



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**10.04.2019 Bulletin 2019/15**

(51) Int Cl.:  
**F04B 17/03 (2006.01) F04B 49/06 (2006.01)**

(21) Application number: **17194730.2**

(22) Date of filing: **04.10.2017**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA ME**  
Designated Validation States:  
**MA MD**

(71) Applicant: **Automation, Press and Tooling, A.P. & T AB**  
**514 32 Tranemo (SE)**

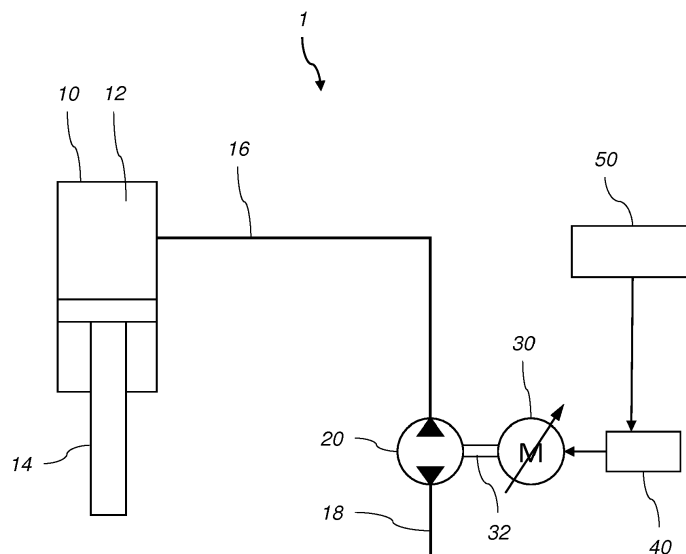
(72) Inventors:  
• **Sundqvist, Per**  
**514 31 Tranemo (SE)**  
• **Carlsson, Thomas**  
**341 39 Ljungby (SE)**

(74) Representative: **AWA Sweden AB**  
**Östra Storgatan 7**  
**553 21 Jönköping (SE)**

(54) **PRESSURE CONTROL OF HYDRAULIC SYSTEM WITH ELECTRIC MOTOR**

(57) The present invention relates to a hydraulic system (1), wherein the system comprises a hydraulic device (10), a hydraulic pump (20) in fluid connection with the pressure chamber of the hydraulic device, an electric motor (30) arranged to drive the hydraulic pump, and a motor drive unit (40) configured to control the operation of the electric motor. The hydraulic system further comprises a

control unit (50) configured to provide a desired motor torque value to the motor drive unit. The motor drive unit is configured to control the operation of the electric motor to a desired torque based on the desired motor torque value. The present invention further relates to a method of controlling pressure in a hydraulic device (10) in a hydraulic system (1).



**Fig. 1**

## Description

### Technical Field

**[0001]** The present disclosure relates to a hydraulic system, and especially to an arrangement of pressure control in the hydraulic system.

### Background

**[0002]** In a hydraulic system, a hydraulic device, such as a hydraulic cylinder, is controlled by a hydraulic pump, driven by an electric motor, in fluid connection via a pipe with a pressure chamber of the hydraulic cylinder. The pump may increase the pressure in the pressure chamber, and thereby moving the cylinder piston.

**[0003]** In one conventional solution, a pressure valve is arranged on the pipe between the hydraulic pump and the hydraulic cylinder. The pressure valve may be controlled to open and thereby release pressure in the pipe and the connected pressure chamber. The pressure valve may for instance be controlled to open when the pressure in the pipe reaches a predetermined threshold. The pressure in the pressure chamber of the hydraulic cylinder may thereby be controlled using the pressure valve. Such system using a pressure valve to control the pressure is however limited in the control of the pressure.

**[0004]** One solution offering further controlling functions is disclosed in EP1882534, wherein a pressure sensor is arranged to detect the pressure in the pressure chamber of the hydraulic cylinder. The detected pressure is compared to a predetermined desired pressure, and the motor/pump is controlled to increase or decrease the pressure to reach the desired pressure. Such system is however slow and complicated, which may further affect the accuracy of the pressure control.

**[0005]** Consequently, there is a need for a hydraulic system with a faster and more accurate pressure control.

### Summary

**[0006]** It is an object of the present invention to provide an improved solution that alleviates the mentioned drawbacks with present devices. The invention is defined by the appended independent claims, with embodiments being set forth in the appended dependent claims, in the following description and in the drawings.

**[0007]** According to a first aspect of the present invention, a hydraulic system is provided, wherein the system comprises a hydraulic device, a hydraulic pump in fluid connection with the hydraulic device, an electric motor arranged to drive the hydraulic pump, and a motor drive unit configured to control the operation of the electric motor. The hydraulic system further comprises a control unit configured to provide a desired motor torque value to the motor drive unit. The motor drive unit is configured to control the operation of the electric motor to a desired torque based on the desired motor torque value.

**[0008]** By controlling the torque of the electric motor to a desired motor torque value to control the pressure in the system, a very fast and accurate pressure control may be provided. One reason this may be provided is that it is less complex, since no external pressure sensors or load cells for feedback is needed. The present invention may further not give any extra load to the control system.

**[0009]** The present invention provides a single control loop in which the control unit may provide a desired motor torque value. The desired motor torque value may correspond to a desired pressure value in the hydraulic device. The desired motor torque value may be used by the motor drive unit as a reference value toward which the torque of the electric motor may be controlled. This may be controlled by the motor drive unit by controlling the current, torque or other parameters to the electric motor. By controlling the torque of the electric motor, the pressure provided by the hydraulic pump may be controlled. An increased set pressure may provide an increased torque in the electric motor. Hence, if the desired motor torque value received by the motor drive unit is greater than the present torque, the motor drive unit may increase the current to the electric motor to increase the torque. This may consequently increase the pressure in the hydraulic device following an increased speed of the pump. A decreased set pressure may provide a decreased torque in the servo motor. Hence, if the desired motor torque value received by the motor drive unit is less than the present torque, the motor drive unit may decrease the current to the servo motor to decrease the torque. This may consequently decrease the pressure in the hydraulic device following a decreased speed of the pump.

**[0010]** Depending on the desired operation of the hydraulic device, the control unit may provide instructions to the motor drive unit to indirectly control the pressure in the hydraulic device by providing a desired motor torque value. The motor drive unit may get feedback of the present torque in the electric motor by the present current consumption of the electric motor. This may further provide an indirect feedback of the fluid pressure in the system.

**[0011]** The control unit may be configured to relate a desired operation of the hydraulic device to a certain motor torque of the electric motor. The desired operation of the hydraulic device may be initiated by a manual operation by a user, or by an automatically controlled operation.

**[0012]** The electric motor may be a servo motor, a reluctance motor or an asynchronous motor. The hydraulic device may be a hydraulic cylinder. The hydraulic system may be a hydraulic press system.

**[0013]** At installation of the hydraulic system, the motor drive unit may be synchronized with the electric motor in the present hydraulic system in order to relate the driving of the electric motor to the torque control thereof. The control unit may then use the torque value sent to the motor drive unit to achieve a desired pressure and oper-

ation of the hydraulic device.

**[0014]** In one embodiment, the hydraulic system may comprise a plurality of hydraulic devices, each pressurized by a hydraulic pump driven by an electric motor, which is controlled by a motor drive unit. Each motor drive unit may receive a desired motor torque value from the control unit. Each motor drive unit may receive an individually set desired motor torque value from the control unit. Alternatively, all motor drive units may receive the same desired motor torque value. In a system comprising more than one hydraulic pump, a more complex pressure control may be possible.

**[0015]** As a first example, two or more hydraulic pumps may be provided to together provide an aggregated hydraulic pressure to the hydraulic device. Depending on the desired pressure, all motor drive units may receive the same desired motor torque value to provide all electric motors be operated with the same torque. If all hydraulic pumps are similar, each pump may then also provide similar portions to the total pressure. Alternatively, one hydraulic pump may be desired to provide a larger portion of the aggregated pressure. The motor drive unit for that electric motor and pump may thereby receive a different desired motor torque value than the motor drive units for the other pumps. The motor drive unit that receives a different desired motor torque value may further receive a desired motor rpm value for the electric motor. The rpm of that electric motor may be set together with the torque in order to avoid that the electric motor reverse due to a lower torque value than for the other electric motors. The motor drive unit that received the desired motor rpm value may control the electric motor to operate at the desired rpm and with the desired torque. The hydraulic pump in direct connection with the electric motor may thereby operate at the same rpm as the electric motor.

**[0016]** As a second example, the system may comprise two hydraulic pumps operable in opposite directions to enable a low aggregated pressure without operating a pump at low speed risking damage to the pump and electric motor. The motor drive units operating the electric motors driving the pumps may thereby receive different desired motor torque values and/or motor rpm values to achieve a desired aggregated pressure to the hydraulic device.

**[0017]** According to a second aspect of the invention, a method of controlling pressure in a hydraulic device in a hydraulic system is provided. The method comprises the step of providing a hydraulic pump in fluid connection with the hydraulic device, wherein the hydraulic pump is driven by an electric motor, providing a desired motor torque value to a motor drive unit controlling the operation of the electric motor, and controlling the torque of the electric motor via the motor drive unit to a desired torque based on the desired motor torque value.

**[0018]** Such method provides advantages and may be used in embodiments as discussed for the hydraulic system above.

## Brief Description of the Drawings

**[0019]** The invention will in the following be described in more detail with reference to the enclosed drawings, wherein:

Fig. 1 show a schematic block view of a hydraulic system according to an embodiment of the invention; Fig. 2 show a schematic block view of a hydraulic system according to an embodiment of the invention; and

Fig. 3 show a flowchart of a method according to an embodiment of the invention.

## Description of Embodiments

**[0020]** The present invention will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like numbers refer to like elements.

**[0021]** Fig. 1 illustrates a hydraulic system 1 comprising a hydraulic device in the form of a hydraulic cylinder 10. The hydraulic cylinder 10 comprises a pressure chamber 12 and a piston 14. The pressure in the pressure chamber 12 controls the position and movement of the piston 14. The pressure of the pressure chamber 12 is provided by a hydraulic pump 20 in fluid connection with the pressure chamber 12 via a pipe 16. The hydraulic pump 20 receives incoming pressure fluid from an incoming pipe 18. The pressure fluid is pressurized by the hydraulic pump 20 and supplied to the pipe 16.

**[0022]** The hydraulic pump 20 is driven by an electric motor 30 via a drive shaft 32. The speed of the electric motor 30 controls the speed of the hydraulic pump 20. The operation of the electric motor 30 is controlled by a motor drive unit 40. The drive unit 40 supplies power to the electric motor 30. The drive unit 40 controls the torque of the electric motor 30 by controlling the supplied current, torque or other parameters to the electric motor 30. By monitoring and controlling the current, torque or other parameters supplied to and consumed by the electric motor 30, the torque of the electric motor 30 is controlled.

**[0023]** The drive unit 40 is communicatively connected to a control unit 50. The control unit 50 transmits a desired torque value for the electric motor 30 to the drive unit 40. The desired torque value corresponds to a motor torque determined to provide a desired pressure in the pressure chamber 12, and further a desired operation of the hydraulic cylinder 10. The control unit 50 is configured to provide a desired torque value that is determined based on a desired operation of the hydraulic cylinder 10. The desired operation is provided either from a manual op-

eration by a user of the hydraulic system 1, or from an automatic operation controlling the hydraulic cylinder 10.

**[0024]** When the hydraulic system 1 is set up, the performance of the electric motor 30, hydraulic pump 20 together with the hydraulic cylinder 10 may be calibrated to provide a system in which the operation of the hydraulic cylinder 10 can be predetermined based on a specific torque of the electric motor 30. When this has been done, the operation of the hydraulic cylinder 10 can be controlled by the control unit 50 by setting a desired torque value for the electric motor 30. No slow continuous feedback of the pressure in the pressure chamber 12 or the pipe 16 is thereby needed during operation of the hydraulic system 1.

**[0025]** In one embodiment, a pressure valve (not shown) can be arranged between the hydraulic pump 20 and the hydraulic cylinder 10, which is configured to release pressure from the pipe 16 when the pressure therein reaches a predetermined threshold. Momentary peaks in the pressure is thereby taken care of by the pressure valve.

**[0026]** Fig. 2 illustrates a hydraulic press system 1' according to an embodiment, comprising two hydraulic pumps 20a, 20b, each driven by an electric motor 30a, 30b via a shaft 32a, 32b. The electric motors 30a, 30b are controlled by a respective drive unit 40a, 40b. Both drive units 40a, 40b receives a desired motor torque value from the control unit 50. Each drive unit 40a, 40b control the respective electric motor 30a, 30b based on the received desired motor torque value. The received motor torque value and/or motor rpm value may be the same to both drive units 40a, 40b, or individually set by the control unit 50, as discussed above. A desired aggregated pressure in the pipe 16 to the hydraulic cylinder 10 can thereby be achieved.

**[0027]** Fig. 3 illustrates a flow chart of a method 100 according an embodiment of the invention. In a first step 102, a hydraulic system 1 is provided comprising the hydraulic cylinder 10 in fluid connection with the hydraulic pump 20. The hydraulic pump 20 is driven by the electric motor 30, which in turn is controlled by the motor drive unit 40. Further, a desired motor torque value is provided 104 to the motor drive unit. Finally, the motor torque is controlled 106 based on the received desired motor torque value.

**[0028]** In the drawings and specification, there have been disclosed preferred embodiments and examples of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation, the scope of the invention being set forth in the following claims.

## Claims

1. A hydraulic system (1) comprising  
a hydraulic device (10);  
a hydraulic pump (20) in fluid connection with the

hydraulic device;

an electric motor (30) arranged to drive the hydraulic pump;

a motor drive unit (40) configured to control the operation of the electric motor;

**characterized in that**

the hydraulic system further comprises a control unit (50) configured to provide a desired motor torque value to the motor drive unit, and

wherein the motor drive unit is configured to control the operation of the electric motor to a desired torque based on the desired motor torque value.

2. The hydraulic system according to claim 1, wherein the control unit (50) is configured to provide the desired motor torque value based on a desired operation of the hydraulic device (10).
3. The hydraulic system according to claim 1 or 2, wherein the hydraulic system comprises a plurality of hydraulic pumps (20), each driven by an electric motor (30) controlled by a motor drive unit (40), wherein the control unit is configured to provide a desired motor torque value to each motor drive unit.
4. The hydraulic system according to claim 3, wherein the control unit (50) is configured to provide similar desired motor torque values to all motor drive units (40).
5. The hydraulic system according to claim 3, wherein the control unit (50) is configured to provide an individual desired motor torque value to each motor drive unit (40).
6. The hydraulic system according to claim 5, wherein the control unit (50) further is configured to provide a desired motor rpm value to at least one motor drive unit (40).
7. A method (100) of controlling pressure in a hydraulic device (10) in a hydraulic system (1), the method comprising the steps of:  
providing (102) a hydraulic pump (20) in fluid connection with the hydraulic device, wherein the hydraulic pump is driven by an electric motor (30),  
providing (104) a desired motor torque value to a motor drive unit (40) controlling the operation of the electric motor, and  
controlling (106) the torque of the motor via the motor drive unit to a desired torque based on the desired motor torque value.
8. The method according to claim 7, wherein the desired motor torque value is provided based on a desired operation of the hydraulic device (10).

9. The method according to claim 7 or 8, wherein a plurality of hydraulic pumps (20), each driven by an electric motor (30) controlled by a motor drive unit (40), are provided, and wherein the step (104) of providing a desired motor torque value comprises providing a desired motor torque value to each motor drive unit. 5
10. The method according to claim 9, wherein similar desired motor torque values are provided to all motor drive units (40). 10
11. The method according to claim 8, wherein an individual desired motor torque value is provided to each motor drive unit (40). 15
12. The method according to claim 11, wherein a desired motor rpm value is provided to at least one motor drive unit (40). 20

25

30

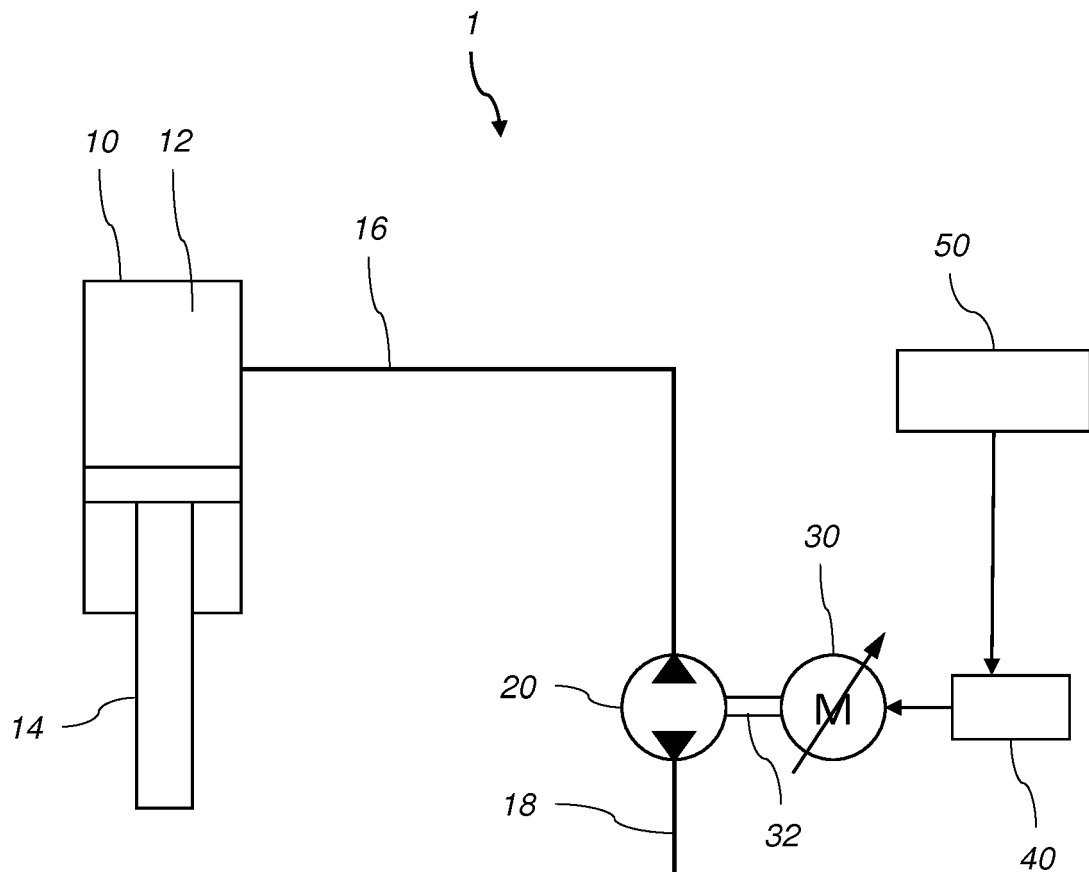
35

40

45

50

55



**Fig. 1**

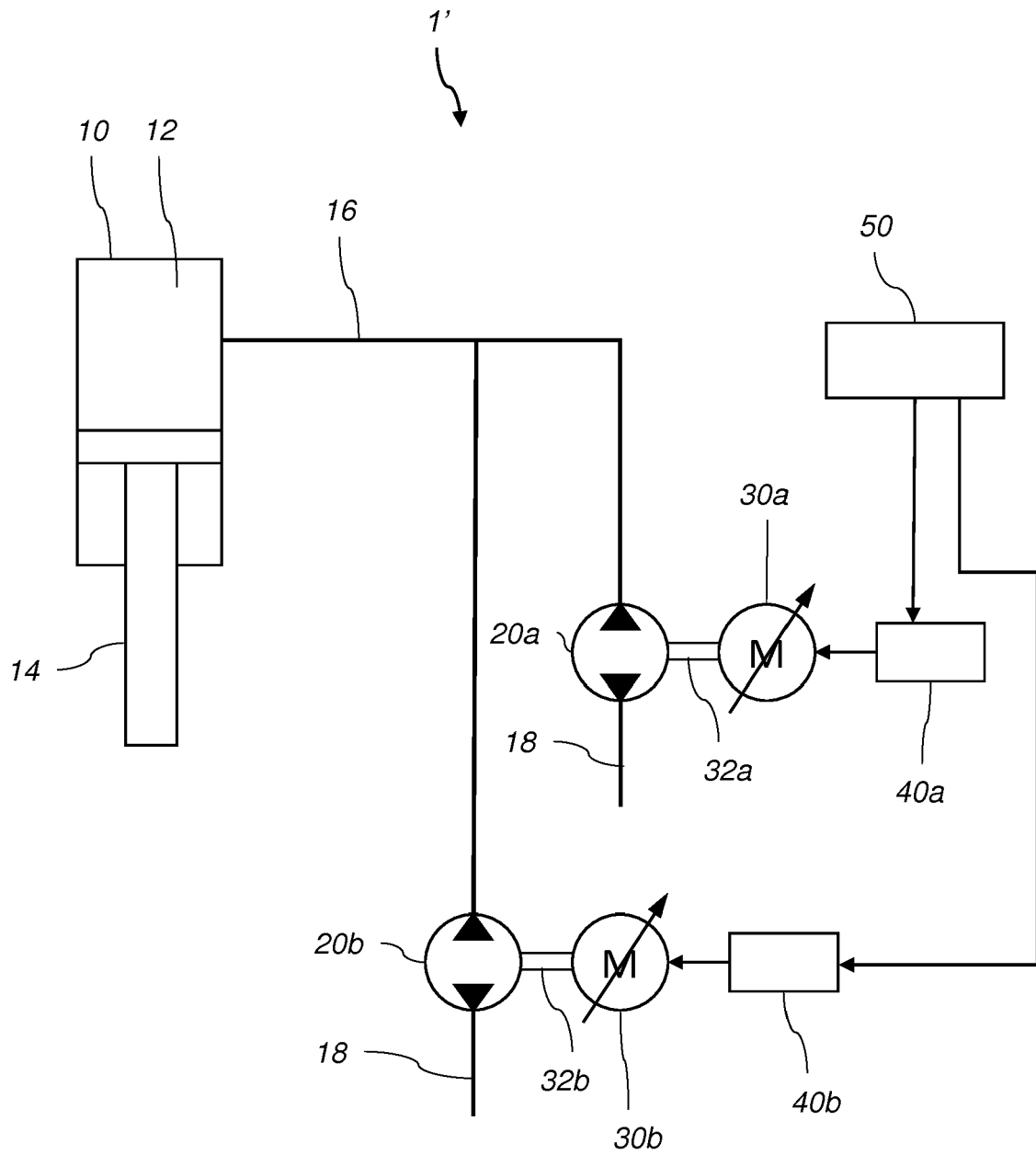
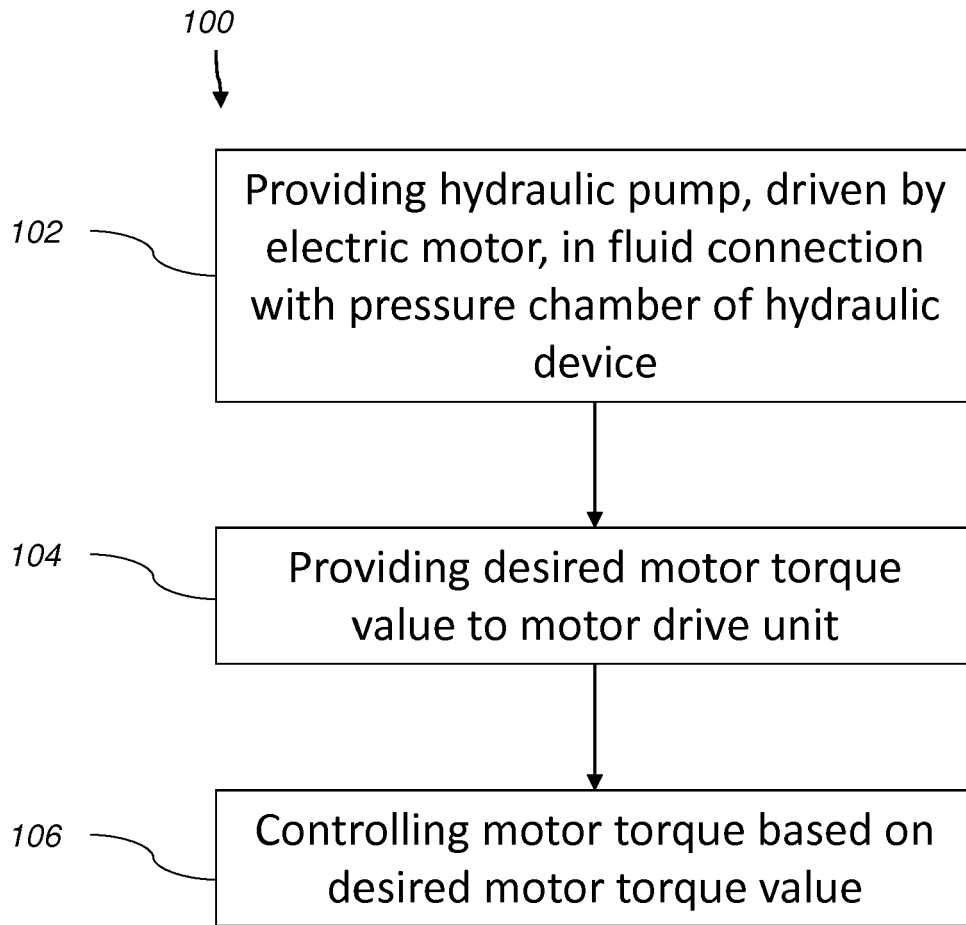


Fig. 2



**Fig. 3**



## EUROPEAN SEARCH REPORT

Application Number  
EP 17 19 4730

5

10

15

20

25

30

35

40

45

50

55

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                               |                                                             |                                         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                                                                                 | Relevant to claim                                           | CLASSIFICATION OF THE APPLICATION (IPC) |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2014/219822 A1 (MUELLER KARSTEN [DE] ET AL) 7 August 2014 (2014-08-07)<br>* paragraph [0031] - paragraph [0045];<br>claims 1-10; figures 1-4 *                                             | 1,7                                                         | INV.<br>F04B17/03<br>F04B49/06          |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2016/084274 A1 (AFSHARI THOMAS [US]) 24 March 2016 (2016-03-24)<br>* paragraph [0023] - paragraph [0025];<br>figure 1 *<br>* paragraph [0029] - paragraph [0031] *<br>* paragraph [0046] * | 1-12                                                        |                                         |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 5 281 774 A (MASAKI TAKANOBU [JP]) 25 January 1994 (1994-01-25)<br>* claim 1; figure 1 *                                                                                                   | 1,7                                                         |                                         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                               |                                                             | TECHNICAL FIELDS SEARCHED (IPC)         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                               |                                                             | F04B                                    |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                               |                                                             |                                         |
| Place of search<br><b>Munich</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                               | Date of completion of the search<br><b>14 December 2017</b> | Examiner<br><b>Fistas, Nikolaos</b>     |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                                                               |                                                             |                                         |

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 17 19 4730

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-12-2017

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| US 2014219822 A1                          | 07-08-2014          | CN 103609016 A             | 26-02-2014          |
|                                           |                     | DE 102011104292 A1         | 20-12-2012          |
|                                           |                     | US 2014219822 A1           | 07-08-2014          |
|                                           |                     | WO 2012171603 A2           | 20-12-2012          |
| -----                                     |                     |                            |                     |
| US 2016084274 A1                          | 24-03-2016          | NONE                       |                     |
| -----                                     |                     |                            |                     |
| US 5281774 A                              | 25-01-1994          | CN 1061576 A               | 03-06-1992          |
|                                           |                     | JP 2505644 B2              | 12-06-1996          |
|                                           |                     | JP H04189273 A             | 07-07-1992          |
|                                           |                     | US 5281774 A               | 25-01-1994          |
| -----                                     |                     |                            |                     |

**REFERENCES CITED IN THE DESCRIPTION**

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

**Patent documents cited in the description**

- EP 1882534 A [0004]