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(54) **ELECTROHYDRAULIC ACTUATOR AND METHOD**

(57) In the presented solution an electrohydraulic actuator (1) comprises an electric motor (6), a first hydraulic unit (2), and a second hydraulic unit (7). The electric motor (6), the first hydraulic unit (2), and the second hydraulic unit (7) are connected together such that they convey energy between them. The first hydraulic unit (2) is arranged to feed hydraulic fluid to a hydraulic actuator (3) and the electric motor (6) is arranged to control the feed of hydraulic fluid to the hydraulic actuator (3) by means of the first hydraulic unit (2). The second hydraulic unit (7) is connected to a hydraulic accumulator (8). Furthermore, when one of the first hydraulic unit (2) and the second hydraulic unit (7) displaces hydraulic fluid to its pressure port (2a, 7a) the other may be arranged to displace hydraulic fluid to a low-pressure port (2b, 7b) and vice versa.

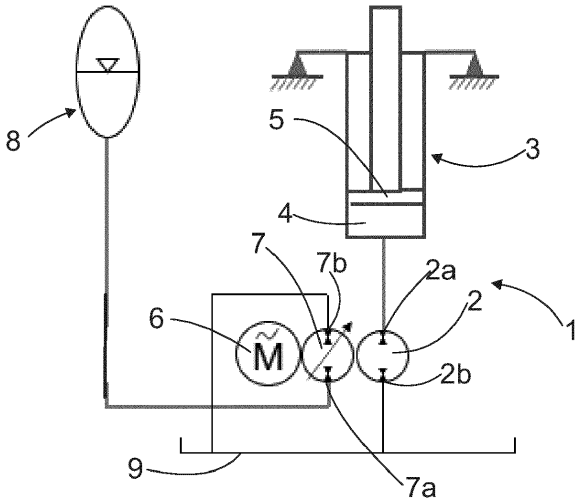

FIG. 1

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F15B 2211/761; F15B 2211/763; F15B 2211/785;
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Description

FIELD OF THE INVENTION

[0001] The present invention relates to electrohydraulic actuators.

BACKGROUND

[0002] Electro-hydraulic actuators (EHA) are apparatuses, in which at least a fluid pressure actuator, a pump driving the actuator and an electric motor rotating the pump are combined. Electro-hydraulic actuators are used in applications, where it is beneficial not to have an external hydraulic system with external pumps, tubing and the like. Electro-hydraulic actuators are also used in applications, where simplicity of system architecture and safety and reliability are essential, such as in aerospace industry.

BRIEF DESCRIPTION

[0003] An object of the present invention is to provide a new type of an electrohydraulic actuator and a new method. The object of the invention is achieved by a method and an electrohydraulic actuator which are characterized by what is stated in the independent claims. Some embodiments of the invention are disclosed in the dependent claims.

[0004] In the presented solution an electrohydraulic actuator comprises an electric motor, a first hydraulic unit, and a second hydraulic unit. The electric motor, the first hydraulic unit, and the second hydraulic unit are connected together such that they convey energy between them. The first hydraulic unit is arranged to feed hydraulic fluid to a hydraulic actuator and the electric motor is arranged to control the feed of hydraulic fluid to the hydraulic actuator by means of the first hydraulic unit. The second hydraulic unit is connected to a hydraulic accumulator. Furthermore, when one of the first hydraulic unit and the second hydraulic unit displaces hydraulic fluid to its pressure port the other may be arranged to displace hydraulic fluid to a low-pressure port and vice versa. In the presented solution it is possible to store energy to the hydraulic accumulator from mechanical movement of the hydraulic actuator or from electrical network, for example. Electrical energy may be transferred to pressure, for example. The energy stored to the hydraulic accumulator may be reused. The energy from the hydraulic accumulator may be used for providing higher momentary power, for example. It is also possible to transfer energy stored to the hydraulic accumulator to electric network. Also, the speed of the hydraulic actuator is controlled in a simple manner. All in all, the solution is simple and reliable.

[0005] According to an embodiment the first hydraulic unit is a fixed displacement hydraulic unit. Such a solution is easy to implement and durable. Because the electric motor rotates the fixed displacement hydraulic unit the control of the hydraulic actuator is versatile.

[0006] According to an embodiment the second hydraulic unit is a variable displacement hydraulic unit. Thereby the control of the flows of the hydraulic fluid may be made in various ways and still the electric motor and the variable displacement hydraulic unit may be simply mechanically connected. Naturally, when a variable displacement hydraulic unit is used having a zero angle it does not displace hydraulic fluid. However, the variable displacement hydraulic unit may be arranged to displace hydraulic fluid. When both the hydraulic units rotate, they displace hydraulic fluid as described above.

[0007] According to an embodiment the electric motor, the first hydraulic unit, and the second hydraulic unit are mechanically connected to each other. Such a solution is durable.

[0008] According to an embodiment the variable displacement hydraulic unit is non-overcenter. Such a solution is cost effective.

[0009] According to an embodiment the hydraulic actuator may be a single-acting cylinder, a double acting cylinder, or a rotating cylinder.

[0010] According to an embodiment the hydraulic actuator is a single-acting cylinder and when one of the first hydraulic unit and the second hydraulic unit displaces hydraulic fluid to its pressure port the other may be arranged to displace hydraulic fluid to a tank via the low-pressure port and vice versa. Such a solution is versatile and reliable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached drawings, in which

Figure 1 shows schematically an electrohydraulic actuator having a single-acting cylinder;
Figure 2 shows schematically an electrohydraulic actuator having a double acting cylinder according to an embodiment;
Figure 3 shows schematically an electrohydraulic actuator having a double acting cylinder according to another embodiment; and
Figure 4 shows schematically an electrohydraulic actuator having a double acting cylinder according to yet another embodiment.

DETAILED DESCRIPTION

[0012] Figure 1 shows an electrohydraulic actuator 1. The electrohydraulic actuator 1 comprises a first hydraulic unit 2. The first hydraulic unit 2 may be a rotating hydraulic unit such as a hydraulic pump/motor. In the embodiment shown in Figure 1 the first hydraulic unit 2 is a fixed displacement hydraulic unit.

[0013] The first hydraulic unit 2 is connected to a hy-

draulic actuator 3. The hydraulic actuator 3 in Figure 1 is a single-acting cylinder. Feeding hydraulic fluid by the first hydraulic unit 2 to a chamber 4 of the hydraulic actuator 3 raises the piston 5 of the hydraulic actuator 3.

[0014] The electric motor 6 rotates the first hydraulic unit 2. For the sake of clarity means for controlling the electric motor are not shown in Figure 1. As is characteristics to an electrohydraulic actuator electric motor 6 is arranged to control the feed of hydraulic fluid to the hydraulic actuator 3 by means of the first hydraulic unit 2.

[0015] The electrohydraulic actuator 1 also comprises a second hydraulic unit 7. The second hydraulic unit 7 may be a rotating hydraulic unit such as a hydraulic pump/motor. In the embodiment shown in Figure 1 the second hydraulic unit 7 is a variable displacement hydraulic unit.

[0016] The second hydraulic unit 7 is connected to a hydraulic accumulator 8. The electric motor 6, the first hydraulic unit 2, and the second hydraulic unit 7 are connected together such that they convey energy between them. The electric motor 6, the first hydraulic unit 2, and the second hydraulic unit 7 may be mechanically or electrically connected to each other.

[0017] When the first hydraulic unit 2 displaces hydraulic fluid to its pressure port the second hydraulic unit 7 displaces hydraulic fluid via its low-pressure port 7b to a tank 9 and vice versa. For example, when the first hydraulic unit 2 is rotated such that it displaces hydraulic fluid to its pressure port 2a for raising the piston 5, the second hydraulic unit 7 displaces hydraulic fluid via its low-pressure port 7b to the tank 9. Simultaneously, energy stored as pressure to the hydraulic accumulator 8 may be used for boosting the feed of hydraulic fluid to the hydraulic actuator 3. Thus, hydraulic fluid may be fed from the hydraulic accumulator 8 to rotate the second hydraulic unit 7. Because the hydraulic units 2 and 7 are connected such that they convey energy between them the energy in the hydraulic accumulator 8 enhances feeding the fluid to the hydraulic actuator 3.

[0018] When the piston 5 is allowed to lower due to gravity, for example, the piston 5 pushes hydraulic fluid to the first hydraulic unit 2 rotating it. The first hydraulic unit 2 displaces hydraulic fluid via its low-pressure port 2b to the tank 9. The rotation of the first hydraulic unit 2 causes the second hydraulic unit 7 to displace hydraulic fluid to its pressure port 7a and therethrough to the hydraulic accumulator 8. Energy is thus stored to the hydraulic accumulator 8. Also, electric energy from an electric network may be stored to the hydraulic accumulator 8 such that the electric motor 6 is rotated, naturally providing that not all the energy supplied to the electric motor 6 is used for other purposes such as raising the piston 5.

[0019] Figures 2, 3, and 4 show electrohydraulic actuators 1 having double acting cylinders 3. Depending on the rotating direction of the first hydraulic unit 2 hydraulic fluid is fed either to a first chamber 4a or to a second chamber 4b. Feeding hydraulic fluid to the first chamber 4a moves the piston 5 upwards in the Figures. Feeding hydraulic fluid to the second chamber 4b moves the piston 5 downwards in the Figures.

[0020] In the embodiment shown in Figure 2 one of the ports of the first hydraulic unit 2 is not directly connected to the tank 9 but to a hydraulic line 11 connected to the second chamber 4b of the hydraulic actuator 3. All in all, the embodiment shown in Figure 2 is simple and reliable. However, when the volumes on the opposite sides of the piston 5 are different, energy cannot be recovered efficiently when the pressure raises above a pressure limit.

[0021] The solutions shown in Figures 3 and 4 obviate the shortcoming mentioned in connection with the embodiment shown in Figure 2. The embodiment shown in Figure 3 comprises a third hydraulic unit 10, which is connected to the first hydraulic unit 2, and the second hydraulic unit 7 such that they convey energy between them. The third hydraulic unit 10 may be a rotating hydraulic unit such as a hydraulic pump/motor. In the embodiment shown in Figure 3 the third hydraulic unit 10 is a fixed displacement hydraulic unit.

[0022] In the embodiments shown in Figures 2 and 3 one of the ports of the second hydraulic unit 7 is directly connected to the hydraulic accumulator 8 and the other port of the second hydraulic unit 7 is directly connected to the tank 9. In the embodiment shown in Figure 4 one of the ports of the second hydraulic unit 7 is not directly connected to the tank 9 but to a hydraulic line 11 connected to the second chamber 4b of the hydraulic actuator 3. The embodiment shown in Figure 4 does not need so many rotating hydraulic units as the embodiment shown in Figure 3. For the sake of clarity valves needed are not mainly shown in the Figures.

[0023] In the embodiment shown in Figure 4 the hydraulic actuator 3 is a double acting cylinder having the first chamber 4a on the first side of the piston 5 and the second chamber 4b on the second side of the piston 5. One of the ports of the first hydraulic unit 2 is directly connected to the first chamber 4a and the other port of the first hydraulic unit 2 is directly connected to the second chamber 4b. One of the ports of the second hydraulic unit 7 is directly connected to the hydraulic accumulator 8 and the other port is directly connected to the second chamber 4b.

[0024] The other port of the second hydraulic unit 7 may be directly connected either to the second chamber 4b or to the first chamber 4a, especially when the volumes of the first chamber 4a and the second chamber 4b are equal. However, in the embodiment shown in Figure 4 the volume of the second chamber 4b is smaller than the volume of the first chamber 4a. That means that the effective surface area of the piston 5 on the side of the second chamber 4b is smaller than the effective surface area of the piston 5 on the side of the first chamber 4a. If the volume of the second chamber 4b is smaller than the volume of the first chamber 4a it is preferable that the other port of the second hydraulic unit 7 is directly connected to the second chamber 4b to enhance efficient energy recovery and overall operation of the electrohy-

draulic actuator 1.

[0025] According to an embodiment both the first hydraulic unit 2 and the second hydraulic unit 7 are fixed displacement hydraulic units. In such a case the electric motor 6, the first hydraulic unit 2, and the second hydraulic unit 7 are electrically connected to each other.

[0026] The variable displacement hydraulic unit may be non-overcenter. When the hydraulic actuator 3 is a double acting cylinder, or a rotating cylinder the second hydraulic unit 7 may be over-center.

[0027] It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. An electrohydraulic actuator, comprising

an electric motor (6), a first hydraulic unit (2), and a second hydraulic unit (7) which are connected together such that they convey energy between them,
the first hydraulic unit (2) being arranged to feed hydraulic fluid to a hydraulic actuator (3) and the electric motor (6) being arranged to control the feed of hydraulic fluid to the hydraulic actuator (3) by means of the first hydraulic unit (2),
the second hydraulic unit (7) being connected to a hydraulic accumulator (8),
whereby the arrangement is such that when one of the first hydraulic unit (2) and the second hydraulic unit (7) displaces hydraulic fluid to its pressure port (2a, 7a) the other may be arranged to displace hydraulic fluid to a low-pressure port (2b, 7b) and vice versa, and
wherein the hydraulic actuator (3) is a single-acting cylinder and when one of the first hydraulic unit (2) and the second hydraulic unit (7) displaces hydraulic fluid to its pressure port (2a, 7a) the other may be arranged to displace hydraulic fluid to a tank (9) via the low-pressure port (2b, 7b) and vice versa, or
wherein the hydraulic actuator (3) is a double acting cylinder having a first chamber (4a) on a first side of a piston (5) and a second chamber (4b) on a second side of the piston (5), one of the ports of the first hydraulic unit (2) is directly connected to the first chamber (4a) and the other port of the first hydraulic unit (2) is directly connected to the second chamber (4b), one of the ports of the second hydraulic unit (7) is directly connected to the hydraulic accumulator (8) and the other port of the second hydraulic unit (7) is directly connected either to the second chamber (4b) or to the first chamber (4a) or to the tank (9).

2. An electrohydraulic actuator as claimed in claim 1, wherein the first hydraulic unit (2) is a fixed displacement hydraulic unit.

3. An electrohydraulic actuator as claimed in claim 1 or 2, wherein the second hydraulic unit (7) is a variable displacement hydraulic unit.

4. An electrohydraulic actuator as claimed in claim 3, wherein the variable displacement hydraulic unit (7) is non-overcenter.

5. An electrohydraulic actuator as claimed in any one of the preceding claims, wherein the electric motor (6), the first hydraulic unit (2), and the second hydraulic unit (7) are mechanically connected to each other.

6. An electrohydraulic actuator as claimed in any one of the preceding claims, wherein the hydraulic actuator (3) is a double acting cylinder having a first chamber (4a) on a first side of a piston (5) and a second chamber (4b) on a second side of the piston (5) and wherein the volume of the second chamber (4b) is smaller than the volume of the first chamber (4a) and said other port of the second hydraulic unit (7) is directly connected to the second chamber (4b).

7. A method in connection with an electrohydraulic actuator the method comprising

providing an electrohydraulic actuator (1), comprising an electric motor (6), a first hydraulic unit (2), and a second hydraulic unit (7) which are connected together such that they convey energy between them,
feeding hydraulic fluid to a hydraulic actuator (3) by the first hydraulic unit (2) and controlling by the electric motor (6) the first hydraulic unit (2) to control the feed of hydraulic fluid to the hydraulic actuator (3),
connecting the second hydraulic unit (7) to a hydraulic accumulator (8), whereby in the method when one of the first hydraulic unit (2) and the second hydraulic unit (7) displaces hydraulic fluid to its pressure port (2a, 7a) the other displaces hydraulic fluid to a low-pressure port (2b, 7b) and vice versa, and
wherein the hydraulic actuator (3) is a single-acting cylinder and when one of the first hydraulic unit (2) and the second hydraulic unit (7) displaces hydraulic fluid to its pressure port (2a, 7a) the other displaces hydraulic fluid to a tank (9) via the low-pressure port (2b, 7b) and vice versa, or
wherein the hydraulic actuator (3) is a double acting cylinder having a first chamber (4a) on a first side of a piston (5) and a second chamber

(4b) on a second side of the piston (5), one of the ports of the first hydraulic unit (2) is directly connected to the first chamber (4a) and the other port of the first hydraulic unit (2) is directly connected to the second chamber (4b), one of the ports of the second hydraulic unit (7) is directly connected to the hydraulic accumulator (8) and the other port of the second hydraulic unit (7) is directly connected either to the second chamber (4b) or to the first chamber (4a) or to the tank (9).

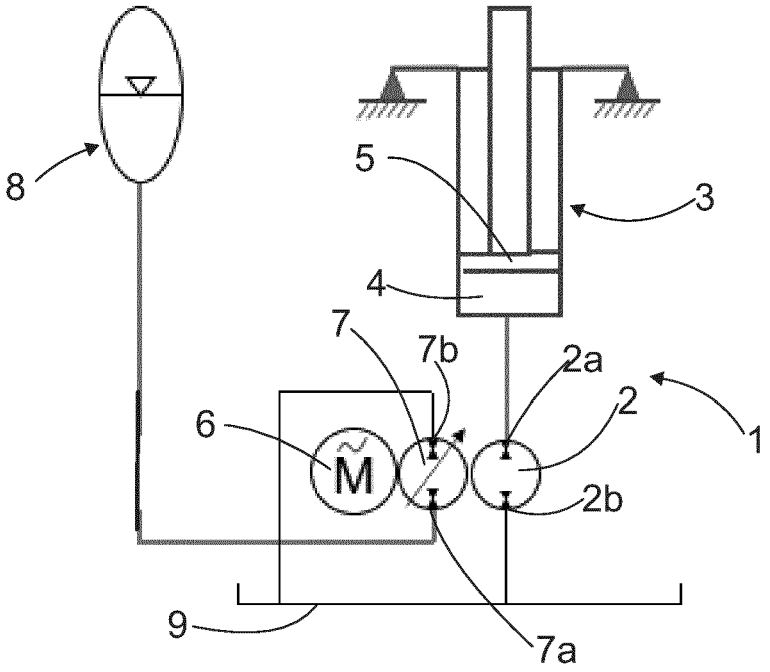

FIG. 1

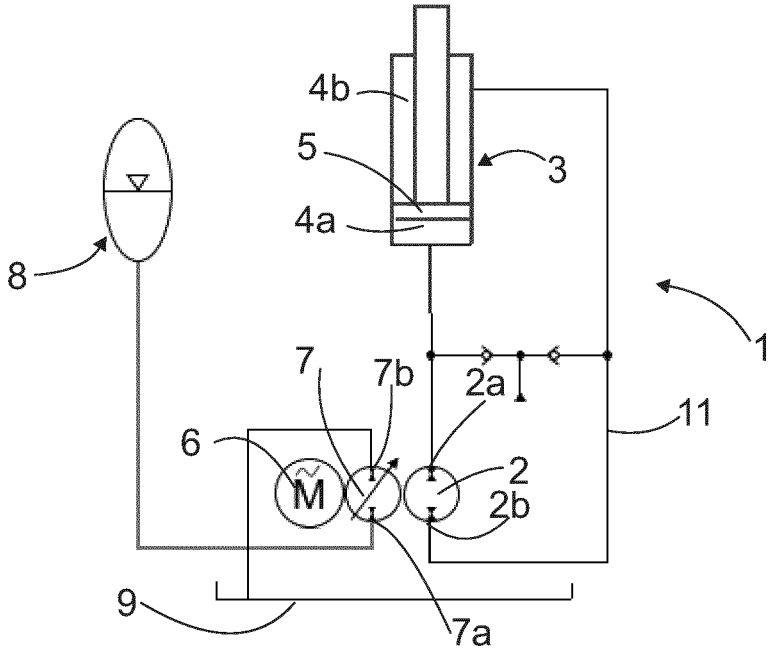

FIG. 2

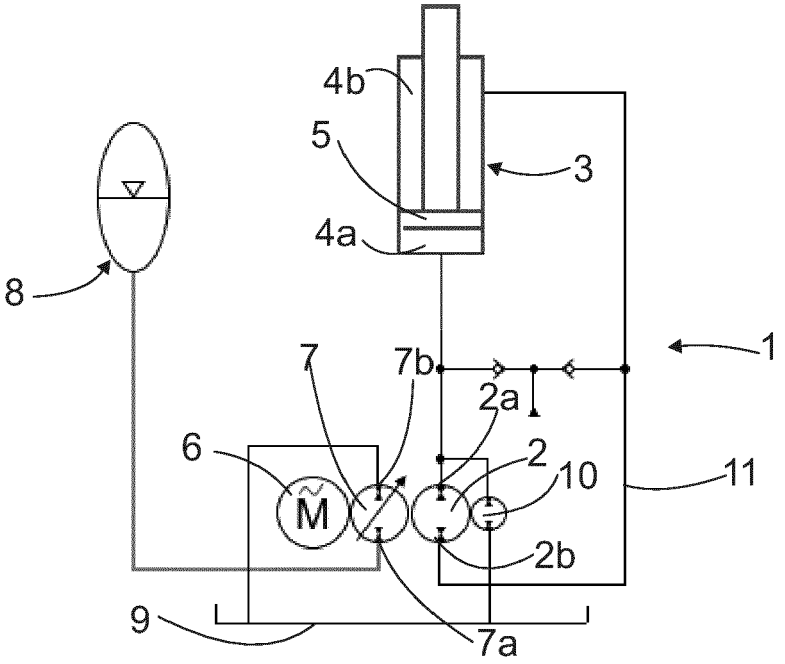

FIG. 3

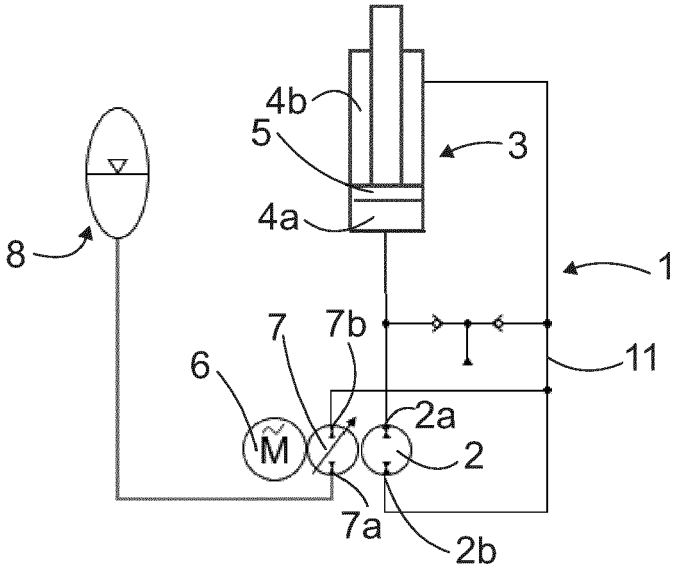

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 8727

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	4 August 2022	Bindreiff, Romain

CATEGORY OF CITED DOCUMENTS

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