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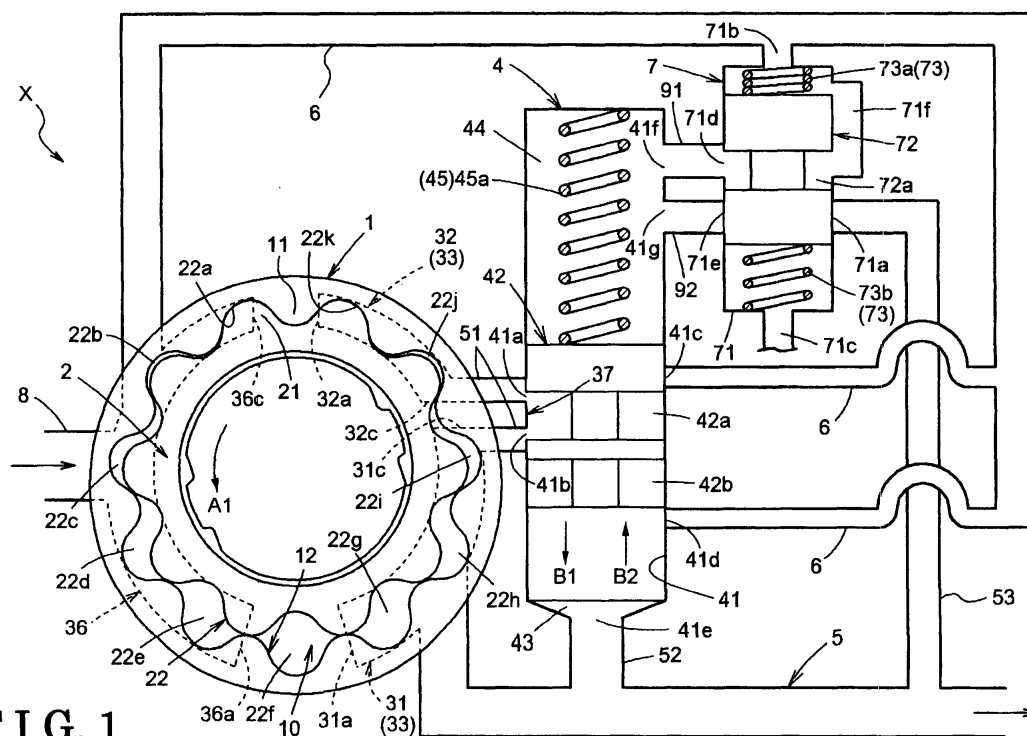
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European Patent Attorneys**Patenta****Radeckestrasse 43****81245 München (DE)**(54) **Oil gear pump**

(57) An oil pump (X, XII, XIII) includes a first control valve (4, 204, 304) including a first valve body (42, 242, 342) provided in a first valve housing (41, 241, 341) for reciprocating therein, the first valve body for controlling discharge pressure of working oil discharged from a pump main body (1), a first valve chamber (43, 243, 343) formed in the first valve housing, the first valve chamber

being applied with the discharge pressure of the working oil from the pump main body, and a second valve chamber (44, 244, 344) formed in the first valve housing, the second valve chamber being supplied with the working oil, and a second control valve (7, 207, 307) activated on the basis of degree of the temperature of the working oil, the second control valve for controlling oil pressure of the working oil flowed into the second valve chamber.

**FIG. 1****EP 1 686 265 A2**

Description

FIELD OF THE INVENTION

[0001] This invention relates to an oil pump with control valves for controlling a discharge pressure of working oil.

BACKGROUND

[0002] A known oil pump for controlling a discharge pressure of working oil is disclosed in JP3531769B. As illustrated in Fig. 15, the disclosed oil pump includes a pump main body 101 having a pump chamber 110, a rotor 102 rotating in the pump chamber 110 by means of a drive source, an inlet port 136 sucking the working oil into the pump chamber 110 in response to a rotation of the rotor 102, first and second outlet ports 131 and 132 discharging the working oil out of the pump chamber 110 in response to the rotation of the rotor 102, a first oil passage 151, a second oil passage 152, a feedback oil passage 106, a control unit 107, and a control valve 104. The first oil passage 151 connects a discharge oil passage 105, which is communicated with parts to be supplied with the working oil, to the first outlet port 131, and delivers the working oil to the discharge oil passage 105 discharged from the first outlet port 131. The second oil passage 152 connects the discharge oil passage 105 to the second outlet port 132, and delivers the working oil to the discharge oil passage 105 from the second outlet port 132. The feedback oil passage 106 is connected to the second oil passage 152 and communicated with the inlet port 136. The control unit 107 outputs a control signal on the basis of degree of oil pressure of the first oil passage 151, degree of oil temperature, degree of throttle angle, degree of rotational speed of an internal combustion engine serving as the drive source, or the like. The control valve 104 is connected to the first oil passage 151, the second oil passage 152, and the feedback oil passage 106, and activated on the basis of the control signal of the control unit 107.

[0003] On this occasion, the control valve 104 is activated by means of a proportional electromagnetic control mechanism 108. The control unit 107 directly or indirectly detects the oil pressure of the first oil passage 151, the oil temperature, the throttle angle, and the rotational speed of the internal combustion engine. Further, the control unit 107 outputs the control signal for operating the control valve 104, on the basis of the signal detected, for obtaining a predetermined discharge characteristic. Thereby, on the basis of use conditions of the internal combustion engine, the disclosed oil pump offers an optimal discharge pressure by means of an electromagnetic control, and reduces an operation of the pump more than required.

[0004] However, the disclosed oil pump includes the proportional electromagnetic control mechanism 108 such as a solenoid, or the like, for activating the control valve 104, the control unit 107 for generating the control

signal relative to the proportional electromagnetic control mechanism 108, and a detecting mechanism such as a sensor, or the like, for outputting information such as degree of the oil pressure, degree of the oil temperature, degree of the throttle angle, or the like, relative to the control unit 107. With the configuration of such oil pump, a structure for controlling the discharge pressure of the oil pump may be complicated and a manufacturing cost of the oil pump may occasionally be expensive.

[0005] A need thus exists for an oil pump, which appropriately controls the discharge pressure on the basis of a temperature of the working oil with a simple structure.

SUMMARY OF THE INVENTION

[0006] According to an aspect of the present invention, an oil pump includes a first control valve including a first valve body provided in a first valve housing for reciprocating therein, the first valve body for controlling discharge pressure of working oil discharged from a pump main body, a first valve chamber formed in the first valve housing, the first valve chamber being applied with the discharge pressure of the working oil from the pump main body, and a second valve chamber formed in the first valve housing, the second valve chamber being supplied with the working oil, and a second control valve activated on the basis of degree of the temperature of the working oil, the second control valve for controlling oil pressure of the working oil flowed into the second valve chamber.

[0007] According the present invention, the second control valve can adjust the position of the valve body on the basis of degree of the temperature of the working oil by controlling the oil pressure of the working oil to be flowed into the second valve chamber facing the first valve chamber to which the discharge pressure of the working oil is applied. The second valve chamber is provided to face the first valve chamber across the valve body. The oil pump according to the embodiments of the present invention can activate the first control valve, which controls the discharge pressure of the working oil, without providing a proportional electromagnetic control mechanism such as a solenoid, or the like. Further, because the second control valve is provided independently from the first control valve to which the discharge pressure from the pump main body is applied, the second control valve, which is activated on the basis of degree of the temperature of the working oil, is not influenced by the pulsation of the discharge pressure of the working oil. Accordingly, the second control valve can be made of a low fatigue strength material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The foregoing and additional features and characteristics of the present invention will become more apparent from the following detailed description considered with reference to the accompanying drawings, wherein:

[0009] Fig. 1 is a conceptual view illustrating a struc-

ture of an oil pump according to a first embodiment of the present invention.

[0010] Fig. 2 is a view illustrating a flow of working oil of a state A without showing a main body of the oil pump according to the first embodiment of the present invention.

[0011] Fig. 3 is a view illustrating a flow of the working oil of a state B without showing the main body of the oil pump according to the first embodiment of the present invention.

[0012] Fig. 4 is a view illustrating a flow of the working oil of a state C without showing the main body of the oil pump according to the first embodiment of the present invention.

[0013] Fig. 5 is a view illustrating a flow of the working oil of a state D without showing the main body of the oil pump according to the first embodiment of the present invention.

[0014] Fig. 6 is a view illustrating a flow of the working oil of a state E without showing the main body of the oil pump according to the first embodiment of the present invention.

[0015] Fig. 7 is a view illustrating a flow of the working oil of an intermediate state without showing the main body of the oil pump according to the first embodiment of the present invention.

[0016] Fig. 8 is a view illustrating a flow of the working oil of a high temperature state without showing the main body of the oil pump according to the first embodiment of the present invention.

[0017] Fig. 9A is a graph indicating a relation, within a normal temperature region of the working oil, between a rotational speed of a rotor and a discharge pressure of the working oil at a discharge oil passage of the oil pump according to the first embodiment of the present invention.

[0018] Fig. 9B is a graph indicating a relation, within a high temperature region of the working oil, between the rotational speed of the rotor and the discharge pressure of the working oil in the discharge oil passage of the oil pump according to the first embodiment of the present invention.

[0019] Fig. 10A is a graph indicating a relation, within the normal temperature region of the working oil, between the rotational speed of the rotor and the discharge pressure of the working oil in the discharge oil passage of an oil pump, which includes a first control valve similar to that of the first embodiment of the present invention, and does not include a second control valve.

[0020] Fig. 10B is a graph indicating a relation, within the high temperature region of the working oil, between the rotational speed of the rotor and the discharge pressure of the working oil in the discharge oil passage of the oil pump, which includes the first control valve similar to that of the first embodiment of the present invention, and does not include the second control valve.

[0021] Fig. 11 is a conceptual view illustrating a structure of an oil pump according to a second embodiment

of the present invention.

[0022] Fig. 12A is a graph indicating a relation, within the normal temperature region of the working oil, between the rotational speed of the rotor and the discharge pressure of the working oil in the discharge oil passage of the oil pump according to the second embodiment of the present invention.

[0023] Fig. 12B is a graph indicating a relation, within the high temperature region of the working oil, between the rotational speed of the rotor and the discharge pressure of the working oil in the discharge oil passage of the oil pump according to the second embodiment of the present invention.

[0024] Fig. 13A is a graph indicating a relation, within the normal temperature region of the working oil, between the rotational speed of the rotor and the discharge pressure of the working oil in the discharge oil passage of an oil pump, which includes the first control valve similar to that of the second embodiment of the present invention, and does not include the second control valve.

[0025] Fig. 13B is a graph indicating a relation, within the high temperature region of the working oil, between the rotational speed of the rotor and the discharge pressure of the working oil in the discharge oil passage of the oil pump, which includes the first control valve similar to that of the second embodiment of the present invention, and does not include the second control valve.

[0026] Fig. 14 is a conceptual view illustrating a structure of an oil pump according to a third embodiment of the present invention.

[0027] Fig. 15 is a conceptual view illustrating a structure of an oil pump of a known art.

DETAILED DESCRIPTION

[0028] Embodiments of the present invention will be explained hereinbelow with reference to the attached drawings. According to the embodiments of the present invention, an oil pump X is explained as an example, which is applied to a vehicle and supplies working oil to each part of an engine by generating an oil pressure by means of the engine serving as a drive source.

[0029] As illustrated in Fig. 1, the oil pump X according to the first embodiment of the present invention includes a pump main body 1 having a rotor 2 rotated by means of a crankshaft, first and second outlet ports 31 and 32 discharging the working oil out of the pump main body 1, an inlet port 36 sucking the working oil into the pump main body 1, a discharge oil passage 5 communicating with each part of the engine, or the like, to be supplied with the working oil, a first control valve 4 controlling a discharge pressure of the working oil from the pump main body 1, a second control valve 7 activated on the basis of degree of temperature of the working oil and controlling an operation of the first control valve 4, and a feedback oil passage 6 feeding back surplus working oil passed through the first control valve 4 to the inlet port 36 side. Each component will be explained in detail hereinbelow.

[0030] The pump main body 1 of the oil pump X is made of metal (e.g. aluminum-based alloy, an iron-based alloy, or the like) and formed with a pump chamber 10 inside thereof. The pump chamber 10 is formed with an internal gear portion 12. The internal gear portion 12 is provided with a plurality of internal gear teeth 11 so as to constitute a driven gear.

[0031] The metal rotor 2 is rotatably provided at the pump chamber 10. The rotor 2 is connected to the crankshaft of the engine serving as the drive source, and is synchronously rotatable with the crankshaft. For example, the rotor 2 is designed to rotate at a revolving speed of from 600 to 7,000 rpm. The rotor 2 is formed with an outer gear portion 22. The outer gear portion 22 is provided with a plurality of outer gear teeth 21 so as to constitute a drive gear. The internal gear teeth 11 and the outer gear teeth 21 are defined by a trochoid curve, a cycloid curve, or the like. The rotor 2 rotates in a direction of arrow A1 shown in Fig. 1. In accordance with a rotation of the rotor 2, the outer gear teeth 21 of the rotor 2 are meshed with the internal gear teeth 11 one after another, and accordingly the internal gear portion 12 is rotated in the identical direction to the rotor 2. Between the outer gear teeth 21 and the internal gear teeth 11, there are formed spaces 22a - 22k. In Fig. 1, a space 22f has the largest volume, and the spaces 22a and 22k have the smallest volume. On this occasion, for example, because the volume of the spaces 22a - 22e is enlarged, the spaces 22a - 22e produce an inlet pressure and they act to suck the working oil. In contrast, because the volume of the spaces 22g - 22k is diminished, the spaces 22g - 22k produce the discharge pressure and they act to discharge the working oil.

[0032] The pump main body 1 is provided with, at a first side thereof, an outlet port array 33 having the first and second outlet ports 31 and 32 discharging the working oil out of the pump main body 1. The outlet port array 33 discharges the working oil out of the pump chamber 10 in accordance with the rotation of the rotor 2. The first outlet port 31 is provided with end side portions 31a and 31c, and the second outlet port 32 is provided with end side portions 32a and 32c. The first and second outlet ports 31 and 32 are communicated with the discharge oil passage 5. Further the pump main body 1 is provided with, at a second side thereof, the inlet port 36. The inlet port 36 sucks the working oil into the pump chamber 10 in accordance with the rotation of the rotor 2. The inlet port 36 is provided with end side portions 36a and 36c. The inlet port 36 is communicated with an inlet oil passage 8 communicating with an oil pan, or the like.

[0033] According to the embodiment of the present invention, the first outlet port 31 is disposed upstream relative to the second outlet port 32 in a rotational direction of the rotor 2 indicated by the arrow A1 in Fig. 1. An opening area of the first outlet port 31 is configured so as to be larger than that of the second outlet port 32.

[0034] The first and second outlet ports 31 and 32 are separated by means of a separating member 37. Thus,

each of the first and second outlet ports 31 and 32 has an individual discharge function. For example, a width of the separating member 37 may be configured to be narrower than a teeth margin positioned between the first outlet port 31 and the second outlet port 32 in order to prevent an increase of the oil pressure, which is caused by a confinement of the working oil at the teeth margin during a compressing process of a space of the teeth margin between the internal gear teeth 11 and the outer gear teeth 21 by means of the rotation of the rotor 2.

[0035] The discharge oil passage 5 communicates with each part of the engine, or the like, to be supplied with the working oil, and supplies the working oil thereto. More particularly, the discharge oil passage 5 supplies the working oil to each part of the engine, which requires a lubrication by means of the working oil or an activation by means of the oil pressure, for example, a bearing such as a journal of the crankshaft of the engine, a valve timing control apparatus, a sliding portion between a cylinder and a piston, or the like. Alternatively, or in addition, the discharge oil passage 5 may be configured to supply the working oil to various parts of the vehicle other than the engine.

[0036] According to the embodiment of the present invention, the discharge oil passage 5 includes a port connecting oil passage 51, which communicates the first outlet port 31 with the second outlet port 32 through the first control valve 4. Further the first outlet port 31 directly communicates with the discharge oil passage 5, and the second outlet port 32 communicates with the discharge oil passage 5 through the port connecting oil passage 51 and the first outlet port 31. The first control valve 4 is provided in midstream of the port connecting oil passage 51.

[0037] The feedback oil passage 6 feeds back the surplus working oil passed through the first control valve 4 to the inlet port 36 side. Alternatively, or in addition, the feedback oil passage 6 may be communicated with the oil pan, or the like, to form a drain oil passage.

[0038] The first control valve 4 is provided in a first valve housing 41 for reciprocating therein. The first control valve 4 includes a first valve body 42, a first valve chamber 43, a second valve chamber 44, and a biasing mechanism 45. The first valve body 42 controls the discharge pressure of the working oil discharged from the pump main body 1 on the basis of its position in the first valve housing 41. As illustrated in Fig. 1, the first valve chamber 43 is formed below the first valve body 42 in the first valve housing 41 and is applied with the discharge pressure of the working oil from the pump main body 1. As illustrated in Fig. 1, the second valve chamber 44 is formed above the first valve body 42 in the first valve housing 41 and is capable of sucking the working oil. The biasing mechanism 45 biases the first valve body 42 in a direction in which the first valve body 42 is moved toward the first valve chamber 43.

[0039] According to the embodiment of the present invention, the first control valve 4 establishes or interrupts

a communication path between the second outlet port 32 and the discharge oil passage 5 by activating the first valve body 42 to establish or interrupt a communication path of the port connecting oil passage 51. Then, the first control valve 4 performs a control for changing the discharge pressure of the operation oil to be discharged to the discharge oil passage 5 between the discharge pressure only from the first outlet port 31 and the discharge pressure from both of the first and second outlet ports 31 and 32. Accordingly, the first control valve 4 controls the discharge pressure of the working oil from the pump main body 1.

[0040] The first valve body 42 is slidably provided in the substantially cylindrical shaped first valve housing 41. According to the embodiment of the present invention, the first valve chamber 43 is located below the first valve body 42 as shown in Fig. 1, and the second valve chamber 44 is located above the first valve body 42 as shown in Fig. 1. The first valve chamber 43 communicates with the discharge oil passage 5 through a first transmission oil passage 52. Thereby, the discharge pressure of the working oil applies to a first surface of the first valve body 42 (i.e., a lower surface of the first valve body 42 in Fig. 1). In contrast, the second valve chamber 44 is provided with a spring 45a of the biasing mechanism 45. The first valve body 42 is biased in a direction in which the first valve body 42 is moved toward the first valve chamber 43 (a direction of B1 in Fig. 1) by means of the spring 45a. With the configuration of the oil pump according to the embodiment of the present invention, a position of the first valve body 42 is defined by means of a balance between a biasing force of the spring 45a in the direction in which the first valve body 42 is moved toward the first valve chamber 43 (the direction of B1 in Fig. 1) and a force of the discharge pressure of the working oil in the first valve chamber 43 in a direction in which the first valve body 42 is moved toward the second valve chamber 44. Further, the second valve chamber 44 communicates with the second control valve 7 through a first intermediate oil passage 91 and a second intermediate oil passage 92. Therefore, the working oil can be flowed into the second control chamber 44 through the second control valve 7.

[0041] The first valve body 42 is provided with two oil passages for controlling a destination of the working oil from the second outlet port 32. According to the embodiment of the present invention, a first oil passage 42a is located at a second valve chamber 44 side (an upper side as viewed in Fig. 1) and a second oil passage 42b is located at a first valve chamber 43 side (a lower side as viewed in Fig. 1).

[0042] The first valve housing 41 includes first and second switch ports 41a and 41b, first and second feedback ports 41c and 41d, a discharge pressure port 41e, and first and second back pressure ports 41f and 41g. The first switch port 41a communicates with the port connecting oil passage 51 at a second outlet port 32 side, and the second switch port 41b communicates with the port

connecting oil passage 51 at a first outlet port 31 side. The first and second feedback ports 41c and 41d communicate with the feedback oil passage 6. The discharge pressure port 41e applies the discharge pressure of the working oil to the first valve chamber 43 by communicating the first valve chamber 43 and the first transmission oil passage 52. The first back pressure port 41f communicates with the first intermediate oil passage 91, and the second back pressure port 41g communicates with the second intermediate oil passage 92.

[0043] The second control valve 7 controls the first control valve 4 on the basis of degree of the temperature of the working oil. More particularly, the second control valve 7 controls the oil pressure of the working oil flowed into the second valve chamber 44 of the first control valve 4 on the basis of degree of the temperature of the working oil. According to the embodiment of the present invention, in a condition where the temperature of the working oil satisfies a predetermined temperature condition J, the second control valve 7 performs a control for establishing a communication path between the second valve chamber 44 and the first valve chamber 43 by establishing a communication path between the second valve chamber 44 of the first control valve 4 and the discharge oil passage 5. More particularly, in a condition where the temperature of the working oil satisfies the temperature condition J, the second control valve 7 performs a control for moving the first valve body 42 of the first control valve 4 to a last end portion of the first valve housing 41 at the first valve chamber 43 side on the basis of a view that the oil pressure in the second valve chamber 44 is substantially equal to that of the first valve chamber 43. In contrast, in a condition where the temperature of the working oil does not satisfy the temperature condition J, the second control valve 7 performs a control for establishing a communication path between the second valve chamber 44 of the first control valve 4 and the feedback oil passage 6. On this condition, the oil pressure in the second valve chamber 44 is adequately lower degree than that of the first valve chamber 43. Therefore, the position of the first valve body 42 is defined by means of the balance between the biasing force of the spring 45a of the biasing mechanism 45 and the force of the oil pressure in the first valve chamber 43. Accordingly, the first control valve 4 controls the discharge pressure of the working oil to be discharged to the discharge oil passage 5 by means of a movement of the first valve body 42 on the basis of degree of the discharge pressure of the working oil.

[0044] According to the embodiment of the present invention, the oil pump X supplies the working oil relative to each part of the engine of the vehicle. Thus, a temperature of the working oil under normal use conditions is assumed to be from room temperature to 110 degrees C., and a temperature of the working oil in a condition where the engine is activated for long periods of time with a heavy load is assumed to be higher degree, for example, approximately from 110 to 130 degrees C. According

to the embodiment of the present invention, in order to change an operating control of the first control valve 4 under such a high temperature state, the temperature condition J is assumed to be approximately from 110 to 130 degrees C.

[0045] According to the embodiment of the present invention, in order to perform the above described control, the second control valve 7 includes a second valve body 72 and a valve body operating mechanism 73. The second valve body 72 reciprocates in a second valve housing 71 and changes a control whether to establish or interrupt the communication path between the second valve chamber 44 and the first valve chamber 43. The valve body operating mechanism 73 activates the second valve body 72 by means of a heat-sensitive expanding and contracting member 73a, which is expanded and contracted in a direction of a reciprocation of the second valve body 72 on the basis of degree of the temperature of the working oil.

[0046] The second valve body 72 is slidably provided in the substantially cylindrical shaped second valve housing 71. The second valve body 72 is provided with a third oil passage 72a for controlling a communication path of the second valve chamber 44 of the first control valve 4

[0047] The second valve housing 71 is provided with a high pressure port 71a, a low pressure port 71b, a drain port 71c, a first communicating port 71d, a second communicating port 71e, and a communicating passage 71f. The high pressure port 71a communicates with the discharge oil passage 5 through a second transmission oil passage 53 and the low pressure port 71b communicates with the feedback oil passage 6. The drain port 71c communicates with the oil pan, or the like, the first communicating port 71d communicates with the first intermediate oil passage 91, and the second communicating port 71e communicates with the second intermediate oil passage 92. The communicating passage 71f communicates the low pressure port 71b with the third oil passage 72a of the second valve body 72 in a condition where the second valve body 72 positions within a predetermined range.

[0048] The valve body operating mechanism 73 is provided with, at a first side of the second valve body 72 (an upper side as viewed in Fig. 1), the heat-sensitive expanding and contracting member 73a, which is expanded and contracted in the direction of the reciprocation of the second valve body 72 on the basis of degree of the temperature of the working oil. The valve body operating mechanism 73 is provided with, at a second side of the second valve body 72 (a lower side as viewed in Fig. 1), an elastic member 73b. According to the embodiment of the present invention, the elastic member 73b includes a spring, and the heat-sensitive expanding and contracting member 73a includes a spring made of shape memory alloy. The working oil from the feedback oil passage 6 flows into a space in the second valve housing 71 in which the heat-sensitive expanding and contracting member 73a is provided through the low pressure port

71b. Therefore, the heat-sensitive expanding and contracting member 73a is normally soaked in the working oil and the temperature of the working oil can be transmitted thereto. In a condition where the temperature of the working oil in the vicinity of the heat-sensitive expanding and contracting member 73a satisfies the temperature condition J, the heat-sensitive expanding and contracting member 73a expands in the direction of the reciprocation of the second valve body 72 and compresses the elastic member 73b to move the second valve body 72 in a second side (the lower side as viewed in Fig. 1). According to the embodiment of the present invention, the temperature condition J is assumed to be approximately from 110 to 130 degrees C. Therefore, in a condition where the temperature of the working oil in the vicinity of the heat-sensitive expanding and contracting member 73a becomes equal to, or higher than, 110 degrees C., the heat-sensitive expanding and contracting member 73a expands in the direction of the reciprocation of the second valve body 72 and moves the second valve body 72 in a vertical direction.

[0049] The second control valve 7 is configured to activate independently from the first control valve 4. With the configuration of the pump main body 1 of the oil pump X according to the embodiment of the present invention, the discharge pressure of the working oil is pulsated. However, the heat-sensitive expanding and contracting member 73a is not influenced by a pulsation of the discharge pressure of the working oil because the second valve body 72 of the second control valve 7 is applied with the discharge pressure of the working oil from a side face thereof through the high pressure port 71a. Accordingly, even when the heat-sensitive expanding and contracting member 73a includes a spring made of shape memory alloy, fatigue strength of which is at a lower degree, a fatigue breakdown of the spring is not generated.

[0050] An operation of the first control valve 4 and the second control valve 7 in response to an increase of a rotational speed of the rotor 2 of the pump main body 1 and an increase of the temperature of the working oil will be explained hereinafter. Illustrated in Figs. 2-8 are a flow of the working oil in various conditions of the first control valve 4 and the second control valve 7.

[0051] Further, illustrated in Figs. 9A-9B are a relation, within a normal temperature region of the working oil (approximately from room temperature to 110 degrees C.) and within a high temperature region of the working oil (approximately from 110 to 130 degrees C.), between the rotational speed of the rotor 2 and the discharge pressure of the working oil in the discharge oil passage 5. Fig. 9A indicates a condition where the temperature of the oil is approximately 80 degrees C. and Fig. 9B indicates a condition where the temperature of the oil is approximately 130 degrees C. On this occasion, a straight line L1 in Figs. 9A-9B indicates a relation between the discharge pressure of the working oil, discharged from both of the first outlet port 31 and the second outlet port 32, and the rotational speed of the rotor 2. Further, a

straight line L2 in Figs. 9A-9B indicates a relation between the discharge pressure of the working oil, discharged only from the first outlet port 31 and the rotational speed of the rotor 2. In Figs. 9A-9B, hatching areas W1 - W4 indicate the oil pressure required at each part to be supplied with the working oil. More particularly, W1 indicates a required oil pressure for the valve timing control apparatus, W2 indicates a required oil pressure for a crank journal, W3 indicates a required oil pressure for a piston jet, which supplies piston cooling oil within a high revolving-speed region of the engine, and W4 indicates a required oil pressure for an idling of the engine. The oil pump X is required to supply the working oil, the oil pressure of which is equal to, or higher than, the above described required oil pressure, to the discharge oil passage 5.

[0052] The operation of the first control valve 4 and the second control valve 7 in a condition where the temperature of the working oil is in the normal temperature region (equal to, or lower than, approximately 110 degrees C), in other words, in a condition where the temperature of the working oil does not satisfy the temperature condition J will be explained hereinafter. On this condition, the second control valve 7 comes into a normal state in which the second control chamber 44 of the first control valve 4 is communicated with the feedback oil passage 6 as illustrated in Figs. 2-6. In this normal state, the second valve body 72 of the second control valve 7 is located at a position in which the first communicating port 71d communicating with the first intermediate oil passage 91 is communicated with the communicating passage 71f communicating with the low pressure port 71b through the third oil passage 72a. Accordingly, the second valve chamber 44 of the first control valve 4 communicates with the feedback oil passage 6. Further, in a condition where the temperature of the working oil is in the normal temperature region (equal to, or lower than, approximately 110 degrees C), in other words, in a condition where the second control valve 7 is held at the normal state, the first control valve 4 activates the first valve body 42 to achieve states of A-E and controls the discharge pressure of the working oil to be discharged to the discharge oil passage 5. Illustrated in Fig. 9A is a relation between the rotational speed of the rotor 2 and the discharge pressure of the working oil from the discharge oil passage 5 under the above described circumstances.

[0053] State A will be explained hereinafter with reference to Fig. 2. Immediately after an engine starting, or the like, within a low revolving-speed region in which the rotational speed of the rotor 2 is at a lower degree (e.g., the rotational speed of the rotor is equal to, or less than, 1,500 rotation), and within a predetermined first region I designated at the lowest pressure region as illustrated in Fig. 9A, in a condition where the discharge pressure of the working oil from both of the first outlet port 31 and the second outlet port 32 is at a lower degree, the first valve body 42 of the first control valve 4 positions at the last end portion of the first valve housing 41 at the first

valve chamber 43 side, and the first control valve 4 performs a control for supplying the working oil discharged from both of the first outlet port 31 and the second outlet ports 32 to the discharge oil passage 5.

[0054] More particularly, the first valve body 42 closes the first and second feedback ports 41c and 41d and communicates the first oil passage 42a with the port connecting oil passage 51 at both of the second outlet port 32 side and the first outlet port 31 side. Thereby, the working oil discharged from the second outlet port 32 is supplied to the discharge oil passage 5 through the first control valve 4 and the first outlet port 31. In other words, in a condition where the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 is in the predetermined first region I, the first control valve 4 communicates both of the first and second outlet ports 31 and 32 with the discharge oil passage 5, and performs a control for supplying the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5. On this occasion, an amount of the working oil to be supplied to the discharge oil passage 5 becomes a sum of a discharge amount of the first outlet port 31 and that of the second outlet port 32. Further, on this occasion, the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 can obtain a characteristic indicated by line O-P illustrated in Fig. 9A. More particularly, the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 can obtain a characteristic that the discharge pressure increases in response to the increase of the rotational speed of the rotor 2.

[0055] The biasing force of the spring 45a of the biasing mechanism 45 and conditions such as a position, a shape, or the like, of the first oil passage 42a and the second oil passage 42b are appropriately designated to achieve the states of A-E by activating the first valve body 42 on the basis of degree of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5.

[0056] State B will be explained hereinafter with reference to Fig. 3. In a condition where the discharge pressure of the working oil from both of the first and second outlet ports 31 and 32 is increased in accordance with the increase of the rotational speed of the rotor 2, and in a condition where the discharge pressure of the working oil exceeds the first region I and reaches a second region II designated at a higher pressure side than the first region I, the first control valve 4 performs a control for supplying some of the working oil from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5 and performs a control for supplying some of the working oil to the feedback oil passage 6 from the first feedback port 41c as illustrated in Fig. 3.

[0057] More particularly, the first valve body 42 moves to the second valve chamber 44 side (an upper side as viewed in Fig. 2) to some degree from the last end portion of the first valve housing 41 at the first valve chamber 43 side as illustrated in Fig. 2 and communicates the first oil

passage 42a of the first valve body 42 with the port connecting oil passage 51, at both of the second outlet port 32 side and the first outlet port 31 side, and with the feedback oil passage 6 while closing the second feedback port 41d. Thereby, some of the working oil discharged from the second outlet port 32 is supplied to the discharge oil passage 5 through the first control valve 4 and the first outlet port 31, and some of the working oil is supplied to the feedback oil passage 6. In other words, in a condition where the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 is in the second region II, the first control valve 4 communicates both of the first and second outlet ports 31 and 32 with both of the discharge oil passage 5 and the feedback oil passage 6, and supplies some of the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5 and some of the working oil to the feedback oil passage 6. On this occasion, the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 can obtain a characteristic indicated by line P-Q illustrated in Fig. 9A. More particularly, on this occasion, the increase of the oil pressure of the working oil (the discharge oil) in the discharge oil passage 5 in response to the increase of the rotational speed of the rotor 2 is lowered because a communication path to the feedback oil passage 6 is established.

[0058] State C will be explained hereinafter with reference to Fig. 4. In a condition where the discharge pressure of the working oil from both of the first and second outlet ports 31 and 32, the first and second outlet ports 31 and 32 being in a condition where some of the working oil is supplied to the feedback oil passage 6, exceeds the second region II and reaches a third region III designated at a higher pressure side than the second region II in accordance with the increase of the rotational speed of the rotor 2, the first control valve 4 performs a control for supplying the working oil discharged from the first outlet port 31 to the discharge oil passage 5 and performs a control for supplying the working oil discharged from the second outlet port 32 to the feedback oil passage 6.

[0059] More particularly, the first valve body 42 moves to the second valve chamber 44 side (an upper side as viewed in Fig. 3) to some degree from a position illustrated in Fig. 3 and communicates the first oil passage 42a with the port connecting oil passage 51 at the second outlet port 32 side, and the feedback oil passage 6 through the first feedback port 41c while closing the second feedback port 41d. On this occasion, the second oil passage 42b communicates only with the port connecting oil passage 51 at the first outlet port 31 side. Thereby, the working oil discharged from the second outlet port 32 is supplied to the feedback oil passage 6 and the working oil discharged from the first outlet port 31 is supplied to the discharge oil passage 5. In other words, in a condition where the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 is in the third region III, the first control valve 4 interrupts a communication path between the second outlet port 32 and the

discharge oil passage 5, establishes a communication path between the second outlet port 32 and the feedback oil passage 6, and further establishes a communication path between the first outlet port 31 and the discharge oil passage 5, and accordingly performs a control for supplying the working oil discharged from the first outlet port 31 to the discharge oil passage 5. On this occasion, the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 can obtain a characteristic indicated by line Q-R illustrated in Fig. 9A. More particularly, on this occasion, an amount of the working oil to be supplied to the discharge oil passage 5 becomes substantially equal to an amount of the working oil discharged from the first outlet port 31.

[0060] State D will be explained hereinafter with reference to Fig. 5. In a condition where the discharge pressure of the working oil from the first outlet port 31 exceeds the third region III and reaches a fourth region IV designated at a higher pressure side than the third region III in accordance with the increase of the rotational speed of the rotor 2, the first control valve 4 performs a control for supplying the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5 as illustrated in Fig. 5.

[0061] More particularly, the first valve body 42 moves to the second valve chamber 44 side (an upper side as viewed in Fig. 4) to some degree from a position illustrated in Fig. 4 and establish a communication path between the second oil passage 42b and the port connecting oil passage 51 at both of the second outlet port 32 side and the first outlet port 31 side, and interrupts a communication path between the port connecting oil passage 51 and the first feedback port 41c, and further closes the second feedback port 41d. Thereby, the working oil discharged from the second outlet port 32 is supplied to the discharge oil passage 5 through the first control valve 4 and the first outlet port 31. In other words, in a condition where the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 is in the fourth region IV, the first control valve 4 establish a communication path between the both of the first and second outlet ports 31 and 32 and the discharge oil passage 5, and accordingly performs a control for supplying the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5. On this occasion, an amount of the working oil to be supplied to the discharge oil passage 5 becomes a sum of an amount of the discharge pressure from the first outlet port 31 and that of the second outlet port 32. According to an example illustrated in Fig. 9A, the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 rapidly increases as indicated by line R-S. Then, in a condition where the oil pressure of the working oil corresponds to the discharge pressure from both of the first and second outlet ports 31 and 32, and in a condition where the discharge pressure of the working oil corresponds to line S-T illustrated in Fig. 9A, the discharge pressure of the working oil reaches the fifth region V and

thus the discharge pressure is relieved.

[0062] State E will be explained hereinafter with reference to Fig. 6. In a condition where the discharge pressure of the working oil from both of the first and second outlet ports 31 and 32 is increased, the pressure of the working oil exceeds the fourth region IV and reached the fifth region V designated at a higher pressure side than the fourth region IV. On this occasion, the first control valve 4 performs a control for supplying some of the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5 as illustrated in Fig. 6, and performs a control for supplying some of the working oil to the feedback oil passage 6 through the first feedback port 41c. Further, the first control valve 4 supplies some of the working oil to the feedback oil passage 6 by establishing a communication path between the first valve chamber 43 and the second feedback port 41d.

[0063] More particularly, the first valve body 42 moves to the second valve chamber 44 side (an upper side as viewed in Fig. 5) to some degree from a position illustrated in Fig. 4 and communicates the second oil passage 42b of the first valve body 42 with the port connecting oil passage 51 at both of the second outlet port 32 side and the first outlet port 31 side and the feedback oil passage 6. Further a communication path between the first valve chamber 43 and the second feedback port 41d is established. Thereby, some of the working oil discharged from the second outlet port 32 is supplied to the discharge oil passage 5 through the first control valve 4 and the first outlet port 31 and some of the working oil is supplied to the feedback oil passage 6. Further, some of the working oil supplied to the discharge oil passage 5 is supplied to the feedback oil passage 6 through the first transmission oil passage 52 and the first valve chamber 43. In other words, in a condition where the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 is in the fifth region V, the first control valve 4 communicates both of the first and second outlet ports 31 and 32 with the discharge oil passage 5 and the feedback oil passage 6, and accordingly performs a control for supplying some of the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5 and performs a control for supplying some of the working oil to the feedback oil passage 6. On this occasion, the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 can obtain a characteristic indicated by line S-T illustrated in Fig. 9A. More particularly, on this occasion, the increase of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 in response to the increase of the rotational speed of the rotor 2 is lowered because the communication path to the feedback oil passage 6 is established.

[0064] By means of the operation of the first control valve 4, the required oil pressure for the valve timing control apparatus (area W1 in Fig. 9A) can be ensured by rapidly increasing the oil pressure (line O-P in Fig. 9A)

in a condition where the rotational speed of the rotor 2 is at a lower degree (a low revolving-speed region of the engine). Further, by means of the operation of the first control valve 4, a load applied to the engine can be reduced by lowering an operation resistance of the oil pump X by controlling the oil pressure at a lower degree (lines P-Q and Q-R in Fig. 9A) for ensuring the required oil pressure for the crank journal (area W2 in Fig. 9A) in a condition where the rotational speed of the rotor 2 is at a medium degree (a medium revolving-speed region of the engine). Moreover, by means of the operation of the first control valve 4, the oil pressure of higher degree (lines R-S and S-T in Fig. 9A) can be generated for ensuring the required oil pressure for the piston jet (area W3 in Fig. 9A) in a condition where the rotational speed of the rotor 2 is at a higher degree (the high revolving-speed region of the engine)

[0065] The operation of the first control valve 4 and the second control valve 7 in a condition where the temperature of the working oil exceeds approximately 110 degrees C. will be explained hereinafter. On this occasion, the second control valve 7 comes into the high temperature state in which the second chamber 44 is communicated with the discharge oil passage 5 as illustrated in Fig. 8 after passing through a medium state in which the second valve chamber 44 is communicated with both of the discharge oil passage 5 and the feedback oil passage 6 as illustrated in Fig. 7. Then the first control valve 4 establishes a communication path between the second valve chamber 44 and the first valve chamber 43 to conform the oil pressure thereof and moves the first valve body 42 to the last end portion of the first valve housing 41 at the first valve chamber 43 side by means of the biasing mechanism 45. Thereby, the first control valve 4 is held at the state A regardless of conditions of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5, and performs a control for supplying the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5.

[0066] The medium state is explained hereinafter with reference to Fig. 7. In a condition where the temperature of the working oil becomes approximately 110 degrees C., the heat-sensitive expanding and contracting member 73a of the second valve body 72 start to expand in the direction of the reciprocation of the second valve body 72, and thereby the elastic member 73b provided at an opposed position from the second valve body 72 is compressed and the second valve body 72 moves downwards as illustrated in Fig. 7. Thereby, the third oil passage 72a is communicated with the high pressure port 71a, the low pressure port 71b, the first communicating port 71d and the second communicating port 71e. Accordingly, the second chamber 44 of the first control valve 4 communicates with both of the discharge oil passage 5 and the feedback oil passage 6, and the working oil is began to flow into the second valve chamber 44. The second control valve 7 temporarily comes into the medi-

um state on the way of shifting to the high temperature state. The second control valve 7 comes into the high temperature state by further expanding of the heat-sensitive expanding and contracting member 73a.

[0067] The high temperature state is explained hereinafter with reference to Fig. 8. In a condition where the temperature of the working oil becomes equal to, or higher than, approximately 110 degrees C., that is, in a condition where the temperature of the working oil satisfies the temperature condition J, the second control valve 7 comes into the high temperature state. On this occasion, the heat-sensitive expanding and contracting member 73a of the valve body operating mechanism 73 further expands in the direction of the reciprocation of the second valve body 72, and thereby the elastic member 73b is further compressed, and the second valve body 72 moves downwards as illustrated in Fig. 8. Therefore, the third oil passage 72a is communicated with the high pressure port 71a and the second communicating port 71e. Accordingly, the second chamber 44 of the first control valve 4 communicates with the discharge oil passage 5 through the second transmission oil passage 53. Therefore, the second valve chamber 44 of the first control valve 4 communicates with the first valve chamber 43 through the discharge oil passage 5, and the oil pressure in the second valve chamber 44 and that of the first valve chamber 43 becomes approximately equal. On this occasion, the first control valve 4 performs a control for moving the first valve body 42 to the last end portion of the first valve housing 41 at the first valve chamber 43 side by means of the biasing mechanism 45. Thereby, the first control valve 4 is held at the state A regardless of the conditions of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5, and performs a control for supplying the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5.

[0068] On this occasion, regardless of the condition of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 corresponding to any one of the regions I-IV, the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 can obtain a characteristic indicated by line O-S illustrated in Fig. 9B. More particularly, on this occasion, the discharge pressure is increased in response to the increase of the rotational speed of the rotor 2. According to the embodiment of the present invention, in order to prevent the oil pump X from being damaged, some of the working oil in the discharge oil passage 5 is supplied to the feedback oil passage 6 for relieving the discharge pressure by means of a relief valve (not shown) provided at the discharge oil passage 5 in a condition where the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 corresponds to the fifth region V designated at the higher pressure side than the fourth region IV. On this occasion, the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 can obtain a characteristic indicated by line

S-T illustrated in Fig. 9B. More particularly, on this occasion, the increase of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5 in response to the increase of the rotational speed of the rotor 2 is lowered.

[0069] The second control valve 7 is activated at a high temperature condition of the oil and the first control valve 4 performs a control for the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5 regardless of the conditions of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5. Thereby, the oil pump X according to the embodiment of the present invention can ensure the required discharge pressure at the high temperature condition of the oil and can also achieve an optimal discharge pressure within the normal temperature region, which is a temperature region of the working oil under the normal use conditions, in other words, less than, or equal to, approximately 110 degrees C. Accordingly, the operation resistance of the oil pump X can be reduced. Therefore, in a condition where the oil pump X is activated by means of the engine of the vehicle, a fuel economy of the engine can be improved.

[0070] Illustrated in Figs. 10A-10B are a relation, within the normal temperature region of the working oil (approximately from room temperature to 110 degrees C.) and within the high temperature region of the working oil (approximately from 110 to 130 degrees C.), between the rotational speed of the rotor 2 and the discharge pressure of the working oil of an oil pump, which has a first control valve similar to that of the first embodiment of the present invention and does not have a second control valve. Illustrated in Fig. 10A is a condition where the temperature of the oil is approximately 80 degrees C., and illustrated in Fig. 10B is a condition where the temperature of the oil is approximately 130 degrees C. A straight line L1 in Figs. 10A-10B indicates a relation between the discharge pressure of the working oil, discharged from both of the first outlet port 31 and the second outlet port 32, and the rotational speed of the rotor 2. Further a straight line L2 in Figs. 10A-10B indicates a relation between the discharge pressure of the working oil, discharged only from the first outlet port 31, and the rotational speed of the rotor 2. A slope of the lines L1 and L2 tends to become gentle in accordance with the increase of the temperature of the oil. It is because a degree of viscosity of the working oil is lowered in response to the increase of the temperature of the oil, a degree of leak of the working oil in the parts to be supplied with the working oil is increased, and accordingly a rate of the increase of the discharge pressure of the working oil relative to the increase of the rotational speed of the rotor is lowered.

[0071] Further, as well as the oil pump X according to the first embodiment of the present invention, the oil pump illustrated in Fig. 10 reduces the load applied to the engine by lowering the operation resistance of the oil pump by controlling the oil pressure at the lower degree in a region in which the rotational speed of the rotor is at

the medium degree (the medium revolving-speed region of the engine), that is, in regions indicated by line P-Q, Q-R, and R-S in Figs. 10A-10B.

[0072] On this occasion, in a condition where the temperature of the working oil becomes at the higher degree, the rate of the increase of the discharge pressure of the working oil relative to the increase of the rotational speed of the rotor is lowered. Therefore, in a condition where the temperature of the working oil becomes at the higher degree, the rotational speed of the rotor is increased for ensuring the discharge pressure more than, or equal to, the predetermined required pressure (areas W1-W4) for the parts to be supplied with the working oil. Thus, the oil pump, which does not have the second control valve 7 is configured to have a control valve, which is a valve corresponding to the first control valve according to the first embodiment of the present invention, for controlling the discharge amount or the discharge pressure of the working oil relative to the rotational speed of the rotor in order to ensure the discharge pressure more than, or equal to, the predetermined required pressure (areas W1-W4) for the parts to be supplied with the working oil even at an assumed highest temperature of the working oil as illustrated in Fig. 10B. More particularly, the pump main body, the control valve, or the like, of the oil pump illustrated in Fig. 10B is configured to supply the working oil, discharge pressure of which is more than, or equal to, each predetermined required oil pressure such as the required oil pressure for the valve timing control apparatus (area W1), the required oil pressure for the crank journal (area W2), the required oil pressure for the piston jet (area W3), and the required oil pressure for the idling of the engine (area W4), to the discharge oil passage 5 in the whole region of the rotational speed of the rotor in a condition where the working oil is at approximately 130 degrees C.

[0073] In a condition where the pump main body, control valve, or the like, of the oil pump is configured on the basis of the assumed highest temperature, if the temperature of the working oil is within the normal temperature region, an effect of decreasing of the operation resistance of the oil pump may occasionally be lowered because a region, in which the discharge pressure of the working oil can be reduced by means of the first control valve 4 at the time of a medium revolving-speed region of the rotor, is narrowed as illustrated in Fig. 10A. More particularly, in a condition where the temperature of the working oil is at the lower degree, the rate of the increase of the discharge pressure of the working oil relative to the increase of the rotational speed of the rotor becomes higher. Therefore, the region in which the discharge pressure is reduced by means of the first control valve 4 is located at a lower rotational speed side as illustrated in Fig. 10A relative to a condition where the temperature of the working oil is at the higher degree as illustrated in Fig. 10B. More particularly, the discharge oil pressure is increased in a condition where the rotational speed of the rotor is relatively lower degree than the rotational speed of the

rotor that requires the required oil pressure for the piston jet (area W3). Thus, a region Y, in which a surplus discharge pressure is generated, is occurred and an effect of decreasing of the load applied to the engine is lowered. Further, the working oil of the vehicle in practice comes into the high temperature region (approximately from 110 to 130 degrees C.) on rare condition such as a condition where the engine is activated for long periods of time with a heavy load, and the working oil of the vehicle in practice is within the normal temperature region (approximately from room temperature to 110 degrees C.) under the normal use conditions. Accordingly, with a discharge control of the working oil as illustrated in Fig. 10, the effect of decreasing of the load applied to the engine may occasionally be low.

[0074] In contrast, with the configuration of the oil pump according to the first embodiment of the present invention, the second control valve 7 is activated at the high temperature condition of the oil and the first control valve 4 performs a control for supplying the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5 regardless of the conditions of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5. Thereby the oil pump X according to the first embodiment of the present invention can ensure the required discharge pressure at the high temperature condition of the oil and can also achieve the optimal discharge pressure within the normal temperature region, which is the temperature region of the working oil under the normal use conditions, in other words, less than, or equal to, approximately 110 degrees C. Therefore, as illustrated in Fig. 9A, the pump main body 1, the first control valve 4, or the like, of the oil pump X can be configured to widely ensure the region in which the discharge pressure of the working oil can be reduced within the normal temperature region. Accordingly, a rotational speed region of the rotor 2, in which the operation resistance of the oil pump X can be reduced within the normal temperature region, can be expanded and the effect of decreasing of the load applied to the engine can be improved.

[0075] With the configuration of the oil pump X having a characteristic of the above described discharge pressure, the pump main body 1 and the first and second outlet ports 31 and 32 may be configured that the discharge pressure of the working oil from the first outlet port 31 (the discharge pressure indicated by line Q-R in Fig. 9A) within the third region III in a condition where the temperature of the working oil is at a lower limit (approximately 110 degrees C.) of the temperature condition J (approximately from room temperature to 110 degrees C.) becomes more than, or equal to, the required oil pressure (areas W1-W2) at the parts to be supplied with the working oil, and the discharge oil pressure of the working oil from the first and second oil ports 31 and 32 within the whole regions of the rotational speed I-V (at least within the first region I and the fifth region V) in a condition where the temperature of the working oil is at a higher

limit (approximately 130 degrees C.) of the temperature condition J becomes more than, or equal to, the required oil pressure (areas W1-W4) at the parts to be supplied with the working oil. With the above described configuration, the discharge pressure, which is more than, or equal to, the required oil pressure at the parts to be supplied with the working oil, can be ensured in both conditions where the temperature of the working oil is at the lower limit of the temperature condition J (approximately 110 degrees C.), at which the discharge pressure of the working oil becomes at the lowest level when the temperature of the working oil does not satisfy the temperature condition J, and where the temperature of the working oil is at the higher limit of the temperature condition J (approximately 130 degrees C.), at which the discharge pressure becomes at the lowest level when the working oil satisfies the temperature condition J. In consequence, the discharge pressure, which is more than, or equal to, the required oil pressure at the parts to be supplied with the working oil, can be ensured under any temperature conditions.

[0076] A second embodiment of the present invention will be explained hereinafter with reference to Fig. 11. As illustrated in Fig. 11, the configuration of an oil pump XII according to the second embodiment of the present invention is basically similar to that of the oil pump X according to the first embodiment of the present invention in a structure. The same structure as described in the aforementioned embodiment is not repeatedly explained. A structure of a first valve body 242 of a first control valve 204 is different from that of the first embodiment of the present invention. The first valve body 242 of the oil pump XII according to the second embodiment of the present invention does not include an oil passage corresponding to the second oil passage 42b of the first embodiment of the present invention, and only includes an oil passage corresponding to the first oil passage 42a of the first embodiment of the present invention. Therefore, the first control valve 204 of the oil pump XII according to the second embodiment of the present invention operates the first valve body 242 for achieving a similar condition to the conditions A-C (Figs. 2-4) of the first control valve 4 according to the first embodiment of the present invention on the basis of degree of the discharge pressure of the working oil to be discharged to the discharge oil passage 5 in a condition where the temperature of the working oil is within the normal temperature region (equal to, or lower than, approximately 110 degrees C.), that is, in a condition where a second control valve 207 is held at a normal state. Further, in a condition where the discharge pressure of the working oil is increased, the oil pump XII according to the second embodiment of the present invention establishes a communication path between a first valve chamber 243 and a second feedback port 241d, and supplies some of the working oil in a discharge oil passage 205 to a feedback oil passage 206 for relieving the discharge pressure. Then, the second control valve 207 performs an opera-

tion similar to that of the oil pump X according to the first embodiment of the present invention.

[0077] Illustrated in Figs. 12A-12B are a relation, within the normal temperature region of the working oil (approximately from room temperature to 110 degrees C.) and within the high temperature region of the working oil (approximately from 110 to 130 degrees C.), between a rotational speed of a rotor 202 and the discharge pressure of the working oil in the discharge oil passage 205. Fig. 12A indicates a condition where the temperature of the oil is approximately 80 degrees C. and Fig. 12B indicates a condition where the temperature of the oil is approximately 130 degrees C. Fig. 12 according to the second embodiment of the present invention corresponds to Fig. 9 according to the first embodiment of the present invention.

[0078] As illustrated in Fig. 12, the oil pump XII according to the second embodiment of the present invention, in a condition where the temperature of the working oil is within the normal temperature region (equal to, or lower than approximately 110 degrees C.), by activating the first control valve 204 on the basis of degree of the discharge pressure of the working oil to be discharged to the discharge oil passage 205, the oil pressure is rapidly increased (line O-P in Fig. 12A) in a condition where the rotational speed of the rotor 202 is at a lower degree (the low revolving-speed region of the engine) for ensuring the required oil pressure for the valve timing control apparatus (area W1 in Fig. 12A), and controls the oil pressure at the lower degree (line P-Q and line Q-R in Fig. 12A) for ensuring the required oil pressure for the crank journal (area W2 in Fig. 12A) in a condition where the rotational speed of the rotor 202 is higher than the medium degree (the medium and high revolving-speed region of the engine). Accordingly, the load applied to the engine can be reduced by lowering the operation resistance of the oil pump XII. The oil pump performing a control illustrated in Fig. 12A may be used as an oil pump for supplying the working oil to an engine, which does not perform the piston jet at the high revolving-speed region, that is, an engine, which does not have the required pressure for the piston jet (area W3) according to the first embodiment of the present invention.

[0079] As well as the oil pump X according to the first embodiment of the present invention, the second control valve 207 is activated at the high temperature condition of the oil and the first control valve 204 performs a control for supplying the working oil discharged from both of the first and second outlet ports 31 and 32 to the discharge oil passage 5 regardless of the conditions of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 5. Thereby the oil pump XII according to the second embodiment of the present invention can ensure the required discharge pressure at the high temperature condition of the oil and can also achieve an optimal discharge pressure within the normal temperature region, which is the temperature region of the working oil under the normal use conditions, in other words,

less than, or equal to, approximately 110 degrees C. Accordingly, the operation resistance of the oil pump XII can be reduced. Therefore, in a condition where the oil pump X is activated by means of the engine of the vehicle, a fuel economy of the engine can be improved.

[0080] Illustrated in Figs. 13A-13B are a relation, within the normal temperature region of the working oil (approximately from room temperature to 110 degrees C.) and within the high temperature region of the working oil (approximately from 110 to 130 degrees C.), between the rotational speed of the rotor and the discharge pressure of the working oil of an oil pump, which has a first control valve similar to that of the second embodiment of the present invention and does not have a second control valve. Illustrated in Fig. 13A is a condition where the temperature of the oil is approximately 80 degrees C., and illustrated in Fig. 13B is a condition where the temperature of the oil is approximately 130 degrees C. Fig. 13 corresponds to Fig. 10 according to the first embodiment of the present invention.

[0081] Further, as well as the oil pump XII according to the second embodiment of the present invention, the oil pump illustrated in Fig. 13 is provided with a control valve (a valve corresponding to the first valve according to the second embodiments of the present invention) for controlling the discharge amount and the discharge pressure of the working oil in order to ensure the discharge pressure more than, or equal to, the predetermined required pressure (areas W1, W2, and W4) at the parts to be supplied with the working oil even at the assumed highest temperature of the working oil as illustrated in Fig. 13B.

[0082] In a condition where the pump main body, control valve, or the like, of the oil pump is configured on the basis of the assumed highest temperature, if the temperature of the working oil is within the normal temperature region, the effect of decreasing of the operation resistance of the oil pump may occasionally be lowered because the region, in which the discharge pressure of the working oil can be reduced by means of the first control valve in a condition where the rotational speed of the rotor is higher than the medium degree, is narrowed as illustrated in Fig. 13A. More particularly, in a condition where the temperature of the working oil is at the lower degree, the rate of the increase of the discharge pressure of the working oil relative to the increase of the rotational speed of the rotor becomes higher degree. Therefore, the region in which the discharge pressure is reduced by means of the first control valve is located at a lower rotational speed side as illustrated in Fig. 13A relative to a condition where the temperature of the working oil is at the higher degree as illustrated in Fig. 13B. Accordingly, the higher degree of the discharge pressure of the working oil is generally outputted from the lower revolving-speed region of the rotor, and the region Y, in which the surplus discharge pressure is generated, is occurred. In consequence, the effect of decreasing of the load applied to the engine may occasionally be lowered.

[0083] In contrast, with the configuration of the oil pump X according to the second embodiment of the present invention, the second control valve 207 is activated at the high temperature condition of the oil and the first control valve 204 performs a control for supplying the working oil discharged from both of the first and second outlet ports 231 and 232 to the discharge oil passage 205 regardless of the conditions of the oil pressure of the working oil (the discharge pressure) in the discharge oil passage 205. Thereby, the oil pump XII according to the second embodiment of the present invention can ensure the required discharge pressure at the high temperature condition of the oil and can also achieve the optimal discharge pressure within the normal temperature region, which is the temperature region of the working oil under the normal use conditions, in other words, less than, or equal to, approximately 110 degrees C. Therefore, as illustrated in Fig. 12A, the pump main body 201, the first control valve 204, or the like, of the oil pump XII can be configured to widely ensure the region in which the discharge pressure of the working oil can be reduced within the normal temperature region. Accordingly, a rotational speed region of the rotor 202, in which the operation resistance of the oil pump XII can be reduced within the normal temperature region, can be expanded and the effect of decreasing of the load applied to the engine can be improved.

[0084] With the configuration of the oil pump XII having a characteristic of the above described discharge pressure, the pump main body 201 and the first and second outlet ports 231 and 232 may be configured that the discharge pressure of the working oil from the first outlet port 231 (the discharge pressure indicated by line Q-R in Fig. 12A) within the third region III in a condition where the temperature of the working oil is at the lower limit (approximately 110 degrees C.) of the temperature condition J (approximately from room temperature to 110 degrees C.) becomes more than, or equal to, the required oil pressure (areas W1-W2) at the parts to be supplied with the working oil, and the discharge oil pressure of the working oil from the first and second oil ports 231 and 232 in a condition where the temperature of the working oil is at the higher limit (approximately 130 degrees C.) of the temperature condition J becomes more than, or equal to, the required oil pressure (areas W1, W2 and W4) at the parts to be supplied with the working oil within the regions from the first region I to the fourth region IV (at least within the first region I). With the above described configuration, the discharge pressure, which is more than, or equal to, the required oil pressure at the parts to be supplied with the working oil, can be ensured in both conditions where the temperature of the working oil is at the lower limit of the temperature condition J (approximately 110 degrees C.), at which the discharge pressure of the working oil becomes at the lowest level when the temperature of the working oil does not satisfy the temperature condition J, and where the temperature of the working oil is at the higher limit of the temperature con-

dition J (approximately 130 degrees C.), at which the discharge pressure becomes at the lowest level when the working oil satisfies the temperature condition J. In consequence, the discharge pressure, which is more than, or equal to, the required oil pressure at the parts to be supplied with the working oil, can be ensured under any temperature conditions.

[0085] A third embodiment of the present invention will be explained hereinafter with reference to Fig. 14. The same structure as described in the aforementioned embodiments is not repeatedly explained. As illustrated in Fig. 14, with the configuration of the oil pump XIII according to the third embodiment of the present invention, the working oil is discharged only from an outlet port 331. Therefore, a first control valve 304 according to the third embodiment of the present invention functions only as the relief valve for a condition where the discharge pressure of the working oil in a discharge oil passage 305 is at the higher degree. Therefore, the first control valve 304 of the oil pump XIII according to the third embodiment of the present invention is activated on the basis of degree of the discharge pressure of the working oil to be discharged to the discharge oil passage 305 in a condition where the temperature of the working oil is within the normal temperature region (equal to, or lower than, approximately 110 degrees C.), that is, in a condition where the second control valve 307 is held at the normal state. Further, in a condition where the discharge pressure of the working oil is increased, the oil pump XIII according to the third embodiment of the present invention establishes a communication path between a first valve chamber 343 and a second feedback port 341d, and supplies some of the working oil in the discharge oil passage 305 to a feedback oil passage 306 for relieving the discharge pressure.

[0086] The oil pump XIII according to the third embodiment of the present invention can perform a control not to operate the first control valve 304 serving as the relief valve in a condition where the temperature of the working oil is at the higher degree. Accordingly, the oil pump XIII according to the third embodiment of the present invention can ensure the required discharge pressure at the high temperature condition of the oil and can also achieve the optimal discharge pressure within the normal temperature region, which is the temperature region of the working oil under the normal use conditions, in other words, less than, or equal to, approximately 110 degrees C.

[0087] According to the embodiments of the present invention, the heat-sensitive expanding and contracting member 73a, 273a, 373a of the second control valve 7, 207, 307 includes a spring made of shape memory alloy. However, the invention is not limited thereto. Alternatively or in addition, a thermostat wax, a bimetal, or the like can be used for the heat-sensitive expanding and contracting member 73a, 273a, 373a. Further, alternatively or in addition, combination of the shape memory alloy, thermostat wax, and the bimetal may be used for the heat-sen-

sitive expanding and contracting member 73a, 273a, 373a.

[0088] According to the embodiments of the present invention, the second control valve 7, 207, 307 establishes the communication path between the second valve chamber 44, 244, 344 and the first valve chamber 43, 243, 343 in a condition where the temperature of the working oil satisfies the predetermined temperature condition J. However, the invention is not limited thereto. Alternatively, or in addition, the second control valve 7, 207, 307 may be configured to adjust an amount of the working oil to be flowed into the second valve chamber 44, 244, 344 of the first control valve 4, 204, 304. Thereby, the second control valve 7, 207, 307 may control the oil pressure of the working oil to be flowed into the second valve chamber 44, 244, 344 by adjusting the amount of the working oil to be flowed into the second valve chamber 44, 244, 344. With such a configuration, the oil pump can be configured without the biasing mechanism 45, 245, 345, or the like, for biasing the first valve body 42, 242, 342 of the first control valve 4, 204, 304 toward the first valve chamber 43, 243, 343 side. The oil pump without the biasing mechanism 45, 245, 345 controls the position of the first valve body 42, 242, 342 in the housing 41, 241, 341 by means of the balance between the oil pressure of the working oil flowed into the second valve chamber 44, 244, 344 and the discharge pressure of the working oil applied to the first valve chamber 43, 243, 343.

[0089] According to the embodiments of the present invention, the oil pump applied to the vehicle engine is explained. However, the invention is not limited thereto. Alternatively, or in addition, the present invention can be applied to any oil pump other than the oil pump of the vehicle or the engine.

[0090] According to the embodiment of the present invention, the second control valve can adjust the position of the valve body on the basis of degree of the temperature of the working oil by controlling the oil pressure of the working oil to be flowed into the second valve chamber facing the first valve chamber to which the discharge pressure of the working oil is applied. The second valve chamber is provided to face the first valve chamber across the valve body. The oil pump according to the embodiments of the present invention can activate the first control valve, which controls the discharge pressure of the working oil, without providing a proportional electromagnetic control mechanism such as a solenoid, or the like. Further, because the second control valve is provided independently from the first control valve to which the discharge pressure from the pump main body is applied, the second control valve, which is activated on the basis of degree of the temperature of the working oil, is not influenced by the pulsation of the discharge pressure of the working oil. Accordingly, the second control valve can be made of a low fatigue strength material.

[0091] The present invention is applicable as long as the first control valve includes the biasing mechanism biasing the first valve body in the direction in which the

first valve body is moved toward the first valve chamber, and the second control valve establishing the communication path between the second valve chamber and the first valve chamber in a condition where the temperature of the working oil satisfies the predetermined temperature condition.

[0092] With the configuration of the oil pump according to the embodiments of the present invention, in a condition where the temperature of the working oil satisfies the predetermined temperature condition, the communication path between the second valve chamber and the first valve chamber is established and the oil pressure in the second valve chamber and that of the first valve chamber becomes approximately equal. Then, the first valve body of the first control valve moves to the last end portion of the first valve housing at the first valve chamber side by means of the biasing mechanism. Accordingly, because the first control valve is configured to control the optimal discharge pressure corresponding to the temperature of the working oil in a condition where the first valve body is positioned at the last end portion of the first valve housing at the first valve chamber side, the oil pump can appropriately control the discharge pressure on the basis of degree of the temperature of the working oil with a simple structure.

[0093] The present invention is applicable as long as the second control valve includes the second valve body reciprocating in the second valve housing and switching the control whether to establish or interrupt the communication path between the second valve chamber and the first valve chamber of the first control valve, and the valve body operating mechanism activating the second valve body by means of the heat-sensitive expanding and contracting member, which is expanded and contracted in the direction of the reciprocation of the second valve body on the basis of degree of the temperature of the working oil.

[0094] According to the embodiments of the present invention, the temperature of the working oil is transmitted, and the second valve body is activated by means of the heat-sensitive expanding and contracting member, which is expanded and contracted in the direction of the reciprocation of the second valve body on the basis of degree of the temperature of the working oil. Therefore, the oil pump can appropriately control the discharge pressure corresponding to the temperature of the working oil with the simple structure. Further, because the second control valve is provided independently from the first control valve to which the discharge pressure from the pump main body is applied, the heat-sensitive expanding and contracting member of the second control valve is not influenced by the pulsation of the discharge pressure of the working oil. Accordingly, the second control valve can be made of the low fatigue strength material.

It is explicitly stated that all features disclosed in the description and/or the claims are intended to be disclosed separately and independently from each other for the purpose of original disclosure as well as for the purpose of

restricting the claimed invention independent of the compositions of the features in the embodiments and/or the claims. It is explicitly stated that all value ranges or indications of groups of entities disclose every possible intermediate value or intermediate entity for the purpose of original disclosure as well as for the purpose of restricting the claimed invention, in particular as limits of value ranges.

Claims

1. An oil pump comprising:

a first control valve (4, 204, 304) including:

a first valve body (42, 242, 342) provided in a first valve housing (41, 241, 341) for reciprocating therein, the first valve body for controlling discharge pressure of working oil discharged from a pump main body (1) on the basis of a position of the first valve body in the first valve housing;

a first valve chamber (43, 243, 343) formed in the first valve housing at a first side of the first valve body, the first valve chamber being applied with the discharge pressure of the working oil from the pump main body; and

a second valve chamber (44, 244, 344) formed in the first valve housing at a second side of the first valve body, the second valve chamber being supplied with the working oil; **characterized in that** the oil pump further includes:

a second control valve (7, 207, 307) activated on the basis of degree of the temperature of the working oil, the second control valve for controlling oil pressure of the working oil flowed into the second valve chamber.

2. The oil pump according to claim 1, wherein the first control valve includes a biasing mechanism (45, 245, 345) biasing the first valve body in a direction in which the first valve body is moved toward the first valve chamber, and the second control valve establishes the communication path between the second valve chamber and the first valve chamber in a condition where the temperature of the working oil satisfies a predetermined temperature condition (J).

3. The oil pump according to claim 1 or 2, wherein the second control valve includes a second valve body (72, 272, 372) reciprocating in a second valve housing (71, 271, 371) and switching a control

whether to establish or interrupt the communication path between the second valve chamber and the first valve chamber, and a valve body operating mechanism (73, 273, 373) operating the second valve body by means of a heat-sensitive expanding and contracting member (73a, 273a, 373a), which is expanded and contracted in a direction of a reciprocation of the second valve body on the basis of degree of the temperature of the working oil.

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4. The oil pump according to any one of claims 1-3, wherein

the valve body operating mechanism includes the heat-sensitive expanding and contracting member provided at a first side of the second valve body and an elastic member (73b, 273b, 373b) provided at a second side of the second valve body.

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5. The oil pump according to any one of claims 1- 4, wherein

the heat-sensitive expanding and contracting member includes a shape memory alloy, a thermostat wax, or a bimetal.

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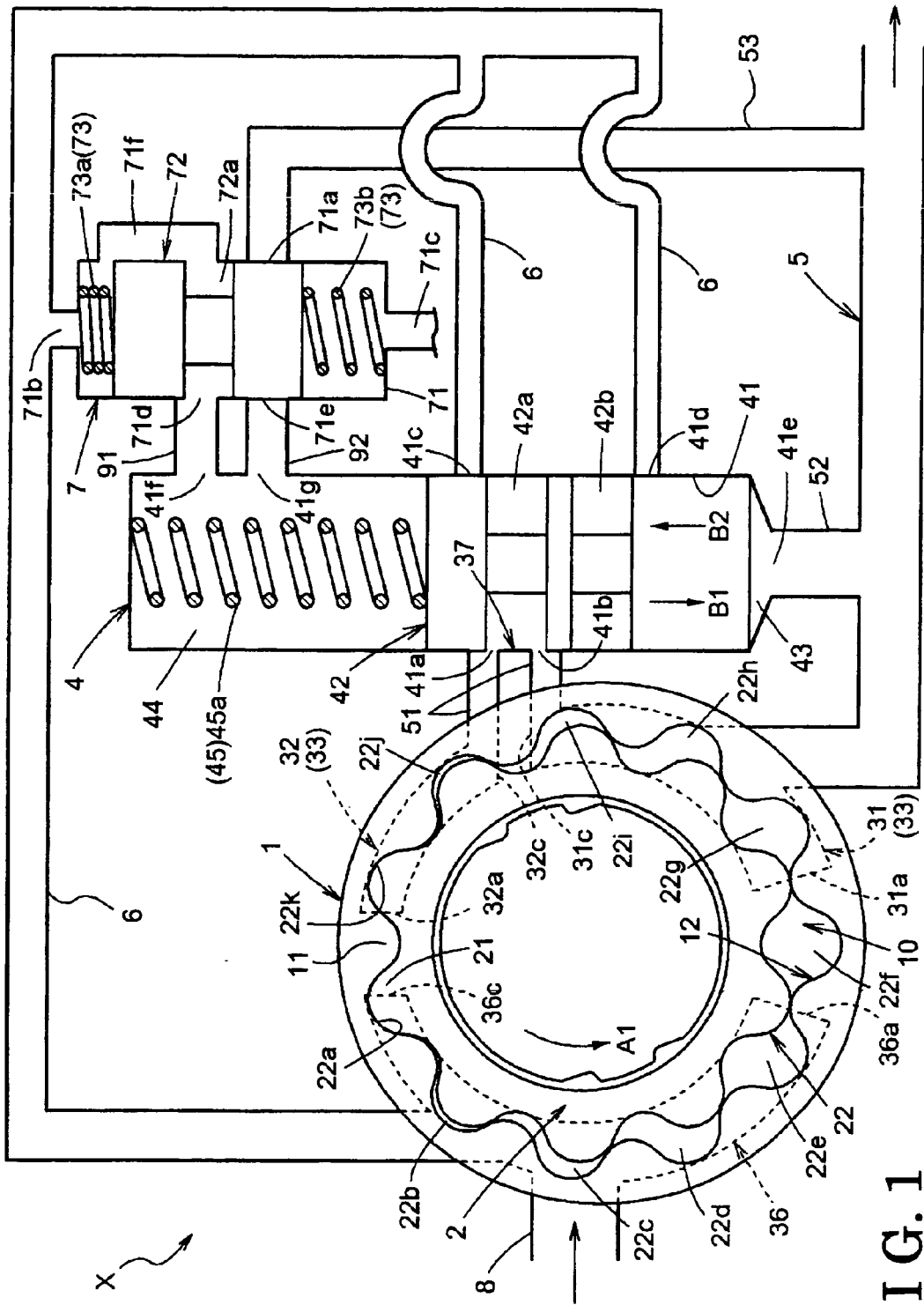


FIG. 1

FIG. 2

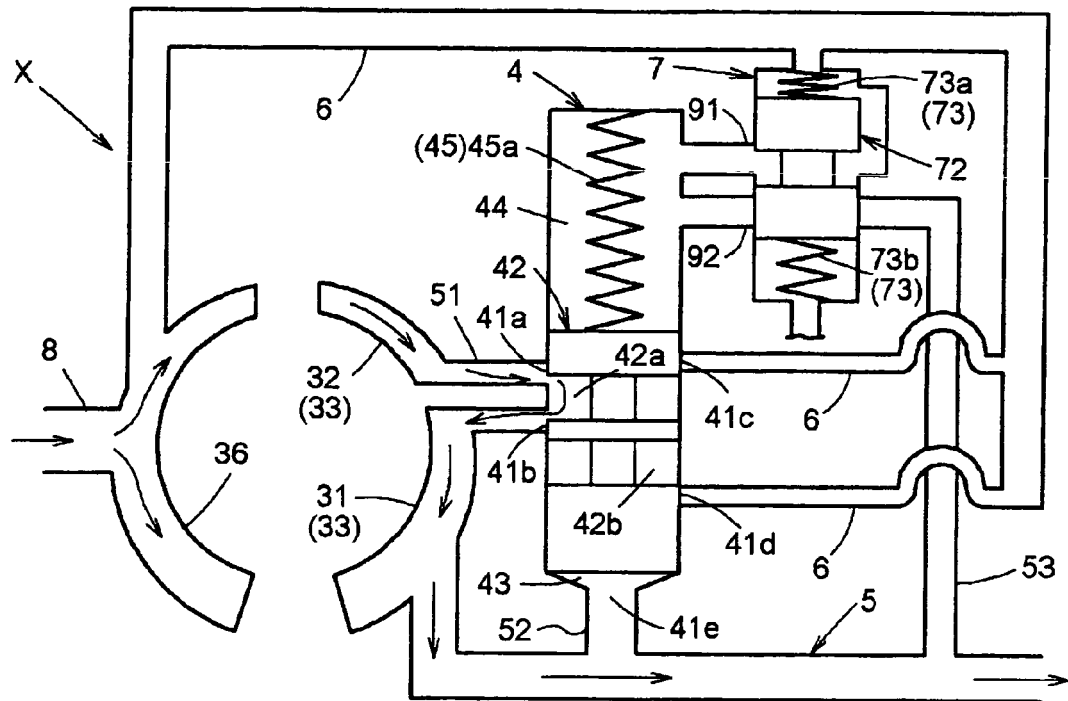


FIG. 3

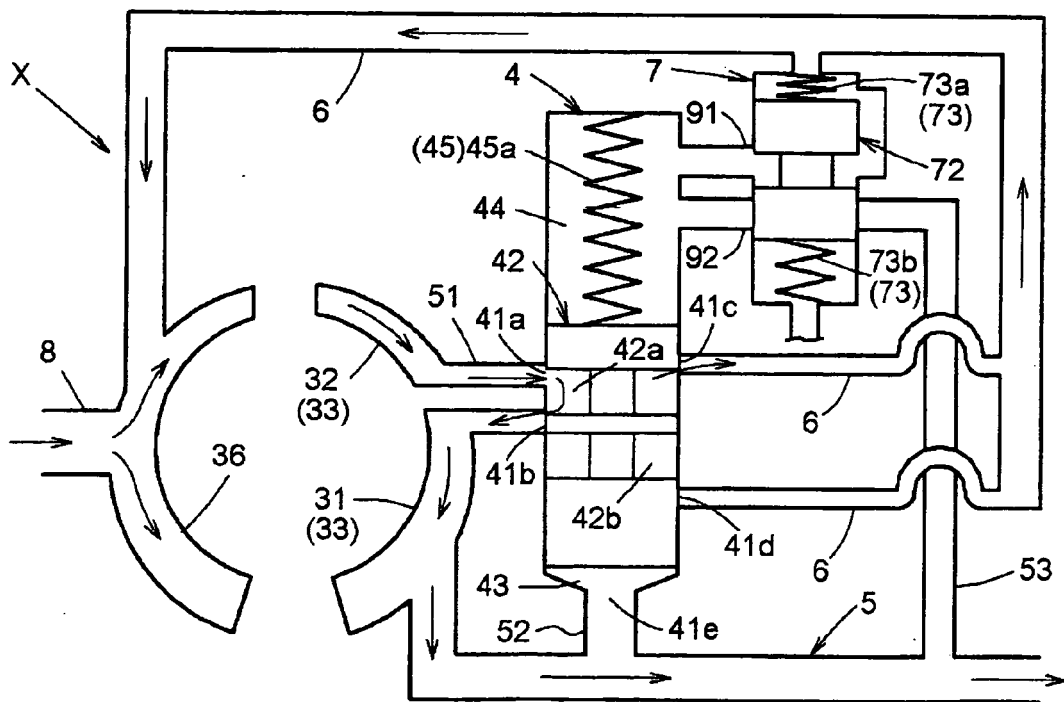


FIG. 4

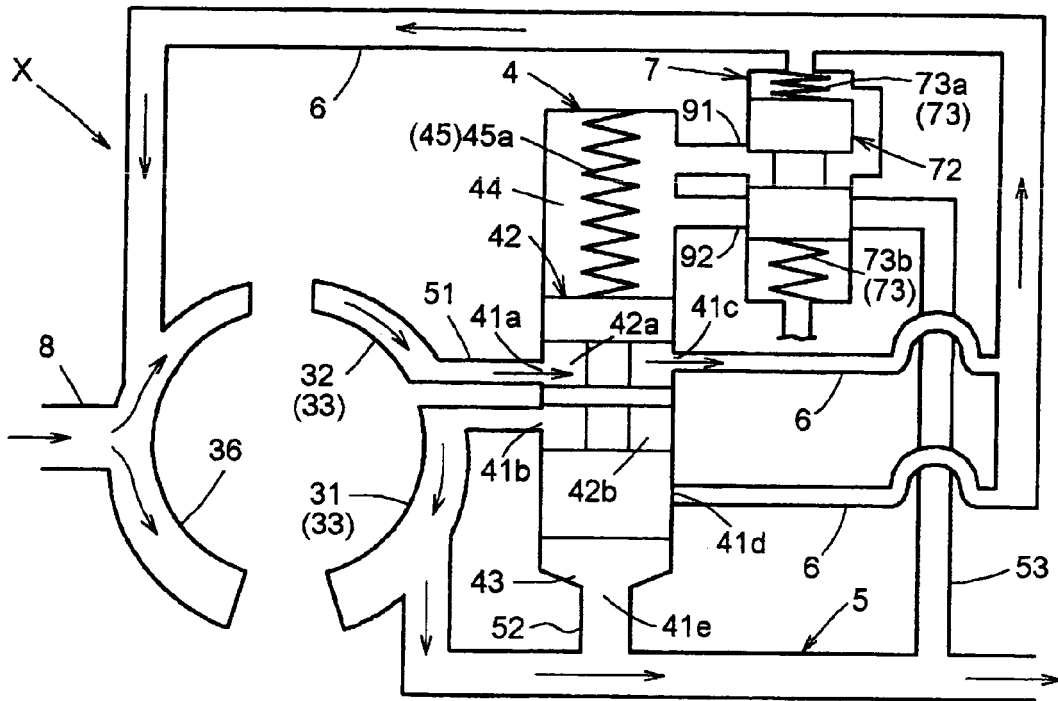


FIG. 5

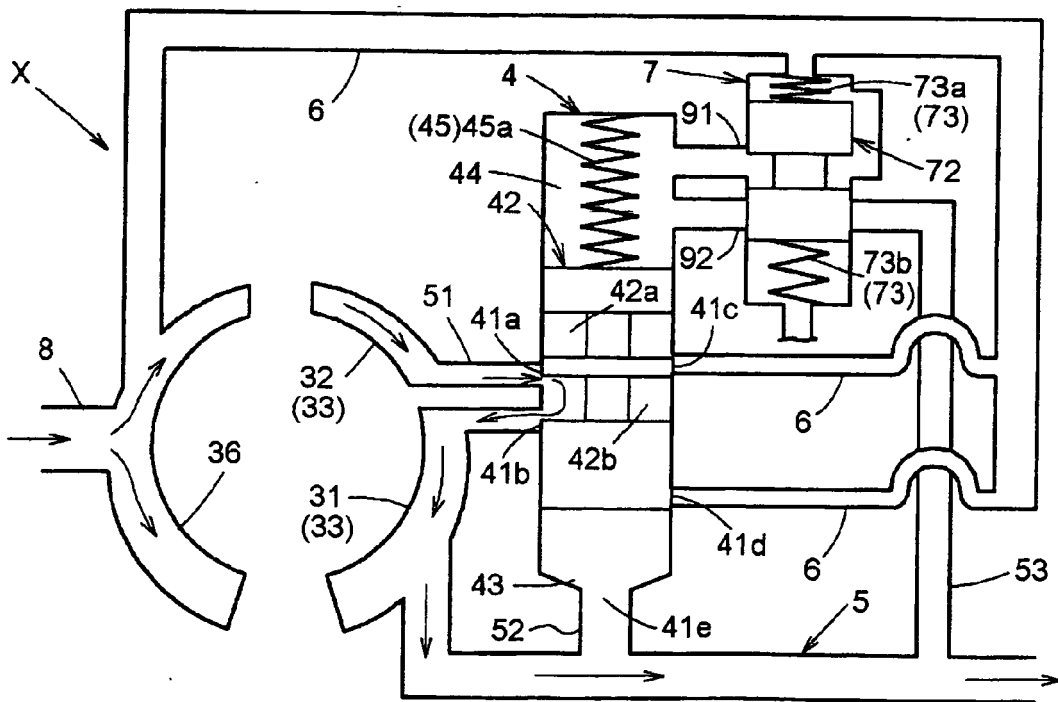


FIG. 6

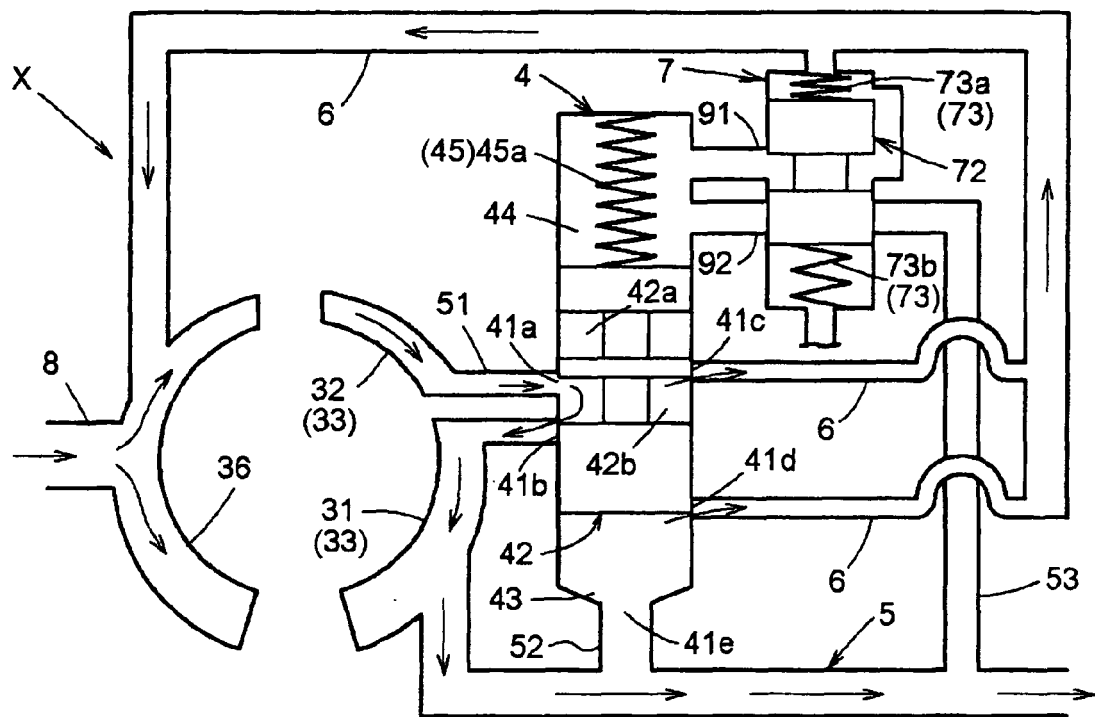


FIG. 7

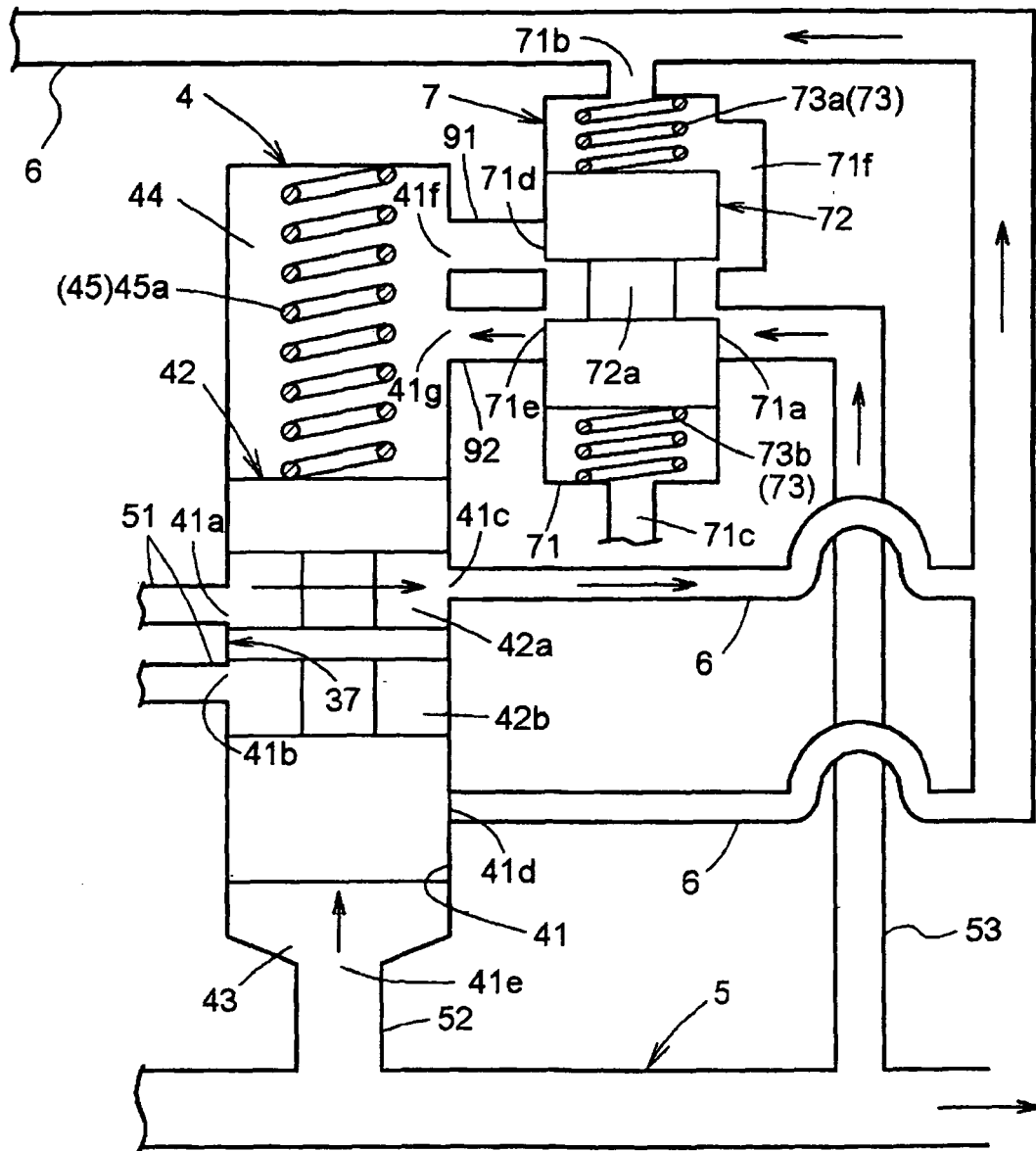


FIG. 8

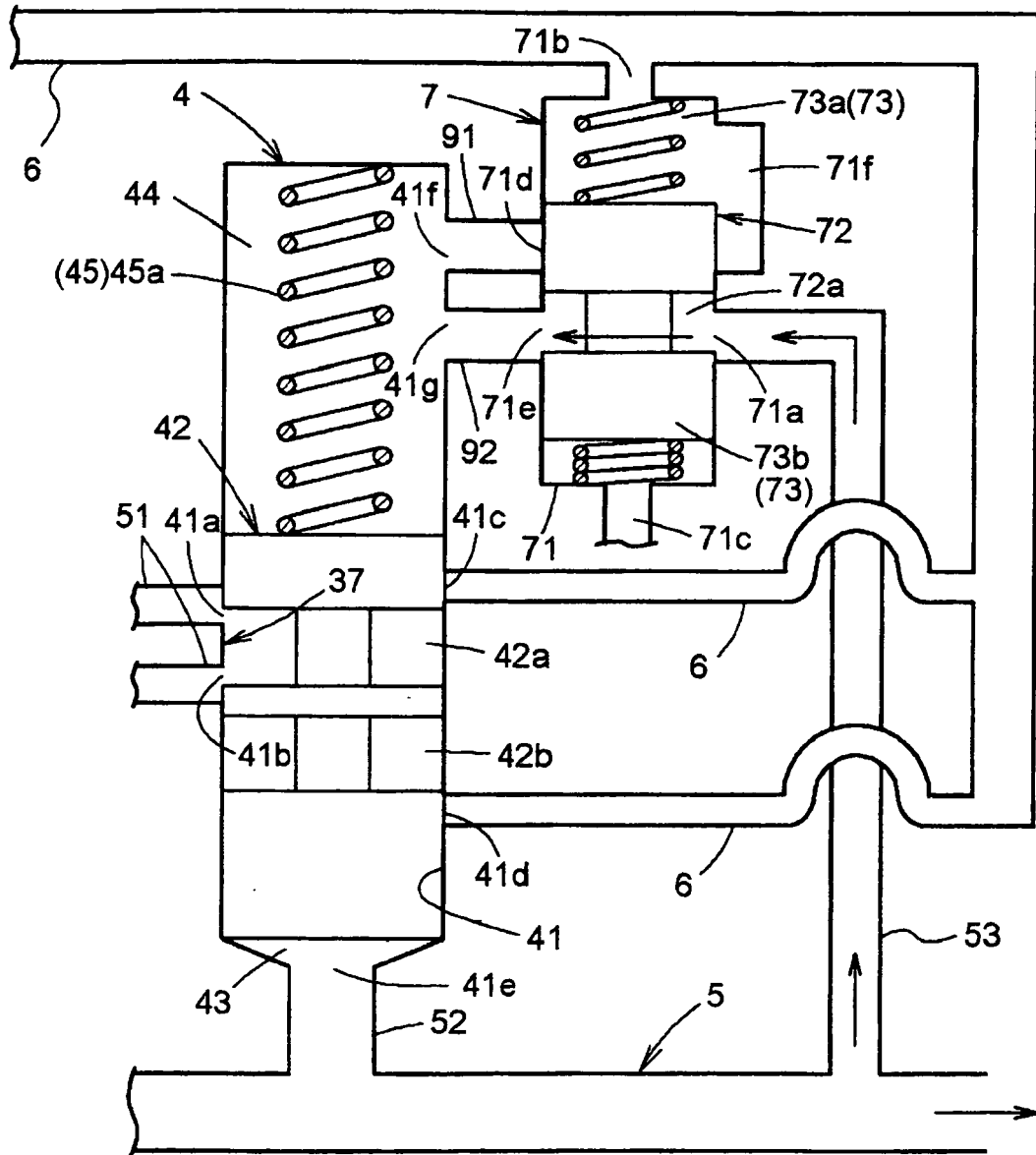


FIG. 9 A

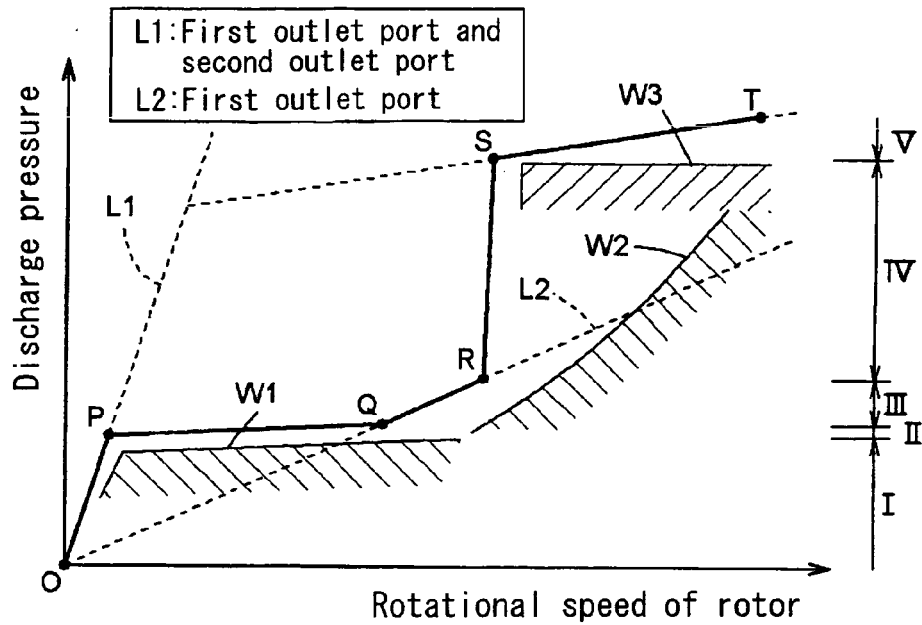


FIG. 9 B

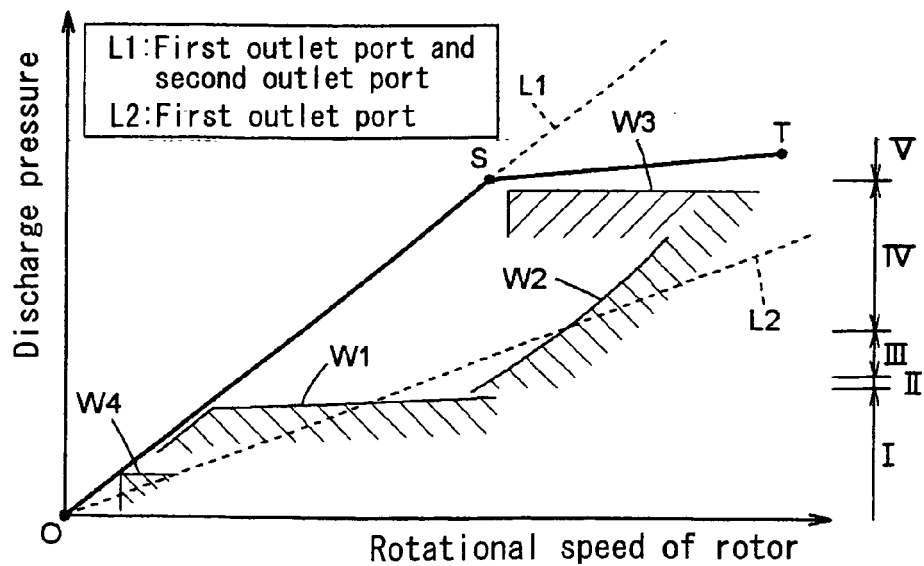


FIG. 10 A

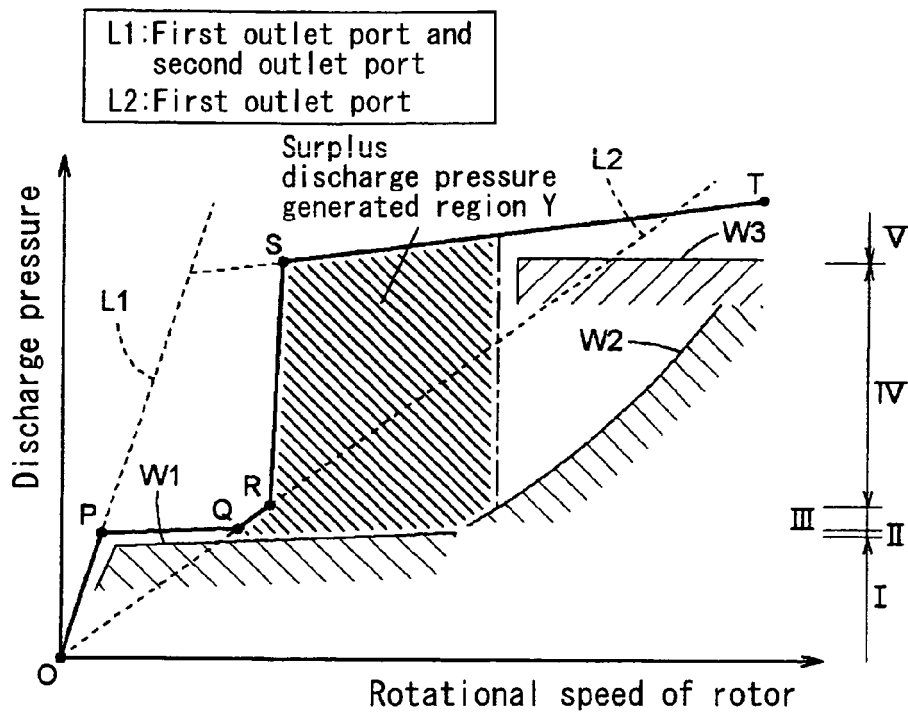


FIG. 10 B

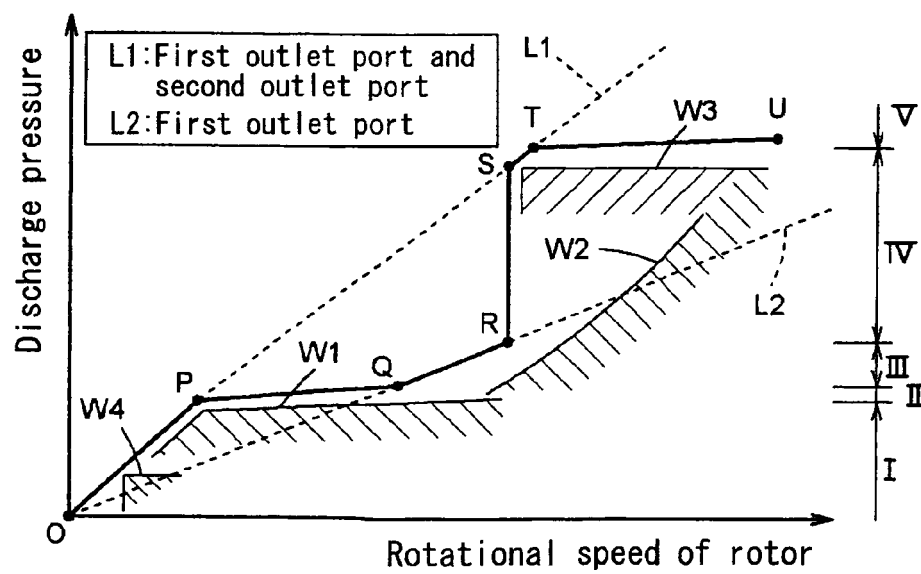


FIG. 11

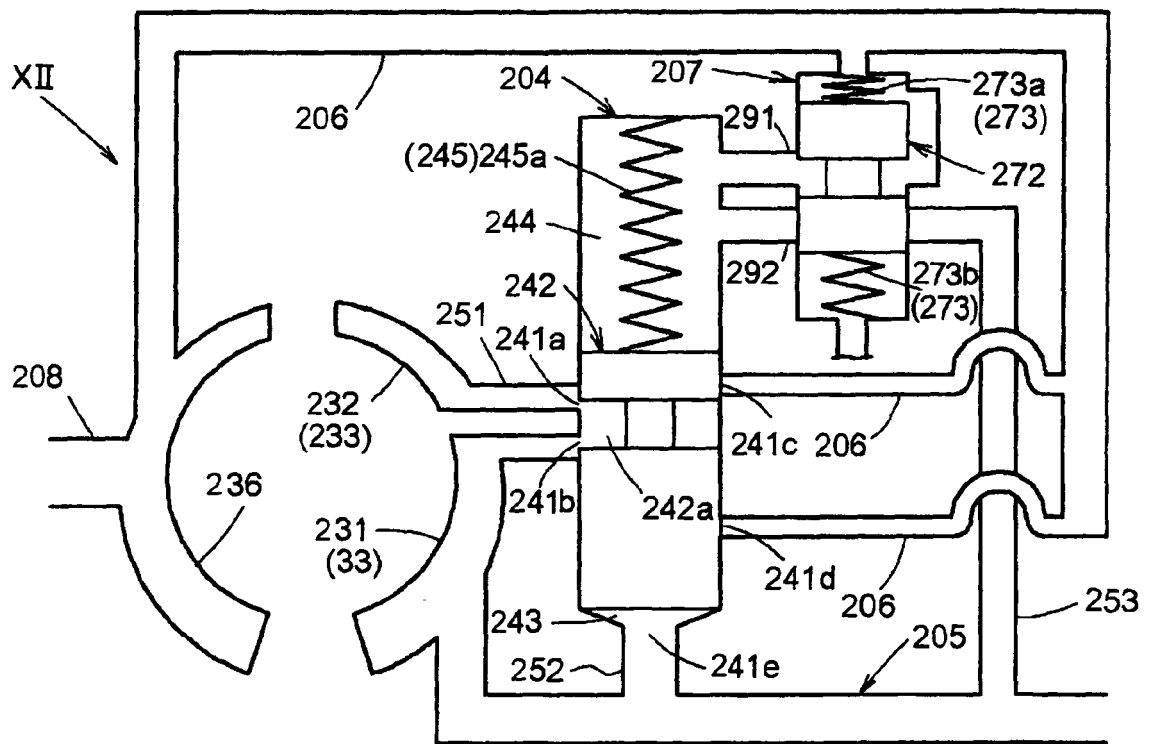


FIG. 12 A

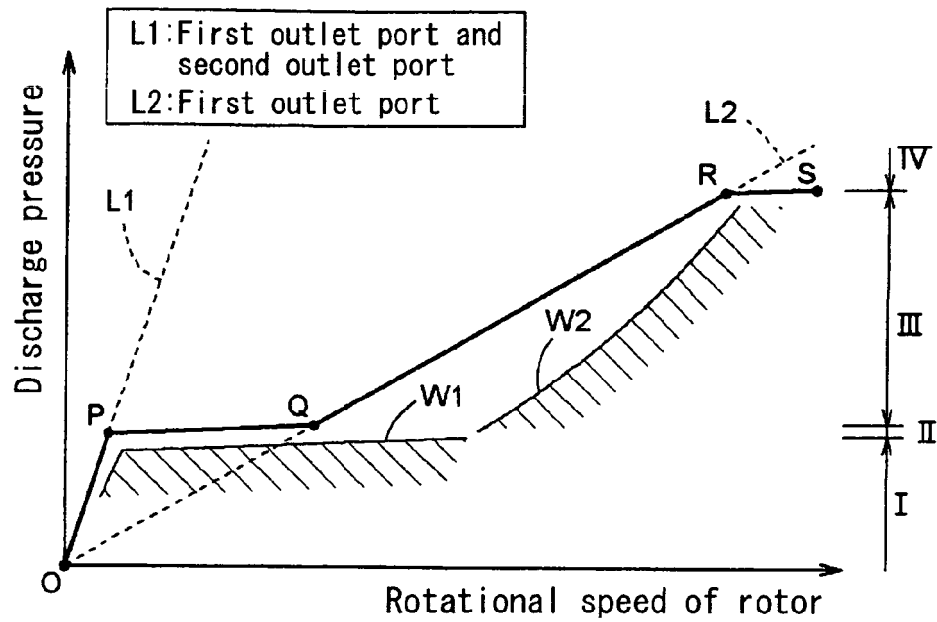


FIG. 12 B

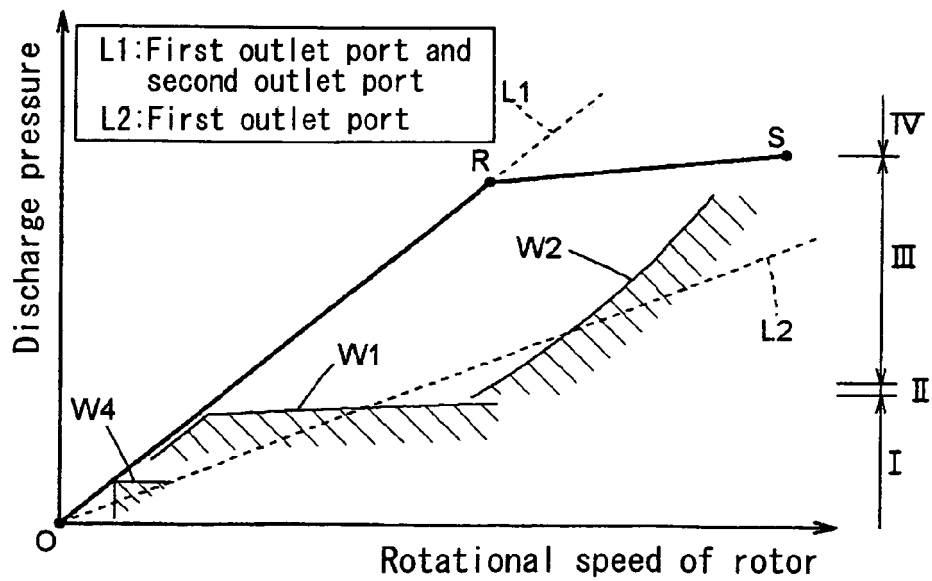


FIG. 13 A

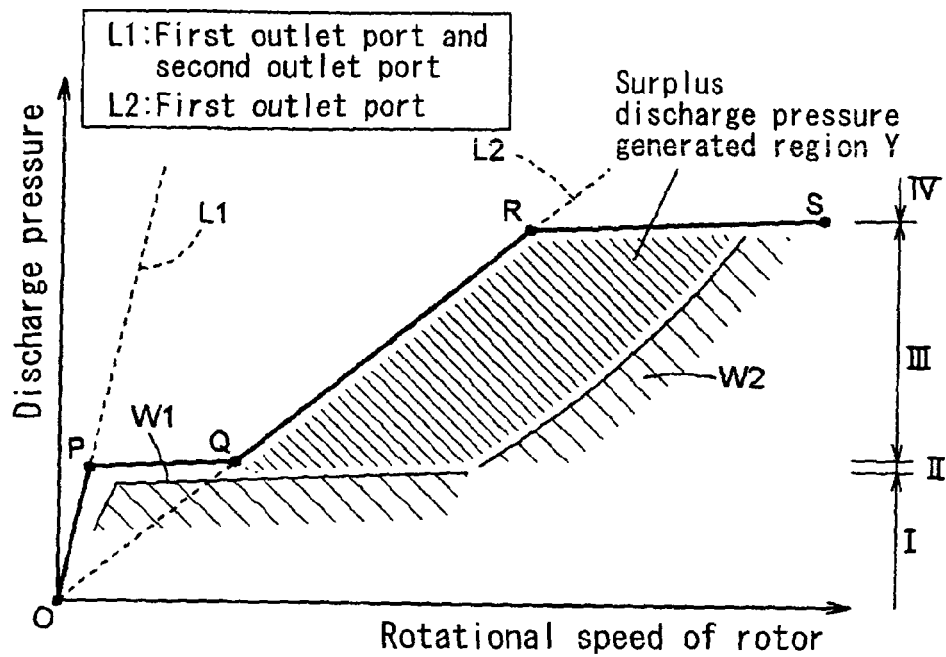


FIG. 13 B

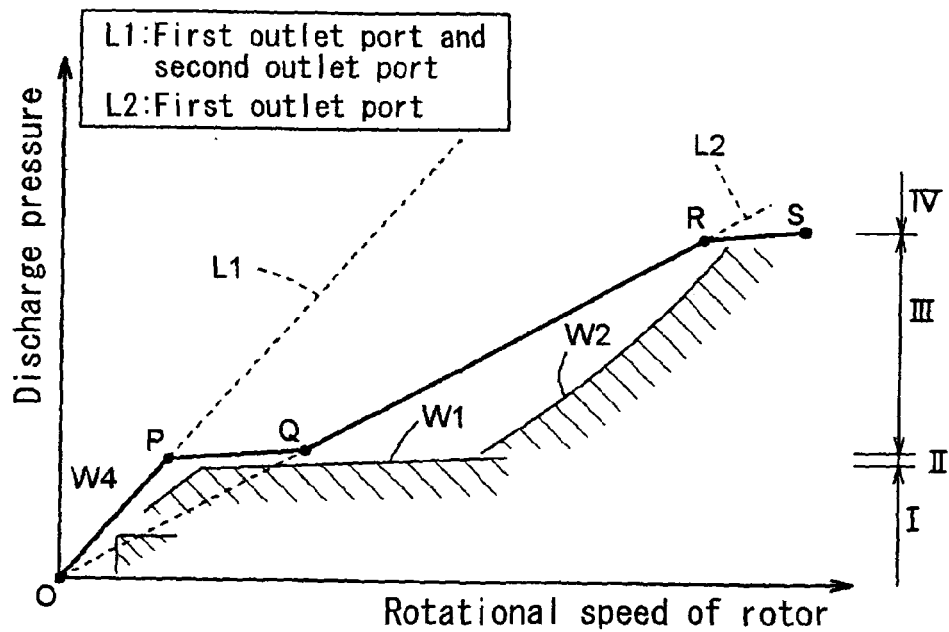


FIG. 14

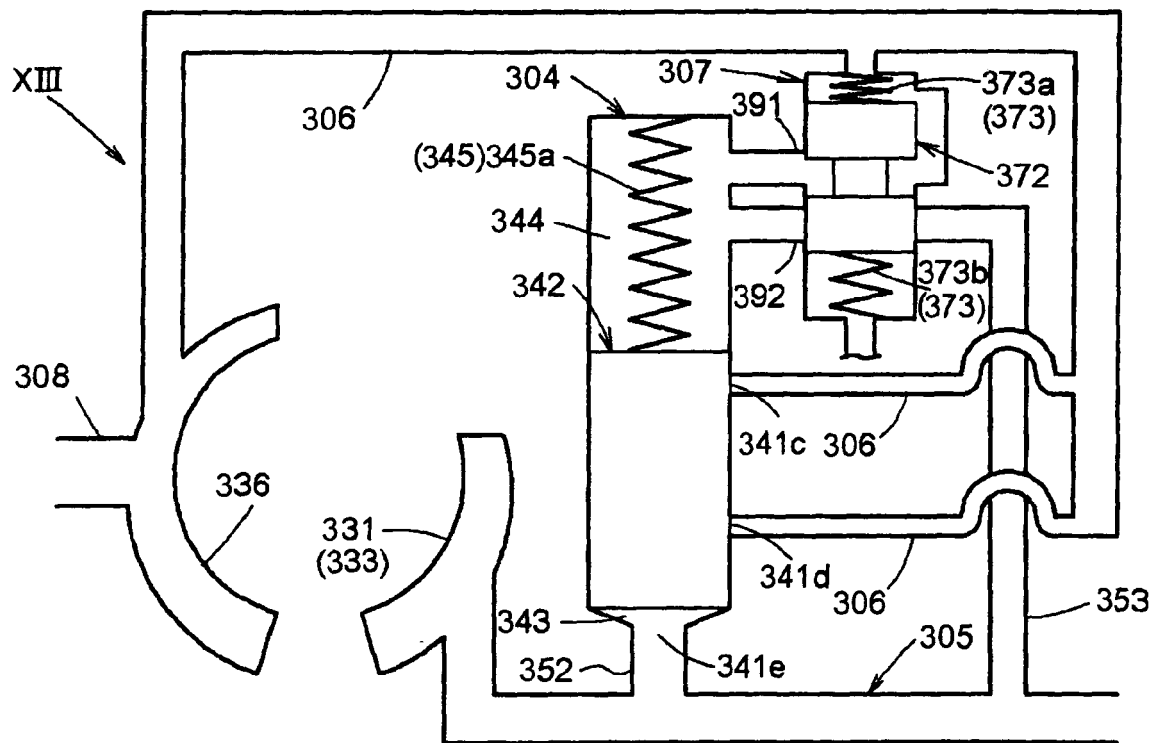


FIG. 15

Conventional work

