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(54) ## VARIABLE DISPLACEMENT VANE PUMP

(57) A variable displacement vane pump includes: a control orifice 104 that imparts resistance to a flow of working oil discharged from pump chambers 6; a flow-amount control valve 102 that operates in accordance with an upstream-downstream differential pressure of the control orifice 104 and controls a flow amount of the working oil discharged from the pump chambers 6; a variable control valve 103 that is operated by the working oil that has passed through the control orifice 104 and controls an amount of eccentricity of a cam ring 4 with respect to a rotor 2 by controlling a pressure difference between a first fluid pressure chamber 15 and a second fluid pressure chamber 16; and a return passage 42 that is connected to the flow-amount control valve 102 and circulates a part of the working oil discharged from the pump chambers 6 through a suction passage 40.

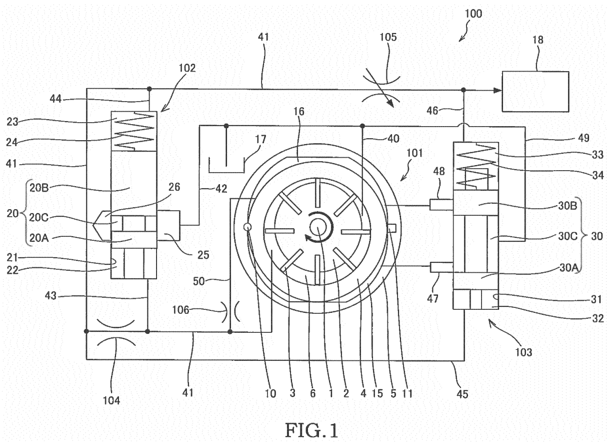

FIG.1

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Description

TECHNICAL FIELD

[0001] The present invention relates to a variable displacement vane pump that is used as a fluid pressure source in a fluid pressure apparatus.

BACKGROUND ART

[0002] As conventional variable displacement vane pumps, there are pumps in which a discharge capacity is changed by changing an amount of eccentricity of a cam ring with respect to a rotor by making the cam ring swing about a pin as a support point.

[0003] JP2009-275537A discloses a variable displacement vane pump that includes a control valve that operates in accordance with an upstream-downstream differential pressure of a flow-amount detection orifice and controls an amount of eccentricity of a cam ring with respect to a rotor, a return passage that returns, to a suction passage, a part of working fluid that has been discharged from pump chambers through a discharge passage, and a flow dividing valve that adjusts an opening area of the return passage to the discharge passage.

[0004] With the variable displacement vane pump disclosed in JP2009-275537A, when the rotating speed of the rotor is increased and the upstream-downstream differential pressure of the flow-amount detection orifice reaches a predetermined value, the amount of eccentricity of the cam ring is reduced by the control valve. Thereby, the discharge capacity of the pump chambers is reduced, and the flow amount discharged from the variable displacement vane pump is controlled so as to achieve a predetermined flow amount.

SUMMARY OF INVENTION

[0005] With the variable displacement vane pump disclosed in JP2009-275537A, when the flow amount of the working fluid discharged from the pump chambers reaches the flow amount at which a predetermined upstream-downstream differential pressure of the flow-amount detection orifice is generated, the flow amount of the working fluid is controlled to a constant flow amount by the control valve so as to maintain the discharge flow amount. Thereby, the working fluid is guided to the return passage at the returning flow amount that is the difference between the discharge flow amount of the variable displacement vane pump controlled by the control valve so as to be constant and the flow amount of the working fluid guided to the discharge passage by being controlled by the flow dividing valve. As described above, with the variable displacement vane pump disclosed in JP2009-275537A, while the discharge flow amount is controlled by the control valve so as to be constant, the returning flow amount is substantially constant.

[0006] With the variable displacement vane pump described above, because the discharge flow amount is controlled by the control valve and the returning flow amount becomes substantially constant, there is a risk in that, when the rotating speed of the pump is high, cavitation may be caused due to insufficient suction.

[0007] An object of the present invention is to provide a variable displacement vane pump that is capable of suppressing occurrence of cavitation.

[0008] According to one aspect of the present invention, A variable displacement vane pump includes: a rotor linked to a driving shaft; a plurality of vanes provided so as to be able to reciprocate in a radial direction relative to the rotor; a cam ring having an inner circumferential surface on which tip ends of the vanes slide by rotation of the rotor; pump chambers defined by the rotor, the cam ring, and pairs of the adjacent vanes; a suction passage configured to guide working fluid to the pump chambers; a first fluid pressure chamber and a second fluid pressure chamber defined in an outer-circumferential accommodating space on outer side of the cam ring, the first fluid pressure chamber and the second fluid pressure chamber being configured to make the cam ring eccentric with respect to the rotor by pressure difference between the first fluid pressure chamber and the second fluid pressure chamber; a control restrictor configured to impart resistance to a flow of the working fluid discharged from the pump chambers; a flow-amount control valve operated in accordance with an upstream-downstream differential pressure of the control restrictor, the flow-amount control valve being configured to control flow amount of the working fluid discharged from the pump chambers; a variable control valve operated by the working fluid that has passed through the control restrictor, the variable control valve being configured to control an amount of eccentricity of the cam ring with respect to the rotor by controlling pressure difference between the first fluid pressure chamber and the second fluid pressure chamber; and a return passage connected to the flow-amount control valve, the return passage being configured to circulate a part of the working fluid discharged from the pump chambers through the suction passage.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

[FIG. 1] FIG. 1 is a hydraulic circuit diagram of a variable displacement vane pump according to an embodiment of the present invention.

[FIG. 2A] FIG. 2A is a graph showing a flow amount characteristic of the variable displacement vane pump according to the embodiment of the present invention and is a diagram showing a case in which a flow amount required for operation of a variable control valve is less than a cracking flow amount of a flow-amount control valve.

[FIG. 2B] FIG. 2B is a graph showing the flow amount characteristic of the variable displacement vane pump according to the embodiment of the present invention and is a diagram showing a case in which the flow amount required for operation of the variable control valve is greater than a maximum flow amount of the flow-amount control valve.

[FIG. 2C] FIG. 2C is a graph showing the flow amount characteristic of the variable displacement vane pump according to the embodiment of the present invention and is a diagram showing a case in which the flow amount required for operation of the variable control valve is greater than the cracking flow amount of the flow-amount control valve, but is less than the maximum flow amount of the flow-amount control valve.

[FIG. 3] FIG. 3 is a hydraulic circuit diagram of a variable displacement vane pump according to a comparative example of the present invention.

[FIG. 4A] FIG. 4A is a graph showing a flow amount characteristic of the variable displacement vane pump according to the comparative example of the present invention and is a diagram showing a case in which the flow amount required for operation of the variable control valve is less than a flow amount controlled by a flow-amount control valve.

[FIG. 4B] FIG. 4B is a graph showing the flow amount characteristic of the variable displacement vane pump according to the comparative example of the present invention and is a diagram showing a case in which the flow amount required for operation of the variable control valve is greater than the flow amount controlled by the flow-amount control valve.

DESCRIPTION OF EMBODIMENTS

[0010] A variable displacement vane pump 100 according to an embodiment of the present invention will be described below with reference to the drawings.

[0011] The variable displacement vane pump 100 (hereinafter, simply referred to as "vane pump ") is used as a hydraulic source for a hydraulic apparatus mounted on a vehicle, such as, for example, a power steering apparatus, a transmission, and the like.

[0012] As shown in FIG. 1, the vane pump 100 includes a pump cartridge 101 that discharges working oil (working fluid), a flow-amount control valve 102 that controls the flow amount of the working oil that is discharged from the pump cartridge 101 through a discharge passage 41 and supplied to a hydraulic apparatus 18, and a variable control valve 103 that controls the flow amount of the working oil that is discharged from the pump cartridge 101.

[0013] In addition, the vane pump 100 further includes a control orifice 104 that is provided in the discharge passage 41 and serves as a control restrictor for imparting resistance to a flow of the working oil discharged from the pump cartridge 101 and a variable orifice 105 that serves as a variable restrictor for imparting resistance to a flow of the working oil that has passed through the control orifice 104.

[0014] In the pump cartridge 101, motive power from an engine (not shown) as a motive-power source is transmitted to an end portion of a driving shaft 1, and a rotor 2 linked to the driving shaft 1 is rotated. The rotor 2 is rotated in the clockwise direction in FIG. 1.

[0015] The pump cartridge 101 includes a plurality of vanes 3 that are provided so as to be able to reciprocate in the radial direction relative to the rotor 2, a cam ring 4 having an inner circumferential surface on which tip ends of the vanes 3 slide by rotation of the rotor 2, and an annular adapter ring 5 that is provided so as to surround the cam ring 4.

[0016] A plurality of pump chambers 6 are defined within the cam ring 4 by an outer circumferential surface of the rotor 2, the inner circumferential surface of the cam ring 4, and pairs of adjacent vanes 3.

[0017] In the pump cartridge 101, as the rotor 2 is rotated, the working oil is sucked into the pump chambers 6 through a suction passage 40 from a tank 17 in a suction region at which the volumes of the pump chambers 6 are expanded, and the working oil is discharged from the pump chambers 6 through the discharge passage 41 in a discharge region at which the volumes of the pump chambers 6 are contracted.

[0018] A support pin 10 for supporting the cam ring 4 is provided on an inner circumferential surface of the adapter ring 5. The cam ring 4 swings around inside the adapter ring 5 about the support pin 10 as a supporting point, and thereby, the cam ring 4 is made eccentric with respect to the center of the rotor 2. As described above, the support pin 10 is the supporting point for the swinging of the cam ring 4.

[0019] At a position axisymmetric to the support pin 10 with respect to the driving shaft 1 in the inner circumferential surface of the adapter ring 5, a seal member 11, which is in sliding contact with an outer circumferential surface of the cam ring 4 when the cam ring 4 swings around, is fitted.

[0020] As described above, in a space between the outer circumferential surface of the cam ring 4 and the inner circumferential surface of the adapter ring 5, which is an outer-circumferential accommodating space on the outer side of the cam ring 4, a first fluid pressure chamber 15 and a second fluid pressure chamber 16 are defined by the support pin 10 and the seal member 11.

[0021] A first fluid pressure passage 47 of the variable control valve 103, which will be described later, is connected to the first fluid pressure chamber 15, and the working oil is guided through the first fluid pressure passage 47. A second fluid pressure passage 48 of the variable control valve 103, which will be described later, is connected to the second fluid pressure chamber 16. A part of the working oil that has been discharged from the pump chambers 6 is guided to the second fluid pressure chamber 16 through a restricting passage 50 provided with an orifice 106.

[0022] The cam ring 4 swings around the support pin

10 by pressure difference of the working oil between the first fluid pressure chamber 15 and the second fluid pressure chamber 16. As the cam ring 4 swings around the support pin 10, the amount of eccentricity of the cam ring 4 with respect to the rotor 2 is changed, and the discharge capacity of the pump chambers 6 is changed. When the pressure in the first fluid pressure chamber 15 is greater than the pressure in the second fluid pressure chamber 16, the amount of eccentricity of the cam ring 4 with respect to the rotor 2 is reduced, and the discharge capacity of the pump chambers 6 is reduced. In contrast, when the pressure in the second fluid pressure chamber 16 is greater than the pressure in the first fluid pressure chamber 15, the amount of eccentricity of the cam ring 4 with respect to the rotor 2 is increased, and the discharge capacity of the pump chambers 6 is increased. As described above, in the vane pump 100, by the pressure difference between the first fluid pressure chamber 15 and the second fluid pressure chamber 16, the amount of eccentricity of the cam ring 4 with respect to the rotor 2 is changed, and the discharge capacity of the pump chambers 6 is changed.

[0023] A return passage 42 that is in communication with the suction passage 40 is connected to the flow-amount control valve 102. A part of the working oil that has been discharged from the pump cartridge 101 is guided to the suction passage 40 through the flow-amount control valve 102 and the return passage 42. The flow-amount control valve 102 has a first spool 20 that moves in response to an upstream-downstream differential pressure between upstream and downstream of the control orifice 104 that imparts resistance to the flow of the working oil that has been discharged from the pump chambers 6. The first spool 20 is inserted into a first-spool accommodating portion 21 in a freely slidable manner. The first spool 20 has a first land portion 20A and a second land portion 20B that are in sliding contact with an inner circumference of the first-spool accommodating portion 21. A first circular groove 20C that opens to an outer circumferential surface of the first spool 20 is formed between the first land portion 20A and the second land portion 20B.

[0024] A first pressure chamber 22 is defined between the first land portion 20A of the first spool 20 and the one end portion of the first-spool accommodating portion 21. A second pressure chamber 23 is defined between the second land portion 20B of the first spool 20 and the other end portion of the first-spool accommodating portion 21. A first control passage 43 that is in communication with the discharge passage 41 at the upstream side of the control orifice 104 is connected to the first pressure chamber 22, and the working oil is guided to the first pressure chamber 22 from the upstream side of the control orifice 104. A second control passage 44 that is in communication with the discharge passage 41 at the downstream side of the control orifice 104 is connected to the second pressure chamber 23, and the working oil that has passed through the control orifice 104 is guided from the downstream side thereof to the second pressure chamber 23. As described above, while the working oil that has been discharged from the pump chambers 6 is guided directly to the first pressure chamber 22, the working oil that has been depressurized by passing through the control orifice 104 is guided to the second pressure chamber 23.

[0025] In the second pressure chamber 23, a first spring 24 serving as a biasing member for biasing the first spool 20 in the direction in which the volume of the second pressure chamber 23 is increased is accommodated. Therefore, the first spool 20 is located at a position where the load based on the upstream-downstream differential pressure of the control orifice 104 and the biasing force exerted by the first spring 24 are balanced.

[0026] A return port 25 that guides the working oil from the first pressure chamber 22 to the return passage 42 is provided on the first-spool accommodating portion 21. In a state in which the upstream-downstream differential pressure of the control orifice 104 is small and the first spring 24 is extended, as shown in FIG. 1, the return port 25 is in a state closed by the first land portion 20A of the first spool 20. As the upstream-downstream differential pressure of the control orifice 104 is increased and the first spool 20 moves against the biasing force exerted by the first spring 24, the return port 25 is opened.

[0027] On the inner circumference of the first-spool accommodating portion 21, a recessed opposing port 26 is formed at a position opposite to the return port 25, in other words, at a position symmetrical to the return port 25 with respect to the axis of the first-spool accommodating portion 21. The working oil that has flown into the opposing port 26 from the first pressure chamber 22 is guided to the return port 25 through the first circular groove 20C. By providing the opposing port 26 on the first-spool accommodating portion 21, the pressure balance acting on the first spool 20 is improved, and the sliding property of the first spool 20 against the first-spool accommodating portion 21 is improved.

[0028] When the rotation speed of an engine, in other words, the pump rotation speed that is the rotation speed of the rotor 2 is low, the upstream-downstream differential pressure of the control orifice 104 is small, and the state in which the return port 25 is closed is achieved. Thus, the working oil is not guided to the return passage 42.

[0029] As the pump rotation speed is increased, the upstream-downstream differential pressure of the control orifice 104 reaches a predetermined value at which the first spool 20 of the flow-amount control valve 102 moves against the biasing force exerted by the first spring 24 and the return port 25 is opened. When the upstream-downstream differential pressure of the control orifice 104 reaches the predetermined value at which the return port 25 is opened, in accordance with an opening area of the return port 25, a part of the working oil that has been discharged from the pump cartridge 101 is guided to the suction passage 40 through the first pressure chamber 22, the return port 25, and the return passage 42. By operation of the flow-amount control valve 102 as described above, a part of the working oil discharged from the pump cartridge 101 is guided to the return passage 42, and the flow amount of the working oil guided to the hydraulic apparatus 18 is controlled so as to achieve a predetermined flow amount. In addition, resistance is imparted to the flow of the working oil passing through the return port 25 in accordance with the opening area of the return port 25. Thus, flowing speed of the working oil guided to the return passage 42 is increased, negative pressure is caused in the return passage 42. Because negative pressure is caused in this way, the working oil is sucked from the tank 17 more effectively, and the working oil can be supercharged to a suction port through the suction passage 40 more effectively. Therefore, occurrence of cavitation in the pump chambers 6 is suppressed.

[0030] The variable orifice 105 is provided at the downstream side of the control orifice 104 in the discharge passage 41. More specifically, the variable orifice 105 is provided on the discharge passage 41 at the downstream side of a location at which the second control passage 44 that is connected to the second pressure chamber 23 of the flow-amount control valve 102 communicates with the discharge passage 41. By providing the variable orifice 105 as described above, the working oil to which resistance has been imparted by the variable orifice 105 is prevented from being guided to the second pressure chamber 23 of the flow-amount control valve 102. The variable orifice 105 is a variable restrictor capable of changing resistance to be imparted to the flow of the working oil passing therethrough by changing its opening area by controlling amount of current flowing to a solenoid (not shown).

[0031] The variable control valve 103 has a second spool 30 that moves in response to the upstream-downstream differential pressure between upstream and downstream of the variable orifice 105 that is generated by guiding, to the variable orifice 105, the working oil that has passed through the control orifice 104. The second spool 30 has a third land portion 30A and a fourth land portion 30B that are in sliding contact with an inner circumference of a second spool accommodating portion 31. A second circular groove 30C that opens to an outer circumferential surface of the second spool 30 is formed between the third land portion 30A and the fourth land portion 30B.

[0032] A third pressure chamber 32 is defined between the third land portion 30A of the second spool 30 and the one end portion of the second spool accommodating portion 31. A fourth pressure chamber 33 is defined between the fourth land portion 30B of the second spool 30 and the other end portion of the second spool accommodating portion 31. A third control passage 45 that is in communication with the discharge passage 41 at a location between the control orifice 104 and the variable orifice 105 is connected to the third pressure chamber 32, and the working oil is guided to the third pressure chamber 32 from the upstream side of the variable orifice 105. A fourth control passage 46 that is in communication with the discharge passage 41 at the downstream side of the variable orifice 105 is connected to the fourth pressure chamber 33, and the working oil is guided to the fourth pressure chamber 33 from the downstream side of the variable orifice 105. As described above, while the working oil that has been discharged from the pump chambers 6 and depressurized by the control orifice 104 is guided to the third pressure chamber 32, the working oil that has been depressurized by passing through the control orifice 104 and the variable orifice 105 is guided to the fourth pressure chamber 33.

[0033] In the fourth pressure chamber 33, a second spring 34 serving as a biasing member for biasing the second spool 30 in the direction in which the volume of the fourth pressure chamber 33 is increased is accommodated. Therefore, the second spool 30 is located at a position where the load based on the upstream-downstream differential pressure of the variable orifice 105 and the biasing force exerted by the second spring 34 are balanced.

[0034] The first fluid pressure passage 47 and the second fluid pressure passage 48 that are in communication with the first fluid pressure chamber 15 and the second fluid pressure chamber 16, respectively, and a drain passage 49 that is in communication with the second circular groove 30C and the suction passage 40 are connected to the second spool accommodating portion 31.

[0035] When the pump rotation speed is low, because the upstream-downstream differential pressure of the variable orifice 105 is small, the second spring 34 is extended, and thereby, the first fluid pressure passage 47 is communicated with the second circular groove 30C and the second fluid pressure passage 48 is closed by the fourth land portion 30B of the second spool 30. In other words, the first fluid pressure chamber 15 is communicated with the drain passage 49 through the second circular groove 30C, and the communication between the second fluid pressure chamber 16 and the second circular groove 30C is closed. The working oil that has been discharged from the pump cartridge 101 is constantly guided to the second fluid pressure chamber 16 through the restricting passage 50. With such a configuration, as shown in FIG. 1, the cam ring 4 is brought into contact with the inner circumferential surface of the adapter ring 5 by the pressure in the second fluid pressure chamber 16, and thereby, the amount of eccentricity of the cam ring 4 with respect to the rotor 2 is maximized.

[0036] As the pump rotation speed is increased and the upstream-downstream differential pressure of the variable orifice 105 is increased, the second spool 30 moves against the biasing force exerted by the second spring 34, and thereby the third pressure chamber 32 is communicated with the first fluid pressure passage 47 and the second circular groove 30C is communicated with the second fluid pressure passage 48.

[0037] As the pump rotation speed is increased further, the opening area of the first fluid pressure passage 47 to the third pressure chamber 32 is increased, and the opening area of the second fluid pressure passage 48 to the second circular groove 30C is increased. The working oil in the third pressure chamber 32 is supplied to the first fluid pressure chamber 15 through the first fluid pressure passage 47, and the working oil in the second fluid pressure chamber 16 is discharged to the tank 17 through the second fluid pressure passage 48, the second circular groove 30C, and the drain passage 49. With such a configuration, the cam ring 4 moves such that the amount of eccentricity with respect to the rotor 2 is reduced in response to the pressure difference between the first fluid pressure chamber 15 and the second fluid pressure chamber 16.

[0038] As the pressure difference between the first fluid pressure chamber 15 and the second fluid pressure chamber 16 is increased in response to the increase in the pump rotation speed, the cam ring 4 is brought into contact with the inner circumferential surface of the adapter ring 5 and the amount of eccentricity of the cam ring 4 is minimized, and thereby, the discharge capacity of the pump chambers 6 becomes a minimum discharge capacity. As described above, because the variable control valve 103 is operated in accordance with the upstream-downstream differential pressure of the variable orifice 105, even when the pump rotation speed is increased, the discharge flow amount of the pump cartridge 101 is controlled so as to be substantially constant.

[0039] The upstream-downstream differential pressure of the variable orifice 105 is generated at amount in accordance with the opening area of the variable orifice 105 that is controlled by the amount of current flow to the solenoid and the passing flow amount passing through the variable orifice 105. Therefore, by controlling the opening area of the variable orifice 105 by the solenoid, it is possible to arbitrarily set the passing flow amount of the variable orifice 105 that generates the upstream-downstream differential pressure for operating the variable control valve 103.

[0040] Next, operation of the vane pump 100 will be described with reference to FIGs. 2 to 4. FIG. 2 is a graph showing the relationship between the pump rotation speed and the flow amount of the working oil of the vane pump 100. FIG. 3 is a hydraulic circuit diagram of a vane pump 200 as a comparative example, FIG. 4 is a graph showing the relationship between the pump rotation speed and the flow amount of the working oil of the vane pump 200. In FIGs. 2 and 4, a flow amount Q shown with a solid line is a supply flow amount of the working oil supplied to the hydraulic apparatus 18, and a flow amount Q1 shown with a broken line is a discharge flow amount of the working oil discharged from the pump cartridge 101. In addition, in FIGs. 2 and 4, a flow amount Q2 shown with a one-dot chain line is a flow amount of the working oil controlled by the flow-amount control valve 102. In addition, in FIGs. 2 and 4, a flow amount Q3 is a passing flow amount of the variable orifice 105 required to generate the upstream-downstream differential pressure for operating the variable control valve 103.

[0041] In the following description, the passing flow amount of the control orifice 104 required to generate the upstream-downstream differential pressure for operating the flow-amount control valve 102 is referred to as "the cracking flow amount", the flow amount Q2 of the working oil controlled by the flow-amount control valve 102 is referred to as "the control flow amount Q2", and the control flow amount of the flow-amount control valve 102 at the pump maximum rotation speed N1 used with the vane pump 100 is referred to as "the maximum control flow amount". In addition, the passing flow amount Q3 of the variable orifice 105 required to generate the upstream-downstream differential pressure for operating the variable control valve 103 is referred to as "the variable-control-setting flow amount Q3", and the discharge flow amount of the pump cartridge 101 that is kept constant by the variable control valve 103 is referred to as "the constant discharge flow amount".

[0042] The variable-control-setting flow amount Q3 is set by controlling the opening area of the variable orifice 105 by changing the amount of current flow to the solenoid. For example, in a case where the opening area of the variable orifice 105 is set, by flow of the working oil passing through the variable orifice 105 at the flow amount greater than the cracking flow amount, such that the upstream-downstream differential pressure for operating the variable control valve 103 is generated, the variable-control-setting flow amount Q3 becomes greater than the cracking flow amount of the flow-amount control valve 102.

[0043] In addition, in a case where the opening area of the variable orifice 105 is set, by flow of the working oil passing through the variable orifice 105 at the flow amount smaller than the cracking flow amount, such that the upstream-downstream differential pressure for operating the variable control valve 103 is generated, the variable-control-setting flow amount Q3 becomes smaller than the cracking flow amount of the flow-amount control valve 102.

[0044] For ease of understanding the vane pump 100, the vane pump 200 as a comparative example will be described with reference to FIGs. 3 and 4.

[0045] As shown in FIG. 3, the vane pump 200 includes the variable control valve 103 that is operated by the upstream-downstream differential pressure of the variable orifice 105 provided on the discharge passage 41 and the flow-amount control valve 102 that is operated by the upstream-downstream differential pressure of the control orifice 104 provided on the discharge passage 41 at the downstream side of the variable orifice 105. In other words, in the vane pump 200, the flow-amount control valve 102 is provided at the downstream side of the variable control valve 103.

[0046] FIG. 4(a) is a diagram showing the relationship between the pump rotation speed and the flow amount in a case where the variable-control-setting flow amount Q3 is set so as to be smaller than the cracking flow amount of the flow-amount control valve 102. FIG. 4(b) is a diagram showing the relationship between the pump rotation speed and the flow amount in a case where the variable-control-setting flow amount Q3 is set so as to be greater than the maximum control flow amount of the flow-amount control valve 102.

[0047] With the vane pump 200, as shown in FIG. 4(a), in a case where the variable-control-setting flow amount Q3 is set so as to be smaller than the cracking flow amount of the flow-amount control valve 102, the discharge flow amount of the working oil from the pump cartridge 101 reaches the variable-control-setting flow amount Q3 in response to the increase in the pump rotation speed, and thereby, the variable control valve 103 is operated. In other words, as the pump rotation speed is increased, before the upstream-downstream differential pressure of the control orifice 104 reaches a predetermined differential pressure at which the flow-amount control valve 102 is operated, the upstream-downstream differential pressure of the variable orifice 105 reaches a predetermined differential pressure at which the variable control valve 103 is operated, and thereby, the variable control valve 103 is operated. Thus, the discharge flow amount from the pump cartridge 101 is controlled to be constant so as to keep the discharge flow amount. In other words, as shown in FIG. 4(a), with the vane pump 200, when the upstream-downstream differential pressure of the variable orifice 105 reaches a predetermined value, the flow amount discharged from the pump cartridge 101 is controlled as the constant discharge flow amount so as to keep the variable-control-setting flow amount Q3.

[0048] As described above, when the variable control valve 103 is operated, because the discharge flow amount from the pump cartridge 101 is not increased even when the pump rotation speed is increased, the discharge flow amount does not reach the cracking flow amount of the flow-amount control valve 102. In other words, even in a case where the variable-control-setting flow amount Q3 that is set so as to be smaller than the cracking flow amount of the flow-amount control valve 102 passes through the control orifice 104, the upstream-downstream differential pressure for operating the flow-amount control valve 102 is not generated at the control orifice 104. Thus, as shown in FIG. 4(a), the flow amount of the working oil that has passed through the variable orifice 105 is not controlled by the flow-amount control valve 102, and the working oil whose flow amount is controlled by the variable control valve 103 so as to achieve the variable-control-setting flow amount Q3 is guided to the hydraulic apparatus 18. As described above, in a case where the variable-control-setting flow amount Q3 is set so as to be smaller than the cracking flow amount of the flow-amount control valve 102, because the flow-amount control valve 102 is not operated, the working oil is not guided to the suction passage 40 through the return passage 42.

[0049] As shown in FIG. 4(b), in a case where the variable-control-setting flow amount Q3 is set so as to be higher than the maximum control flow amount of the flow-amount control valve 102, the discharge flow amount from the pump cartridge 101 is increased in response to the increase in the pump rotation speed and reaches the cracking flow amount of the flow-amount control valve 102. Thus, the upstream-downstream differential pressure of the control orifice 104 reaches a predetermined value and the flow-amount control valve 102 is operated, and thereby, the return port 25 is opened. The flow amount of the working oil that has been discharged from the pump cartridge 101 is controlled by the flow-amount control valve 102 so as to achieve the control flow amount Q2 and the working oil is guided to the hydraulic apparatus 18. In this case, because the variable control valve 103 is in a non-operating state, the cam ring 4 is in the maximum eccentric state and the discharge capacity of the pump chambers 6 is maintained in the maximum state. Therefore, as the pump rotation speed is further increased, the discharge flow amount from the pump cartridge 101 is increased in a manner proportional to the increase in the pump rotation speed. When the discharge flow amount from the pump cartridge 101 is increased and reaches the variable-control-setting flow amount Q3, the upstream-downstream differential pressure of the variable orifice 105 reaches a predetermined value. Thereby, the variable control valve 103 is operated, and as shown in FIG. 4(b), the discharge flow amount from the pump cartridge 101 is controlled so as to achieve the variable-control-setting flow amount Q3 as the constant discharge flow amount.

[0050] As described above, with the vane pump 200, because the variable control valve 103 is provided at the upstream side of the flow-amount control valve 102, as the pump rotation speed is increased, the discharge flow amount from the pump cartridge 101 is controlled by the variable control valve 103 so as to achieve the variable-control-setting flow amount Q3, and so, the discharge flow amount does not exceeds the variable-control-setting flow amount Q3. Therefore, a part of the working oil guided to the flow-amount control valve 102 at the variable-control-setting flow amount Q3 is guided to the suction passage 40 as the returning flow amount. In other words, in the vane pump 200, as shown in FIG. 4(b), the returning flow amount guided to the return passage 42 is a difference between the control flow amount Q2 and the variable-control-setting flow amount Q3 as the constant discharge flow amount.

[0051] In contrast, in the vane pump 100, as shown in FIG. 2(a), in a case where the variable-control-setting flow amount Q3 is set so as to be smaller than the cracking flow amount of the flow-amount control valve 102 by controlling the amount of current flow to the solenoid, similarly to the vane pump 200, the flow-amount control valve 102 is not operated and the working oil is not guided to the suction passage 40 through the return passage 42. In this case, all of the working oil discharged from the pump cartridge 101 is guided to the hydraulic apparatus

18.

[0052] As shown in FIG. 2(b), in a case where the variable-control-setting flow amount Q3 is set so as to be greater than the maximum control flow amount of the flow-amount control valve 102, similarly to the vane pump 200, the discharge flow amount from the pump cartridge 101 of the vane pump 100 is increased in response to the increase in the pump rotation speed and reaches the cracking flow amount of the flow-amount control valve 102. Thereby, the working oil whose flow amount is controlled by the flow-amount control valve 102 so as to achieve the control flow amount Q2 is guide to the hydraulic apparatus 18. In addition, a part of the working oil discharged from the pump cartridge 101 through the return passage 42 is guided to the suction passage 40.

[0053] As described above, in a case where the variable-control-setting flow amount Q3 is set so as to be greater than the maximum control flow amount of the flow-amount control valve 102, because the control flow amount Q2 does not reach the variable-control-setting flow amount Q3 even when the pump rotation speed is increased, the variable control valve 103 is not operated and the cam ring 4 of the pump cartridge 101 is maintained in the maximum eccentric state. Therefore, the discharge capacity of the pump chambers 6 is maintained in the maximum state, and the discharge flow amount from the pump cartridge 101 is increased in a manner proportional to the increase in the pump rotation speed. Therefore, as shown in FIG. 2(b), the difference between the discharge flow amount Q 1 of the pump cartridge 101, in which the discharge capacity of the pump chambers 6 is in the maximum state (the cam ring 4 is in the maximum eccentric state), and the control flow amount Q2 can be used as the returning flow amount.

[0054] FIG. 2(c) is a diagram showing a case in which the variable-control-setting flow amount Q3 is set between the cracking flow amount of the flow-amount control valve 102 and the maximum control flow amount. In this case, until the control flow amount Q2 reaches the variable-control-setting flow amount Q3, the difference between the discharge flow amount Q1 of the pump cartridge 101, in which the discharge capacity of the pump chambers 6 is in the maximum state, and the control flow amount Q2 is guided to the suction passage 40 as the returning flow amount.

[0055] As the pump rotation speed is increased, the control flow amount Q2 reaches the variable-control-setting flow amount Q3, and the upstream-downstream differential pressure of the variable orifice 105 reaches a predetermined value, the variable control valve 103 is operated. Thereby, as shown in FIG. 2(c), even when the pump rotation speed is increased, the discharge flow amount from the pump cartridge 101 is controlled so as to achieve the constant discharge flow amount at which the discharge flow amount becomes constant. Therefore, the working oil is guided to the hydraulic apparatus 18 at the variable-control-setting flow amount Q3, and the difference between the discharge flow amount Q1 as the constant discharge flow amount and the variable-control-setting flow amount Q3 is guided to the return passage 42 as the returning flow amount.

[0056] As described above, with the vane pump 100, because the variable control valve 103 is operated by the working oil whose flow amount is controlled by the flow-amount control valve 102 so as to achieve the control flow amount Q2, the variable control valve 103 is not operated until the control flow amount Q2 reaches the variable-control-setting flow amount Q3, and the amount of eccentricity of the cam ring 4 is maintained in the maximum state. In other words, the discharge capacity of the pump chambers 6 is maintained at the maximum discharge capacity. Thereby, with the vane pump 100, the working oil can be discharged from the pump cartridge 101 at the flow amount equal to or greater than the variable-control-setting flow amount Q3 in response to the increase in the pump rotation speed, and the difference between the discharge flow amount Q1 and the control flow amount Q2 can be guided to the suction passage 40 as the returning flow amount. Therefore, with the vane pump 100, it is possible to secure greater returning flow amount.

[0057] The variable-control-setting flow amount Q3 is set on the basis of, for example, the pump rotation speed.

[0058] The setting shown in FIG. 2(a), in which the variable-control-setting flow amount Q3 is set so as to be smaller than the cracking flow amount of the flow-amount control valve 102, is used when the pump rotation speed is low, for example. By reducing the discharge flow amount from the pump cartridge 101, torque of the vane pump 100 is reduced, and it is possible to improve a fuel consumption efficiency of a vehicle.

[0059] The setting shown in FIG. 2(b), in which the variable-control-setting flow amount Q3 is set so as to be greater than the maximum control flow amount of the flow-amount control valve 102, is used when the pump rotation speed is high, for example. By setting the variable-control-setting flow amount Q3 so as to be greater than the maximum control flow amount of the flow-amount control valve 102, it is possible to secure greater returning flow amount, and so, occurrence of the cavitation can be suppressed when the pump rotation speed is high.

[0060] When the flow amount guided to the hydraulic apparatus 18 reaches the required flow amount in response to the increase in the pump rotation speed, as shown in FIG. 2(c), the variable-control-setting flow amount Q3 may be set between the maximum control flow amount of the flow-amount control valve 102 and the cracking flow amount. By setting the variable-control-setting flow amount Q3 as described above, it is possible to secure greater returning flow amount while supplying a constant flow amount to the hydraulic apparatus 18. Thereby, occurrence of the cavitation is suppressed when the pump rotation speed is high, and it is possible to prevent loss of energy caused by guiding the working oil to the hydraulic apparatus 18 at the flow amount exceeding the required amount and to improve the fuel consumption efficiency.

[0061] The settings of the variable-control-setting flow amount Q3 are not limited to those based on the pump rotation speed, and the setting may be performed on the basis of a driving state of a vehicle, an operating state of the hydraulic apparatus 18, and so forth. For example, even when the pump rotation speed is low, when a gear of a vehicle is shifted, the vane pump 100 may be operated so as to output large torque by setting the variable-control-setting flow amount Q3 so as to be equal to or greater than the maximum control flow amount of the flow-amount control valve 102 and by maintaining the cam ring 4 in the maximum eccentric state.

[0062] According to the embodiment mentioned above, the advantages described below are afforded.

[0063] According to the vane pump 100, a part of the working oil discharged from the pump chambers 6 of the pump cartridge 101 is guided to the return passage 42 by the flow-amount control valve 102, and the flow amount of the working oil is controlled so as to achieve the control flow amount Q2. Thereby, the variable control valve 103 is operated by the working oil whose control flow amount is controlled by the flow-amount control valve 102. When the pump rotation speed is low and the control flow amount Q2 is smaller than the variable-control-setting flow amount Q3, the variable control valve 103 is not operated and the discharge capacity of the pump chambers 6 is maintained in the maximum state. As described above, because the variable control valve 103 is operated by the working fluid whose flow amount is controlled by the control flow amount Q2, it is possible to discharge the working fluid from the pump chambers 6 of the pump cartridge 101 at the flow amount equal to or greater than the variable-control-setting flow amount Q3. Therefore, the difference between the discharge flow amount from the pump chambers 6 that is increased to the variable-control-setting flow amount Q3 or more in response to the increase in the pump rotation speed and the control flow amount Q2 is guided to the return passage 42. Therefore, it is possible to circulate greater amount of the working oil through the return passage 42 and to suppress occurrence of the cavitation.

[0064] In addition, by performing the setting such that the upstream-downstream differential pressure for operating the variable control valve 103 is generated by passing the working fluid through the variable orifice 105 of the vane pump 100 at the flow amount greater than the cracking flow amount, in other words, by setting the variable-control-setting flow amount Q3 so as to be greater than the cracking flow amount of the flow-amount control valve 102, it is possible to operate the flow-amount control valve 102 before the variable control valve 103 in response to the increase in the discharge flow amount Q1 of the pump cartridge 101 due to the increase in the pump rotation speed. Thereby, it is possible to operate the variable control valve 103 with the working fluid whose flow amount is controlled so as to achieve the control flow amount Q2. Therefore, it is possible to secure greater returning flow amount by discharging the working fluid from the pump chambers 6 of the pump cartridge 101 at the flow amount equal to or greater than the variable-control-setting flow amount Q3, and to prevent occurrence of the cavitation.

[0065] Embodiments of this invention were described above, but the above embodiments are merely examples of applications of this invention, and the technical scope of this invention is not limited to the specific constitutions of the above embodiments.

[0066] In the above-mentioned embodiment, the amount of eccentricity of the cam ring 4 with respect to the rotor 2 is controlled by the pressure difference between the pressure of the working oil guided to the first fluid pressure chamber 15 and the pressure of the working oil guided to the second fluid pressure chamber 16. In contrast, it may be possible to provide a biasing member (for example, a coil spring) that biases the cam ring 4 in the direction in which the amount of eccentricity is increased. In this case, the amount of eccentricity of the cam ring 4 is controlled by the biasing force exerted by the biasing member and the pressure difference between the first fluid pressure chamber 15 and the second fluid pressure chamber 16.

[0067] This application claims priority based on Japanese Patent Application No.2015-90303 filed with the Japan Patent Office on April 27, 2015, the entire contents of which are incorporated into this specification.

Claims

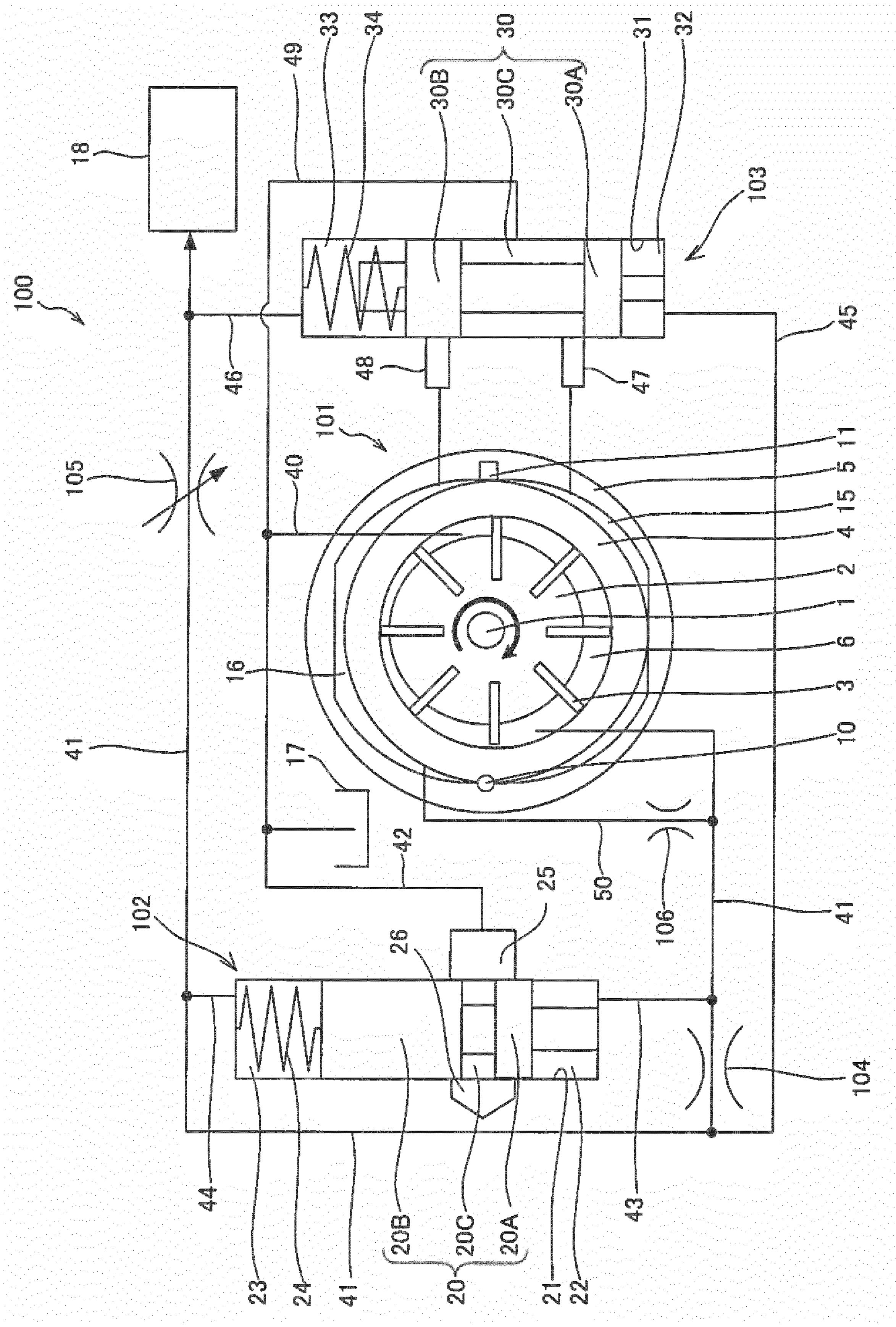
1. A variable displacement vane pump comprising:

a rotor linked to a driving shaft;
a plurality of vanes provided so as to be able to reciprocate in a radial direction relative to the rotor;
a cam ring having an inner circumferential surface on which tip ends of the vanes slide by rotation of the rotor;
pump chambers defined by the rotor, the cam ring, and pairs of the adjacent vanes;
a suction passage configured to guide working fluid to the pump chambers;
a first fluid pressure chamber and a second fluid pressure chamber defined in an outer-circumferential accommodating space on outer side of the cam ring, the first fluid pressure chamber and the second fluid pressure chamber being configured to make the cam ring eccentric with respect to the rotor by pressure difference between the first fluid pressure chamber and the second fluid pressure chamber;
a control restrictor configured to impart resistance to a flow of the working fluid discharged from the pump chambers;

a flow-amount control valve operated in accordance with an upstream-downstream differential pressure of the control restrictor, the flow-amount control valve being configured to control flow amount of the working fluid discharged from the pump chambers;
a variable control valve operated by the working fluid that has passed through the control restrictor, the variable control valve being configured to control an amount of eccentricity of the cam ring with respect to the rotor by controlling pressure difference between the first fluid pressure chamber and the second fluid pressure chamber; and
a return passage connected to the flow-amount control valve, the return passage being configured to circulate a part of the working fluid discharged from the pump chambers through the suction passage.

2. The variable displacement vane pump according to claim 1, further comprising
a variable restrictor capable of changing resistance imparted to a flow of the working fluid that has passed through the control restrictor, wherein
the variable control valve is operated in accordance with the upstream-downstream differential pressure of the variable restrictor.

3. The variable displacement vane pump according to claim 2, wherein
an opening area of the variable restrictor is set such that the upstream-downstream differential pressure for operating the variable control valve is generated by allowing the working fluid to pass through the variable restrictor at a flow amount that is greater than a passing flow amount of the control restrictor for generating the upstream-downstream differential pressure for operating the flow-amount control valve.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20B
20C
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26
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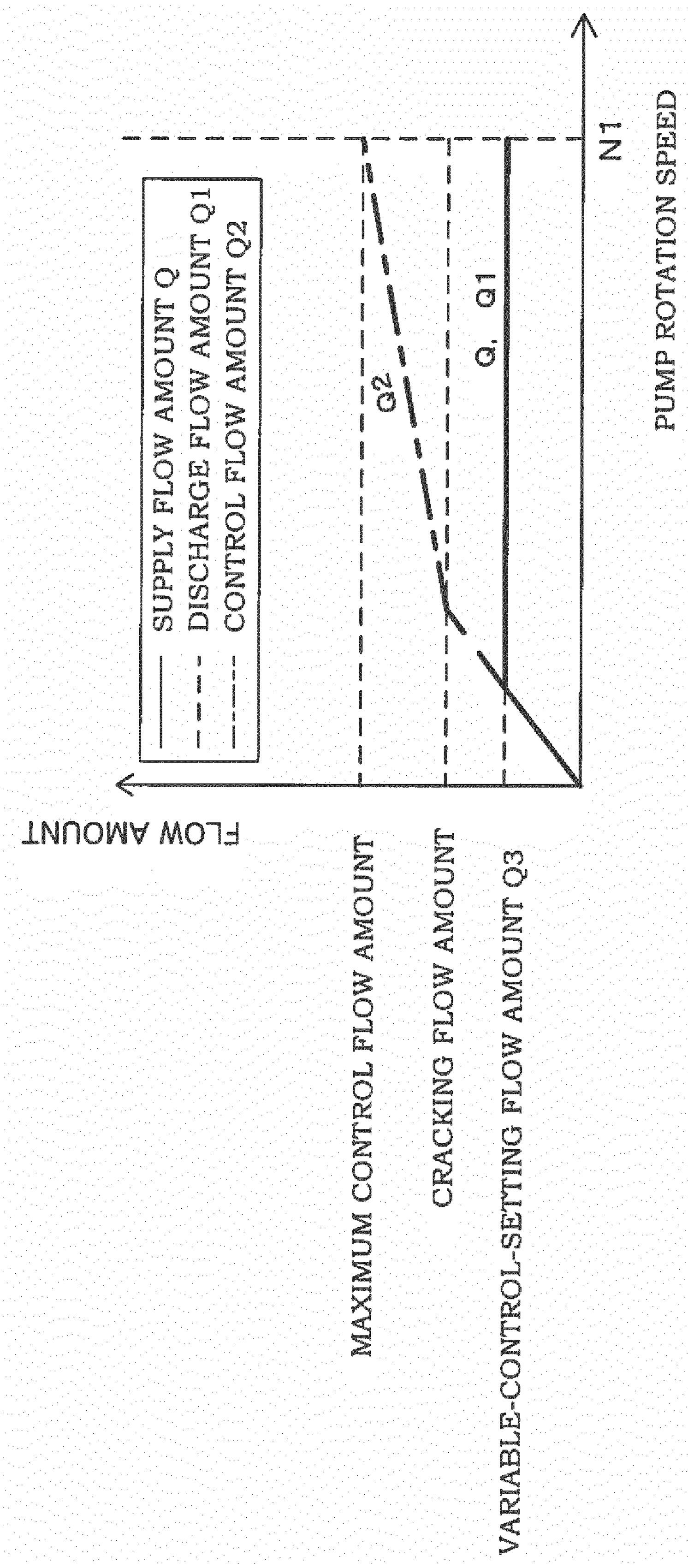
FIG. 1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Q2
Q, Q1
N1
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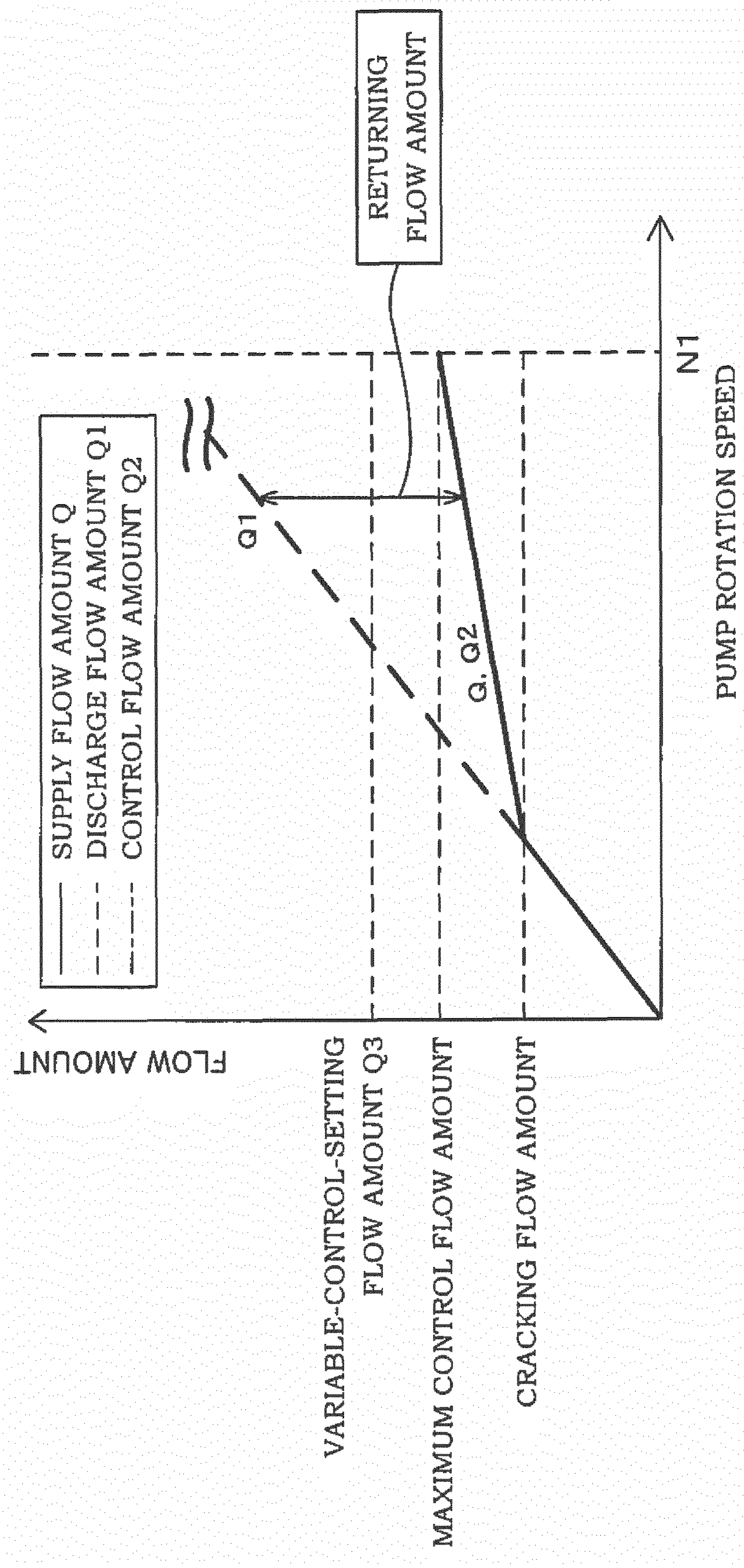
FLOW AMOUNT
MAXIMUM CONTROL FLOW AMOUNT
CRACKING FLOW AMOUNT
VARIABLE-CONTROL-SETTING FLOW AMOUNT Q3

FIG.2A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Q1
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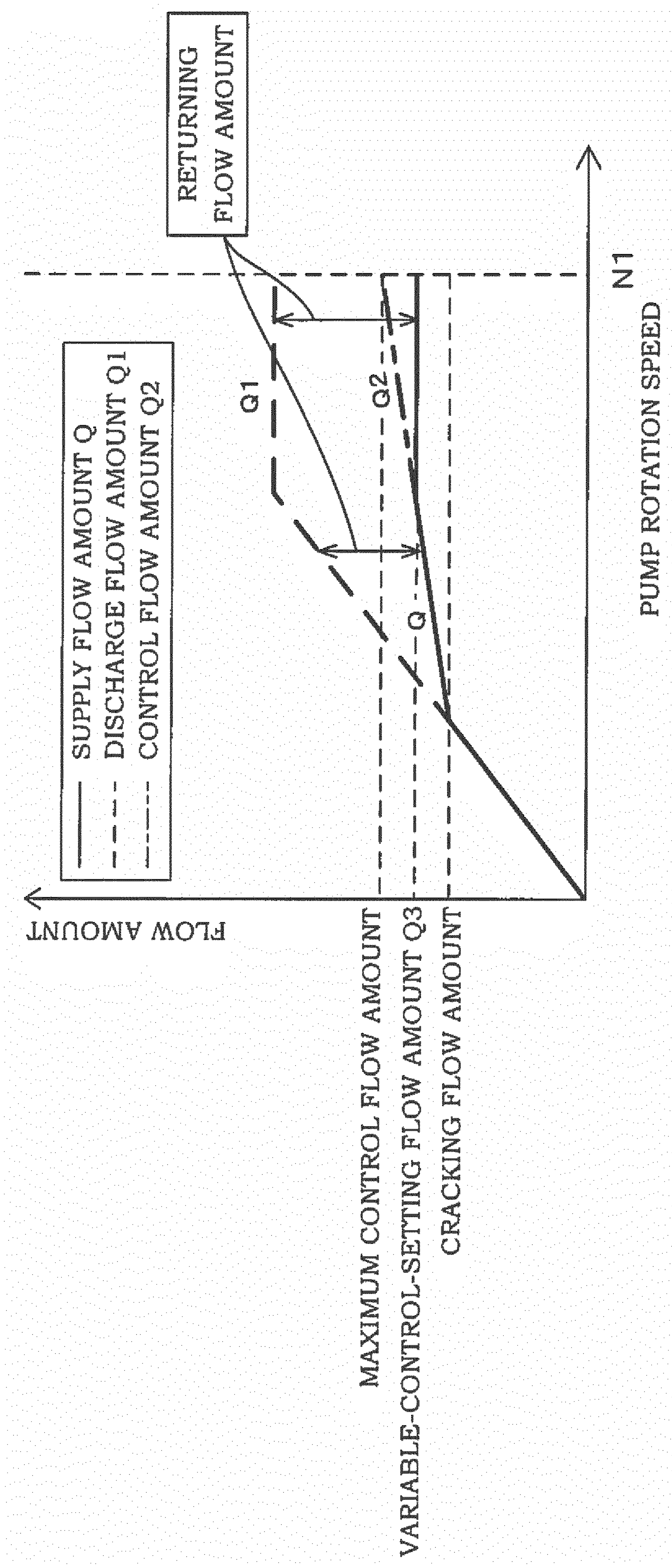
FLOW AMOUNT Q3
MAXIMUM CONTROL FLOW AMOUNT
CRACKING FLOW AMOUNT
PUMP ROTATION SPEED

FIG.2B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DISCHARGE FLOW AMOUNT Q1
CONTROL FLOW AMOUNT Q2
Q1
Q2
Q
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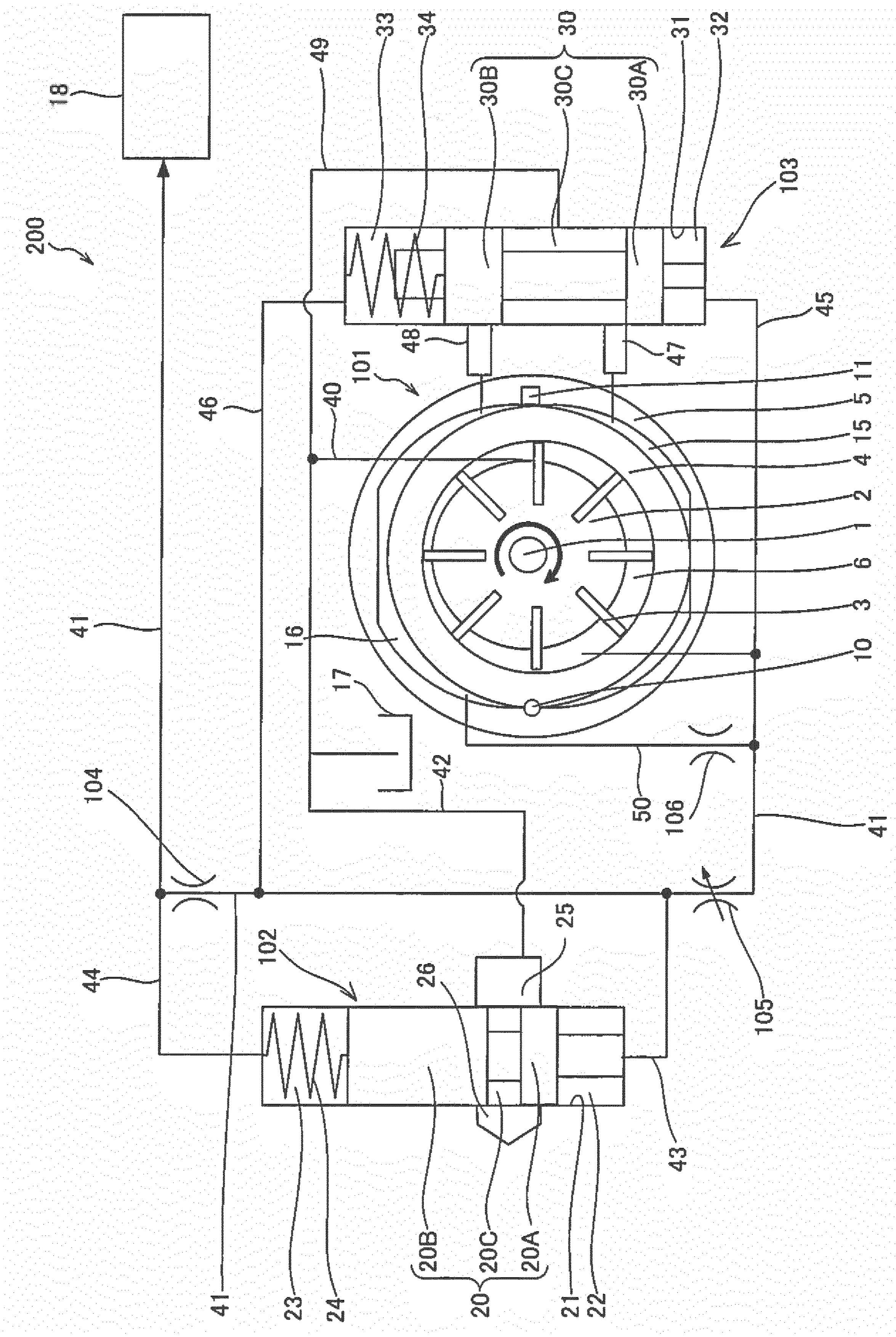
PUMP ROTATION SPEED
FLOW AMOUNT
MAXIMUM CONTROL FLOW AMOUNT
VARIABLE-CONTROL-SETTING FLOW AMOUNT Q3
CRACKING FLOW AMOUNT

FIG.2C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102
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34
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30C
30A
30
31
32
103
45
47
48
101
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15
4
2
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6
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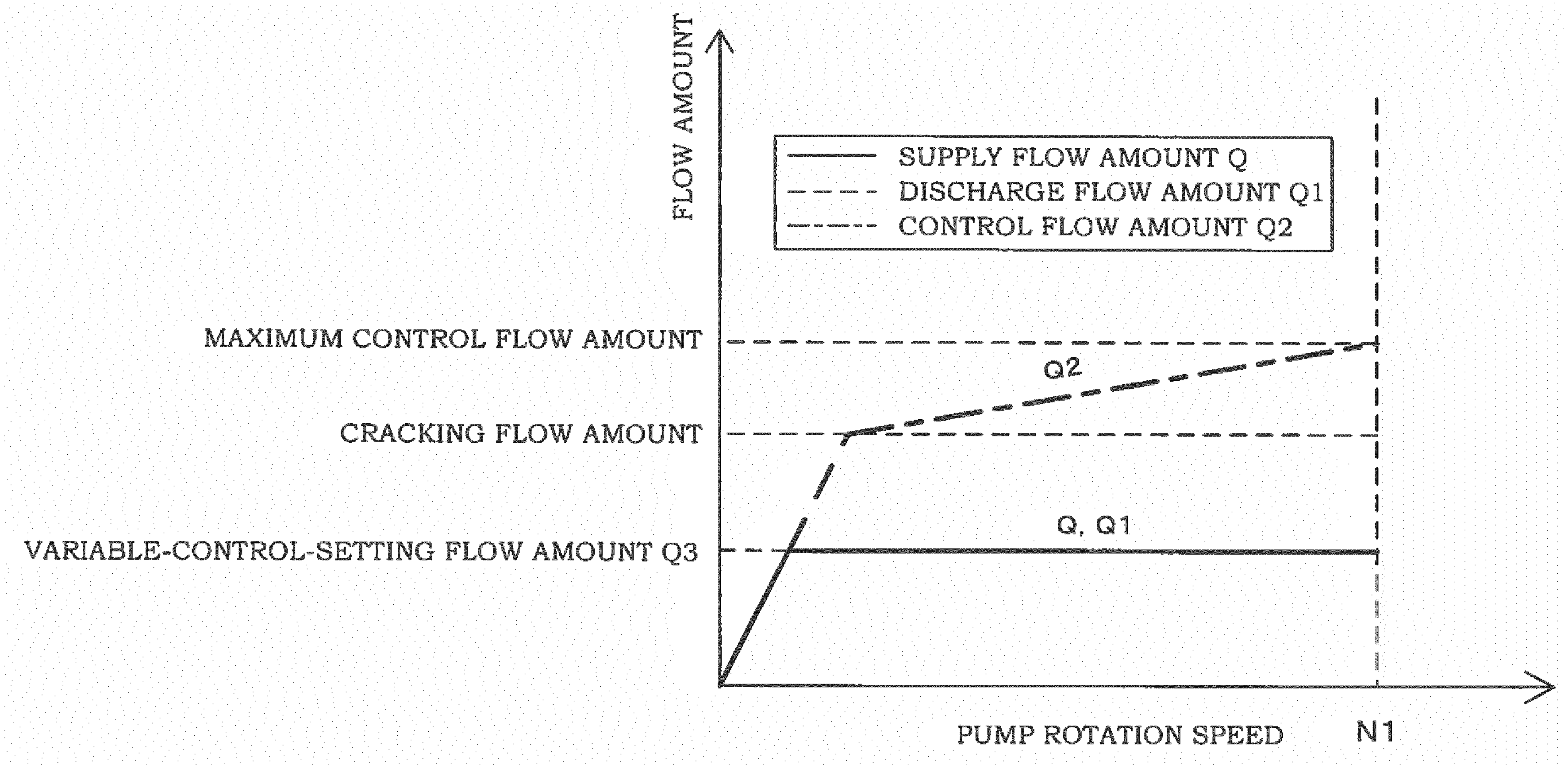
10
16
17
42
50
106
41

FIG.3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MAXIMUM CONTROL FLOW AMOUNT
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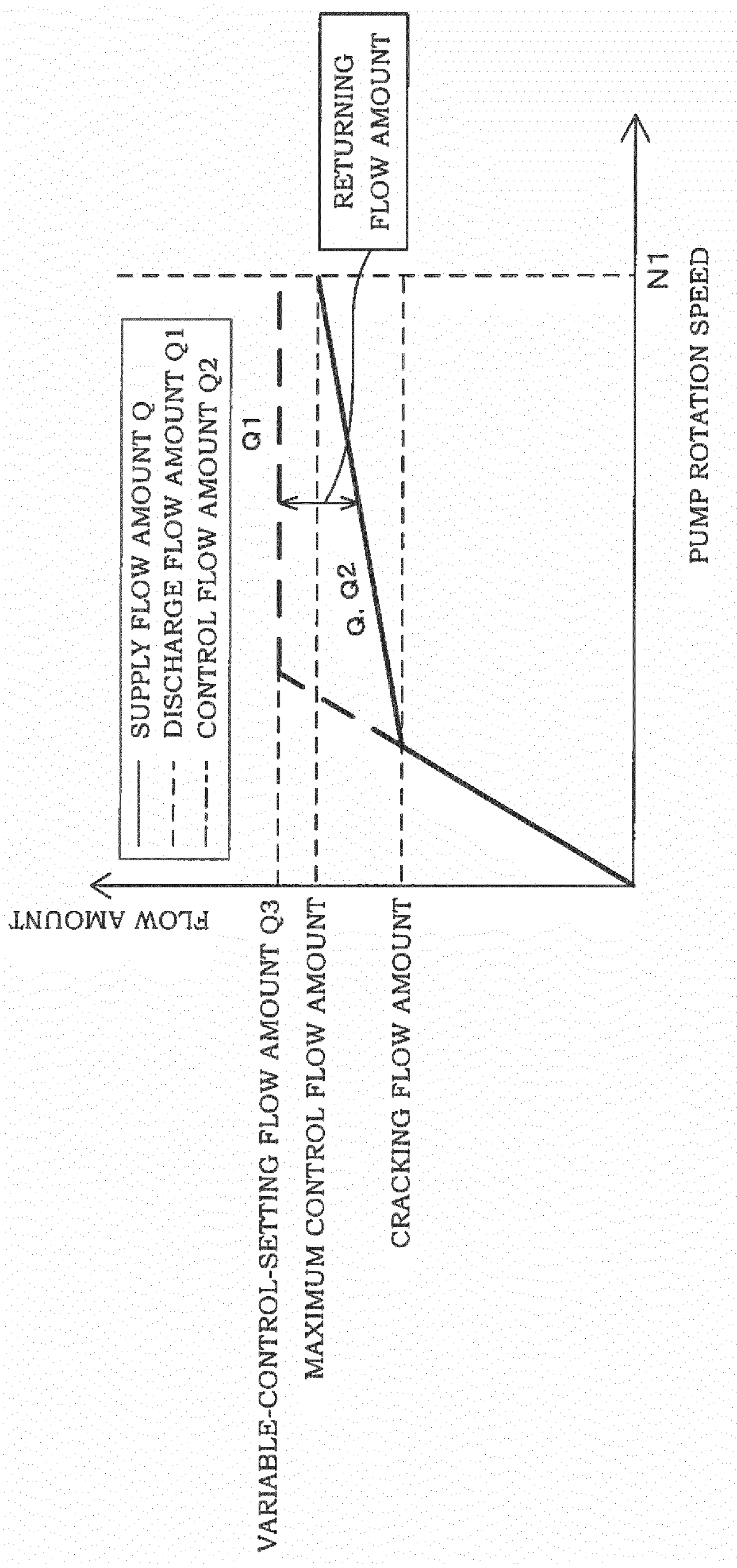
VARIABLE-CONTROL-SETTING FLOW AMOUNT Q3
PUMP ROTATION SPEED
N1

FIG.4A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DISCHARGE FLOW AMOUNT Q1
CONTROL FLOW AMOUNT Q2
Q1
Q, Q2
N1
PUMP ROTATION SPEED
FLOW AMOUNT
VARIABLE-CONTROL-SETTING FLOW AMOUNT Q3
MAXIMUM CONTROL FLOW AMOUNT
CRACKING FLOW AMOUNT

FIG.4B

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/062416

A. CLASSIFICATION OF SUBJECT MATTER
F04C14/24(2006.01)i, *F04C2/344*(2006.01)i, *F04C14/22*(2006.01)i, *F04C14/26*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04C14/24, F04C2/344, F04C14/22, F04C14/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2002-276565 A (Showa Corp.), 25 September 2002 (25.09.2002), paragraphs [0021] to [0058]; fig. 1 to 5 (Family: none)	1-3
A	JP 2009-264192 A (Kayaba Industry Co., Ltd.), 12 November 2009 (12.11.2009), paragraphs [0010] to [0068]; fig. 1 to 6 & US 2009/0269233 A1 paragraphs [0018] to [0078]; fig. 1 to 6	1-3
A	JP 56-148693 A (Mitsubishi Motors Corp.), 18 November 1981 (18.11.1981), page 2, upper right column, line 13 to lower left column, line 13; fig. 1 (Family: none)	1-3

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 July 2016 (06.07.16)	19 July 2016 (19.07.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/062416

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 26145/1983(Laid-open No. 131989/1984) (Aisin Seiki Co., Ltd.), 04 September 1984 (04.09.1984), specification, page 6, line 13 to page 8, line 11; fig. 1 to 4 (Family: none)	1-3
A	US 2005/0100447 A1 (DESAI, Mihir C.), 12 May 2005 (12.05.2005), entire text; all drawings & EP 1531271 A2	1-3

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2009275537 A **[0003] [0004] [0005]**
- JP 2015090303 A **[0067]**