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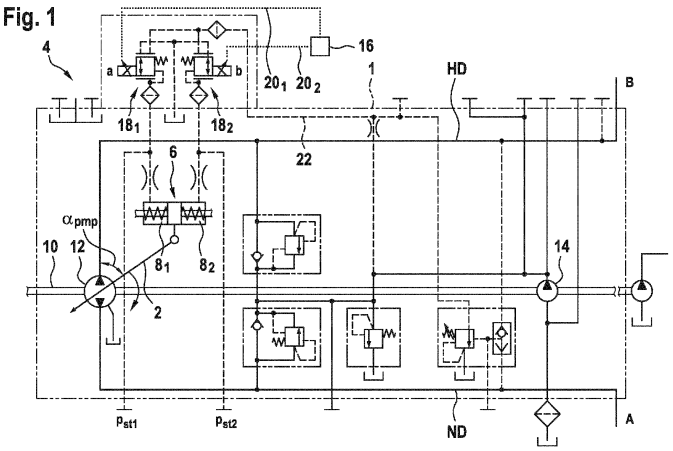
(54) **METHOD OF ADJUSTING THE CONTROL SYSTEM OF A HYDRAULIC PUMP**

(57) The present invention relates to a method of adjusting 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 provided 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 an adjusting unit (4) for adjusting the displacement of said hydraulic pump, wherein said displacement is adjustable by adjusting an angle of inclination (αpmp) of an inclined element (2), wherein said adjusting unit (4) has an adjusting cylinder (6) with a first adjusting pressure chamber (81) in which, by means of a first valve (181), it is possible to set a first control pressure (pst1) that depends on a first current intensity (I1) of the first valve (181) and that is configured to affect the inclination (αpmp) of said inclined element (2), in which said control unit (4) is configured so 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), said method makes it possible to maintain the hydraulic motor in a stationary condition of zero speed due to the fact that the control pressure or the first current intensity is calculated on the basis of a pressure sensed in the hydraulic circuit..

Fig. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to the field of a method for regulating 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 swashplate hydraulic pumps (so-called ET pumps) are usually used in a closed circuit. 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 angle of inclination of the pump to decrease.

[0003] The advantage of these ET pumps is that the power and pressure controls are very simple. However, load sensitivity leads to the problem that the pumps are not always held to zero by the spring preload of the pump control device. High speeds and negative pressures cause the forces to oscillate. In applications, this leads to the fact that if the pump is not activated, the vehicle from a particular slope can roll off very quickly. In many cases, such as stopping on a slope, starting on a slope after opening the parking brake, to a more difficult operation of the machine.

[0004] Currently, this behavior is accepted after a certain point, or pumps are configured with higher preloads.

[0005] Therefore, the goal is to provide a method to solve these problems without having to resort to additional components or having particularly complex control systems.

SUMMARY

[0006] The present invention relates to a method containing the features listed in claim 1.

[0007] The purpose of the present invention is achieved by an algorithm/method or generally by pump control software that ensures that sufficient control pressure is always provided when a pump angle close to 0° is required to prevent the pump from moving due to motor forces. With this logic, one can do without increasing spring preloads and thus maximum control pressures. Notably, these higher control pressures lead to lower hydrostatic transmission efficiency.

[0008] According to a form of embodiment of the present invention, there is provided a method for adjusting a hydraulic pump control system for a hydrostatic drive system, wherein said hydrostatic drive system comprises said hydraulic pump, the rotation of which is provided by a drive motor, and at least one hydraulic motor connected in a closed circuit to said hydraulic pump, wherein said hydraulic pump has a control unit for adjusting the displacement of said hydraulic pump, wherein said displacement is adjustable by adjusting an angle of inclination of an inclined element, wherein said regulating unit has a regulating cylinder with a first chamber of the regulating pressure in which, by means of a first valve a first regulating pressure can be set which depends on a first current intensity of the first valve and which is configured so as to affect the inclination of said inclined element, wherein said regulating unit is configured so that an increase in the delivery pressure of the hydraulic pump tends to cause a reduction in the displacement of the hydraulic pump, said method being characterized by comprising the following steps:

a. Receiving an information regarding the fact that the desired value of said angle of inclination of said inclined element is a predetermined value close to zero (in the present invention, a value close to zero has been indicated because in some cases leakage compensation along the hydraulic circuit may be required), so that, due to said angle of inclination close to zero, the flow rate of said hydraulic pump is reduced to a value close to zero;
b. Measure a pressure along said closed circuit;
c. Calculate a value of said first regulating pressure or said first current intensity capable of ensuring that said angle of inclination of said inclined element reaches said predetermined value, so that the value of the displacement of said hydraulic pump reaches a value close to zero, wherein said calculation is made on the basis of said pressure measured in said step b;
d. Set said control pressure or said first current intensity calculated in said step c.

[0009] Alternatively to the formulation used to describe step a. the following two sub-steps can be described:

- Receive information regarding the fact that the desired rotational speed of the hydraulic motor is zero;
- Identify an angle of inclination of the inclined element that allows this zero hydraulic motor speed to be achieved.

[0010] In addition, with this logic, excessive rolling on slopes can be avoided and transitions can be improved by activating and deactivating the parking brake.

[0011] Preferable forms of implementation are shown in the dependent claims.

BRIEF DESCRIPTION OF THE FIGURES

[0012] The present invention will be described with reference to the appended figures in which the same num-

bers and/or reference 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 for calculating 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 thereon and on the basis of the required pump tilt angle according to a particular embodiment of the present invention;

Figure 3 shows a conceptual diagram of the control method according to a form of embodiment of the present invention.

DETAILED DESCRIPTION

[0013] In the following, the present invention is described by referring to particular forms of embodiment as illustrated in the attached drawing plates. However, the present invention is not limited to the particular embodiments described in the following detailed description and depicted in the figures, but rather the embodiments described exemplify simply 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 skilled in the art.

[0014] In this description, the term operating machine 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.

[0015] Figure 1 shows a hydraulic diagram of a traction system for an operating machine with respect to which an adjustment 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 for a mobile working machine (not shown), such as a bulldozer, is formed.

[0016] 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 αpmp 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.

[0017] A first control pressure pst1 acts in the first chamber of the control pressure 81 in the direction of an increase in the oscillation angle αpmp and thus in the direction of an increase in pump displacement 12. In the opposite direction to this, a second control pressure pst2 in the second chamber 82 acts in the direction of a reduction in the oscillation angle αpmp and thus in the direction of a reduction in pump displacement 12. In this way, a difference in control pressure Δpst can be defined given by the difference of the first and second control pressures pst1, pst2, this difference in control pressure Δpst by definition always acts in the direction of an increase in the angle of oscillation αpmp and thus in the displacement itself.

[0018] Through 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 αpmp.

[0019] 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 αpmp. 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.

[0020] 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 pst1, pst2 is proportional to the respective current intensity (I1, I2).

[0021] The two pressure reducing valves 181, 182 are fed on the inlet side via a supply pressure line 22 from supply pump 14.

[0022] With reference to Figure 2, a method of adjusting the hydraulic pump 12 will now be presented that can guarantee a tilt angle αpmp close to zero regardless of external conditions (e.g., whether the operating machine is uphill or not), and thus of the load to which the pump is subjected, under a condition of zero speed of the hydraulic motor of the hydrostatic drive system shown in Figure 1. In the present invention, "near-zero" angle is

used to denote a situation at which the hydraulic motor is stationary and therefore the pump provides no volume or only the volume capable of compensating for losses on the hydraulic circuit, thus allowing zero speed of the hydraulic motor.

[0023] The figure shows the value of the first and second intensities of current I1, I2, or the required control pressure pst, for a given number of revolutions of the drive motor or a quantity dependent on it (in the case shown in the figure, the number of revolutions is 2000 rpm), required to maintain a given angle of inclination αpmp (e.g., an angle equal to zero or equal to a value that can allow for compensation of losses on the hydraulic circuit). As shown in the figure, it is clear that as the load increases (e.g., if the operating machine is uphill), a greater current or pressure in absolute value will be needed to obtain an angle of inclination equal to zero, since due to the pressure in the circuit and the low stiffness of the spring, the angle of inclination of the pump leg will tend to increase in absolute value.

[0024] The dashed horizontal curve at a current or pressure of 0 represents the state of the art, i.e., what occurred before the introduction of a method according to the present invention. For example, for a pressure delta of 300 bar, if no current or regulating pressure were supplied, it would result in an angle of inclination of about 10°, which represents about 50 percent with respect to the maximum angle that such an inclined element can assume. This will then result in the operating machine being unable to remain stationary in any way and depending on operating conditions will tend to move.

[0025] As mentioned, the curve is specific for a given number of revolutions. Therefore, according to the particular example shown in the figure, there will be several curves saved for different numbers of revolutions. Alternatively, a function may be used that has as input variables the number of revolutions of the drive motor (or pump) and the motor load, and as output variables the current or pressure required to maintain a precise value (e.g., equal to 0) of the tilt angle. An alternative will instead be explained later with reference to Figure 3.

[0026] Figure 3 shows a conceptual diagram of the control method according to a particular embodiment of the present invention.

[0027] The control unit 16 is the unit that is suitable for adjusting the hydraulic pump 12. Reference number 100 is used to indicate the standard control type of the hydraulic pump. According to this standard control method, the hydraulic pump is adjusted on the basis of an input signal that corresponds to a desired speed of the operating machine or a current speed of the drive motor.

[0028] With the reference number 99 an input signal is indicated that goes to determine whether it is required that hydraulic pump 12 is to be controlled according to the standard control 100 or whether a special control is required, whereby a predetermined swing angle of hydraulic pump 12 is required. For example, the predetermined swing angle of hydraulic pump 12 may be desired in the case where it is determined that for a required speed of zero of the hydraulic motor, a pump swing angle of zero or equal to a value that allows hydraulic losses to be compensated for. In that particular case then signal 99 goes to tell control unit 16 that swing angle control is required and therefore goes to interrupt standard pump control 12.

[0029] In a first step 101 the determination of the required direction of movement of the operating machine on which said hydrostatic drive system is placed takes place. Parallel to this step 101 is the measurement of a pressure 102 at at least one point of the closed circuit along which the hydraulic pump 12 is located. Such pressure information could be, for example, the pressure difference between upstream and downstream of hydraulic pump 12.

[0030] The two pieces of information 101 and 102 are then combined with each other in a step 103 until an intermediate value of the first control pressure pst1 or the first current intensity I1 is obtained, by means of, for example, the curve shown in Figure 2. Such an intermediate value can, for example, be calculated directly if, instead of using the curve shown in Figure 2, a curve is used, the shape of which is independent of the number of revolutions of hydraulic pump 12.

[0031] The influence of the number of revolutions is then considered in a later step. In step 104 in fact, on the basis of said speed of said drive motor or said quantity dependent on it (for example, on the basis of the number of revolutions of the hydraulic pump itself) a multiplicative factor is calculated. Said intermediate value is then multiplied with said multiplicative factor to obtain a final value of said first control pressure (pst1) or said first current intensity (I1) to be sent to the control unit 16.

[0032] The present invention further describes a computational unit adapted to perform a method according to any of the preceding claims.

[0033] In addition, the present description includes a computer program that induces a computing unit to perform a method as described in the present invention.

[0034] A readable storage medium comprising the computer program stored thereon described above is also described.

[0035] Although the present invention has been described with reference to the forms of embodiment described above, it is clear to the branch expert that various modifications, variations, and improvements of the present invention can be made in light of the teaching described above and within the scope of the appended claims without departing from the subject matter and scope of protection of the invention.

[0036] 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.

[0037] 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. A method of adjusting a hydraulic pump control system (12) for a hydrostatic traction system, wherein said hydrostatic traction system includes said hydraulic pump (12), the rotation of which is provided 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 an adjustment unit (4) for adjusting the displacement of said hydraulic pump, wherein said displacement is adjustable by adjusting an angle of inclination (αpmp) 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), a first regulating pressure (pst1) can be set which depends on a first current intensity (I1) of the first valve (181) and which is configured to affect the inclination (αpmp) of said inclined element (2), in which said control unit (4) is configured so 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), said method being **characterized by** comprising the following steps:

   a. Receiving an information regarding the fact that the desired rotational speed of said hydraulic motor is zero;
   b. Identify an angle of inclination (αpmp) of said inclined element (2) that allows to reach said speed of said hydraulic motor equal to zero;
   c. Measure a pressure along said closed circuit;
   d. Calculate a value of said first regulating pressure (pst1) or said first current intensity (I1) capable of ensuring that said angle of inclination (αpmp) of said inclined element (2) reaches said value identified in said step b., wherein said calculation is made on the basis of said pressure measured in said step b;
   e. set said first control pressure (pst1) or said first current intensity (I1) calculated in said step d..

2. Method according to claim 1 or 2, wherein said pressure measured in said step b corresponds to the pressure difference between the inlet and outlet of said hydraulic pump (12).

3. Method according to any one of claims 1 or 2, wherein said angle of inclination (αpmp) of said inclined element (2) identified in said step b. is a value equal to zero or equal to a value that allows a zero speed of said hydraulic motor to be maintained, so as to allow losses in said closed circuit to be compensated for.

4. A method according to any one of claims 1 to 3, wherein to calculate said value of said first control pressure (pst1) or said first current intensity (I1) in said step c. the rotational speed of said drive motor or a quantity dependent thereon is also taken into account.

5. Method according to claim 4, wherein on the basis of said pressure measured in said step b, in said step c. an intermediate value of said first regulating pressure (pst1) or said first current intensity (I1) is calculated, wherein on the basis of said speed of said drive motor or said magnitude dependent thereon a multiplicative factor is calculated, wherein said intermediate value is then multiplied with said multiplicative factor to obtain a final value of said first regulating pressure (pst1) or said first current intensity (I1).

6. A method according to any one of claims 1 to 5, wherein said method further comprises the step of determining a required direction of movement of an operating machine on which said hydrostatic drive system is positioned, wherein said information is combined with the value of the pressure measured in said step b. to calculate said value of said first control pressure (pst1) or said first current intensity (I1).

7. A computational unit containing means for performing a method according to any of the preceding claims.

8. An operating machine comprising a hydrostatic drive system, wherein said hydrostatic drive system comprises said hydraulic pump (12), the rotation of which is provided 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 an adjusting unit (4) for adjusting the displacement of said hydraulic pump, wherein said displacement is adjustable by adjusting an angle of inclination (αpmp) of an inclined element (2), wherein said adjusting unit (4) has an adjusting cylinder (6) with a first adjusting pressure chamber (81) in which, by means of a first valve (181) a first regulating pressure can be set which depends on a first current intensity (I1) of the first valve (181) and which is configured to affect the inclination (αpmp) of said inclined element (2), wherein said regulating unit (4) is configured such 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 calculation unit according to claim 7.

9. A computer program comprising instructions which, when the program is executed by a computer, cause the computer to perform the steps of the method of any one of claims 1 to 6.

10. A computer-readable storage medium comprising instructions which, when executed by a computer, cause the computer to execute the method steps of any one of claims 1 to 6.

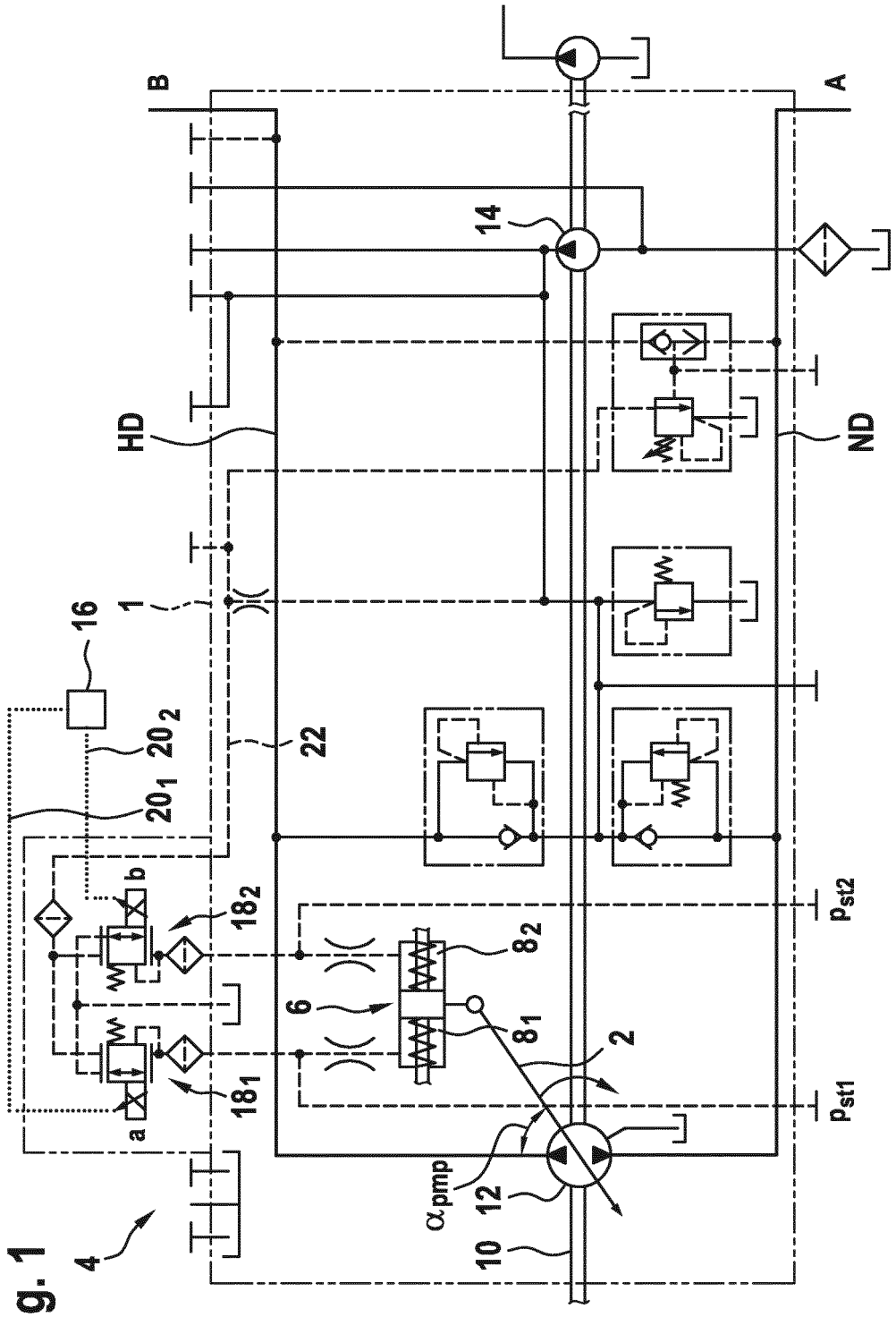
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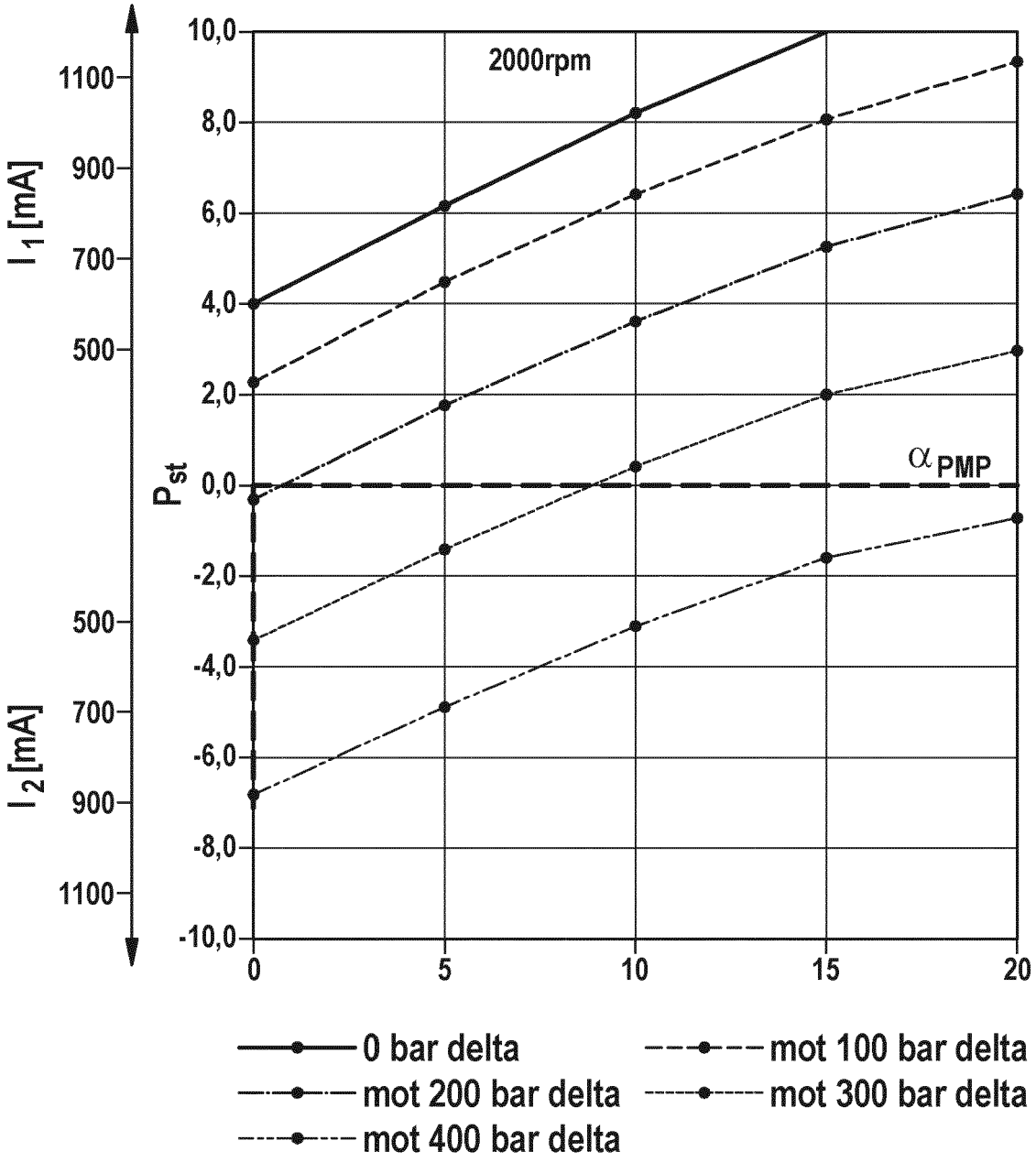
Fig. 1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mot 400 bar delta

Fig. 2

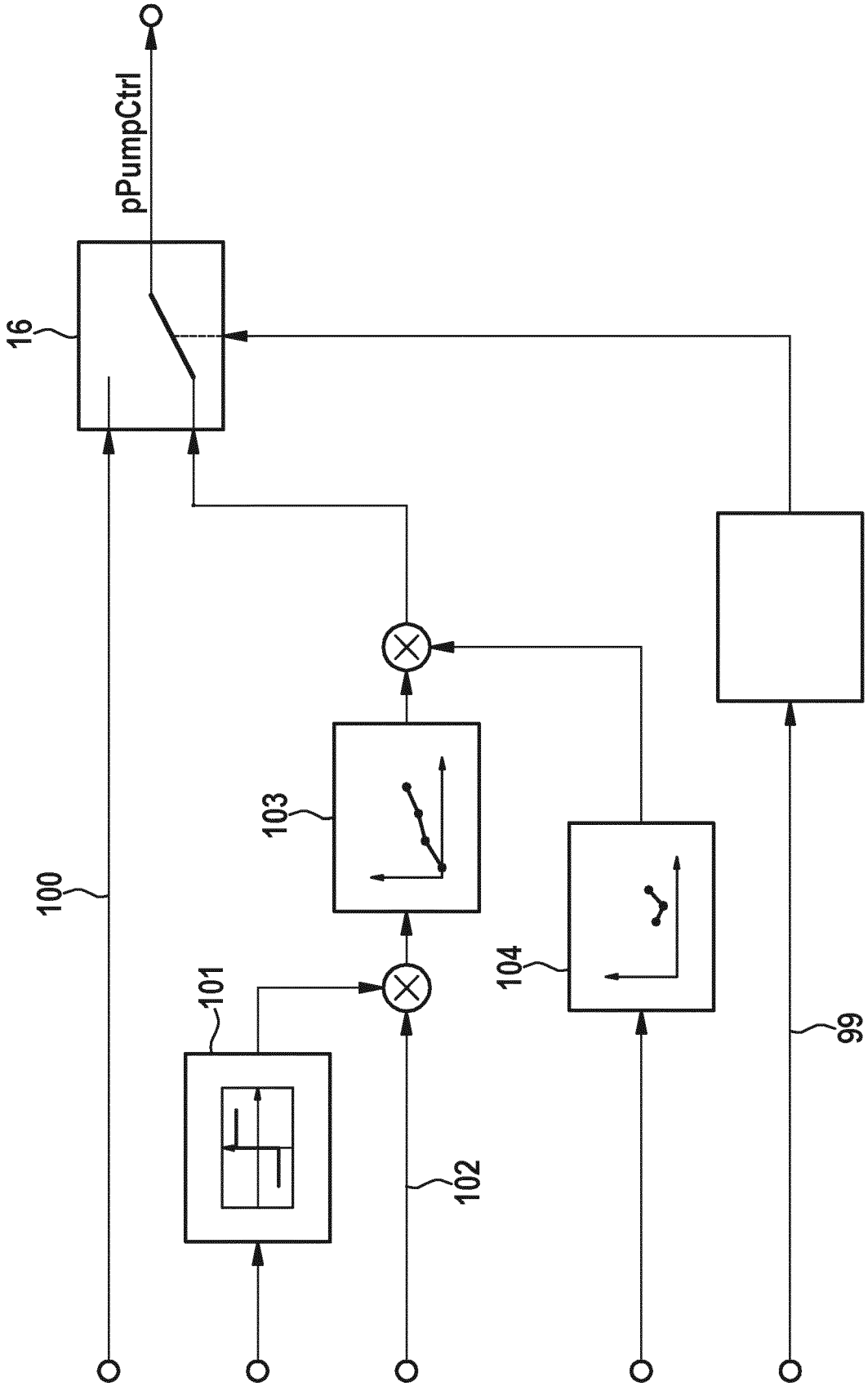

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 23 17 1759

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC) F04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	18 September 2023	Ricci, Saverio

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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