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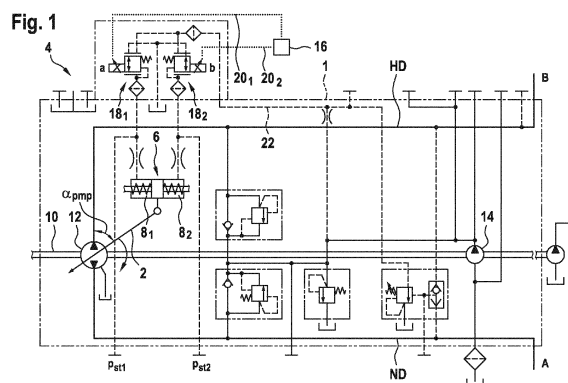
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(54) CALIBRATION METHOD OF A HYDRAULIC PUMP CONTROL SYSTEM

- a. discharge pressure value of said hydraulic pump (12);
- b. Measure the value of said first current intensity (I_1) and/or said first control pressure required to arrive at each operating condition;
- c. Compare the value of said first current intensity (I_1) and/or said first control pressure with a reference value of each operating condition;
- d. Correct said function according to the comparison made at said step c.



EP 4 273 398 A1

Description

TECHNICAL SCOPE

[0001] The present invention relates to the field of a method for calibrating the control system of a hydraulic pump for a hydrostatic drive system, a computing unit adapted to perform such a method, an operating machine includes such a computing unit, a computer program that induces a computing unit to perform such a method, and a readable storage medium on which such a program is stored.

BACKGROUND

[0002] In hydraulic traction drives, load-sensitive axial-piston tilting-plate hydraulic pumps (so-called ET pumps) in a closed loop are usually used. Such pumps presented the characteristic that an increase in load tends to decrease the pump's tilt angle. Therefore, if, for example, the operating machine starts a climb, the load that the machine has to support will go up. This will then cause the pump's angle of inclination to decrease.

[0003] Among other things, the sensitivity of the pump to the specific load defines the driving behavior of the machine, especially with regard to pressure/power control and load dependence during constant speed driving.

[0004] Load sensitivity is an inherent characteristic of the pump itself, and it is known that it is basically impossible to make a series of pumps having the same sensitivity during production. In order to ensure the same driving performance of the machines, several methods have been realized that allow the pump to be used regardless of the degree of sensitivity of the pump just out of production:

- I. Adjustment of the pump by means of a torque screw to ensure the same load sensitivity;
- II. Closed-loop control circuits that can adjust pressure and/or swing angle and thus compensate for tolerances.

[0005] However, the approach(s) described above have the disadvantage of being associated with increased costs that are due to additional components, adjustment procedures, or additional sensors.

[0006] The goal, therefore, is to provide a method for solving these problems without having to resort to additional components or having particularly complex control systems.

SUMMARY

[0007] The present invention relates to a control method the features listed in claim 1.

[0008] By means of the method described in claim 1, it is effectively possible to regulate the hydraulic pump independently of the sensitivity of the pump. Such a method

is applicable in any type of pump control method, either in terms of controlling the pump based on the speed of the pump itself or the drive motor and or controlling the pump based on a desired speed of the pump itself.

[0009] Preferable forms of implementation are indicated in the dependent claims.

BRIEF DESCRIPTION OF THE FIGURES

[0010] The present invention will be described with reference to the appended figures in which the same reference numerals and/or marks indicate the same and/or similar and/or corresponding parts of the system.

Figure 1 shows a hydraulic diagram of a propulsion of an operating machine according to a scheme known from the state of the art;

Figure 2 shows a function to calculate the first current intensity and/or the first control pressure as a function of a rotational speed of the drive motor or a quantity dependent on it and based on the angle of inclination of the pump;

Figure 3a and 3b show the characteristic curve of two pumps having two different load sensitivities.

DETAILED DESCRIPTION

[0011] In the following, the present invention is described by reference to particular forms of embodiment as illustrated in the accompanying drawing plates. However, the present invention is not limited to the particular forms of embodiment described in the following detailed description and depicted in the figures, but rather the forms of embodiment described simply exemplify the various aspects of the present invention, the scope of which is defined by the claims. Further modifications and variations of the present invention will appear clear to the person in the art.

[0012] In this description, the term vehicle is used to refer to any man-driven (or even remotely operated) mechanical means of transporting people, animals or things, whether circulating on the road or usable off the road, such as at construction sites, quarries or mining operations, etc. Thus an example of a vehicle may be, for example, a construction machine such as a bulldozer. In general, a vehicle is defined as any vehicle capable of performing vehicle displacement.

[0013] Figure 1 shows a hydraulic diagram of a traction system with respect to which a calibration method may be used according to a form of embodiment of the present invention. Only the components essential to the invention are described. The system has a casing 1 on which two working connections A, B are formed to which a working line (not shown) of a closed circuit is connected respectively, for example one or more hydraulic motors may be connected to said working connections A, B. In this way

a drive system is formed for a mobile working machine (not shown), such as a bulldozer.

[0014] The axial piston pump 12 is made with an oblique disc 2 (also referred to more generally as an oblique element) whose angle of oscillation α_{pmp} can be set by means of an adjusting unit 4, so as to go to adjust the displacement of the pump itself. A double-action regulating cylinder 6 is used for this purpose, which has a first chamber 8₁ of the regulating pressure and a second chamber 8₂ of the regulating pressure acting in the opposite direction to the first chamber.

[0015] A first control pressure p_{st1} acts in the first chamber of the control pressure 8₁ in the direction of an increase in the oscillation angle α_{pmp} and thus in the direction of an increase in pump displacement 12. In the opposite direction to this, a second control pressure p_{st2} in the second chamber 8₂ acts in the direction of a decrease in the oscillation angle α_{pmp} and thus in the direction of a decrease in pump displacement 12. In this way, a difference in control pressure Δp_{st} can be defined given by the difference of the first and second control pressures p_{st1} , p_{st2} , this difference in control pressure Δp_{st} by definition always acts in the direction of an increase in the oscillation angle α_{pmp} and thus in the displacement itself.

[0016] Via a drive shaft 10 of the axial piston pump, its drive unit is driven and in addition also a feed pump 14. Drive shaft 10 can be driven by a diesel engine (not shown) or alternatively also by an electric motor and rotates with a variable number of revolutions. This number of revolutions acts together with the control pressure difference in the direction of an increase in the oscillation angle α_{pmp} .

[0017] If the axial piston pump shown feeds through its working ports A, B numerous traction motors of the mobile work machine, in case of forward travel B must be thought of as a high pressure port, so that the channel connected with working port B is identified with high pressure HD, while the other channel connected with working port A is identified with reduced pressure ND. The high pressure HD, which is also referred to as working pressure, acts in the direction of a reduction in the oscillation angle α_{pmp} . These relationships are called axial piston pump characteristic and are stored in an electronic control unit 16 in the form of formulas and/or as characteristic diagrams and/or characteristic lines or more ingenerally functions.

[0018] The two control pressures are controlled by two pressure reducing valves 18₁, 18₂. These respectively have an electric magnet a, b, which via a respective electrical line 20₁, 20₂ is connected with the electronic control unit 16. The two pressure reduction valves 18₁, 18₂ are designed so that the respective control pressure p_{st1} , p_{st2} is proportional to the respective current intensity.

[0019] The two pressure reducing valves 18₁, 18₂ are fed on the inlet side via a supply pressure line 22 from the supply pump 14.

[0020] The system shown in Figure 1 can be adjusted

in two different modes.

[0021] The first mode is shown in patent application DE 10 2018 210 694 A1. In that document, it is shown how the pump is adjusted, based on a desired speed of the operating machine. As shown in Figure 3 of that document, for the calculation of regulation pressures, it is necessary to go to the pump characteristic curve that describes the degree of pump sensitivity depending on the pump discharge pressure. This curve is shown in Figure 3 with reference number 32. It is clear, however, that this curve is specific to the pump itself, and therefore, for pumps having a slightly different sensitivity, this curve would not provide a particularly accurate value of the degree of sensitivity.

[0022] The inventor has discovered that it is possible to carry out a method of calibrating the pump using software, instead of going directly to adjust the calibration of the pump itself. Such a method includes the following steps:

Defining at least a first state of the hydrostatic drive system at which said calibration is to be performed, wherein said first state comprises one or more operating conditions, wherein each operating condition comprises a hydraulic pump discharge pressure value 12;

- a. Measure the value of said first current intensity and/or said first control pressure p_{st1} , p_{st2} required to arrive at each operating condition;
- b. Compare the value of said first current intensity and/or said first control pressure p_{st1} , p_{st2} with a reference value of each operating condition;
- c. Correct the sub-function describing the pump sensitivity based on the pump discharge pressure of the pump according to the comparison made at said step c.

[0023] With this method of calibration, it is actually possible to go in and correct the degree of sensitivity of the pump without going in and changing the physical characteristics of the pump itself (as was done until now). Such a state at which this calibration is carried out could be a blocked state at which said hydraulic motor is braked or at which the flow rate of fluid passing through said hydraulic pump 12 is reduced to a volume close to zero so that said hydraulic pump 12 delivers only enough volume in this first state to cover losses along said hydrostatic drive system.

[0024] The second mode is shown in patent application DE 10 2020 207 284 A1 and will be briefly summarized here with reference to Figure 2.

[0025] The circuit diagram shown in Figure 2 is used to determine the control pressure p_{st1} , p_{st2} or current intensity or a quantity dependent on them. First, a current speed n of hydraulic pump 12 and a selected direction of travel T are determined. The speed n hydraulic pump 12 is calculated from a speed n_{Eng} of the drive motor (such as an electric or diesel motor). The speed n or n_{Eng} is filtered by means of a filter element PT1 and then

serves as an input variable on one side of a control element with a (so-called) characteristic curve Q 100 and on the other side of a control element with a (so-called) blocking characteristic curve 120.

[0026] The blocking condition corresponds to a condition in which said hydraulic motor is braked or at which the flow rate of fluid passing through said hydraulic pump 12 is reduced to a volume close to zero so that said hydraulic pump 12 delivers only enough volume to cover losses along said hydrostatic drive system.

[0027] Therefore, the blocking characteristic curve 120 is a curve describing the control pressure p_{Block} (which is nothing but the control pressure p_{st1} , p_{st2} described above, at a blocking condition) required as a function of the speed of the drive motor or hydraulic pump 12.

[0028] The Q condition corresponds to a condition in which hydraulic pump 12 delivers a maximum flow rate, at which the flow rate of fluid passing through said hydraulic pump 12 is increased to a maximum value.

[0029] Therefore, characteristic curve Q 100 is a curve that describes the control pressure p_Q (which is nothing but the control pressure p_{st1} , p_{st2} described above, at a maximum flow condition) required as a function of the speed of the drive motor or hydraulic pump 12.

[0030] Both characteristic curves 100, 120 are monotonically increasing functions that define a respective control pressure p_{Block} , p_Q as a function of speed n and n_{Eng} , respectively.

[0031] These two control pressures p_{Block} , p_Q are the input variables of an interpolation element with an interpolation function 140. The interpolation function 140 defines the resultant control pressure p_{st} for the two pressure reducing valves 8_1 , 8_2 , which according to the invention (at least over an average range of speed n or n_{Eng}) is a combination of the control pressure p_Q of the Q characteristic 100 and the control pressure p_{Block} of the block characteristic 120. Furthermore, according to the invention, this interpolation function depends on the tilt angle α_{pmp} of the hydraulic pump 12. At a tilt angle α_{pmp} of 0° , the control pressure p_{st} corresponds to the control pressure p_{Block} , and at a maximum tilt angle α_{pmp} , the control pressure p_{st} corresponds to the control pressure p_Q .

[0032] In the example shown in the figure, the resulting control pressure p_{st} is also equal to the control pressure p_{Block} for low tilt angles α_{pmp} and the control pressure p_Q for high tilt angles α_{pmp} . At an intermediate range of the tilt angle α_{pmp} , the combination of the two control pressures p_{Block} , p_Q is used to determine the control pressure p_{st} , where the values of the two control pressures p_{Block} , p_Q are weighted more or less depending on the value of the tilt angle of the hydraulic pump 12.

[0033] In summary, the method includes the following steps:

- Calculate on the basis of the rotational speed of the drive motor or said quantity dependent thereon a value of a blocking current intensity and/or a blocking

control pressure, wherein said calculation is performed by means of a blocking subfunction (the blocking curve 120);

- 5 - Calculate on the basis of said rotational speed of the drive motor or of said magnitude dependent thereon a value of a flow rate current intensity and/or a flow rate control pressure, , wherein said calculation is made by means of a flow rate subfunction (the flow rate curve 100);
- 10 - obtain a current value of said angle of inclination α_{pmp} of said inclined element 2 (e.g., by means of a flow rate balancing equation, then by calculation, or based on a sensor placed on the hydraulic pump),
- 15 - Calculate said first current intensity (I_1) and/or said first control pressure based on said tilt angle α_{pmp} , said blocking current intensity and/or said blocking control pressure, said flow rate current intensity and/or said flow rate control pressure, e.g., by interpolation curve 140.
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[0034] It is clear, however, that both curves 100, 120 are curves specific to the pump itself and therefore, for pumps having slightly different sensitivity, these curves would not provide a particularly accurate value of the required p_{Block} , p_Q control pressures.

[0035] In fact, as shown in Figure 3 (which shows two characteristic curves of two different pumps) the characteristic curve of each pump varies considerably. If, for example, the curve on the left is taken, it can be seen that in order to realize a pressure delta of 300 bar at a tilt angle α_{pmp} of 5 degrees, a much smaller change in current/control pressure p_{sA} is required than is needed p_{sB} for the pump whose characteristic is shown in figure 3b. Therefore, this different sensitivity with respect to a load change results in a significant difference in the response of the pump whose characteristic is shown in figure 3a compared with that shown in figure 3b.

[0036] The inventor discovered that it is possible to carry out a method of calibrating the pump via software, instead of going to directly adjust the calibration of the pump itself, allowing one to go to directly calibrate the 100, 120 curves. This method includes the following steps:

Defining at least a first state of said hydrostatic drive system at which said calibration is to be performed, wherein said first state comprises one or more operating conditions, wherein each operating condition comprises a discharge pressure value of said hydraulic pump (12);

- a. Measure the value of said first current intensity (I_1) and/or said first control pressure required to arrive at each operating condition;
- b. Compare the value of said first current intensity (I_1) and/or said first control pressure with a reference value of each operating condition;

c. Correct said function according to the comparison made at said step c.

[0037] The inventor has found that it is particularly advantageous if that first state coincides with the locked state since that condition is very easy to achieve and therefore such calibration can be done particularly easily.

[0038] The condition shown with p_{sA} and p_{sB} in Figure 3 can be considered very close to a lockout condition because it is a particularly small angle of pump inclination. Therefore, according to the method described above, it will suffice to define at least one pressure (e.g., 400 bar) and see what current I or what control pressure p_{st} is required to reach that pressure in such a locked state. This value will then be compared with a reference value. For example, in the case shown in figure 3, if we assume that curve 3a represents the reference curve we will go and compare the current/pressure value needed to reach for example 400 bar in figure 3b and compare it with the reference value in figure 3a. This difference will then be used to go to correct the blocking curve.

[0039] According to a preferred form of realization, this process is repeated for two operating conditions each containing a discharge pressure, so that there are two different points to be used for correction.

[0040] According to a preferred form of embodiment, a first operating condition comprises a discharge pressure value of said hydraulic pump 12 corresponding to a maximum usable pressure in said hydrostatic drive system, wherein said discharge pressure in said first operating condition is preferably between 400 and 500 bar, even more preferably being 450 bar. Further, a second operating condition comprises a discharge pressure value of said hydraulic pump 12 preferably being between 150 and 300 bar, even more preferably being equal to 200 bar, wherein said discharge pressure of said second operating condition preferably corresponds to the discharge pressure of said hydraulic pump 12 in a maximum flow condition.

[0041] In addition, the calibration method includes the following steps:

- Correct said blocking sub-function (the curve 120) based on the comparison made against one or more reference values. Such correction may, for example, be made by calculating a ratio of the measured current/pressure value to the reference value and then multiplying the reference curve by that value;
- Correcting said flow sub-function (the 100 curve) on the basis of said correction of said blocking sub-function.

[0042] The present invention further describes a computational unit adapted to perform a method according to any of the preceding claims.

[0043] Further, the present description includes a computer program that induces a computing unit to perform

a method as described in the present invention.

[0044] Also described is a readable storage medium comprising the computer program stored thereon described above.

[0045] Although the present invention has been described with reference to the forms of embodiment described above, it is clear to the person skilled in the art that various modifications, variations, and improvements of the present invention in light of the teaching described above and within the scope of the appended claims are possible without departing from the subject matter and scope of protection of the invention.

[0046] Finally, those areas that are believed to be known by experts in the field have not been described to avoid overshadowing the described invention unnecessarily.

[0047] Accordingly, the invention is not limited to the forms of embodiment described above, but is only limited by the scope of protection of the appended claims.

Claims

1. Method for calibrating a hydraulic pump control system (12) for a hydrostatic drive system, wherein said hydrostatic drive system comprises said hydraulic pump (12), the rotation of which is ensured by a drive motor, and at least one hydraulic motor connected in a closed circuit to said hydraulic pump (12), wherein said hydraulic pump (12) has a regulating unit (4) for adjusting the displacement of said hydraulic pump, wherein said displacement is adjustable by adjusting a tilt angle (α_{pmp}) of an inclined element (2), wherein said regulating unit (4) has a regulating cylinder (6) with a first regulating pressure chamber (8₁) in which, by means of a first valve (18₁) it is possible to set a first control pressure (p_{st1}) which depends on a first current intensity (I_1) of said first valve (18₁) and which is configured to influence the inclination (α_{pmp}) of said inclined element (2), wherein said control unit (4) is configured in such a way that an increase in the delivery pressure of said hydraulic pump (2) tends to cause a reduction in the displacement of said hydraulic pump (12), said control system includes a function allowing to calculate said first current intensity (I_1) and/or said first control pressure (p_{st1}) as a function of a rotation speed of said drive motor or of a variable dependent thereon and on the basis of said tilt angle (α_{pmp}); said method being **characterized in that** said function is calibrated and **in that** said calibration comprises said steps:

- a. Defining at least a first state of said hydrostatic drive system at which said calibration is to be performed, wherein said first state comprises one or more operating conditions, wherein each operating condition comprises a value of delivery pressure of said hydraulic pump (12);

- b. Measuring the value of said first current intensity (I_1) and/or said first control pressure (p_{st1}) required to reach each operating condition;
- c. Compare the value of said first current intensity (I_1) and/or said first control pressure (p_{st1}) with a reference value of each operating condition;
- d. Correcting said function according to the comparison made in said step c.
2. Method according to claim 1, wherein said hydraulic pump is an axial piston pump.
3. Method according to any one of claims 1 or 2, wherein said first state comprises at least two operating conditions.
4. Method according to claim 3, wherein a first operating condition comprises a discharge pressure value of said hydraulic pump (12) corresponding to a maximum usable pressure in said hydrostatic traction system, wherein said discharge pressure in said first operating condition is preferably between 400 and 500 bar, even more preferably being equal to 450 bar, and wherein a second operating condition comprises a discharge pressure value of said hydraulic pump (12) preferably between 150 and 300 bar, even more preferably being equal to 200 bar.
5. Method according to any one of claims 1 to 4, wherein said function comprises the following sub-functions:
- Calculating, on the basis of said rotational speed of said drive motor or of said variable dependent thereon, a value of a blocking current intensity and/or a blocking control pressure (p_{Block}), wherein said blocking current intensity and/or said blocking control pressure (p_{Block}) correspond respectively to a hypothetical value of current and pressure which would be needed to regulate said hydraulic pump (12) in a blocking condition, at which said hydraulic motor is braked or at which the fluid flow rate passing through said hydraulic pump (12) is reduced to a volume close to zero, so that said hydraulic pump (12) delivers only a volume sufficient in this first state to cover losses along said hydrostatic drive system, wherein said calculation is performed by means of a blocking sub-function (120);
 - Calculating, on the basis of said rotational speed of said drive motor or of said variable dependent thereon, a value of a flow rate current intensity and/or of a flow rate control pressure (p_Q), wherein said flow rate current intensity and/or said flow rate control pressure (p_Q) correspond respectively to a hypothetical value of current and pressure which would be needed to regulate said hydraulic pump (12) in a condition of maximum flow of said hydraulic pump (12), at which the flow rate of fluid passing through said hydraulic pump (12) is increased until it reaches a maximum value, wherein said calculation is performed by means of a flow sub-function (100);
 - obtaining a current value of said tilt angle (α_{pmp}) of said inclined element (2),
 - Calculating said first current intensity (I_1) and/or said first control pressure based on said tilt angle (α_{pmp}), said blocking current intensity and/or said blocking control pressure, said flow current intensity and/or said flow control pressure.
6. Method according to claim 5, wherein said first state coincides with said blocking condition.
7. Method according to any one of claims 5 or 6, when dependent on claim 4, wherein said discharge pressure of said second operating condition corresponds to a value of the discharge pressure in said maximum flow condition.
8. Method according to any one of claims 5 to 7, wherein said step d. comprises the following sub-steps:
- Correcting said blocking sub-function (120) on the basis of said comparison of said step c.;
 - Correcting said flow sub-function (100) on the basis of said correction of said blocking sub-function (120).
9. A data processing device comprising means for carrying out a method according to any one of the preceding claims.
10. An operating machine comprising a hydrostatic drive system, wherein said hydrostatic drive system comprises said hydraulic pump (12), the rotation of which is ensured by a drive motor, and at least one hydraulic motor connected in a closed circuit to said hydraulic pump (12), wherein said hydraulic pump (12) has a regulating unit (4) for adjusting the displacement of said hydraulic pump, wherein said displacement is adjustable by adjusting a tilt angle (α_{pmp}) of an inclined element (2), wherein said regulating unit (4) has a regulating cylinder (6) with a first regulating pressure chamber (8_1) in which, by means of a first valve (18_1) it is possible to set a first regulating pressure which depends on a first current intensity (I_1) of the first valve (18_1) and which is configured to influence the inclination (α_{pmp}) of said inclined element (2), wherein said regulating unit (4) is configured in such a way that an increase in the delivery

pressure of the hydraulic pump (2) tends to cause a reduction in the displacement of the hydraulic pump (12), wherein said operating machine comprises a data processing device according to claim 9.

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11. A computer program comprising instructions which, when the program is executed by a computer, cause the computer to carry out the steps of the method of any of claims 1 to 8.

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12. A computer-readable storage medium comprising instructions which, when executed by a computer, cause the computer to carry out the steps of the method of any of claims 1 to 8.

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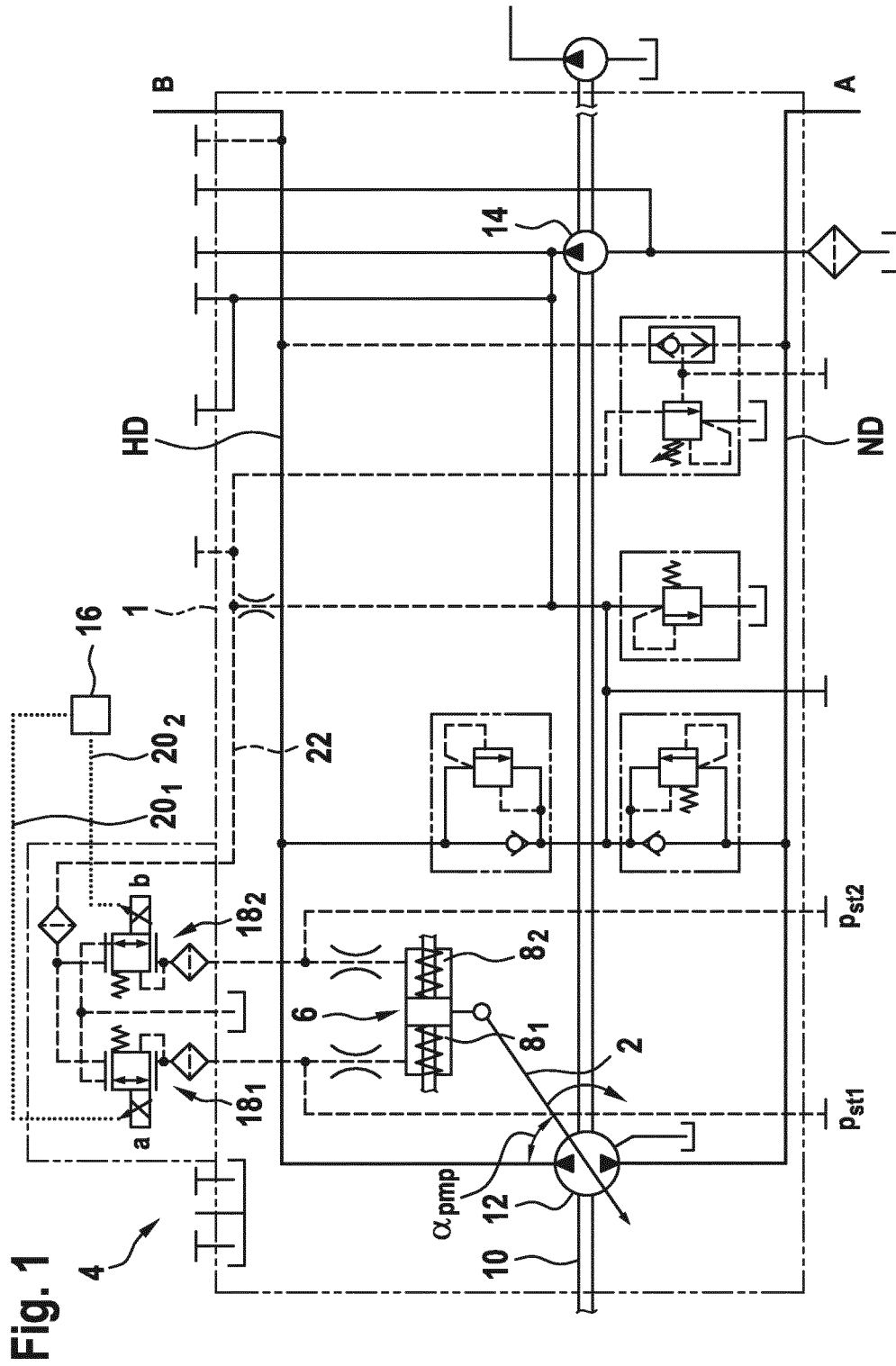
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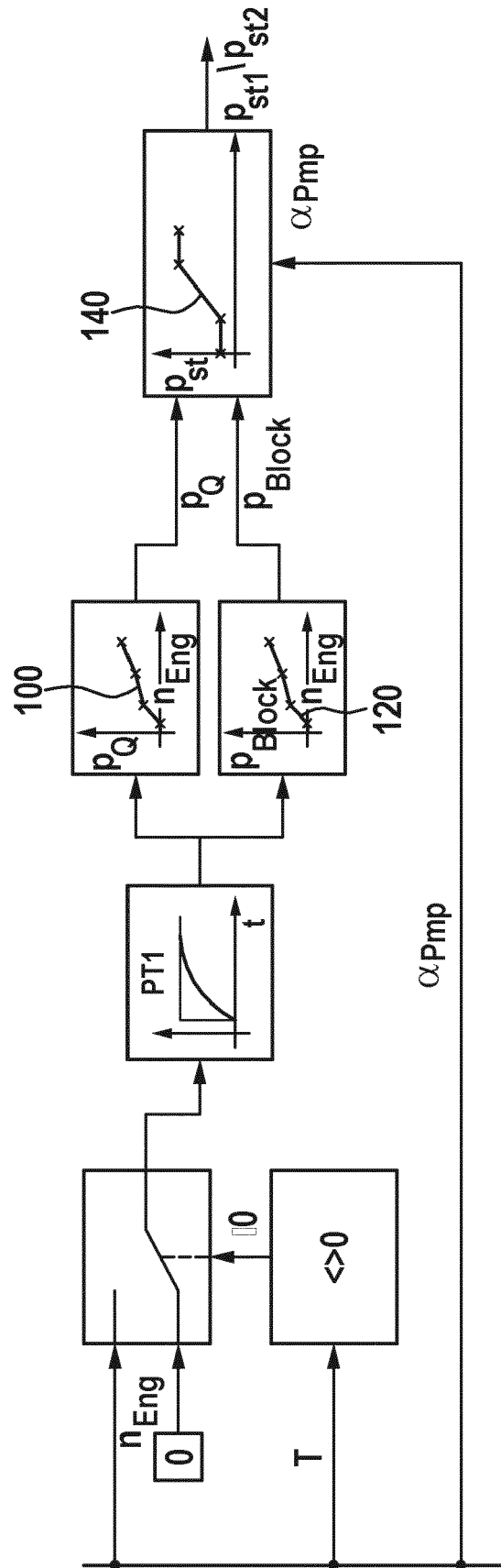


Fig. 2

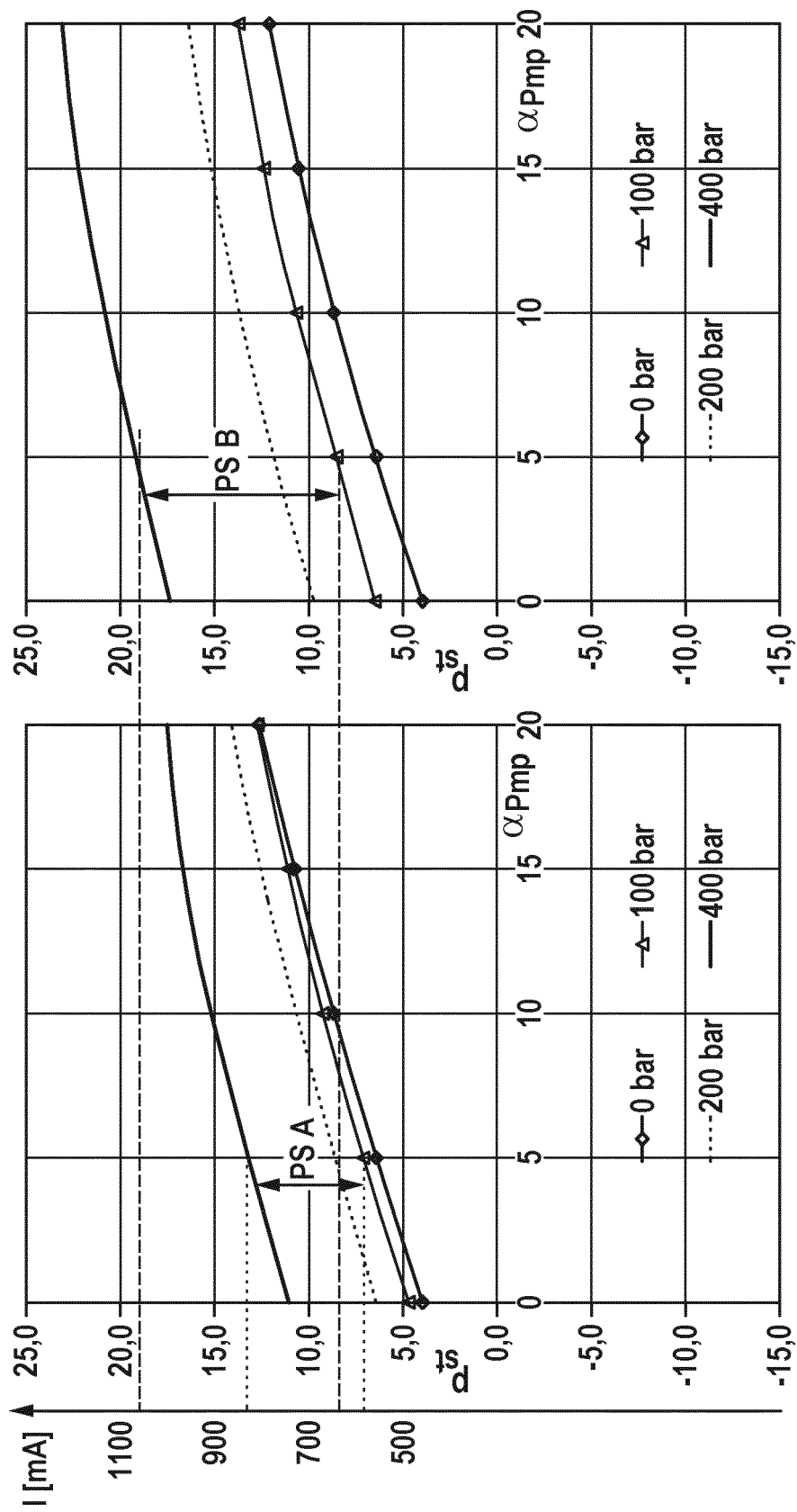


Fig. 3a

Fig. 3b



EUROPEAN SEARCH REPORT

Application Number

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EPO FORM 1503 03.82 (P04C01)

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 5 June 2023	Examiner Jurado Orenes, A
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