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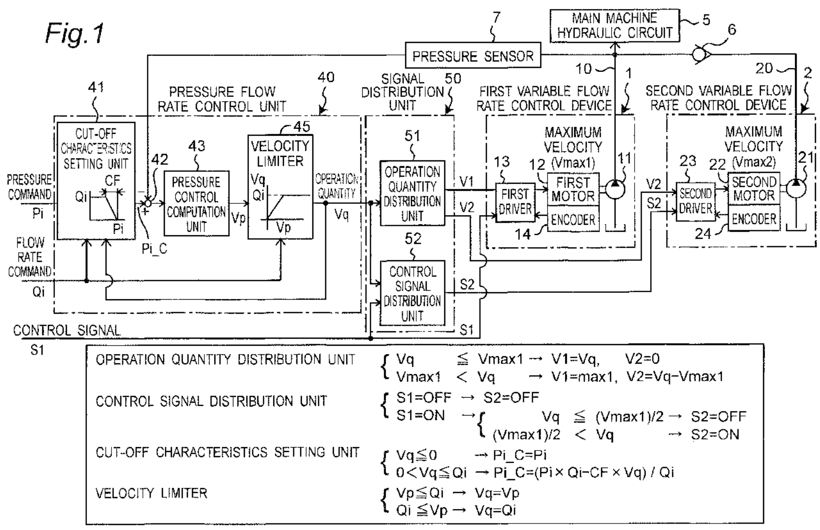
(54) CONFLUENT CONTROL SYSTEM

(57) There is provided a confluence control system capable of switching smooth transfer between single drive and confluent drive without any shock. When a flow rate is reduced to a necessary value or less by cut-off characteristics, operation of a second variable flow rate control device 2 is stopped to save energy. An operation quantity distribution unit 51 drives only a first motor 12 by a first velocity signal V1 through a first driver 13, when an operation quantity Vq from a pressure flow rate control unit 40 is at or lower than a maximum velocity Vmax1 of the first motor 12. When the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12, the operation quantity distribution unit 51 drives the first motor 12 at the maximum velocity Vmax1 through the first driver 13, and drives a second motor 22 by a second velocity signal V2 (V2 = Vq - Vmax1) through a second driver 23. As a result, the confluence control system can make smooth transfer from the single drive to the confluent drive without any shock.

Fig.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a confluence control system for use in a hydraulic system or the like in an injection molding machine, a press machine or the like, for instance.

BACKGROUND ART

[0002] Among conventional confluence control systems of this type is a system shown in Fig. 5 (see JP 4-78306 A).
[0003] In the confluence control system, a solenoid proportional valve 110 is connected to a discharge line 103 of a variable displacement pump 101, and a discharge line 103a of a fixed displacement pump 104 merges with the discharge line 103. A check valve 105 is provided on and an unload valve 106 is connected to the discharge line 103a. The unload valve 106 is controlled by output from a comparator 111.
[0004] On the other hand, a swash plate drive cylinder 108 for driving a swash plate of the variable displacement pump 101 is controlled by a swash plate control valve 109.
[0005] When a flow rate command value qref inputted into the comparator 111 is smaller than a specified value, the unload valve 106 is turned off to be in a position N1, so that oil discharged from the fixed displacement pump 104 is returned to a tank 102 and so that only oil discharged from the variable displacement pump 101 is delivered to an actuator. On this occasion, the solenoid proportional valve 110 has an opening according to the flow rate command value qref, the swash plate control valve 109 operates so as to make a constant differential pressure between upstream and downstream sides of the solenoid proportional valve 110, and thus a discharge quantity of the variable discharge pump 101 is controlled through the swash plate drive cylinder 108.
[0006] When the flow rate command value qref is increased so that the discharge quantity of the variable displacement pump 101 reaches a maximum flow rate that is a limit value, on the other hand, the unload valve 106 is turned on by a signal from the comparator 111 so as to take a position N2. Thus communication between the fixed displacement pump 104 and the tank 102 is cut off, and oil discharged from the fixed displacement pump 104 is delivered to the discharge line 103 through the check valve 105 and joins oil discharged from the variable displacement pump 101.
[0007] Such control over the unload valve 106 makes it possible to continuously control a discharge flow rate q of oil up to a total displacement composed of a displacement of the variable displacement pump 101 and a displacement of the fixed displacement pump 104, as shown in Fig. 6.
[0008] In the conventional confluence control system, however, oil from the variable displacement pump 101 and oil from the fixed displacement pump 104 join after the discharge quantity of the variable displacement pump 101 reaches the limit, and therefore the flow rate of the oil sharply increases immediately after the joining as shown in Fig. 6. That is, sharp increase in the flow rate and pressure of the oil occurs and causes a shock in a transition region 50 in which status of oil supply from only the variable displacement pump 101 is changed to status of oil supply from both the variable displacement pump 101 and the fixed displacement pump 104. There may occur a similar problem when the status of oil supply from both the variable displacement pump 101 and the fixed displacement pump 104 is changed to the status of oil supply from only the variable displacement pump 101.

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0009] It is a primary object of the invention to provide a confluence control system for merging liquid discharged from a plurality of pumps, the system capable of achieving smooth transfer without any shock in switching between single drive and confluent drive.

SOLUTION TO PROBLEM

[0010] In order to attain the object, the confluence control system of the invention comprises:

a first variable flow rate control device capable of discharging liquid into a first discharge line with control over a flow rate of the liquid,
a second variable flow rate control device capable of discharging liquid into a second discharge line merging with the first discharge line, with control over a flow rate of the liquid,
a check valve that is provided in the second discharge line so that flow from the second variable flow rate control device to the first discharge line is in a forward direction,

a pressure sensor for detecting a pressure in the first discharge line,

a pressure flow rate control unit that receives one pressure command, one flow rate command, and a signal representing a detected pressure from the pressure sensor and that outputs an operation quantity required for obtaining a pressure and a flow rate according to the pressure command and the flow rate command, and

an operation quantity distribution unit that receives the operation quantity from the pressure flow rate control unit, and that produces first and second velocity signals on basis of the operation quantity and outputs the first and second velocity signals to the first and second variable flow rate control devices so that the first variable flow rate control device discharges liquid with a flow rate continuously changing according to the operation quantity and so that the second variable flow rate control device does not discharge liquid, when the operation quantity is not larger than a predetermined set value, or that produces the first and second velocity signals on basis of the operation quantity and outputs the first and second velocity signals to the first and second variable flow rate control devices so that the first and second variable flow rate control devices respectively discharge liquid with a total flow rate continuously changing according to the operation quantity, when the operation quantity exceeds the set value.

[0011] According to the above configuration, the pressure flow rate control unit receives the one pressure command, the one flow rate command, and the signal representing the detected pressure from the pressure sensor, and outputs to the operation quantity distribution unit the operation quantity required for obtaining the pressure and the flow rate according to the pressure command and the flow rate command.

[0012] The operation quantity distribution unit produces the first and second velocity signals on basis of the operation quantity and respectively outputs the first and second velocity signals to the first and second variable flow rate control devices so that the first variable flow rate control device discharges the liquid with the flow rate continuously changing according to the operation quantity and so that the second variable flow rate control device does not discharge the liquid, when the operation quantity is not larger than the predetermined set value, or produces the first and second velocity signals on basis of the operation quantity and outputs the first and second velocity signals to the first and second variable flow rate control devices, respectively, so that the first and second variable flow rate control devices respectively discharge the liquid with the total flow rate continuously changing according to the operation quantity, when the operation quantity exceeds the set value.

[0013] According to the invention, the discharged flow rate from the first variable flow rate control device and the discharged flow rate from the second variable flow rate control device are merged, and the first and second variable flow rate control devices are controlled by the first and second velocity signals produced by division of the operation quantity in the operation quantity distribution unit, so that switching between single drive and confluent drive can be smoothed without any shock.

[0014] According to the invention, the operation quantity distribution unit provided on downstream side of the pressure flow rate control unit suspends operation of the second variable flow rate control device when the flow rate is decreased to the predetermined set value or lower values by the pressure flow rate control unit, so that energy saving can be achieved.

[0015] In one embodiment, the operation quantity distribution unit outputs the operation quantity as the first velocity signal to the first variable flow rate control device and outputs the second velocity signal being zero to the second variable flow rate control device, when the operation quantity is not larger than the set value, or outputs the set value as the first velocity signal to the first variable flow rate control device, sets a value obtained by subtraction of the set value from the operation quantity as the second velocity signal, and outputs the second velocity signal to the second variable flow rate control device, when the operation quantity exceeds the set value.

[0016] According to the embodiment, the operation quantity not more than the set value becomes the first velocity signal and the second velocity signal becomes zero, the operation quantity exceeding the set value makes the set value the first velocity signal and causes the value obtained by the subtraction of the set value from the operation quantity to become the second velocity signal, and thus the first and second velocity signals can be produced by simple computations.

[0017] In one embodiment, the first and second variable flow rate control devices are composed of fixed displacement pumps and servo motors for driving the fixed displacement pumps.

[0018] According to the embodiment, the first and second variable flow rate control devices composed of the fixed displacement pumps and the servo motors for driving the fixed displacement pumps are simple in structure and inexpensive.

[0019] In one embodiment, the pressure flow rate control unit limits a value calculated by a pressure control computation based on the pressure command and the signal representing the detected pressure from the pressure sensor so that the value does not exceed a value according to the flow rate command.

[0020] According to the embodiment, the value calculated by the pressure control computation is limited so as not to exceed the value according to the flow rate command, and thus the pressure lower than the target value causes automatic flow rate control to be performed with simple computations.

[0021] One embodiment comprises a control signal distribution unit that receives a control signal representing activation or suspension of the first variable flow rate control device and a signal, representing the operation quantity, from the pressure flow rate control unit, that outputs the control signal representing suspension of the second variable flow rate control device when the operation quantity is not larger than a threshold smaller than the set value, and that outputs the control signal representing drive of the second variable flow rate control device when the operation quantity exceeds the threshold.

[0022] According to the embodiment, the control signal representing the suspension of the control is outputted by the control signal distribution unit to the second variable flow rate control device so that reduction in power consumption and energy saving can be achieved, when the operation quantity is not larger than the threshold smaller than the set value, and the control signal representing start of the control is outputted to the second variable flow rate control device so as to attain standby status, when the operation quantity exceeds the threshold, thereby ensuring the activation of the second variable flow rate control device with satisfactory response without any shock.

[0023] According to one embodiment, the pressure flow rate control unit comprises
a cut-off characteristics setting unit for setting cut-off characteristics of pressure override in a pressure-flow rate characteristics diagram on basis of signals representing the pressure command, the flow rate command, and the operation quantity from the pressure flow rate control unit and outputting a pressure command provided with the cut-off characteristics.

[0024] According to the embodiment, the pressure flow rate control unit includes the cut-off characteristics setting unit for outputting the pressure command provided with the cut-off characteristics, so that a cut-off width can freely be adjusted to improve stability of the system.

[0025] According to one embodiment, the cut-off characteristics setting unit calculates the pressure command provided with the cut-off characteristics on basis of expressions (1) and (2).

[0026]

$$Vq \leq 0 \rightarrow Pi\_C = Pi \quad (1)$$

$$0 < Vq \leq Qi \rightarrow Pi\_C = (Pi \cdot Qi - CF \cdot Vq)/Qi \quad (2)$$

wherein Pi_C is the pressure command provided with the cut-off characteristics,
Vq is the operation quantity outputted from the pressure flow rate control unit,
Pi is the pressure command,
Qi is the flow rate command, and
CF is a predetermined constant representing a cut-off width.

[0027] According to the embodiment, the cut-off characteristics are provided on basis of the expressions (1) and (2), and thus can be provided by simple computations.

ADVANTAGEOUS EFFECTS OF INVENTION

[0028] According to the invention, the discharged flow rate from the first variable flow rate control device and the discharged flow rate from the second variable flow rate control device are merged, and the first and second variable flow rate control devices are continuously controlled by the first and second velocity signals produced by the division of the operation quantity in the operation quantity distribution unit, so that the switching between single drive and confluent drive can be smoothed without any shock.

[0029] According to the invention, the operation quantity distribution unit provided on downstream side of the pressure flow rate control unit suspends operation of the second variable flow rate control device when the flow rate is decreased to the predetermined set value or lower values by the pressure flow rate control unit, so that energy saving can be achieved.

BRIEF DESCRIPTION OF DRAWINGS

[0030]

Fig. 1 is a block diagram of a confluence control system in accordance with an embodiment of the invention;
Fig. 2 is a diagram showing flow rate characteristics between flow rate commands and flow rates;
Fig. 3 is a diagram showing pressure-flow rate characteristics between pressures and flow rates;
Fig. 4 is an enlarged illustration of Fig. 3;
Fig. 5 is a hydraulic circuit diagram of a conventional confluence control system; and

Fig. 6 is a graph showing a relation between flow rate command values and discharge flow rates in the conventional confluence control system.

DESCRIPTION OF EMBODIMENTS

[0031] Hereinbelow, the invention will be described in detail with reference to an embodiment shown in the drawings.
[0032] As shown in Fig. 1, a confluence control system includes a first variable flow rate control device 1, a second variable flow rate control device 2, a pressure flow rate control unit 40, and a signal distribution unit 50.
[0033] The first variable flow rate control device 1 has a first fixed displacement pump 11, a first motor 12 for driving the first fixed displacement pump 11, a first driver 13 for driving the first motor 12, and an encoder 14 for detecting an angle of rotation of the first motor 12, and hydraulic oil as an example of liquid is discharged with flow rate control from the first fixed displacement pump 11 on basis of control over rotation velocity of the first motor 12. The first motor 12, the first driver 13, and the encoder 14 form an example of a servo motor.
[0034] The second variable flow rate control device 2 has a second fixed displacement pump 21, a second motor 22 for driving the second fixed displacement pump 21, a second driver 23 for driving the second motor 22, and an encoder 24 for detecting an angle of rotation of the second motor 22, and hydraulic oil is discharged with flow rate control from the second fixed displacement pump 21 on basis of control over rotation velocity of the second motor 22. The second motor 22, the second driver 23, and the encoder 24 form an example of a servo motor.
[0035] In the embodiment, such use of the first and second fixed displacement pumps 11 and 21, instead of variable displacement pumps, in the first and second variable flow rate control devices 1 and 2 simplifies structures thereof.
[0036] The first fixed displacement pump 11 of the first variable flow rate control device 1 discharges hydraulic oil into a first discharge line 10 and supplies the oil to a main machine hydraulic circuit 5. A pressure of the hydraulic oil in the first discharge line 10 is detected by a pressure sensor 7. The second fixed displacement pump 21 of the second variable flow rate control device 2 discharges hydraulic oil into a second discharge line 20 merging with the first discharge line 10. In the second discharge line 20 is provided a check valve 6 in which flow from the second fixed displacement pump 21 of the second variable flow rate control device 2 to the first discharge line 10 is in a forward direction, so that the hydraulic oil may be prevented from flowing backward from the first discharge line 10 to the second discharge line 20.
[0037] The pressure flow rate control unit 40 receives one pressure command Pi, one flow rate command Qi, and a signal representing the detected pressure from the pressure sensor 7, calculates a quantity Vq of operation required for obtaining a pressure and a flow rate according to the pressure command Pi and the flow rate command Qi, and outputs the quantity Vq to the signal distribution unit 50.
[0038] Specifically, the pressure flow rate control unit 40 includes a cut-off characteristics setting unit 41, a summing point 42, a pressure control computation unit 43, and a velocity limiter 45.
[0039] The cut-off characteristics setting unit 41 receives the pressure command Pi, the flow rate command Qi, and the operation quantity Vq, calculates a pressure command Pi_C provided with cut-off characteristics on basis of the pressure command Pi, the flow rate command Qi, and the operation quantity Vq so that cut-off control similar to substantial cut-off of the flow rate command Qi is carried out, as shown in Figs. 3 and 4, on condition that the pressure (load pressure) detected by the pressure sensor 7 exceeds, e.g., 90% of a maximum command pressure (maximum target pressure), and outputs the pressure command Pi_C to the summing point 42.
[0040] The pressure command Pi_C provided with cut-off characteristics is calculated with use of the following expressions (1) and (2).
[0041]

$$Vq \leq 0 \rightarrow Pi\_C = Pi \quad (1)$$

$$0 < Vq \leq Qi \rightarrow Pi\_C = (Pi \cdot Qi - CF \cdot Vq)/Qi \quad (2)$$

wherein Pi_C is the pressure command provided with the cut-off characteristics,
Vq is the operation quantity outputted from the pressure flow rate control unit 40,
Pi is the pressure command,
Qi is the flow rate command, and
CF is a predetermined constant representing a cut-off width.
[0042] The pressure command Pi_C provided with cut-off characteristics is calculated on basis of simple operations

using the above expressions (1) and (2).

[0043] In the embodiment, as shown in Figs. 3 and 4, a cut-off width (difference between the target pressure and a pressure at which the cut-off control is started) CF is set at 10% of the maximum target pressure. In general, the cut-off width CF is set at 5 to 10% of the maximum target pressure because the width smaller than the range is prone to make the control unstable.

[0044] $Vq < 0$ within $Vq \leq 0$ of the expression (1) corresponds to status in which the load pressure is decreased by reverse rotation of the first motor 12 when the pressure command Pi is lowered for decreasing the pressure of the first discharge line 10 from pressure keeping status (status in which a hydraulic cylinder not shown is pressed against a load with a high pressure without moving in the main machine hydraulic circuit 5).

[0045] In Figs. 3 and 4, pressure axes and flow rate axes are both expressed by percentage to maximum value, broken lines represent flow rates in the first fixed displacement pump 11, chain lines represent flow rates in the second fixed displacement pump 21, and solid lines represent total flow rates of the first and second fixed displacement pumps 11 and 21. Fig. 4 is an enlarged illustration of main part of Fig. 3.

[0046] A method of providing the cut-off characteristics is not limited to the use of the expressions (1) and (2) described above, and publicly known various methods can be used therefor. For instance, there may be used expressions that provide an operation quantity such that control along the solid lines in Figs. 3 and 4 is performed on basis of a flow rate command, a pressure command, and a detected value from the pressure sensor in contrast to the cut-off characteristics setting unit 41 or there may be used a storage device stored with a look-up table for drawing the solid lines of Figs. 3 and 4. Alternatively, the cut-off characteristics setting unit itself may be omitted and the cut-off characteristics may be provided by characteristics of a relief valve or the like.

[0047] On the other hand, the summing point 42 outputs to the pressure control computation unit 43 a signal obtained by subtraction of the detected signal, from the pressure sensor 7, from the pressure command Pi_C provided with the cut-off characteristics.

[0048] The pressure control computation unit 43 receives the signal from the summing point 42, carries out a PID (proportional-plus-integral-plus-derivative) control computation, for instance, and outputs a resultant pressure signal Vp to the velocity limiter 45. The pressure control computation unit 43, however, may carry out other publicly known pressure control computations such as PI (proportional-plus-integral) control computation.

[0049] The velocity limiter 45 limits the pressure signal Vp from the pressure control computation unit 43 so that the pressure signal Vp may not exceed a value according to the flow rate command Qi, and thus outputs the operation quantity Vq.

[0050] Since the operation quantity Vq is obtained with the limitation on the pressure signal Vp from the pressure control computation unit 43 such that the pressure signal Vp may not exceed the value according to the flow rate command Qi, flow rate control is automatically performed with a simple computation, when the pressure is lower than the target value.

[0051] The signal distribution unit 50 includes an operation quantity distribution unit 51 and a control signal distribution unit 52. The operation quantity distribution unit 51 divides the operation quantity Vq into a first velocity signal V1 and a second velocity signal V2 in accordance with a rule that will be described later, and outputs the first velocity signal V1 and the second velocity signal V2 to the first driver 13 of the first variable flow rate control device 1 and the second driver 23 of the second variable flow rate control device 2, respectively. The control signal distribution unit 52 receives a control signal S1 and the operation quantity Vq, produces a control signal S2 in accordance with a rule that will be described later, and distributes, i.e., outputs the control signal S2 to the second driver 23 of the second variable flow rate control device 2.

[0052] The operation quantity distribution unit 51 outputs the operation quantity Vq as the first velocity signal V1 to the first driver 13 of the first variable flow rate control device 1 and outputs the second velocity signal V2 that is zero to the second driver 23 of the second variable flow rate control device 2, when the operation quantity Vq is not larger than a predetermined set value, e.g., a maximum velocity Vmax1 of the first motor 12. Also, the operation quantity distribution unit 51 outputs the set value Vmax1 as the first velocity signal V1 to the first driver 13 of the first variable flow rate control device 1 and outputs a value (Vq - Vmax1), obtained by subtraction of the set value Vmax1 from the operation quantity Vq, as the second velocity signal V2 to the second driver 23 of the second variable flow rate control device 2, when the operation quantity Vq exceeds the set value Vmax1.

[0053] More specifically, the operation quantity distribution unit 51 produces the first and second velocity signals V1 and V2 in accordance with a velocity distribution algorithm below.

[0054]

$$Vq \leq Vmax1 \rightarrow V1 = Vq,\ V2 = 0$$

$$Vmax1 < Vq \rightarrow V1 = Vmax1,\ V2 = Vq - Vmax1$$

wherein Vq is the operation quantity,
Vmax1 is the maximum velocity of the first motor 12 of the first variable flow rate control device 1,
V1 is the first velocity signal, and
V2 is the second velocity signal.

[0055] When the operation quantity Vq is not larger than the maximum velocity Vmax1 of the first motor 12, i.e., when the flow rate command is not larger than 40% in Fig. 2, the operation quantity distribution unit 51 sets the first velocity signal V1 and the second velocity signal V2 to be the operation quantity Vq and zero, respectively, so as to drive only the first motor 12 by the first velocity signal V1 (V1 = Vq) through the first driver 13 and so as to stop the second motor 22 by the second velocity signal V2 (V2 = 0), thereby achieving energy saving.

[0056] In Fig. 2, the flow rate commands and the flow rates are both expressed by percentage to maximum value, a broken line represents flow rates in the first fixed displacement pump 11, a chain line represents flow rates in the second fixed displacement pump 21, and a solid line represents a total flow rate of the first and second fixed displacement pumps 11 and 21.

[0057] When the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12, i.e., when the flow rate command exceeds 40% in Fig. 2, the operation quantity distribution unit 51 sets the first velocity signal V1 to be the maximum velocity Vmax1 so as to drive the first motor 12 at the maximum velocity Vmax1 through the first driver 13 and so as to drive the second motor 22 by the second velocity signal V2 (V2 = Vq - Vmax1) through the second driver 23.

[0058] The operation quantity distribution unit 51 drives only the first motor 12 by the first velocity signal V1 through the first driver 13, when the operation quantity Vq is not larger than the maximum velocity Vmax1 of the first motor 12, or drives the first motor 12 at the maximum velocity Vmax1 through the first driver 13 and drives the second motor 22 by the second velocity signal V2 (V2 = Vq - Vmax1) through the second driver 23, when the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12, ensuring that transfer from single drive in which hydraulic oil is discharged from only the first fixed displacement pump 11 to confluent drive in which hydraulic oil from the first and second fixed displacement pumps 11 and 21 is merged is smoothed without any shock as shown in Fig. 2.

[0059] The operation quantity distribution unit 51 is capable of obtaining the first and second velocity signals V1 and V2 with use of the simple computation as described above.

[0060] On the other hand, the control signal distribution unit 52 receives the first control signal S1 that represents bringing the first driver 13 of the first variable flow rate control device 1 into activated status or stopped status, as ON or OFF, and a signal that represents the operation quantity Vq from the pressure flow rate control unit 40. Herein, the first control signal S1 "OFF" does not mean controlling the velocity of the first motor 12 to zero but means stopping the control itself over the first motor 12. When the first control signal S1 is OFF, the control signal distribution unit 52 outputs the second control signal S2 of OFF representing the stopped status to the second driver 23 of the second variable flow rate control device 2. The control signal distribution unit 52 outputs the second control signal S2 of OFF to the second driver 23 of the second variable flow rate control device 2, when the first control signal S1 is ON and the operation quantity Vq received from the pressure flow rate control unit 40 is not larger than a predetermined threshold (Vmax1)/2 smaller than the set value Vmax1, or outputs the second control signal S2 of ON representing the activated status to the second driver 23 of the second variable flow rate control device 2, when the operation quantity Vq exceeds the threshold (Vmax1)/2. The threshold (Vmax1)/2 is a value representing a half of the maximum velocity Vmax1 of the first motor 12 that corresponds to the set value.

[0061] More specifically, the control signal distribution unit 52 produces the second control signal S2 in accordance with a control signal distribution algorithm that will be described below, and outputs the second control signal S2 to the second driver 23 of the second variable flow rate control device 2.

[0062]

$$S1 = OFF \rightarrow S2 = OFF$$

$$S1 = ON \rightarrow Vq \leq (Vmax1)/2 \rightarrow S2 = OFF$$

$$(Vmax1)/2 < Vq \rightarrow S2 = ON$$

wherein Vq is the operation quantity, and

Vmax1 is the maximum velocity of the first motor 12 of the first variable flow rate control device 1.

[0063] When the operation quantity Vq is not larger than a half of the maximum velocity Vmax1 of the first motor 12, the control signal distribution unit 52 sets the second control signal S2 to be OFF and turns off the second driver 23 of the second variable flow rate control device 2 so as to cease power consumption, thereby achieving energy saving.

[0064] The second variable flow rate control device 2 suspends rotation of the second fixed displacement pump 21 and discharge of hydraulic oil because the second driver 23 receives the second velocity signal V2 (V2=0) until the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12, and the second control signal S2 should be essentially allowed to be OFF until the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12. In the embodiment, however, the control signal distribution unit 52 sets the second control signal S2 ON and turns on the second driver 23 of the second variable flow rate control device 2 to attain standby status when the operation quantity Vq exceeds a half of the maximum velocity Vmax1 of the first motor 12, and the second driver 23 is therefore capable of operating with reception of the second velocity signal V2 (V2 = Vq - Vmax1) and driving the second motor 22 with satisfactory response the instant that the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12. Therefore, the transfer from the single drive in which hydraulic oil is discharged from only the first fixed displacement pump 11 of the first variable flow rate control device 1 to the confluent drive in which hydraulic oil from the first fixed displacement pump 11 of the first variable flow rate control device 1 and from the second fixed displacement pump 21 of the second variable flow rate control device 2 is merged can be quickened and smoothed without any steps, as shown in Fig. 2.

[0065] Once the one pressure command Pi and the one flow rate command Qi are inputted into the pressure flow rate control unit 40 in the confluence control system having the above configuration, the cut-off characteristics setting unit 41 calculates the pressure command Pi_C provided with the cut-off characteristics with use of the following expressions (1) and (2)on basis of the pressure command Pi, the flow rate command Qi, and the operation quantity Vq.

[0066]

$$Vq \leq 0 \rightarrow Pi\_C = Pi \quad (1)$$

$$0 < Vq \leq Qi \rightarrow Pi\_C = (Pi \cdot Qi - CF \cdot Vq)/Qi \quad (2)$$

[0067] Once the detection pressure (load pressure) detected by the pressure sensor 7 exceeds a value (Pi - CF), the cut-off control similar to the substantial cut-off of the flow rate command Qi is carried out, as shown in Figs. 3 and 4, on basis of the pressure command Pi_C.

[0068] The pressure command Pi_C is inputted from the cut-off characteristics setting unit 41 into the summing point 42. The detection signal from the pressure sensor 7 is subtracted from the pressure command Pi_C at the summing point 42, and the resultant signal is inputted from the summing point 42 into the pressure control computation unit 43.

[0069] The pressure control computation unit 43 receives the signal from the summing point 42 and carries out PID (proportional-plus-integral-plus-derivative) control, and the resultant pressure signal Vp is inputted into the velocity limiter 45.

[0070] The velocity limiter 45 limits the pressure signal Vp from the pressure control computation unit 43 so that the pressure signal Vp may not exceed a value according to the flow rate command Qi, obtains the operation quantity Vq, and outputs the operation quantity Vq to the signal distribution unit 50.

[0071] The operation quantity distribution unit 51 of the signal distribution unit 50 produces the first and second velocity signals V1 and V2 in accordance with a velocity distribution algorithm below on basis of the operation quantity Vq and the maximum velocity Vmax1, as the set value, of the first motor 12.

[0072]

$$Vq \leq Vmax1 \rightarrow V1 = Vq,\ V2 = 0$$

$$Vmax1 < Vq \rightarrow V1 = Vmax1,\ V2 = Vq - Vmax1$$

[0073] When the operation quantity Vq is not larger than the maximum velocity Vmax1 of the first motor 12, i.e., when the flow rate command is not larger than 40% in Fig. 2, the operation quantity distribution unit 51 sets the first velocity signal V1 and the second velocity signal V2 to be the operation quantity Vq and zero, respectively, so as to drive only the first motor 12 by the first velocity signal V1 (V1 = Vq) through the first driver 13 and so as to stop the second motor 22 by the second velocity signal V2 (V2 = 0), thereby achieving energy saving.

[0074] When the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12, i.e., when the flow rate command exceeds 40% in Fig. 2, the operation quantity distribution unit 51 sets the first velocity signal V1 to be the maximum velocity Vmax1 so as to drive the first motor 12 at the maximum velocity Vmax1 through the first driver 13 and drives the second motor 22 by the second velocity signal V2 (V2 = Vq - Vmax1) through the second driver 23.

[0075] The operation quantity distribution unit 51 drives only the first motor 12 by the first velocity signal V1 through the first driver 13 when the operation quantity Vq is not larger than the maximum velocity Vmax1 of the first motor 12, or drives the first motor 12 at the maximum velocity Vmax1 through the first driver 13 and drives the second motor 22 by the second velocity signal V2 (V2 = Vq - Vmax1) through the second driver 23 when the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12, ensuring that the transfer from the single drive in which hydraulic oil is discharged from only the first fixed displacement pump 11 to the confluent drive in which hydraulic oil from the first and second fixed displacement pumps 11 and 21 is merged is smoothed without any shock, as shown in Fig. 2.

[0076] In the confluence control system, in which the operation quantity distribution unit 51 is provided on downstream side of the pressure flow rate control unit 40 to divide the operation quantity Vq from the pressure flow rate control unit 40, to produce the first velocity signal V1 and the second velocity signal V2, and to input the signals into the first and second drivers 13, 23, excess of the pressure over the value (Pi - CF) in the cut-off characteristics causes gradual decrease in the rotation velocity of the second motor 22 and gradual decrease in the discharge flow rate of the second fixed displacement pump 21 from 60%, and the pressure of 96% makes the discharge flow rate zero as seen from Fig. 4 that is the enlarged illustration of main part of Fig. 3. On the other hand, the first motor 12 runs at a constant rotation velocity and the discharge flow rate of the first fixed displacement pump 11 is constant at 40% until the pressure reaches 96%, the pressure in excess of 96% causes gradual decrease in the rotation velocity of the first motor 12 and gradual decrease in the discharge flow rate of the first fixed displacement pump 11 from 40%, and the pressure of 100% makes the discharge flow rate zero.

[0077] As the operation quantity distribution unit 51 provided on downstream side of the pressure flow rate control unit 40 thus divides the operation quantity Vq from the pressure flow rate control unit 40 and produces the first velocity signal V1 and the second velocity signal V2, the operation of the second fixed displacement pump 21 is suspended according to the cut-off characteristics on condition that the flow rate is decreased with the high pressure not lower than 96%, that is, the discharge quantity of the second fixed displacement pump 21 is made zero when the pressure is in a range of 96 to 100%, so that energy saving can be achieved.

[0078] If the flow rate command Qi were divided on upstream side of the pressure flow rate control unit 40, both the first fixed displacement pump 11 and the second fixed displacement pump 21 would be driven until the pressure would come just near to 100%, so that energy saving could not be achieved.

[0079] On the other hand, the control signal distribution unit 52 produces the second control signal S2 in accordance with a control signal distribution algorithm that will be described below, and outputs the second control signal S2 to the second driver 23 of the second variable flow rate control device 2.

[0080]

$$S1 = OFF \rightarrow S2 = OFF$$

$$S1 = ON \rightarrow Vq \leq (Vmax1)/2 \rightarrow S2 = OFF$$

$$(Vmax1)/2 < Vq \rightarrow S2 = ON$$

wherein Vq is the operation quantity, and

Vmax1 is the maximum velocity of the first motor 12 of the first variable flow rate control device 1.

[0081] When the operation quantity Vq is not larger than a half of the maximum velocity Vmax1 of the first motor 12, the control signal distribution unit 52 sets the second control signal S2 to be OFF and turns off the second driver 23 of the second variable flow rate control device 2 so as to cease power consumption, thereby achieving energy saving.

[0082] The control signal distribution unit 52 sets the second control signal S2 ON and turns on the second driver 23 of the second variable flow rate control device 2 to attain standby status when the operation quantity Vq exceeds a half of the maximum velocity Vmax1 of the first motor 12, and the second driver 23 is therefore capable of operating with reception of the second velocity signal V2 (V2 = Vq - Vmax1) and driving the second motor 22 with satisfactory response the instant that the operation quantity Vq exceeds the maximum velocity Vmax1 of the first motor 12. Thus the transfer from the single drive in which hydraulic oil is discharged from only the first fixed displacement pump 11 of the first variable flow rate control device 1 to the confluent drive in which hydraulic oil from the first fixed displacement pump 11 of the first variable flow rate control device 1 and from the second fixed displacement pump 21 of the second variable flow rate control device 2 is merged can be quickened and smoothed without any steps, as shown in Fig. 2.

[0083] Though the first variable flow rate control device 1 and the second variable flow rate control device 2 are used in the embodiment, a third variable flow rate control device, a fourth variable flow rate control device and the like may additionally be used to join discharged hydraulic oil from the third variable flow rate control device, the fourth variable flow rate control device and the like to the first discharge line 10 through respective check valves.

[0084] In the embodiment, the operation quantity distribution unit 51 produces the first and second velocity signals V1 and V2 on basis of the operation quantity Vq and the maximum velocity Vmax1, as the predetermined set value, of the first motor 12 in accordance with a velocity distribution algorithm:

$$Vq \leq Vmax1 \rightarrow V1 = Vq,\ V2 = 0$$

$$Vmax1 < Vq \rightarrow V1 = Vmax1,\ V2 = Vq - Vmax1$$

The set value, however, may be slightly smaller than the maximum rotation velocity Vmax1 of the first motor 12.

[0085] The velocity distribution algorithm of the operation quantity distribution unit is not limited to the examples described above but may be such that characteristics can be expressed by polygonal lines, a curved line and/or the like having a large number of inflection points, provided that the algorithm produces the first and second velocity signals on basis of the operation quantity so that the first variable flow rate control device 1 may discharge liquid with a flow rate continuously changing according to the operation quantity and so that the second variable flow rate control device 2 may not discharge liquid, when the operation quantity is not larger than the predetermined set value, or produces the first and second velocity signals on basis of the operation quantity so that the first and second variable flow rate control devices 1, 2 may discharge fluid with a total flow rate continuously changing according to the operation quantity, when the operation quantity exceeds the set value.

[0086] In the embodiment, which has a ratio of the maximum rotation velocity Vmax1 of the first motor 12 to a maximum rotation velocity Vmax2 of the second motor 22 being 4:6 and discharge displacements Vcc of the first fixed displacement pump 11 and the second fixed displacement pump 21 being the same, switching between the single drive and the confluent drive is performed at a point of the flow rate command of 40% as a result of division with Vmaxl·Vcc: Vmax2·Vcc=4:6. The maximum rotation velocities Vmax1, Vmax2 of the first and second motors 12, 22 and the discharge displacements Vcc1, Vcc2 of the first and second fixed displacement pumps 11, 21, however, may have any desired values. The switching between the single drive and the confluent drive is performed at a point of the flow rate command with a percentage divided by the ratio Vmax1·Vcc:Vmax2·Vcc.

[0087] The pressure flow rate control unit 40 and the signal distribution unit 50 of the embodiment may be composed of softwares, digital circuits, or analog circuits.

[0088] Though the first and second fixed displacement pumps 11, 21 are used in the embodiment, one of these pumps can be a variable displacement pump so as to control the discharge quantity.

[0089] Inverters can be used as the drivers.

[0090] As the pressure sensor, a current sensor may be used that detects a drive current for the first motor 12 and that thereby detects the pressure of the first discharge line 10 indirectly.

[0091] Though the liquid is hydraulic oil in the embodiment, not only hydraulic oil but any type of liquid can be used and the invention can be applied to any type of hydraulic system.

Claims

1. A confluence control system comprising:

a first variable flow rate control device (1) capable of discharging liquid into a first discharge line (10) with control over a flow rate of the liquid,

a second variable flow rate control device (2) capable of discharging liquid into a second discharge line (20) merging with the first discharge line (10), with control over a flow rate of the liquid,
a check valve (6) that is provided in the second discharge line (20) so that flow from the second variable flow rate control device (2) to the first discharge line (10) is in a forward direction,
a pressure sensor (7) for detecting a pressure in the first discharge line (10),
a pressure flow rate control unit (40) that receives one pressure command (Pi), one flow rate command (Qi), and a signal representing a detected pressure from the pressure sensor (7) and that outputs an operation quantity (Vq) required for obtaining a pressure and a flow rate according to the pressure command (Pi) and the flow rate command (Qi), and
an operation quantity distribution unit (51) that receives the operation quantity (Vq) from the pressure flow rate control unit (40), and that produces first and second velocity signals (V1 and V2) on basis of the operation quantity (Vq) and outputs the first and second velocity signals to the first and second variable flow rate control devices (1 and 2) so that the first variable flow rate control device (1) discharges liquid with a flow rate continuously changing according to the operation quantity (Vq) and so that the second variable flow rate control device (2) does not discharge liquid, when the operation quantity (Vq) is not larger than a predetermined set value, or that produces the first and second velocity signals (V1 and V2) on basis of the operation quantity (Vq) and outputs the first and second velocity signals to the first and second variable flow rate control devices (1 and 2) so that the first and second variable flow rate control devices (1 and 2) respectively discharge liquid with a total flow rate continuously changing according to the operation quantity (Vq), when the operation quantity (Vq) exceeds the set value.

2. The confluence control system as claimed in Claim 1, wherein
the operation quantity distribution unit (51) outputs the operation quantity (Vq) as the first velocity signal (V1) to the first variable flow rate control device (1) and outputs the second velocity signal (V2) being zero to the second variable flow rate control device (2), when the operation quantity (Vq) is not larger than the set value, or outputs the set value as the first velocity signal (V1) to the first variable flow rate control device (1), sets a value obtained by subtraction of the set value from the operation quantity (Vq) as the second velocity signal (V2), and outputs the second velocity signal (V2) to the second variable flow rate control device (2), when the operation quantity (Vq) exceeds the set value.

3. The confluence control system as claimed in Claim 1 or 2, wherein
the first and second variable flow rate control devices (1 and 2) are composed of fixed displacement pumps (11 and 21) and servo motors for driving the fixed displacement pumps (11 and 21) .

4. The confluence control system as claimed in Claim 1, wherein
the pressure flow rate control unit (40) limits a value calculated by a pressure control computation based on the pressure command (Pi) and the signal representing the detected pressure from the pressure sensor (7) so that the value does not exceed a value according to the flow rate command (Qi).

5. The confluence control system as claimed in Claim 1, further comprising
a control signal distribution unit (52) that receives a control signal representing activation or suspension of the first variable flow rate control device (1) and a signal, representing the operation quantity (Vq), from the pressure flow rate control unit (40), that outputs the control signal representing suspension of the second variable flow rate control device (2) when the operation quantity (Vq) is not larger than a threshold smaller than the set value, and that outputs the control signal representing drive of the second variable flow rate control device (2) when the operation quantity (Vq) exceeds the threshold.

6. The confluence control system as claimed in Claim 1, wherein
the pressure flow rate control unit (40) comprises
a cut-off characteristics setting unit (41) for setting cut-off characteristics of pressure override in a pressure-flow rate characteristics diagram on basis of signals representing the pressure command (Pi), the flow rate command (Qi), and the operation quantity (Vq) from the pressure flow rate control unit (40) and outputting a pressure command provided with the cut-off characteristics.

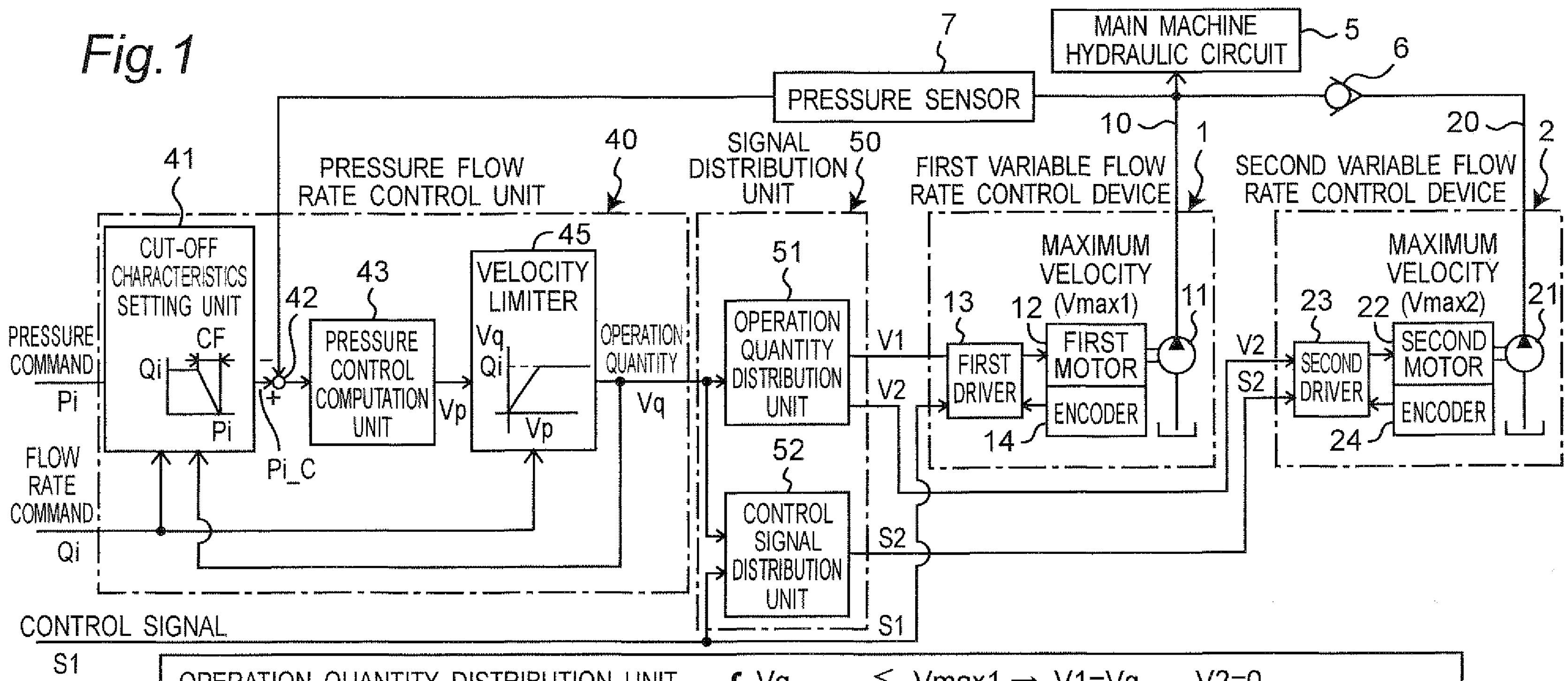
7. The confluence control system as claimed in Claim 6, wherein
the cut-off characteristics setting unit (41) calculates the pressure command provided with the cut-off characteristics on basis of expressions (1) and (2):

$$Vq \leq 0 \rightarrow Pi\_C = Pi \quad (1)$$

$$0 < Vq \leq Qi \rightarrow Pi\_C = (Pi \cdot Qi - CF \cdot Vq)/Qi \quad (2)$$

wherein Pi_C is the pressure command provided with the cut-off characteristics,
Vq is the operation quantity outputted from the pressure flow rate control unit (40),
Pi is the pressure command,
Qi is the flow rate command, and
CF is a predetermined constant representing a cut-off width.

Fig. 1



OPERATION QUANTITY DISTRIBUTION UNIT	Vq ≦ Vmax1 → V1=Vq, V2=0 Vmax1 < Vq → V1=max1, V2=Vq−Vmax1
CONTROL SIGNAL DISTRIBUTION UNIT	S1=OFF → S2=OFF S1=ON → { Vq ≦ (Vmax1)/2 → S2=OFF; (Vmax1)/2 < Vq → S2=ON }
CUT-OFF CHARACTERISTICS SETTING UNIT	Vq≦0 → Pi_C=Pi 0<Vq≦Qi → Pi_C=(Pi × Qi−CF × Vq) / Qi
VELOCITY LIMITER	Vp≦Qi → Vq=Vp Qi ≦Vp → Vq=Qi

Fig.2

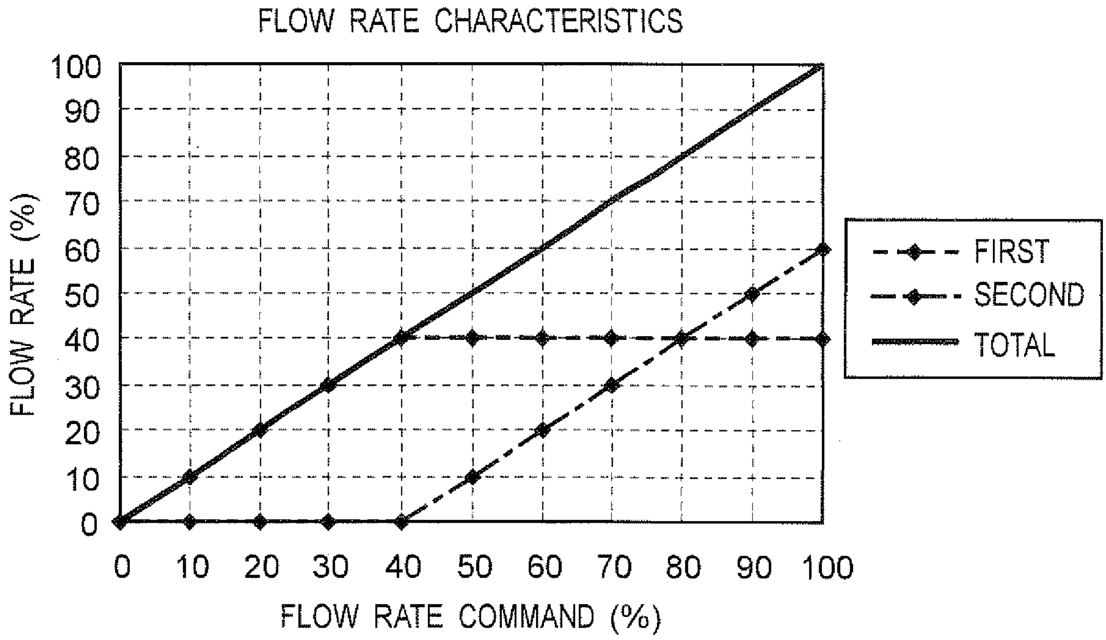
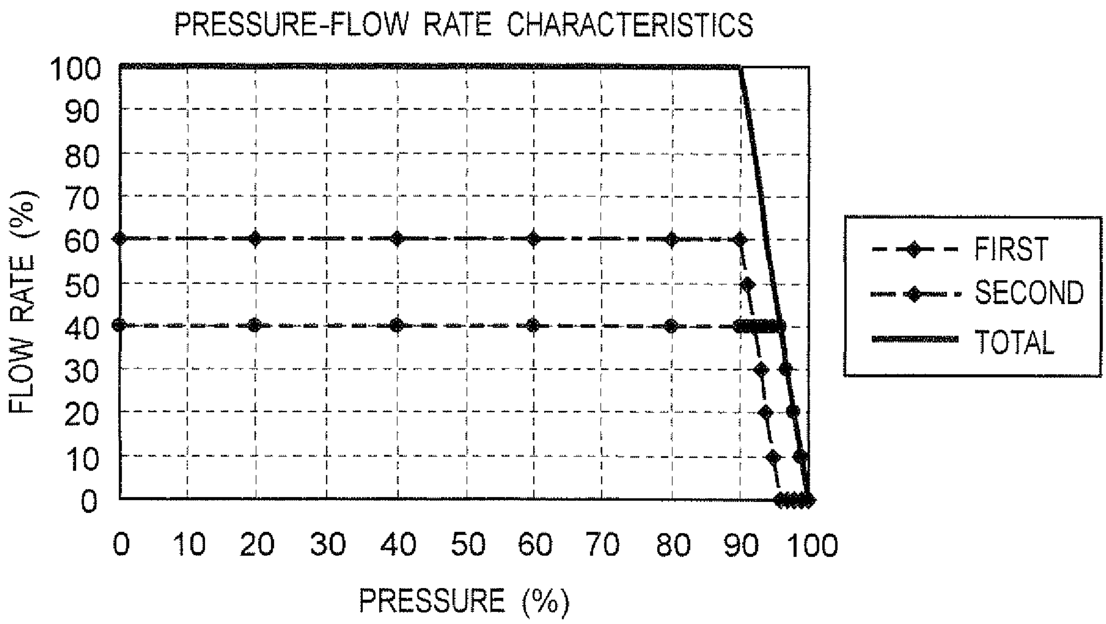

FLOW RATE CHARACTERISTICS
FLOW RATE (%)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
FLOW RATE COMMAND (%)
FIRST
SECOND
TOTAL

Fig.3


PRESSURE-FLOW RATE CHARACTERISTICS
FLOW RATE (%)
100
90
80
70
60
50
40
30
20
10
0
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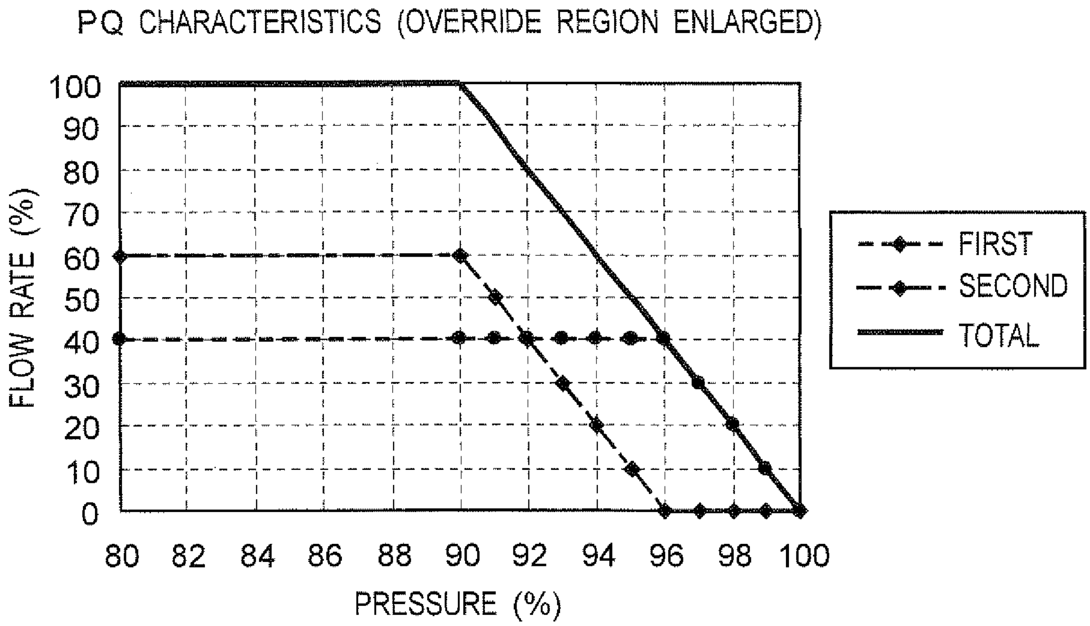
10
20
30
40
50
60
70
80
90
100
PRESSURE (%)
FIRST
SECOND
TOTAL

Fig.4


PQ CHARACTERISTICS (OVERRIDE REGION ENLARGED)
FLOW RATE (%)
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90
80
70
60
50
40
30
20
10
0
80
82
84
86
88
90
92
94
96
98
100
PRESSURE (%)
FIRST
SECOND
TOTAL

Fig.5

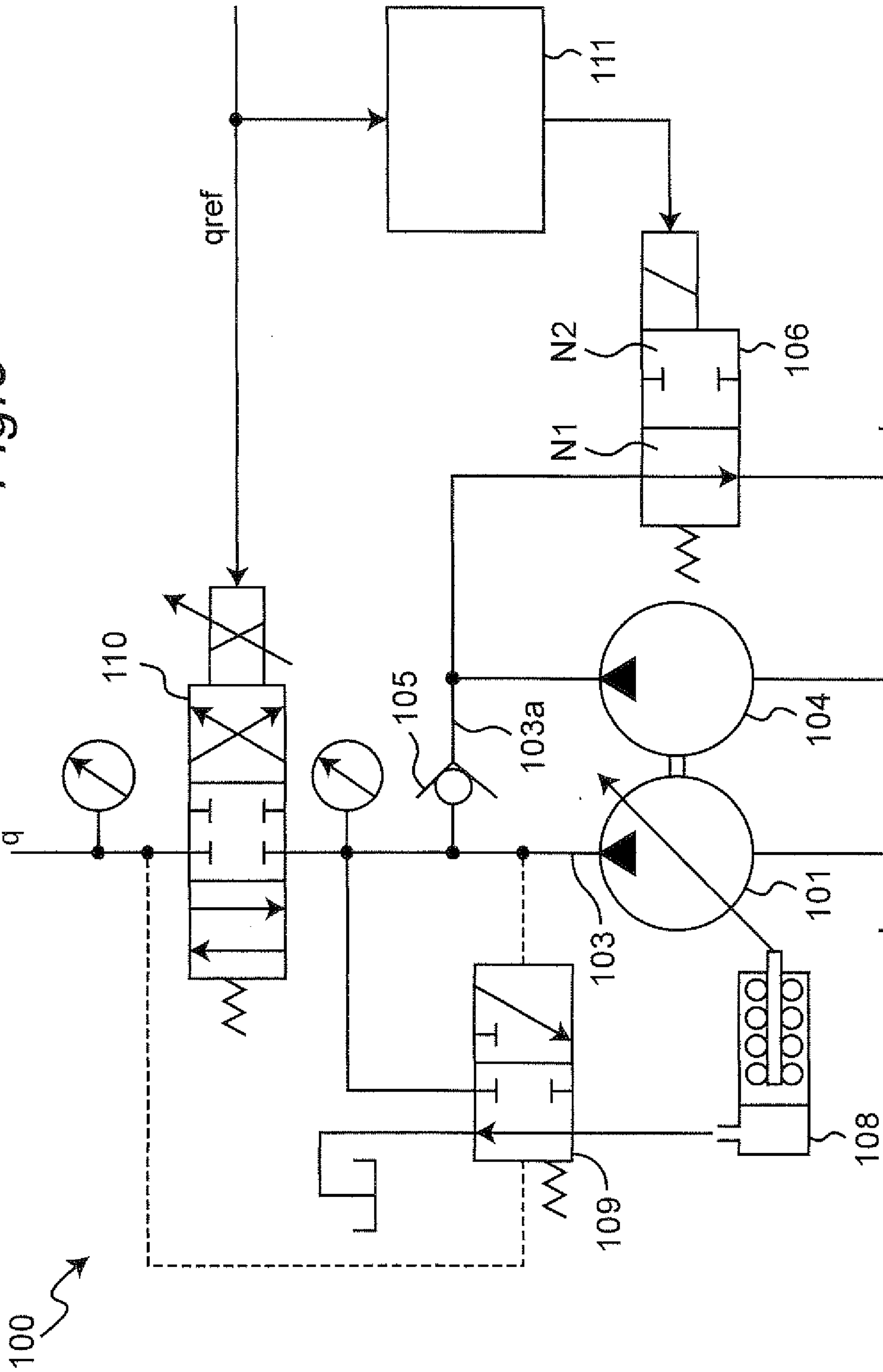
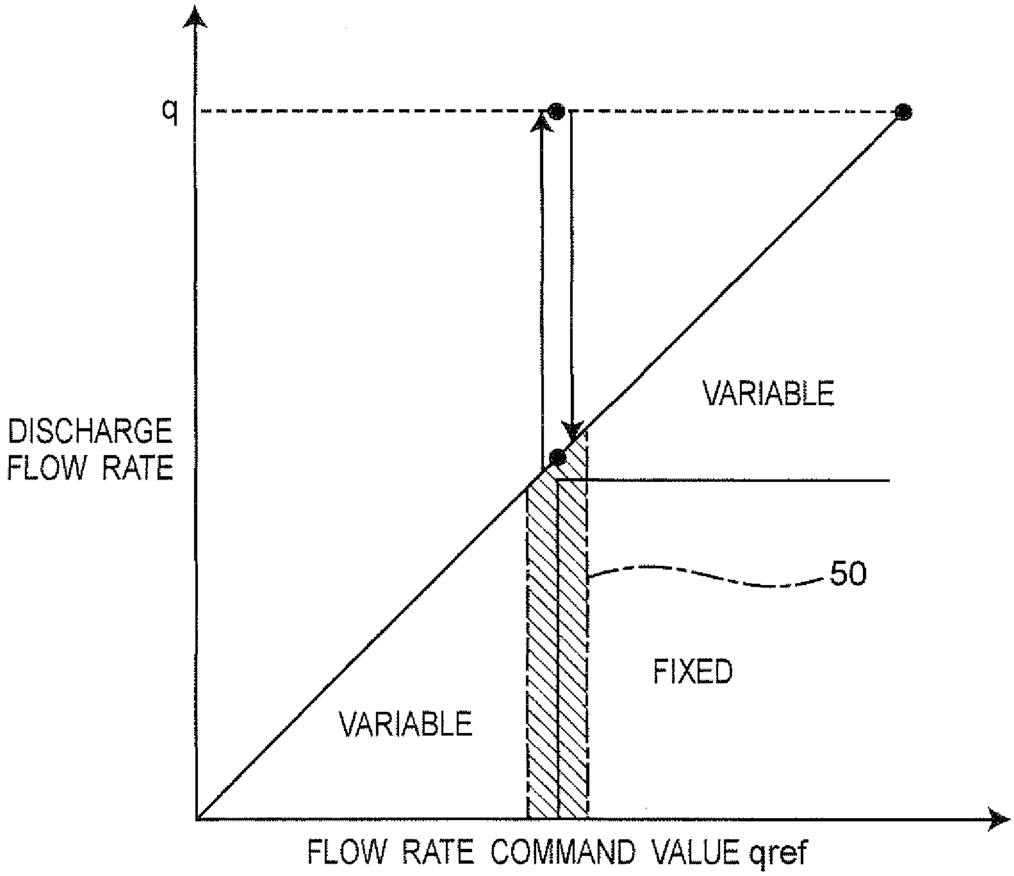


Fig.6


q
DISCHARGE
FLOW RATE
VARIABLE
50
FIXED
VARIABLE
FLOW RATE COMMAND VALUE qref

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2008/073087

A. CLASSIFICATION OF SUBJECT MATTER
F15B11/02(2006.01)i, *F15B11/00*(2006.01)i, *F15B11/028*(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)
F15B11/00-11/22

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	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 72151/1983(Laid-open No. 176513/1984) (Kojima Press Industry Co., Ltd.), 26 November, 1984 (26.11.84), Full text; Fig. 2 (Family: none)	1-7
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 162377/1979(Laid-open No. 79690/1981) (The Japan Steel Works, Ltd.), 27 June, 1981 (27.06.81), Full text; Fig. 2 (Family: none)	1-7

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 March, 2009 (10.03.09)	24 March, 2009 (24.03.09)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/073087

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 1-318774 A (Daikin Industries, Ltd.), 25 December, 1989 (25.12.89), Full text; Fig. 1 (Family: none)	1-7
Y	JP 5-196001 A (Tokimec Inc.), 06 August, 1993 (06.08.93), Full text; Fig. 1 (Family: none)	1-7
Y	JP 2001-90671 A (Daikin Industries, Ltd.), 03 April, 2001 (03.04.01), Full text; Fig. 1 & US 6537032 B1 & EP 1134421 A1 & WO 2001/021959 A1 & CN 1336988 A	1-7
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A	JP 63-13903 A (Kabushiki Kaisha Fukushima Seisakusho), 21 January, 1988 (21.01.88), Full text; all drawings (Family: none)	1
A	JP 2000-249103 A (Daikin Industries, Ltd.), 12 September, 2000 (12.09.00), Full text; all drawings (Family: none)	1
A	JP 2003-214351 A (Nachi-Fujikoshi Corp.), 30 July, 2003 (30.07.03), Full text; all drawings (Family: none)	1
A	JP 2003-278707 A (The Japan Steel Works, Ltd.), 02 October, 2003 (02.10.03), Full text; all drawings (Family: none)	1

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REFERENCES CITED IN THE DESCRIPTION

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