion of the asymmetric actuator. The last drawback is the compensation of static load, in each prior art solution a constant torque should be applied to the pump drive shaft in order to resist a static load.

Purpose of the Invention

Present invention is related to the hydrostatic transmission circuit fulfill of needs that mentioned above, eliminating of all disadvantages and providing additional advantages.

In an asymmetrical actuator due to its inherent geometry the inflow rate to the actuator and the outflow rate from the actuator are different. The most common asymmetric actuator used in most industrial applications is the double acting single rod hydraulic cylinders. The surface of the piston areas are different, thus the volume of the fluid swept by the piston in extension and retraction case is different. A conventional hydrostatic circuit cannot be utilized to drive an asymmetric actuator, because of the unequal flow rates due to area differences. One solution that is mention above is to utilize a second pump, which increases the expenditure of the total system. In the presented invention a solution to unequal flow rate compensation with single pump is proposed.

It is the main object of the invention to provide hydrostatic drive which allows to control the motion of an asymmetric actuator, for example a double acting single rod hydraulic cylinder with different piston surface areas, by using a single pump with variable flow rate by means of changing of displacement or drive speed or both of them.

According to the invention the object is achieved by utilizing a flow compensation valve. The flow compensation valve provides volumetric flow equalization and compensates the unequal flow generated from the inherent geometry of the asymmetric actuator. The flow compensation valve connects the low pressure line to the accumulator line, by this way the excess or deficient flow rate in the closed hydraulic circuit is compensated

The other object of the invention is to compensate static load acting on the actuator and energy recovery. In order to achieve energy recovery object a four quadrant pump which is able to work in pumping or motoring mode and a hydraulic accumulator are utilized to provide the storage of hydraulic energy. In order to achieve the static load compensation goal the flow compensation valve spool surface areas and orifices are arranged accordingly. In the neutral position of the compensation valve the two chamber pressures of are equalized to the accumulator pressure, thus the net force due to the area difference of the actuator the static load is compensated.

The flow compensation valve operates by pilot pressure the spool position is determined by the two chamber pressures of the actuator. The spool of the flow compensation valve does not have to be symmetric, according to the area ratio of the actuator the pilot pressure acting surfaces of the spool can be arranged so that the static load compensation or other operating conditions can be arranged accordingly.

The other objective of the invention is to change the geometry of the spool of the flow compensation valve, adjusting of the orifice areas for neutral position of the spool and thus adjusting of possible flow rate breakings and reducing of oscillation and providing of constant flow transmission to the system.

The two chamber pressures of the actuator do not act directly on the spool surface of the flow compensation valve. Two adjustable pilot orifices provide smooth operation of the valve spool thus prevents spool oscillations due to sudden pressure fluctuations.

In the proposed closed loop hydraulic circuit, there will be hydraulic oil deficiency due to leakage flow of the hydraulic pump and other hydraulic equipment. The deficient flow due to leakage is compensated by the accumulator over the flow compensation valve. The other purpose of the invention is to change the accumulator by utilizing a charge pump and unloading valve, so that the accumulator is always pressurized over a predetermined pressure level. The charge pump delivers flow continuously, if the accumulator pressure is over a predetermined level, the unloading valve directs the charge pump flow rate to the hydraulic reservoir over a filtration unit, if the pressure level is under the predetermined level, the unloading valve directs the charge pump flow rate to the accumulator, so that the pressure of

the accumulator is increased. The charge pump does not have to work continuously, it may only operate when the accumulator pressure decrease below its predetermined level.

The invention will be described with its structural and characteristic features and with entire advantages in more detail with reference to the accompanying drawings and because of that assessment should be made by taking into consideration of these drawings and detailed description.

Brief Description of the Drawings

In order to understand ideally structuring of the present invention associated with the additional members it should be assessed with the figures that explained below.

Figure 1: Schematic view of the hydraulic actuator together with other members of the hydrostatic transmission circuit the present invention.
Figure 2: Flow Compensation Valve, where the pressure acting valve spool surface areas are equal to each other
Figure 3: Flow Compensation Valve where the pressure acting valve spool surface areas are not equal to each other

Reference Numbers

1. Asymmetric hydraulic actuator
2. Cylinder rod of the hydraulic actuator
3. Piston of the hydraulic actuator
4. Hydraulic actuator cap side chamber
5. Hydraulic actuator rod side chamber
6. Cap side hydraulic transmission line
7. Rod side hydraulic transmission line
8. Hydraulic accumulator
9. Hydraulic accumulator gas
10. Hydraulic fluid
11. Check valve
12. Hydraulic accumulator pressure relief valve

13. Terminal port
14. Terminal port
15. Accumulator charge pump pressure line
16. Unloading valve
17. Unloading valve pilot pressure line
18. Pressure relief valve of hydraulic actuator cap side line
19. Pressure relief valve of hydraulic actuator rod side line
20. Hydraulic transmission line
21. Check valve
22. Check valve
23. Flow compensation valve
24. Flow compensation valve pilot line orifice
25. Flow compensation valve pilot line orifice
26. Spring of the flow compensation valve connected to the cap side of the hydraulic actuator line.
27. Spring of the flow compensation valve connected to the rod side of the hydraulic actuator line.
28. Pump with variable flow rate, by means of changing displacement, drive speed or both
29. Pump drive unit
30. Charge pump drive unit
31. Charge pump with fix displacement
32. Fluid reservoir
33. Spool of the flow compensation valve
34. Pilot pressure acting surface area of the flow compensation valve connected to the cap side of the hydraulic actuator line.
35. Pilot pressure acting surface area of the flow compensation valve connected to the rod side of the hydraulic actuator line.
36. Oil filter
37. Accumulator charging circuit tank line
38. Cap side surface of the hydraulic cylinder piston
39. Rod side surface of the hydraulic cylinder piston

Detailed Description of the Invention

In this detailed description preferred structures of hydrostatic transmission circuit that subject in invention will be explained with the aim of understanding the subject matter and these are of course in no manner intended to be limiting to the invention.

This invention is a hydrostatic transmission circuit in which motion control of an asymmetric hydraulic actuator (1) (for example, double acting single rod hydraulic cylinder) thanks to using of a flow adjustable pump (28) by changing its drive speed or displacement or both. In the present invention energy recovery is performed by utilizing a hydraulic pump (28) and motor (29) assembly which are capable of working in 4 quadrants and furthermore hydraulic energy can be stored providing a hydraulic accumulator (8).

Hydraulic transmission circuit which subject of the invention consists of an asymmetrical actuator (1), hydraulic accumulator (8), flow adjustable pump with working on 4-quadrant (28), preferably a servo motor (29), charge pump (31), unloading valve (16), check valve (11) that working on one direction between hydraulic accumulator (8) and charge pump (31), hydraulic accumulator (8) pressure relief valve (12), pressure relief valve (18) of cap side of the hydraulic actuator line (6), pressure relief valve (19) of rod side of the hydraulic actuator line (7), check valve (21) between the cap side of the hydraulic actuator line (6) and accumulator (8), check valve (22) between the rod side of the hydraulic actuator line (7) and accumulator (8), flow compensation valve (23), hydraulic oil reservoir (32) and hydraulic oil filter (36). There are several transmission lines among the mentioned circuit members. These lines are composed of cap side of the hydraulic actuator transmission line (6), rod side of the hydraulic actuator transmission line (7), accumulator (8) – charge pump (31) pressure line (15), unloading valve (16) pilot pressure line (17), hydraulic transmission line (20) between the hydraulic accumulator (8) and flow compensation valve (23) and accumulator charge circuit tank line (37).

In figure 1, hydraulic circuit scheme, which is the subject of the invention, is shown. Single rod double acting hydraulic cylinder (1) drawn on the top of circuit scheme is qualified as asymmetrical hydraulic actuator. Rod (2) and piston (3) that is moving inside of the hydraulic actuator (1) cylinder are rigidly connected to each other. There exist two chambers in the

hydraulic actuator (1). The first is named as cap side chamber (4) where the swept fluid volume is determined by the piston surface area (38) only. The second one is named as rod side chamber (5), where the swept fluid volume is determined by the net surface area (39) of the hydraulic piston (3) and rod (2). Hydraulic actuator (1) piston (3) moves between said cap side chamber (4) and rod side chamber (5). The surface area (38) that piston (3) interacts with cap side chamber (4) is larger than the surface area (39) that interacts with rod side chamber (5). Due to this inherent geometry of the asymmetric hydraulic actuator (1) the swept volume of the hydraulic oil is different for extension and retraction case. Thus the inflow (outflow) rate to the cap side chamber (4) and the outflow (inflow) rate from the rod side chamber (5) are dependent by a ratio determined by the piston (3) and rod (2) surface areas.

Cap side chamber (4) of hydraulic actuator (1) is connected to cap side connection port (13) of the flow adjustable pump (28) by the hydraulic transmission line (6). Rod side chamber (5) of hydraulic actuator (1) is connected to the rod side connection port (14) of flow adjustable pump (28). In the extension case of the hydraulic actuator (1) the hydraulic oil is sucked from the rod side connection port (14) of flow adjustable pump (28) and transmitted to cap side chamber (4) of the hydraulic actuator (1) over the cap side connection port (13). In the retraction case of the hydraulic actuator (1) suction is employed over the cap side connection port (13) of flow adjustable pump (28) and transmitted to rod side chamber (5) of hydraulic actuator (1) over rod side connection port (14).

During the movement of the hydraulic actuator (1) due to different piston (3) surface areas and leakage flow rates of the hydraulic equipment excess or deficient flow rates occurs in the closed hydraulic circuit. This flow rate difference is eliminated by the hydraulic fluid (10) stored in the hydraulic accumulator (8). The flow compensation valve (23) determines the transmission direction of the hydraulic fluid (10) from (to) the hydraulic accumulator (8) to (from) which chamber of the hydraulic actuator (1).

Hydraulic accumulator (8) is connected to flow compensation valve (23) by the hydraulic transmission line (20). Said flow compensation valve (23) is connected to cap side hydraulic transmission line (6) and rod side transmission line (7). The deficient or excess flow rate that is generated on cap side hydraulic transmission line (6) or rod side transmission line (7) is compensated by the accumulator (8) by changing the spool (33) position of the flow compensation valve (23).

The position of the flow compensation valve (23) depends on the force applied by hydraulic actuator (1). If the cap side chamber (4) is pressurized and it is the working side, the rod side chamber (5) is connected to accumulator (8) thanks to spool positioning of the flow compensation valve (23). On the contrary of this if the rod side chamber (5) of hydraulic actuator (1) is pressurized and is active, the inactive, non-working cap side chamber (4) is connected to the accumulator (8) thanks to positioning of the flow compensation valve spool (33).

Flow compensation valve (23) consist of orifices (24, 25),springs (26, 27) and valve spool (33). In figure 2, there is a representative image related to flow compensation valve (23) structure. In this structure valve spool (33) piston surface (34, 35) areas are identical. Said springs (26, 27) provide neutral positioning of the valve spool (33). Orifices (24, 25) prevents the direct action of the pressures in rod side hydraulic transmission line (7) and cap side hydraulic transmission line (6) on the valve spool (33) surfaces and damps out the possible pressure fluctuations, and valve spool (33) oscillations. The pilot pressure acting on the spool surface area (34) of the valve spool (33) is closely related with the cap side chamber (4) pressure of the hydraulic actuator. Likewise the pilot pressure acting on the spool surface area (35) of the valve spool (33) is closely related with the rod side chamber (5) pressure of the hydraulic actuator. The areas of the valve surfaces (34, 35) might be identical or different according to the application. In figure 3, there is a representative image of a structure that the spool (33) surface areas (34, 35) of the flow compensation valve (33) are not equal. If the spool area surfaces (34, 35) are arranged so that the ratio of the spool area surfaces (34) and the area ratio of the hydraulic actuator cap side piston surface (38) and rod side piston surface (39) are dependent by a predetermined ratio, then the flow compensation valve (23) will change position according to the net force acting on the hydraulic actuator (1) only. In this case the static load carrying capacity is zero, and the non-working chamber of the hydraulic actuator will always be connected to the accumulator line (20).

Thanks to hydraulic accumulator (8) not only the flow difference due to the geometry of hydraulic actuator (1) is provided but also the leakage flow from the closed hydraulic circuit is also compensated. Due to the leakage flows the pressure of the stored fluid (10) in the hydraulic accumulator (8) drops. In order to increase the hydraulic accumulator (8) pressure

to a predetermined pressure level a charge pump (31) delivers flow to hydraulic accumulator (8).

The charge pump (31) driven by electrical motor (30) sucks oil from fluid reservoir (32) and pressurizes accumulator charge pressure line (15). Pressurized fluid opens the check valve (11) and charges the accumulator through hydraulic transmission line (20). Accumulator pressure line (20) is connected with pilot pressure port (17) of the unloading valve (16). In case of accumulator pressure increases above a predetermined level, unloading valve (16) directs the flow coming from the charge pump (31) to reservoir line (37). Flow in accumulator charge circuit reservoir line (37) pass through oil filter (36) and reaches to the hydraulic reservoir (32). Accumulator (8) pressure is limited by a pressure relief valve (12). If the accumulator pressure is higher than the pre-set pressure level of the pressure relief valve (12) the hydraulic oil (10) inside the accumulator (8) is directed to the tank line (37).

CLAIMS

The invention claimed is

1. A hydrostatic drive comprising

A single flow adjustable pump (28) by means of changing drive speed or displacement or both and capable of operating in 4-quadrants;

An asymmetric actuator (1), for example double acting single rod cylinder, comprising a cap side chamber defined by the piston surface area and rod side chamber defined by the piston and rod surface area, the hydraulic pump being connected between the two chambers of the hydraulic actuator (1),

wherein the hydraulic pump (28) is driven preferably by a servo motor (29) capable of energy regeneration,

wherein the drive comprises a flow compensation valve (23) with one port connected to hydraulic accumulator (8) and the other two ports connected to the two chambers (4, 5) of the hydraulic actuator (1), and being compensating the unequal flow rate difference due to the geometry of the actuator via connecting the non-working chamber of the hydraulic actuator (1) to the accumulator (8), and having adjustable orifices (24, 25) in order to damp out possible pressure fluctuations and smooth positioning of the spool (33), having identical or different spool surface areas (34, 35) in order to carry static load or change spool positioning according to net force acting on the actuator (1),

wherein the drive comprises an accumulator charge circuit maintaining the accumulator over a pre-determined pressure level and consisting of a charge pump (31) delivering flow to the unloading valve (16), and preferably electric motor (30) driving the charge pump (31), unloading valve (16) being operated by the accumulator pressure via port (17), and determining the direction of the flow delivered flow whether to the accumulator of reservoir, pressure relief valve (12) limiting the maximum pressure of the accumulator, check valve (11), and oil filter (36),

wherein the drive comprises pressure relief valves (18, 19) connected between the cap side chamber, rod side chamber of the hydraulic actuator transmission lines (6, 7) and accumulator line (20) limiting the chamber pressures,

wherein the drive comprises check valves (21, 22) preventing cavitation in the cap side hydraulic transmission line (6) and rod side hydraulic transmission line (7) Hydraulic transmission circuit according to claim 1 and has a

characteristic as asymmetric actuator motion control with energy recovery thanks to a 4 quadrant pump (28).

2. Hydraulic transmission circuit according to claim 1 has a characteristic as hydraulic actuator (1) is single rod double acting asymmetric hydraulic cylinder.
3. Hydraulic transmission circuit according to claim 1 to 2 has a characteristic as pump with adjustable flow rate via variable drive speed or variable displacement or both, can be running on motoring and pumping mode and preferably driven by servo motor (29).
4. Hydraulic transmission circuit according to claim 1 to 3 has a characteristic as in case of the pump (28) is variable displacement it is driven by a motor (29) that has a constant drive speed.
5. Hydraulic transmission circuit according to claim 1 to 4 has a characteristic as in case of the pump (28) is constant displacement its drive speed is adjusted by servo motor (29) regulating the flow that transmitted to the asymmetric hydraulic actuator (1) chambers.
6. Hydraulic transmission circuit according to claim 1 to 5 has a characteristic as deficient or redundant flow rate of the closed hydraulic circuit due to asymmetric actuator (1) geometry is compensated by the hydraulic accumulator (8) over the flow compensation valve (23).
7. Hydraulic transmission circuit according to claim 1 to 6 has a characteristic as the flow compensation valve (23) consisting of orifices (24, 25), springs (26, 27) and valve spool (33).
8. Hydraulic transmission circuit according to claim 7 to 8 has a characteristic as compensation of unequal flow rate by directing the hydraulic oil (10) inside the accumulator (8) to the relevant chambers of the hydraulic actuator (1) over the flow compensation valve (23).
9. Hydraulic transmission circuit according to claim 8 to 9 has a characteristic as the orifices (24, 25) damps out the effect of sudden pressure fluctuations in cap side (6) and rod side (7) hydraulic transmission line.
10. Hydraulic transmission circuit according to claim 10 has a characteristic as the springs (26, 27) provide positioning of the flow compensation valve spool (33) in neutral position
11. Hydraulic transmission circuit according to claim 11 has a characteristic as the flow compensation valve (23) always connects the non-working low pressure line

of the hydraulic actuator (1) to the accumulator line (20) so that the accumulator (8) compensates the deficient or excess flow rate.

12. Hydraulic transmission circuit according to claim 12 has a characteristic as the pilot pressure acting surfaces (34, 35) of the flow compensation vale spool (33) does not have to be identical, in order to change spool (33) position according to net force acting on the hydraulic actuator (1) or carry different static loads and provide continuous flow transmission without oscillations.
13. Hydraulic transmission circuit according to claim 13 has a characteristic as the the flow compensation vale spool (33) is characterized by identical or different pilot pressure acting surfaces (34, 35) according to the application.
14. Hydraulic transmission circuit according to claim 14 has a characteristic as the hydraulic accumulator (8) provides the compensation of the unequal flow rate due to the inherent asymmetric geometry of the actuator (1) and provides hydraulic energy storage.
15. Hydraulic transmission circuit according to claim 15 has a characteristic as the hydraulic accumulator (8) pressure is maintained over a predetermined pressure level providing an unloading valve (16) and is limited by a pressure relief valve (12).
16. Hydraulic transmission circuit according to claim 16 has a characteristic as the static load acting on the hydraulic actuator (1) is carried by the hydraulic accumulator (8).
17. Hydraulic transmission circuit according to claim 17 has a characteristic as the servo motor (29) converts the energy transmitted from the system to electrical energy.
18. Hydraulic transmission circuit according to claim 18 has a characteristic as the hydraulic accumulator (8) is charged by a charge pump (31).
19. Hydraulic transmission circuit according to claim 19 has a characteristic as the charge pump (31) do not delivers continuous flow to the closed hydraulic circuit, but delivers flow only to maintain the hydraulic accumulator (8) pressure over a predetermined value set by the unloading valve (16), otherwise the delivered flow by the charge pump (31) is directed to the hydraulic oil reservoir (32).
20. Hydraulic transmission circuit according to claim 20 has a characteristic as the said charge pump (31) is driven by the electric motor (30).

21. The invention relates closed hydraulic transmission circuit in order to drive an asymmetric actuator (1) by utilizing a single flow adjustable pump (28) by means of changing drive speed or displacement or both, and utilizing a flow compensation valve (23) and hydraulic accumulator (8).

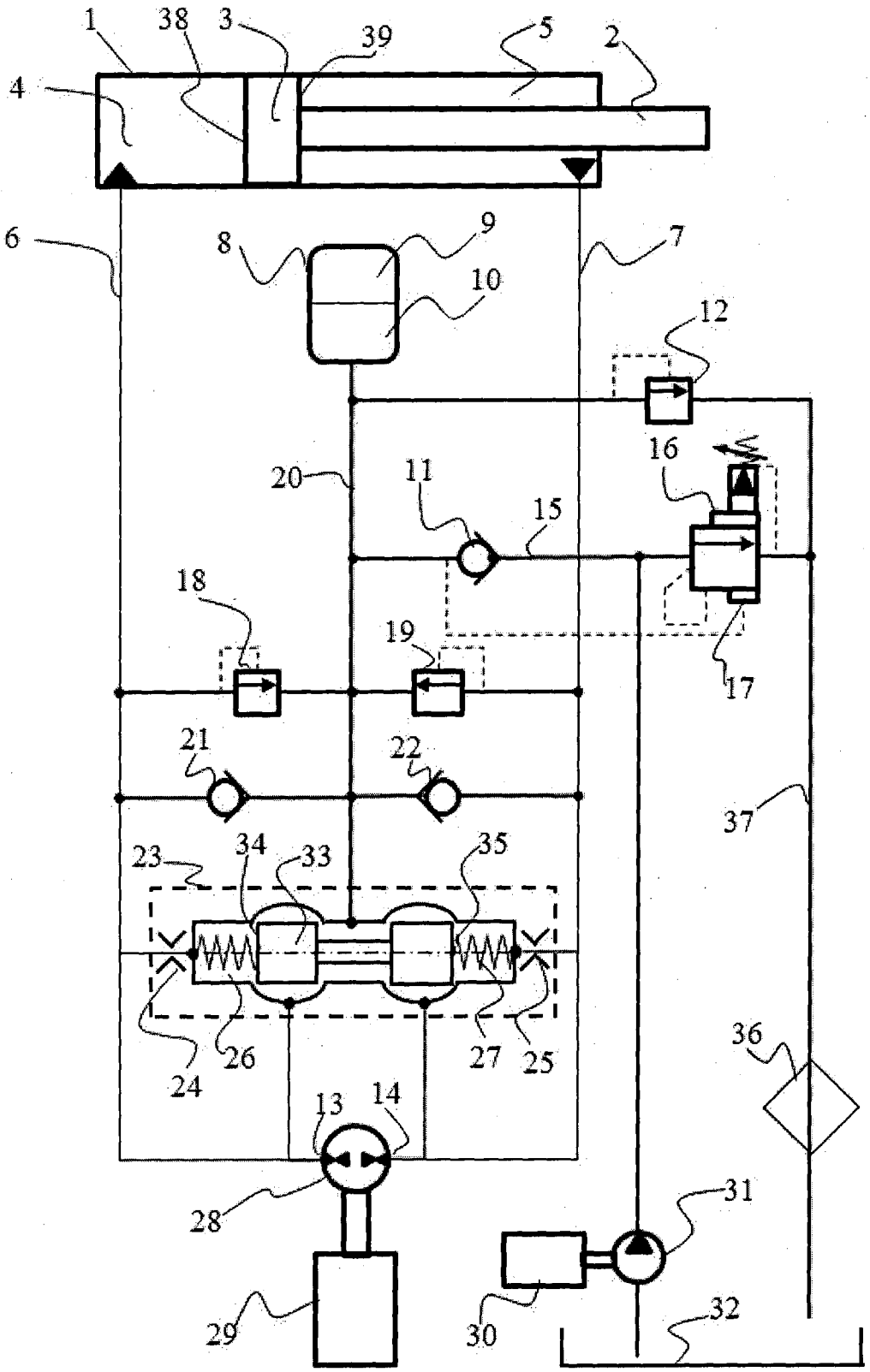
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Figure 1

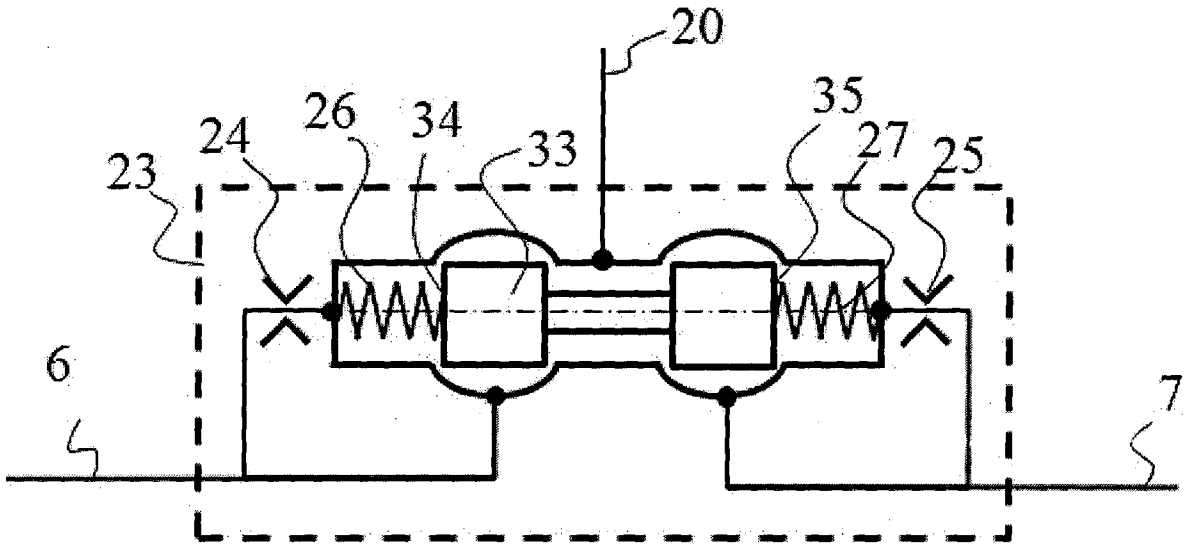
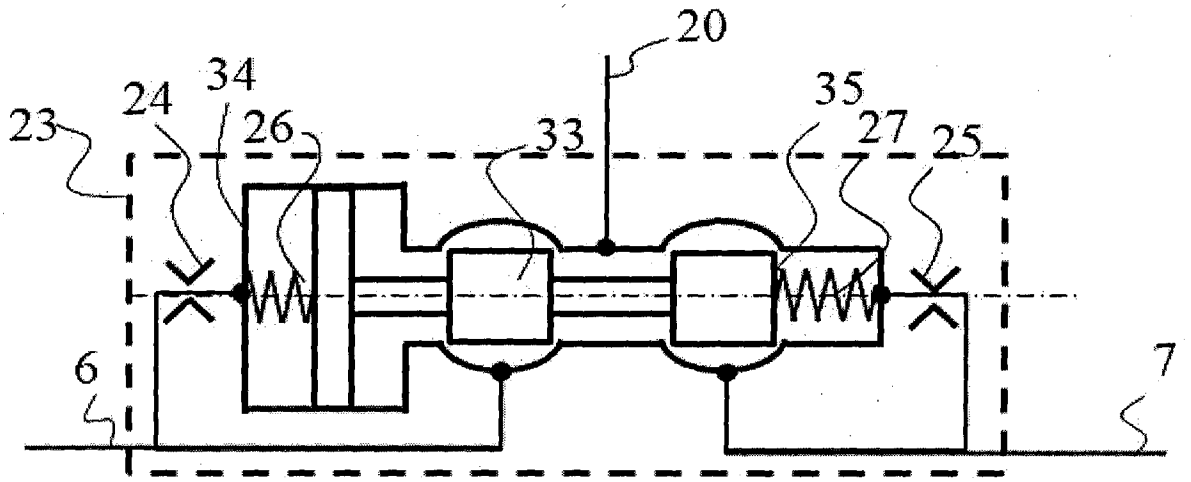


Figure 2



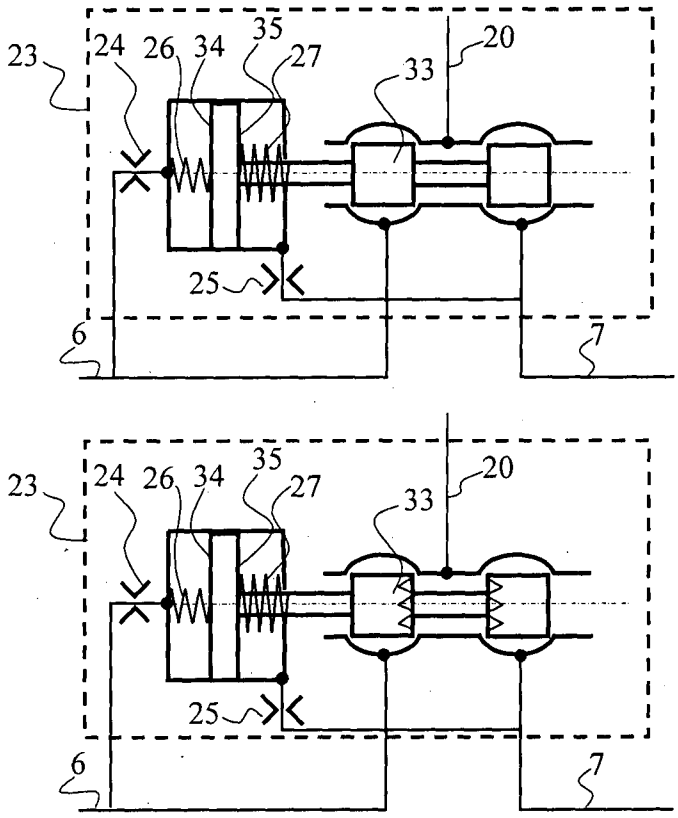


Figure 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/TR2012/000074

A. CLASSIFICATION OF SUBJECT MATTER
INV. F15B7/00
ADD.

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)
F15B

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/120278 A1 (POLLEE DEAN R [US]) 14 May 2009 (2009-05-14) paragraph [0008] - paragraph [0012]; figure 2	1-21
Y	JP 58 170902 A (NIPPON AIR BRAKE CO) 7 October 1983 (1983-10-07) abstract; figure 1	1-21
Y	WO 2009/102740 A2 (PARKER HANNIFIN CORP [US]; PERSSON BENGT-GORAN [SE]; VANDERLAAN DALE [] 20 August 2009 (2009-08-20) page 2, line 17 - page 3, line 24; figures 1-13 page 12, line 22 - page 26, line 30	1-21

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

☒ See patent family annex.

* Special categories of cited documents :

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 December 2012	21/12/2012

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	Bindreiff, Romain

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/TR2012/000074

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009120278 A1	14-05-2009	NONE	
JP 58170902 A	07-10-1983	NONE	
WO 2009102740 A2	20-08-2009	EP 2252799 A2	24-11-2010
		KR 20100116664 A	01-11-2010
		US 2011030364 A1	10-02-2011
		WO 2009102740 A2	20-08-2009