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(54) **PUMP DEVICE**

(57) A pump device includes: a main pump (101) and a sub pump (102) that supply hydraulic oil to the hydraulic device (23); and a switching valve (40) that switches so as to supply the hydraulic oil discharged from the sub pump (102) to the hydraulic device (23), or to return the hydraulic oil discharged from the sub pump (102) to the suction side. The main pump (101) and the sub pump (102) each include: a rotor (2) connected to a common drive shaft (1), a discharge port (9) into which the hydraulic oil discharged from a pump chamber (7) is led, and a groove-shaped discharge-side notch formed from an opening edge of the discharge port (9) toward a direction opposite to a rotation direction of the rotor (2). The switching valve (40) switches according to a rotation speed of the drive shaft (1). At least one discharge-side notch (9b) of the sub pump (102) is formed so that a resistance applied to the flow of the hydraulic oil passing there-through is greater than that of the discharge-side notch (9b) of the main pump (101).

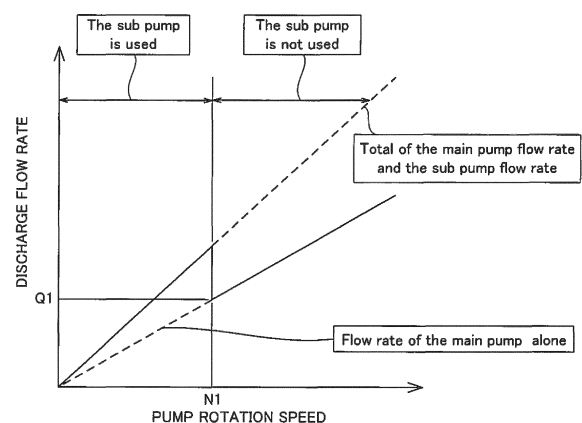


FIG. 5

Description

TECHNICAL FIELD

[0001] The present invention relates to a pump device.

BACKGROUND ART

[0002] JP2010-14101A discloses a multiple vane pump in which the rotors of a first vane pump and a second vane pump are connected by a common drive shaft so as to be connected in parallel.

[0003] During startup of this multiple vane pump, a working fluid is supplied to a fluid pressure device by the first vane pump and the second vane pump. In the multiple vane pump, if the rotation speed of the pump increases and the discharge flow rate of the second vane pump reaches or exceeds a necessary flow rate, the working fluid discharged from the first vane pump is returned to a suction passage, and working fluid is supplied to the fluid pressure device by the second vane pump alone.

[0004] This kind of vane pump includes a groove-shaped notch which is in communication with a discharge port in order to prevent sudden fluctuations in the pressure of the working fluid that is led to a high-pressure chamber.

SUMMARY OF INVENTION

[0005] In such a multiple vane pump, in order to prevent sudden pressure fluctuations of the working fluid during high rotation of the pump, the notch is formed so as to have a long length and a large cross-section area so that the resistance applied to the flow of working fluid passing therethrough is relatively small. During high rotation of the pump, by decreasing the resistance applied by the notch so as to promote the flow of working fluid from the high-pressure chamber to a pump chamber through the notch, the rate of pressure rise within the pump chamber relative to the rotation angle of the pump increases. Thereby, the pump chamber communicates with the high-pressure chamber in a state in which the pressure has risen sufficiently such that sudden fluctuations in the pressure of the working fluid are prevented, and the occurrence of vibrations and noise during high rotation of the pump is suppressed.

[0006] However, during low rotation of the pump, the movement speed of the vanes in the rotation direction of the rotor decreases compared to that during high rotation of the pump, and thus the flow of working fluid from the high-pressure chamber to the pump chamber through the notch is easily promoted. Therefore, during low rotation of the pump, the rate of pressure rise within the pump chamber relative to the rotation angle of the pump is high. Accordingly, if the length of the notch is formed to be relatively long and the cross-section area of the notch is formed to be relatively large, during low rotation of the

pump, the rate of pressure rise within the pump chamber relative to the rotation angle of the pump may become too high. Consequently, if the notch is formed to have a long length and a large cross-section area, sudden pressure fluctuations may occur during low rotation of the pump, and this can lead to the occurrence of vibrations and noise.

[0007] An object of the present invention is to suppress the occurrence of vibrations and noise in a pump device including a main pump and a sub pump.

[0008] According to one aspect of the present invention, a pump device for supplying working fluid to a fluid pressure device is provided. The pump device includes: a main pump configured to supply the working fluid to the fluid pressure device through a first discharge passage, a sub pump configured to supply the working fluid to the fluid pressure device through a second discharge passage that joins with the first discharge passage, a return passage configured to return the working fluid discharged from the sub pump to a suction side, and a switching valve configured to switch regarding whether or not to return the working fluid discharged from the sub pump to the suction side through the return passage. The main pump and the sub pump each include: a rotor connected to a common drive shaft, a plurality of vanes provided so as to be capable of reciprocating in a radial direction relative to the rotor, a cam ring having an inner peripheral surface. Distal ends of the vanes being configured to be in sliding contact with the inner peripheral surface in accordance with rotation of the rotor. The main pump and the sub pump each include: pump chambers defined by the rotor, the cam ring, and adjacent pair of the vanes, a discharge port into which the working fluid discharged from the pump chamber is led, and a groove-shaped discharge-side notch formed from an opening edge of the discharge port toward a direction opposite to a rotation direction of the rotor. The switching valve is configured to switch according to a rotation speed of the drive shaft. At least one discharge-side notch of the sub pump is formed so that a resistance applied to the flow of the working fluid passing therethrough is greater than that of the discharge-side notch of the main pump.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

[FIG. 1] FIG. 1 is a cross-section view of a pump device according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a plan view when viewed in the direction of arrow A in FIG. 1 of a pump cartridge in a main pump of the pump device according to the embodiment of the present invention.

[FIG. 3] FIG. 3 is a plan view when viewed in the direction of arrow B in FIG. 1 of a pump cartridge in a sub pump of the pump device according to the embodiment of the present invention.

[FIG. 4] FIG. 4 is a hydraulic circuit diagram of the pump device according to the embodiment of the present invention.

[FIG. 5] FIG. 5 is a graph illustrating the flow rate characteristics of the pump device according to the embodiment of the present invention.

[FIG. 6A] FIG. 6A is an enlarged view illustrating the relationship among a pump chamber, a discharge port, and a notch in the main pump of the pump device according to the embodiment of the present invention.

[FIG. 6B] FIG. 6B is an enlarged view illustrating the relationship among a pump chamber, a discharge port, and a notch in the sub pump of the pump device according to the embodiment of the present invention.

[FIG. 7A] FIG. 7A is a cross-section view illustrating a notch shape of the notch in the main pump of the pump device according to the embodiment of the present invention.

[FIG. 7B] FIG. 7B is a cross-section view illustrating a notch shape of the notch in the sub pump of the pump device according to the embodiment of the present invention.

[FIG. 7C] FIG. 7C is a view superimposing FIG. 7A and FIG. 7B.

[FIG. 8A] FIG. 8A is a cross-section view illustrating an alternative embodiment of the notch shape of the notch in the main pump of the pump device according to the embodiment of the present invention.

[FIG. 8B] FIG. 8B is a cross-section view illustrating an alternative embodiment of the notch shape of the notch in the sub pump of the pump device according to the embodiment of the present invention.

[FIG. 8C] FIG. 8C is a view superimposing FIG. 8A and FIG. 8B.

[FIG. 9A] FIG. 9A is a cross-section view illustrating another alternative embodiment of the notch shape of the notch in the main pump of the pump device according to the embodiment of the present invention.

[FIG. 9B] FIG. 9B is a cross-section view illustrating another alternative embodiment of the notch shape of the notch in the sub pump of the pump device according to the embodiment of the present invention.

[FIG. 9C] FIG. 9C is a view superimposing FIG. 9A and FIG. 9B.

[FIG. 10] FIG. 10 is a hydraulic circuit diagram illustrating an alternative embodiment of the pump device according to the embodiment of the present invention.

[FIG. 11] FIG. 11 is a plan view of a center plate in an alternative embodiment of the pump device according to the embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0010] A pump device 100 according to an embodiment of the present invention will now be explained below referring to the drawings.

[0011] The pump device 100 is used as a hydraulic supply source of a hydraulic device mounted in a vehicle, such as a power steering device or a transmission.

[0012] As shown in FIGS. 1 to 3, in the pump device 100, a rotor 2 of a main pump 101 and a rotor 2 of a sub pump 102 are connected to a common drive shaft 1 to which motive power of an engine 24 (refer to FIG. 4) is transmitted, and the rotors 2 are rotated by means of the rotation of the drive shaft 1. FIGS. 2 and 3 respectively illustrate pump cartridges 21 and 22 of the main pump 101 and the sub pump 102, and FIG. 2 is a plan view when viewed from the direction of arrow A in FIG. 1 whereas FIG. 3 is a plan view when viewed from the direction of arrow B in FIG. 1. The rotor 2 rotates clockwise in FIG. 2, and rotates counterclockwise in FIG. 3.

[0013] The hydraulic oil (working fluid) discharged from the main pump 101 is constantly supplied to a hydraulic device (fluid pressure device) 23 (refer to FIG. 4). Meanwhile, the hydraulic oil discharged from the sub pump 102 is supplied to the hydraulic device 23 or returned to the suction side according to the operation of a switching valve 40 (refer to FIG. 4).

[0014] As shown in FIGS. 2 and 3, the main pump 101 and the sub pump 102 include: a plurality of vanes 3 provided such that they can move reciprocally in the radial direction relative to the rotor 2, and a cam ring 4 that accommodates the rotor 2. The distal end of each vane 3 slidably contacts a cam surface 4a on the inner periphery of the cam ring 4 in accordance with the rotation of the rotor 2.

[0015] In the rotor 2, slits 16 having an opening on the outer peripheral surface are formed radially at predetermined intervals, and the vanes 3 are slidably inserted into the slits 16.

[0016] On the base end side of each slit 16, a back pressure chamber 17 to which pump discharge pressure is led is defined. Adjacent back pressure chambers 17 communicate with each other by an arc-shaped groove 2a formed in the rotor 2, and pump discharge pressure is constantly led to the groove 2a. Each vane 3 is pressed in the direction in which the vane 3 comes out from the slit 16 by the pressure of the back pressure chamber 17 and the centrifugal force generated by the rotation of the rotor 2, and the distal end of each vane 3 abuts the cam surface 4a on the inner periphery of the cam ring 4. Thereby, on the inside of the cam ring 4, a plurality of pump chambers 7 are defined by the outer peripheral surface of the rotor 2, the cam surface 4a of the cam ring, and the adjacent pairs of vanes 3. Each pump cartridge 21, 22 is constituted by the rotor 2, the vanes 3, and the cam ring 4.

[0017] The cam ring 4 is an annular member in which the cam surface 4a on the inner periphery has an ap-

proximately elliptical shape. The cam ring 4 includes a suction region 4b that expands the capacity of the pump chambers 7 in accordance with the rotation of the rotor 2, and a discharge region 4c that contracts the capacity of the pump chambers 7 in accordance with the rotation of the rotor 2.

[0018] A center plate 5 is disposed between the pump cartridges 21 and 22 of the main pump 101 and the sub pump 102, and a side plate 6 is disposed on the side of each pump cartridge 21, 22 (refer to FIG. 1). In this way, each pump cartridge 21, 22 is sandwiched between the center plate 5 and the side plate 6, and the pump chambers 7 are sealed by the center plate 5 and the side plate 6.

[0019] In the center plate 5, suction ports 8, which open toward the suction region 4b of the cam ring 4 and which lead hydraulic oil to the pump chambers 7, are formed.

[0020] In each side plate 6, two arc-shaped discharge ports 9, which open toward the discharge region 4c of the cam ring 4 and to which hydraulic oil discharged by the pump chambers 7 is led, are formed.

[0021] Groove-shaped notches (discharge-side notches) 9a, 9b, which extend from the opening edges of the discharge ports 9 toward the direction opposite of the rotation direction of the rotor 2, are formed in the side plates 6 of the main pump 101 and the sub pump 102. By forming these notches 9a, 9b, the flow of hydraulic oil from the pump chambers 7 to the discharge ports 9 through the notches 9a, 9b is promoted in accordance with the rotation of the rotor 2, and thus sudden pressure fluctuations in a high-pressure chamber 12 to be explained later are prevented.

[0022] During the course of one rotation of the rotor 2, the pump chambers 7 suction hydraulic oil through the suction port 8 in the suction region 4b of the cam ring 4 and discharge the suctioned hydraulic oil through the discharge port 9 in the discharge region 4c of the cam ring 4, and then suction hydraulic oil through the suction port 8 in the suction region 4b of the cam ring 4 and discharge the suctioned hydraulic oil through the discharge port 9 in the discharge region 4c of the cam ring 4. In this way, the pump chambers 7 expand and contract in accordance with the rotation of the rotor 2, and perform suction/discharge of the hydraulic oil two times over the course of one rotation of the rotor 2.

[0023] As shown in FIG. 1, the drive shaft 1 is rotatably supported via bushes 18 on a first pump body 10 and a second pump body 11. The side plate 6 and the pump cartridge 21 of the main pump 101 are laminated and accommodated within a pump accommodation recess 10a formed in the first pump body 10. The side plate 6 and the pump cartridge 22 of the sub pump 102 as well as the center plate 5 are laminated and accommodated within a pump accommodation recess 11a formed in the second pump body 11. In this way, the main pump 101 is accommodated in the first pump body 10 and the sub pump 102 is accommodated in the second pump body 11.

[0024] The surfaces having an opening of the first

pump body 10 and the second pump body 11 are abutted to each other to integrally fasten the first pump body 10 and the second pump body 11 together, and thereby the pump accommodation recesses 10a and 11a are sealed.

[0025] The cam rings 4 and the side plates 6 of the main pump 101 and the sub pump 102 are restrained from rotating by two positioning pins 19 (refer to FIGS. 2 and 3) that are inserted into the center plate 5. Relative rotation of the center plate 5 and the side plates 6 relative to the cam ring 4 is restricted by the positioning pins 19. Thereby, positioning of the suction region 4b of the cam ring 4 and the suction ports 8 of the center plate 5 is achieved, and positioning of the discharge region 4c of the cam ring 4 and the discharge ports 9 of the side plates 6 is achieved.

[0026] In the first pump body 10 and the second body pump 11, a high-pressure chamber 12 into which hydraulic oil discharged from the discharge ports 9 flows is formed. The hydraulic oil of the high-pressure chamber 12 is supplied to the hydraulic device 23 through a first discharge passage 32 and a second discharge passage 34 (refer to FIG. 4). The hydraulic oil of the high-pressure chamber 12 is led to the arc-shaped groove 2a of the rotor 2 through a through-hole 6a formed in the side plates 6, and then is led to the back pressure chambers 17.

[0027] Next, the hydraulic circuit of the pump device 100 will be explained referring to FIG. 4.

[0028] A suction passage 31 connected to a tank 36 is connected to the suction ports 8 of the main pump 101 and the sub pump 102.

[0029] The first discharge passage 32 is connected to the discharge ports of the main pump 101, and hydraulic oil is constantly supplied from the main pump 101 to the hydraulic device 23 through the first discharge passage 32.

[0030] A switching passage 33 is connected to the discharge ports 9 of the sub pump 102. The switching valve 40, which switches the flow of hydraulic oil discharged from the sub pump 102, is provided in the switching passage 33.

[0031] The following are connected to the switching valve 40: the second discharge passage 34 that supplies hydraulic oil to the hydraulic device 23; and a return passage 35 that returns hydraulic oil to the suction side. The second discharge passage 34 is provided so as to join with the first discharge passage 32.

[0032] The switching valve 40 switches regarding whether or not to return the hydraulic oil discharged from the sub pump 102 to the suction side through the return passage 35. In more detail, the switching valve 40 selectively switches so as to supply the hydraulic oil discharged from the sub pump 102 to the hydraulic device 23 through the second discharge passage 34, or to return the hydraulic oil discharged from the sub pump 102 to the suction side through the return passage 35. In other words, the hydraulic oil discharged from the sub pump 102 is selectively led to either the hydraulic device 23 or

the suction passage 31 by the switching operation of the switching valve 40.

[0033] The switching valve 40 has a first communication position 40a in which communication is established between the switching passage 33 and the second discharge passage 34, and a second communication position 40b in which communication is established between the switching passage 33 and the return passage 35. The switching valve 40 is an electromagnetic switching valve in which the position is switched by a control current output from a controller 30. The switching valve 40 is set to the second communication position 40b by a biasing force of a spring 42 when a solenoid 41 is not energized, and is set to the first communication position 40a against the biasing force of the spring 42 when the solenoid 41 is energized.

[0034] The position of the switching valve 40 is switched according to, for example, the rotation speed of the engine 24 that is input into the controller 30, i.e. a pump rotation speed which is the rotation speed of the drive shaft 1 and the rotor 2. The switching valve 40 is not limited to an electromagnetic switching valve, and may also be a pilot-type switching valve in which the switching operation is performed by a pilot liquid pressure.

[0035] In this way, the main pump 101 suctions hydraulic oil from the tank 36 through the suction passage 31, and supplies the hydraulic oil to the hydraulic device 23 through the first discharge passage 32. The sub pump 102 suctions hydraulic oil from the tank 36 through the suction passage 31, and supplies the hydraulic oil to the hydraulic device 23 through the second discharge passage 34 or returns the hydraulic oil to the suction side through the return passage 35.

[0036] Next, the operation of the pump device 100 will be explained.

[0037] During startup of the pump device 100, the switching valve 40 is set to the first communication position 40a.

[0038] Hydraulic oil discharged from the main pump 101 is supplied to the hydraulic device 23 regardless of which position the switching valve 40 is in.

[0039] Hydraulic oil discharged from the sub pump 102 is supplied to the hydraulic device 23 through the second discharge passage 34.

[0040] Thereby, hydraulic oil in a flow rate which is the combined total of the discharge flow rates of the main pump 101 and the sub pump 102 is supplied to the hydraulic device 23.

[0041] FIG. 5 is a graph illustrating the relationship between the discharge flow rate and the rotation speed of the pump device 100. In FIG. 5, the solid line represents the overall discharge flow rate of the pump device 100, and the dashed lines represent the combined discharge flow rate of the main pump 101 and the sub pump 102 and the discharge flow rate of the main pump 101 alone. As shown in FIG. 5, the discharge flow rate of the pump device 100 increases in accordance with an increase in

the pump rotation speed. If the pump rotation speed reaches a predetermined pump rotation speed N_1 and the discharge flow rate of the main pump 101 alone reaches or exceeds a required flow rate Q_1 of the hydraulic device 23, the switching valve 40 is switched to the second communication position 40b. Thereby, the hydraulic oil discharged from the sub pump 102 is returned to the suction side through the return passage 35.

[0042] In this way, when the pump rotation speed is less than the pump rotation speed N_1 at which the discharge flow rate of the main pump 101 reaches the required flow rate Q_1 (hereinafter referred to as "during low rotation of the pump"), hydraulic oil discharged from the main pump 101 and the sub pump 102 is supplied to the hydraulic device 23. Further, when the pump rotation speed is at or above the pump rotation speed N_1 (hereinafter referred to as "during high rotation of the pump"), the discharge flow rate of the main pump 101 alone is supplied to the hydraulic device 23, and the hydraulic oil discharged from the sub pump 102 is returned to the suction side. In other words, the sub pump 102 is used as a pressure source supplying hydraulic oil to the hydraulic device 23 during low rotation of the pump, and is not used as such a pressure source during high rotation of the pump.

[0043] Next, referring to FIGS. 6 and 7, the notch shape of the main pump 101 and the sub pump 102 will be explained in detail. In the following, a state in which communication between the pump chamber 7 and the suction port 8 is blocked in accordance with rotation of the rotor 2 will be referred to as a "reference state" (the dashed lines in FIG. 6), a state in which there is direct communication between the pump chamber 7 and the discharge port 9 without using the notches 9a, 9b will be referred to as a "communication state" (the solid lines in FIG. 6), and a region in the space between the reference state and the communication state will be referred to as a "transition region". Further, a position in the reference state of a vane 3b which is on the front side in the rotation direction among the pair of vanes 3a, 3b that define the pump chamber 7 will be referred to as a "reference position" (refer to FIG. 6), and a cross-section area that intersects a center line C (refer to FIGS. 2, 3, and 6) of the notches 9a, 9b at a position separated by an angle α from the reference position will be referred to as a "notch opening area".

[0044] The notches 9a, 9b of the main pump 101 and the sub pump 102 are formed so that the cross-section shape that is perpendicular to the longitudinal direction thereof, i.e. the cross-section shape intersecting the center line C, is an approximately triangular shape. Further, the notches 9a, 9b of the main pump 101 and the sub pump 102 are formed in a tapered shape in which the cross-section area of the notch gradually decreases from the opening edge on the rear side in the rotation direction of the discharge port 9 toward the rear in the rotation direction of the rotor 2.

[0045] FIGS. 6A and 6B illustrate the relationship

among the pump chamber 7, the suction port 8, the discharge port 9, and the notches 9a, 9b. As shown in FIGS. 6A and 6B, the relationship among the pump chamber 7, the suction port 8, and the discharge port 9 is the same in the main pump 101 and the sub pump 102, but the shapes of the notches 9a and 9b are different from each other.

[0046] The notch 9b of the sub pump 102 is formed so that the resistance applied to the flow of hydraulic oil passing therethrough is greater than that of the notch 9a of the main pump 101 in the space where the vane 3b on the front side in the rotation direction passes through the transition region from the reference state shown by the dashed lines in FIG. 6B to the communication state shown by the solid lines in FIG. 6B. In other words, the notch 9b of the sub pump 102 is formed so that the pressure loss of the hydraulic oil led from the pump chamber 7 through the notch 9b increases compared to the notch 9a of the main pump 101 in the space where the vane 3b passes through the transition region. In detail, in at least a portion within the range of the transition region, an opening area S2 (refer to FIG. 7B) of the notch 9b at a position separated from the reference position by an angle α (refer to FIGS. 6A and 6B) in the sub pump 102 is formed to be smaller than an opening area S1 (refer to FIG. 7A) of the notch 9a at a position separated from the reference position by an angle α in the main pump 101.

[0047] In the pump device 100 according to the present embodiment, as shown in FIGS. 6A and 6B and FIGS. 7A to 7C, the notches 9a, 9b of the main pump 101 and the sub pump 102 are formed so that the depths D and the opening widths W are equivalent to each other. In contrast, as shown in FIGS. 7A to 7C, the lengths of the notches 9a, 9b toward the rotation direction of the rotor 2 are formed so that a length L2 of the notch 9b in the sub pump 102 is shorter than a length L1 of the notch 9a in the main pump 101. By forming the notches 9a, 9b of the main pump 101 and the sub pump 102 in this way, the opening area S2 of the notch 9b in the sub pump 102 is smaller than the opening area S1 of the notch 9a in the main pump 101. Thereby, the notch 9b of the sub pump 102 applies a greater resistance to the flow of hydraulic oil passing therethrough than the notch 9a of the main pump 101.

[0048] Herein, a pump device as a comparative embodiment will be explained in order to facilitate the understanding of the pump device 100.

[0049] The main pump and the sub pump in the pump device according to the comparative embodiment have groove-shaped notches that are formed in the same shape and extend from the opening edge of the discharge port toward the rear side in the rotation direction of the rotor. The notches are formed so that the lengths are long and the cross-section areas are large, and the resistance applied to the hydraulic oil is relatively small.

[0050] During high rotation of the pump, the movement speed of the vanes in the rotation direction of the rotor

is fast, and thus it becomes difficult to lead hydraulic oil from the discharge ports into the pump chambers through the notches, and the rate of pressure rise within the pump chambers is slow compared to during low rotation. Therefore, in the pump device according to the comparative embodiment, the notches are formed so that the resistance applied to the hydraulic oil passing therethrough is relatively small, and thus it becomes easier to lead hydraulic oil from the discharge ports into the pump chambers through the notches. Thereby, even during high rotation of the pump in which the rate of pressure rise is relatively slow, the pressure difference between the pump chambers and the high-pressure chamber decreases when the pump chambers and the high-pressure chamber are in direct communication, and pressure fluctuations can be moderated. Therefore, the occurrence of noise and vibrations during high rotation of the pump can be suppressed. In this way, the notches of pump device according to the comparative embodiment are formed in shapes for suppressing the occurrence of noise and vibrations during high rotation.

[0051] Meanwhile, during low rotation of the pump, the movement speed of the vanes in the rotation direction of the rotor is slow, and thus it becomes easy to lead hydraulic oil from the discharge ports into the pump chambers through the notches compared to during high rotation of the pump, and the rate of pressure rise within the pump chambers becomes relatively fast. Therefore, during low rotation of the pump in the pump device according to the comparative embodiment, the rate of pressure rise is fast compared to during high rotation, and hydraulic oil from the discharge ports is led to the pump chambers through the notches which further promotes the rise in pressure, and this causes sudden fluctuations in the pressure within the pump chambers. Therefore, noise and vibrations occur during low rotation of the pump in the main pump and the sub pump of the pump device according to the comparative embodiment.

[0052] In contrast, in the pump device 100, the notches 9a of the main pump 101 are formed so that the resistance applied to the hydraulic oil passing therethrough is relatively small, and the notches 9b of the sub pump 102 are formed so that the resistance applied to the hydraulic oil passing therethrough is large compared to the notches 9a of the main pump 101. Thereby, during low rotation of the pump in the sub pump 102, a situation in which an excessive amount of hydraulic oil is led from the discharge ports 9 to the pump chambers 7 through the notches 9b is suppressed. Therefore, sudden increases in the pressure of the pump chambers 7 of the sub pump 102 during low rotation are prevented, and pressure fluctuations when the pump chambers 7 are in direct communication with the discharge ports 9 become moderate, and the occurrence of noise and vibrations can be suppressed.

[0053] During high rotation of the pump, the discharge ports 9 of the sub pump 102 communicate with the return passage 35, and hydraulic oil discharged from the sub

pump 102 is returned to the suction side. In other words, the pump chambers 7 of the sub pump 102 during high rotation of the pump communicate with the discharge ports 9 which communicate with the suction side and have low pressure. In this way, even with the notches 9b in which the resistance applied to the flow of hydraulic oil passing therethrough is relatively large, i.e. even with the notches 9b that is formed in a shape conforming to low rotation of the pump, during high rotation of the pump, the high-pressure chamber 12 communicates with the suction side and pressure is released, and thus sudden fluctuations of the pressure in the high-pressure chamber 12 of the sub pump 102 do not occur. Therefore, the occurrence of vibrations and noise in the sub pump 102 during high rotation is suppressed.

[0054] In other words, the notches 9a of the main pump 101, which is used during low rotation of the pump and during high rotation of the pump, are formed in a shape for suppressing noise and vibrations during high rotation, and the notches 9b of the sub pump 102, which is not used during high rotation, are formed in a shape for suppressing noise and vibrations during low rotation. Thereby, vibrations and noise can be suppressed in the pump device 100.

[0055] According to the above embodiment, the following effects are achieved.

[0056] According to the pump device 100, the sub pump 102 has notches 9b in which the resistance applied to hydraulic oil passing therethrough is greater than that of the main pump 101, and thus during low rotation of the pump, the flow of hydraulic oil passing through the notches 9b is suppressed by the resistance. Therefore, sudden fluctuations in the pressure of the hydraulic oil when the pump chambers 7 and the high-pressure chamber 12 are in communication are prevented, and the occurrence of vibrations and noise in the sub pump 102 during low rotation of the pump can be suppressed. Further, if the rotation speed of the pump device 100 increases, hydraulic oil discharged from the sub pump 102 is led to the suction side of the low pressure by the switching valve 40. Therefore, even if the sub pump 102 is provided with the notches 9b that apply a relatively large resistance to the hydraulic oil, the occurrence of vibrations and noise in the sub pump 102 during high rotation can be suppressed. Accordingly, the occurrence of vibrations and noise can be suppressed in the pump device 100 which includes the main pump 101 and the sub pump 102.

[0057] Next, an alternative embodiment of the above-described embodiment will be explained.

[0058] In the above-described embodiment, the main pump 101 and the sub pump 102 do not have notches that communicate with the suction ports 8. However, as shown in FIG. 11, groove-shaped notches (suction-side notches) 8a, 8b that extend from the opening edge of the suction ports 8 in the direction opposite to the rotation direction of the rotor 2 may be formed in the center plate 5. In this case as well, the suction-side notches 8b of the sub pump 102 are preferably formed so that the resist-

ance applied to hydraulic oil passing therethrough becomes greater compared to the suction-side notches 8a of the main pump 101, such that, for example, the length of the suction-side notches 8b of the sub pump 102 is less than that of suction-side notches 8a of the main pump 101 as shown in FIG. 11. Thereby, in the sub pump 102 during low rotation of the pump, pressure fluctuations when the pump chambers 7 on the high-pressure side and the discharge ports 8 on the low-pressure side are in communication can be moderated. Therefore, the occurrence of noise and vibrations in the pump device 100 can be further suppressed. FIG. 11 is a plan view of the center plate 5 when viewed from the sub pump 102 side, and the arrow in FIG. 11 represents the rotation direction of the rotor 2.

[0059] The notch shapes of the main pump 101 and the sub pump 102 are not limited to the shapes described above, and any shape can be used as long as the notches 9b of the sub pump 102 are formed so that the resistance applied to the hydraulic oil is greater than that of the notches 9a of the main pump 101. Concrete embodiments thereof shall be explained below referring to FIGS. 8 and 9. FIGS. 8 and 9 are cross-section views illustrating the opening area of the notches 9a, 9b of the main pump 101 and the sub pump 102 in the reference state.

[0060] As shown in FIG. 8, the notches 9a, 9b of the main pump 101 and the sub pump 102 may be formed so that the lengths L and the opening widths (not illustrated) are equivalent to each other, whereas the depth D2 of the notch 9b of the sub pump 102 is smaller than the depth D1 of the notch 9a of the main pump 101. Thereby, the resistance applied to the hydraulic oil passing through the notch 9b of the sub pump 102 becomes greater than that of the notch 9a of the main pump 101.

[0061] Further, as shown in FIG. 9, comparing the transition regions of the main pump 101 and the sub pump 102, a region R1 in which the opening area S2 of the notch 9b of the sub pump 102 is larger than the opening area S1 of the notch 9a of the main pump 101 and a region R2 in which the opening area S2 of the notch 9b of the sub pump 102 is smaller than the opening area S1 of the notch 9a of the main pump 101 may be formed. In this case as well, the notches 9a, 9b of the main pump 101 and the sub pump 102 are formed so that the notch 9b of the sub pump 102 applies a greater resistance on the whole to the hydraulic oil passing therethrough compared to the notch 9a of the main pump 101 in the space where the vane 3b on the front side in the rotation direction moves through the transition region. Thereby, effects similar to those of the above-described embodiment are achieved.

[0062] In the above-described embodiment, the main pump 101 and the sub pump 102 have the same number of vanes 3. Instead of this configuration, the number of vanes 3 in the main pump 101 may be different from that in the sub pump 102. If the number of vanes 3 is different between the main pump 101 and the sub pump 102, the capacity of each pump chamber 7 defined by the vanes

3 will also differ, and thus the positions in the circumferential direction at which the discharge ports 8 are formed will be different. In this case as well, the notch 9b of the sub pump 102 applies a greater resistance on the whole to the hydraulic oil passing therethrough compared to the notch 9a of the main pump 101 in the space where the vane 3b on the front side in the rotation direction that defines the pump chamber 7 moves through the transition region. Thereby, effects similar to those of the above-described embodiment are achieved.

[0063] In the above-described embodiment, the two notches 9a of the main pump 101 are formed in the same shape as each other. The two notches 9b of the sub pump 102 are also formed in the same shape as each other. Instead of this configuration, the notches 9a of the main pump 101 may be formed in different shapes from each other. Further, the notches 9b of the sub pump 102 may also be formed in different shapes from each other. In order to suppress noise and vibrations of the pump device 100, both of the two notches 9b of the sub pump 102 preferably apply a greater resistance to the hydraulic oil than the notches 9a of the main pump 101. However, for example, one notch 9b of the sub pump 102 may be formed in the same shape as that of the notches 9a of the main pump 101, while the other notch 9b may be formed so as to apply a greater resistance to hydraulic oil passing therethrough than the notches 9a of the main pump 101. In this way, as long as at least one of the notches 9b of the sub pump 102 is formed so as to apply a greater resistance to hydraulic oil passing therethrough than the notches 9a of the main pump 101.

[0064] In the above-described embodiment, the main pump 101 and the sub pump 102 each have two discharge ports 9. Instead of this configuration, there may be one discharge port 9, or three or more discharge ports 9. In these cases as well, as long as at least one of the notches 9b of the sub pump 102 is formed so as to apply a greater resistance to hydraulic oil passing therethrough than the notches 9a of the main pump 101.

[0065] In the above-described embodiment, a single notch 9a, 9b is formed to be in communication with each discharge port 9 in the main pump 101 and the sub pump 102. Instead of this configuration, two or more notches 9a, 9b that communicate with a single discharge port 9 may be formed. In this case, the notches 9a, 9b of the main pump 101 and the sub pump 102 may be formed so that the total resistance applied to the hydraulic oil passing through the plurality of notches 9b that communicate with one discharge port 9 of the sub pump 102 is greater than the total resistance applied to the hydraulic oil passing through the notches 9a that communicate with one of the discharge ports 9 of the main pump 101.

[0066] In the above-described embodiment, the switching valve 40 is provided to the switching passage 33, and the second discharge passage 34 and the return passage 35 are connected to the switching valve 40. Instead of this configuration, as shown in FIG. 10, the second discharge passage 34 may be in direct communica-

tion with the sub pump 102 and the return passage 35 may be provided so as to branch from the second discharge passage 34. In this case, a check valve 37 that permits only the flow of hydraulic oil from the second discharge passage 34 to the first discharge passage 32 is provided to the second discharge passage 34, and the return passage 35 is provided so as to branch from the upstream side of the check valve 37 in the second discharge passage 34. Further, a switching valve 140 is provided to the return passage 35. The switching valve 140 has a blocked position 140a in which the return passage 35 is blocked, and an open position 140b in which the return passage 35 is opened. The position switching operation of the switching valve 140 switches regarding whether or not to return the hydraulic oil discharged from the sub pump 102 to the suction side through the return passage 35. The pump device 100 may have such a configuration, and even in this case, the pump device 100 achieves effects similar to those of the above-described embodiment.

[0067] Embodiments of this invention were described above, but the above embodiments are merely examples of applications of this invention, and the technical scope of this invention is not limited to the specific constitutions of the above embodiments.

[0068] This application claims priority based on Japanese Patent Application No.2015-112566 filed with the Japan Patent Office on June 2, 2015, the entire contents of which are incorporated into this specification by reference.

Claims

1. A pump device for supplying working fluid to a fluid pressure device, the pump device comprising:

a main pump configured to supply the working fluid to the fluid pressure device through a first discharge passage;
a sub pump configured to supply the working fluid to the fluid pressure device through a second discharge passage that joins with the first discharge passage;
a return passage configured to return the working fluid discharged from the sub pump to a suction side; and
a switching valve configured to switch regarding whether or not to return the working fluid discharged from the sub pump to the suction side through the return passage,
wherein the main pump and the sub pump each comprise:

a rotor connected to a common drive shaft;
a plurality of vanes provided so as to be capable of reciprocating in a radial direction relative to the rotor;

a cam ring having an inner peripheral surface, wherein distal ends of the vanes being configured to be in sliding contact with the inner peripheral surface in accordance with rotation of the rotor;
 pump chambers defined by the rotor, the cam ring, and adjacent pair of the vanes;
 a discharge port into which the working fluid discharged from the pump chamber is led;
 and
 a groove-shaped discharge-side notch formed from an opening edge of the discharge port toward a direction opposite to a rotation direction of the rotor,

is at or above a predetermined pump rotation speed.

wherein the switching valve is configured to switch according to a rotation speed of the drive shaft, and
 wherein at least one discharge-side notch of the sub pump is formed so that a resistance applied to the flow of the working fluid passing there-through is greater than that of the discharge-side notch of the main pump.

2. The pump device according to claim 1, wherein the main pump and the sub pump each further comprise a suction port configured to lead the working fluid to the pump chamber,
 and an opening area of the discharge-side notch of the sub pump at a position separated from a reference position by a predetermined angle is formed to be smaller than an opening area of the discharge-side notch of the main pump at a position separated from the reference position by a predetermined angle, the reference position being a position of the vane that is on the front side in the rotation direction among the pair of vanes that define the pump chamber when communication between the pump chamber and the discharge port is blocked in accordance with the rotation of the rotor.

3. The pump device according to claim 1, wherein the main pump and the sub pump each further comprise a groove-shaped suction-side notch formed from an opening edge of the suction port toward the direction opposite to the rotation direction of the rotor, the suction port being configured to lead the working fluid to the pump chamber,
 wherein at least one suction-side notch of the sub pump is formed so that a resistance applied to the flow of the working fluid passing therethrough is greater than that of the suction-side notch of the main pump.

4. The pump device according to claim 1, wherein the switching valve configured to switch so as to return the working fluid to the suction side through the return passage when the rotation speed of the drive shaft

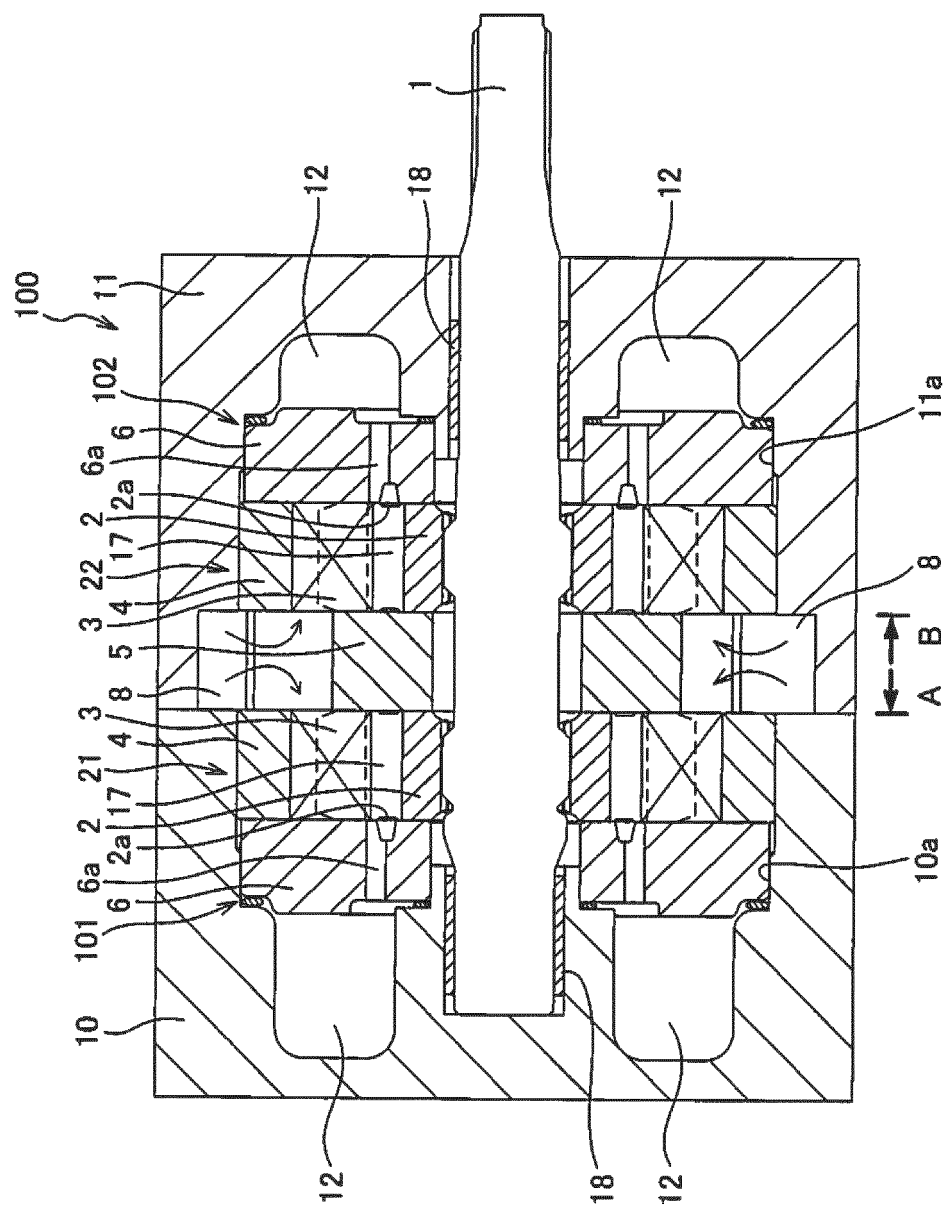


FIG. 1

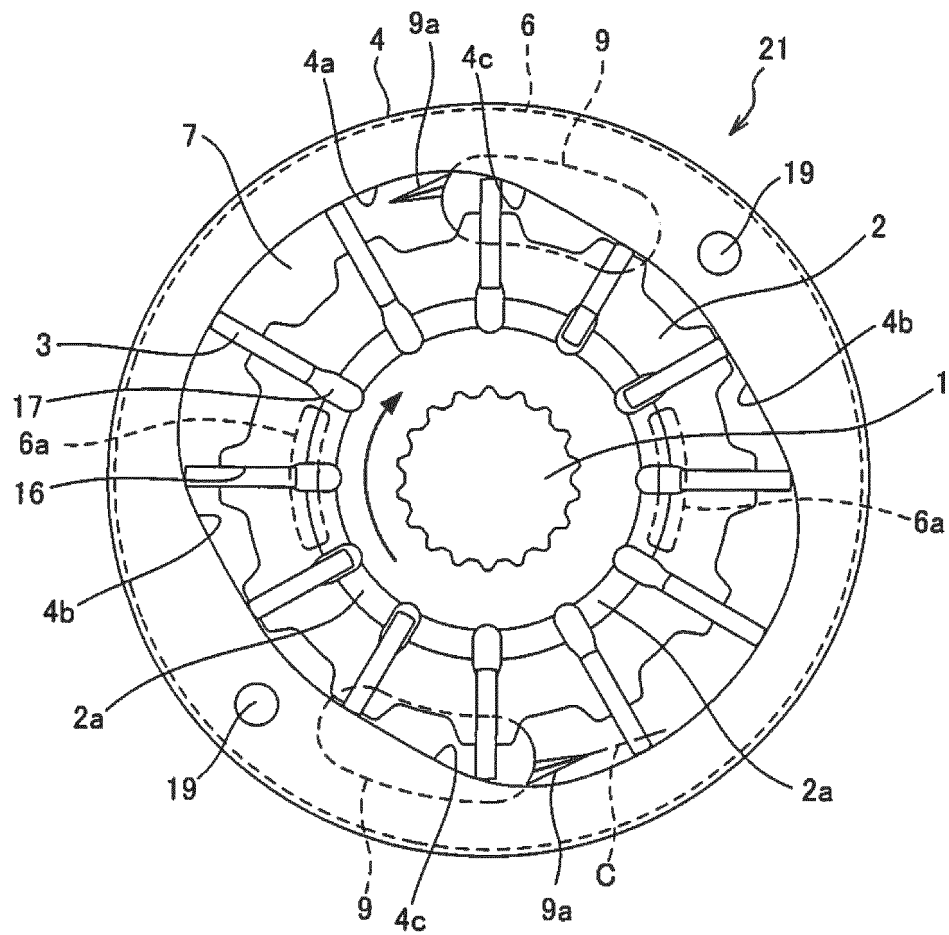


FIG. 2

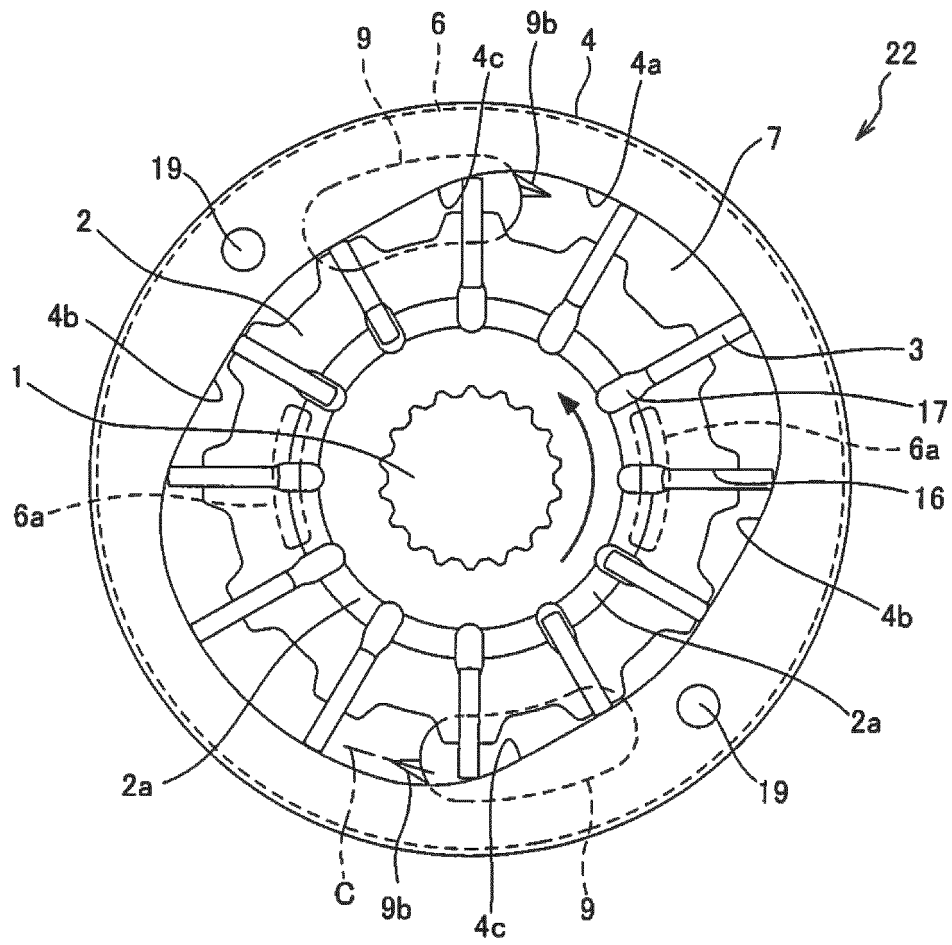


FIG. 3

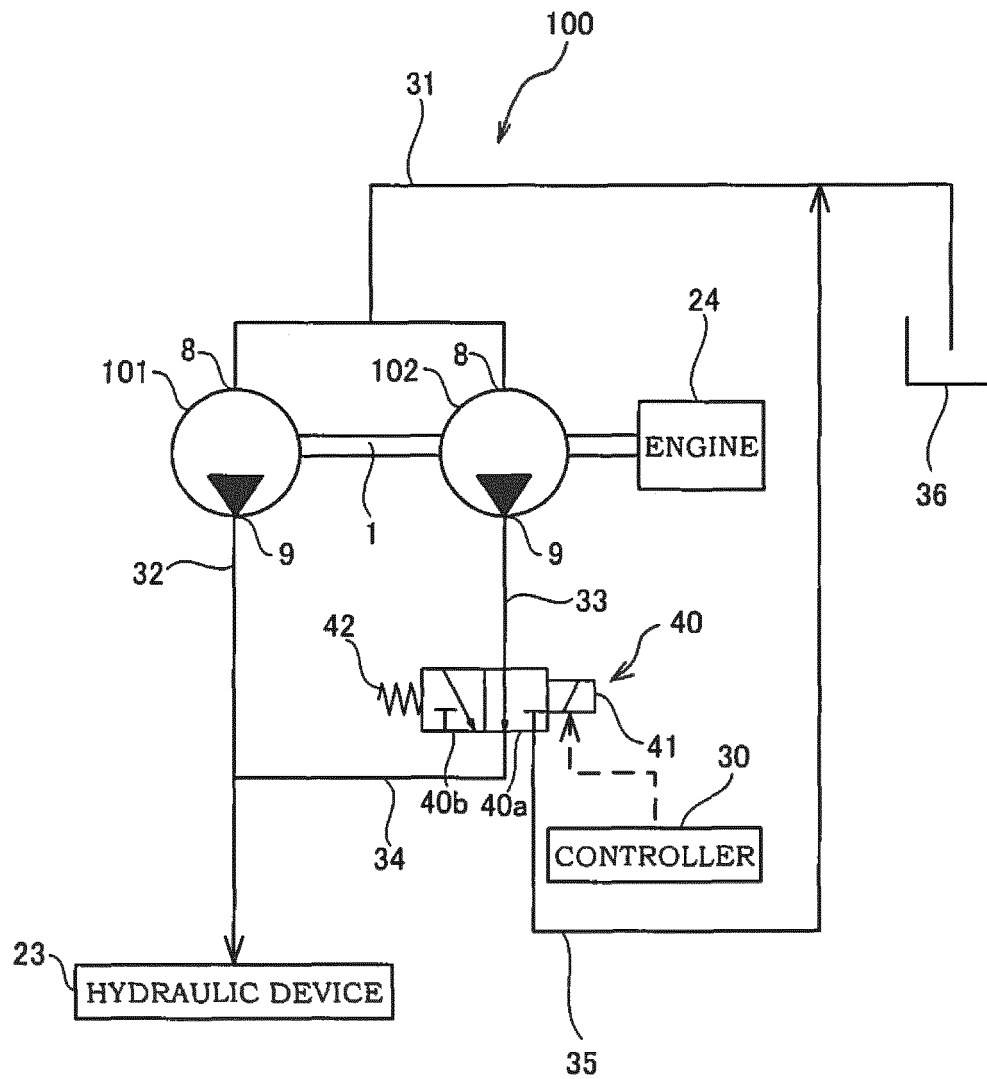


FIG. 4

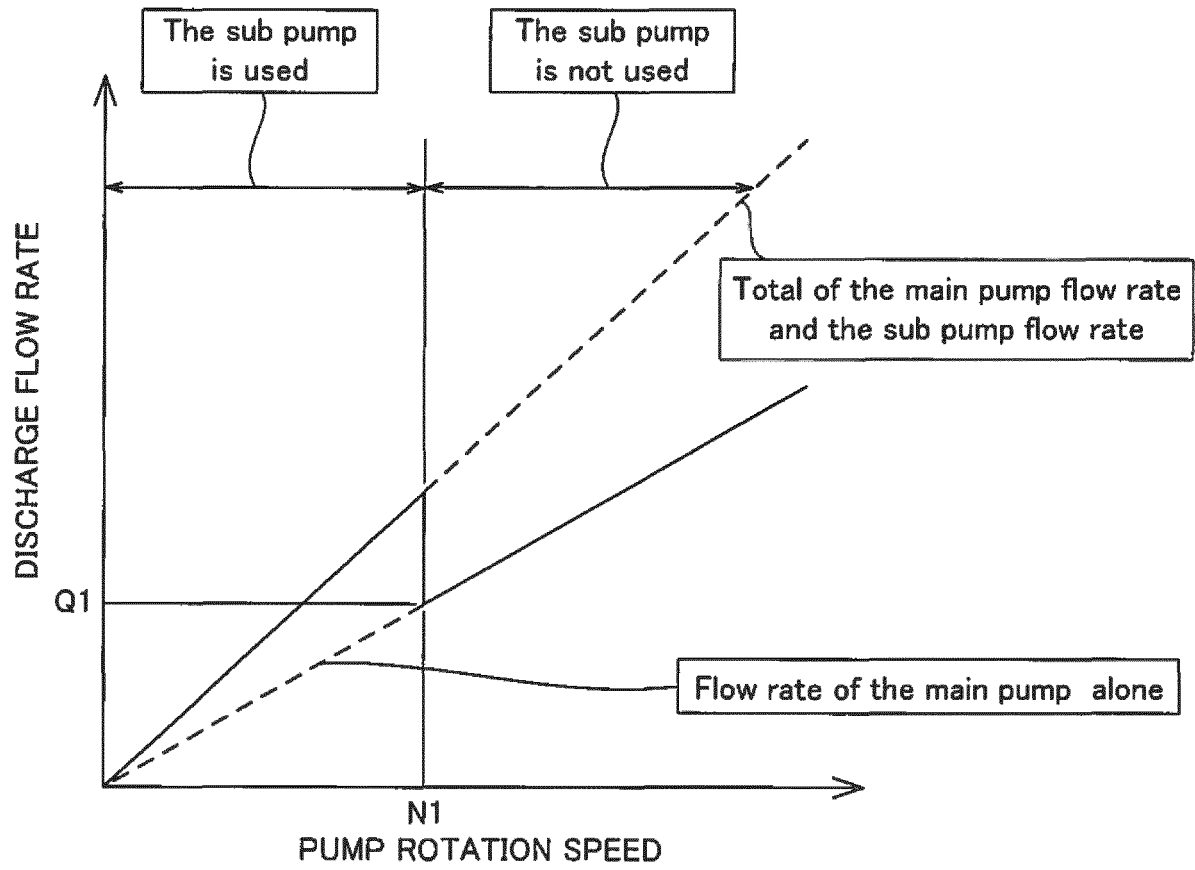


FIG. 5

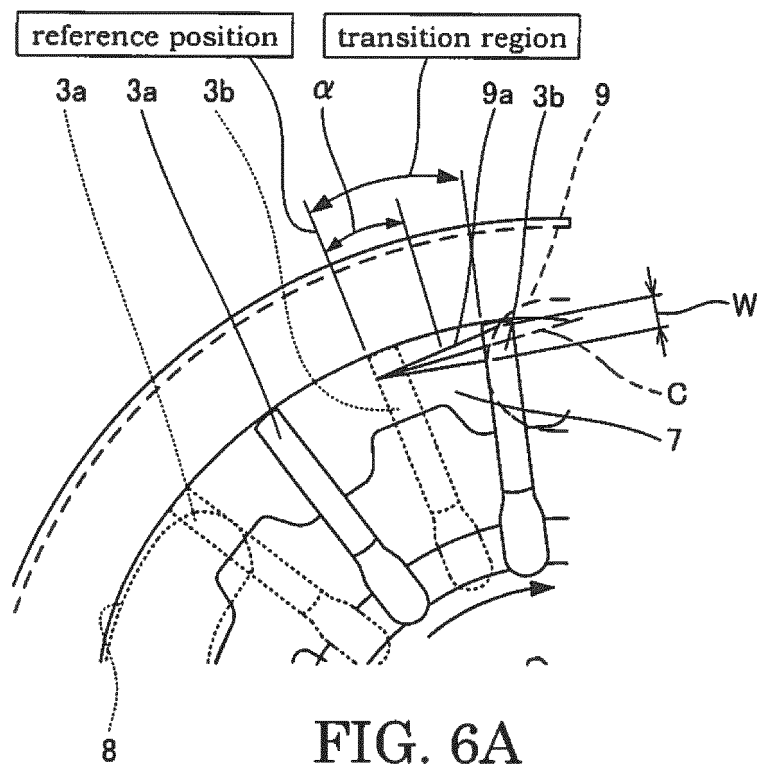


FIG. 6A

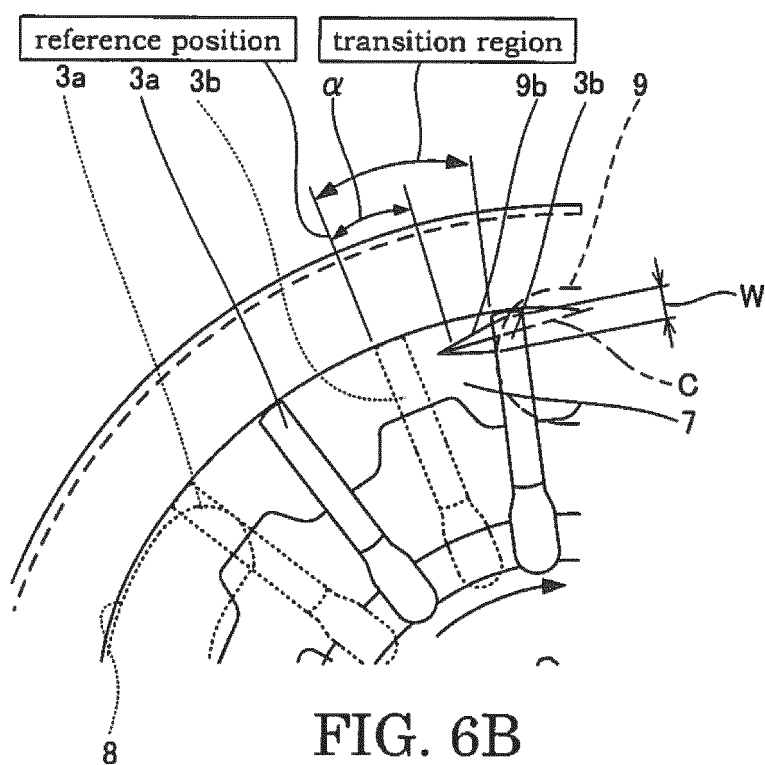


FIG. 6B

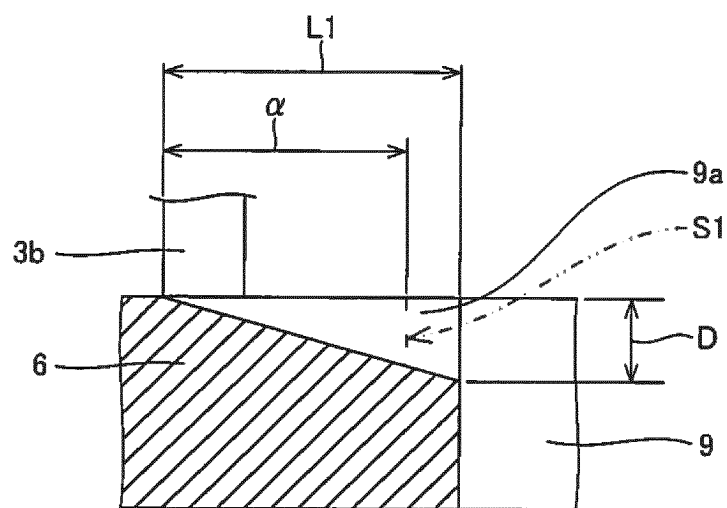


FIG. 7A

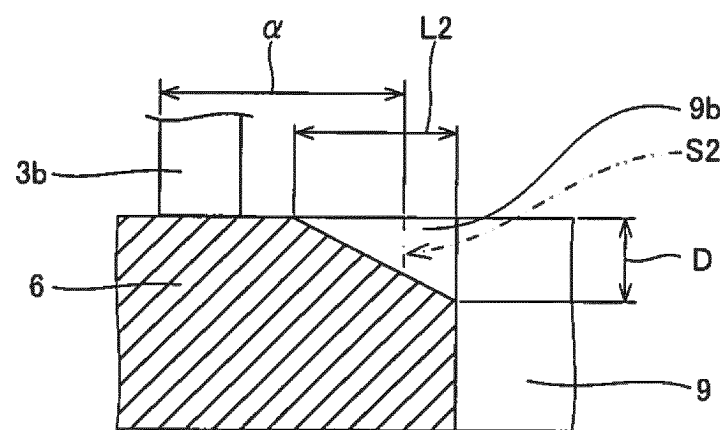


FIG. 7B

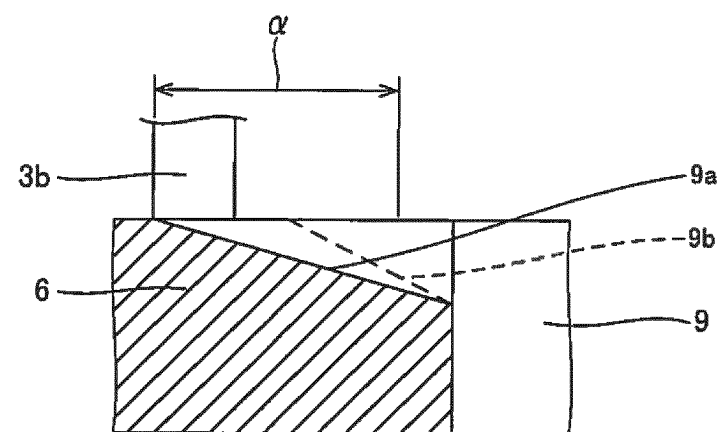
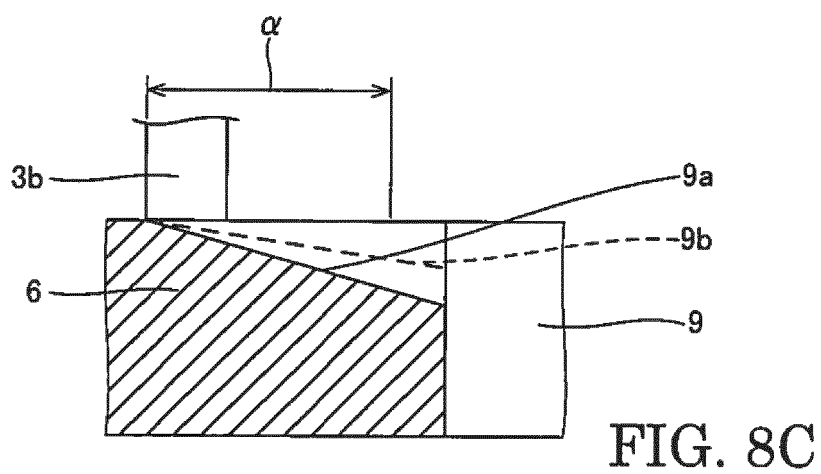
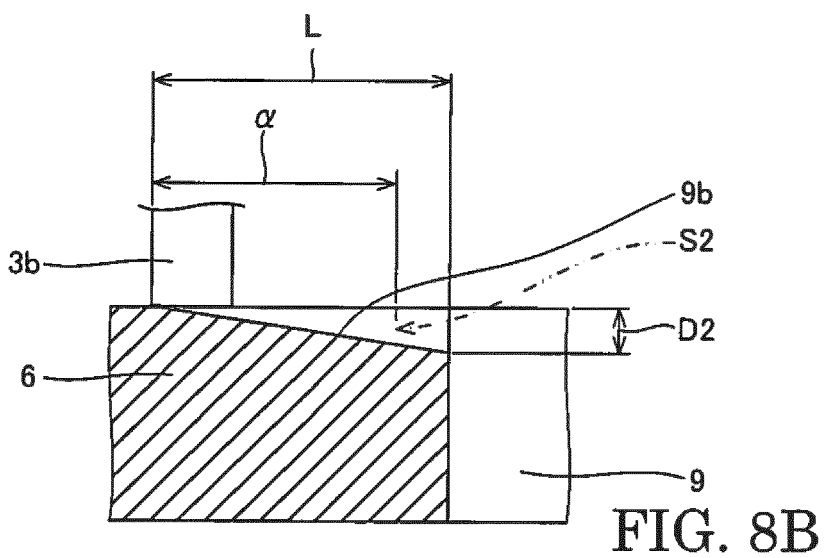
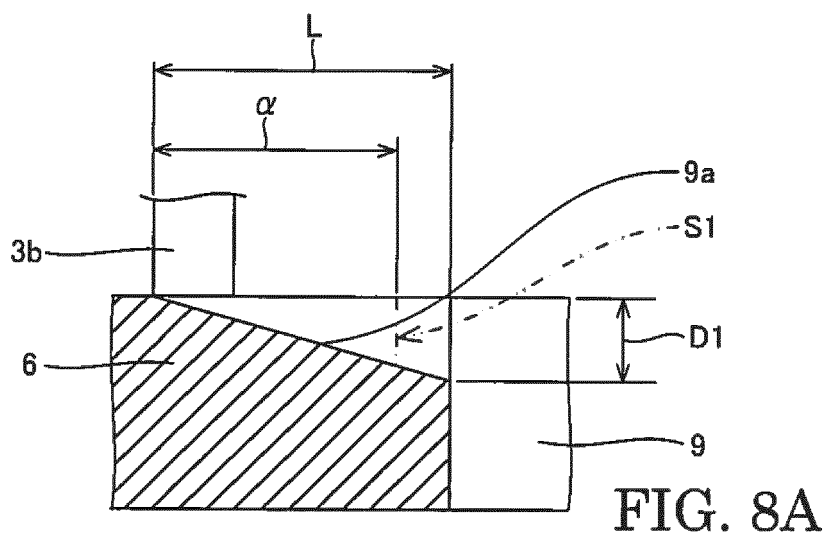


FIG. 7C



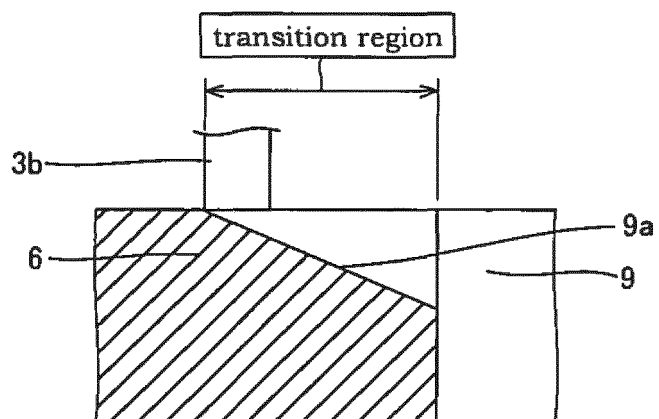


FIG. 9A

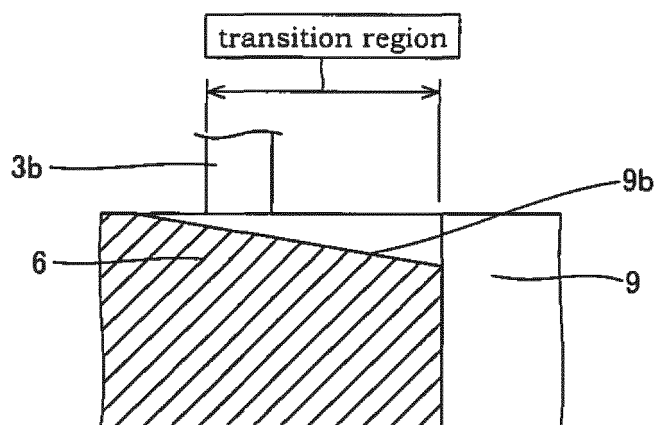


FIG. 9B

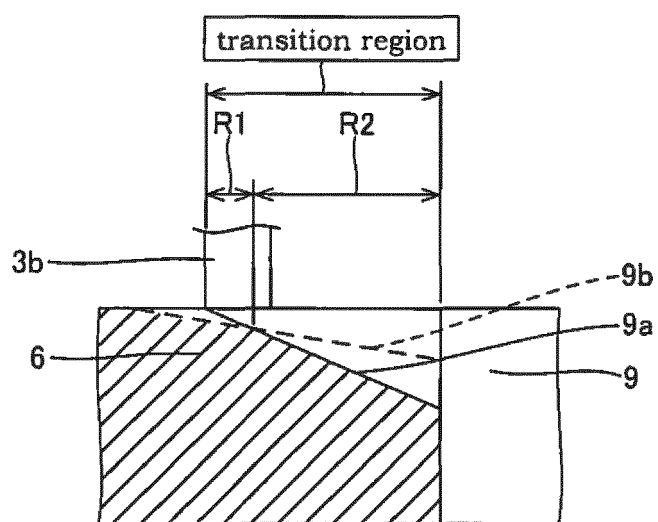


FIG. 9C

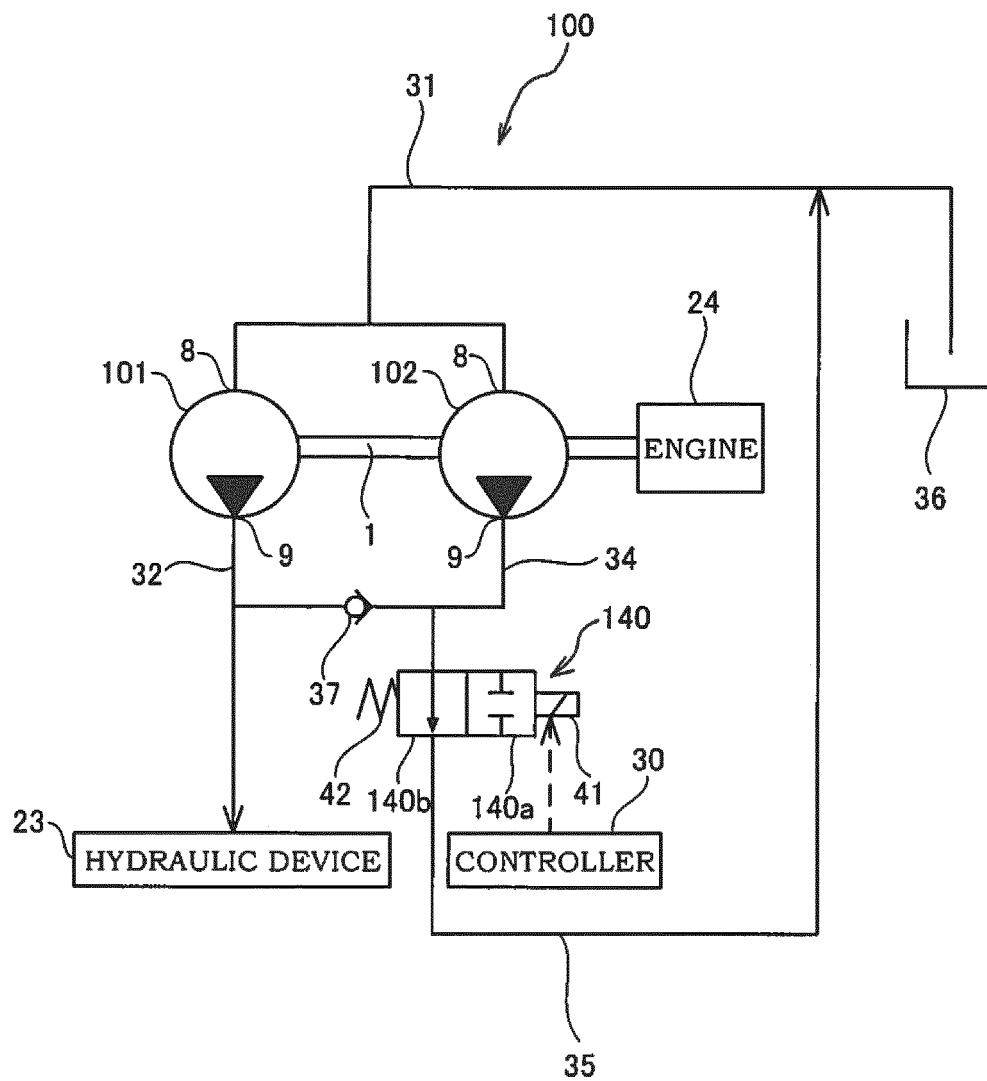


FIG. 10

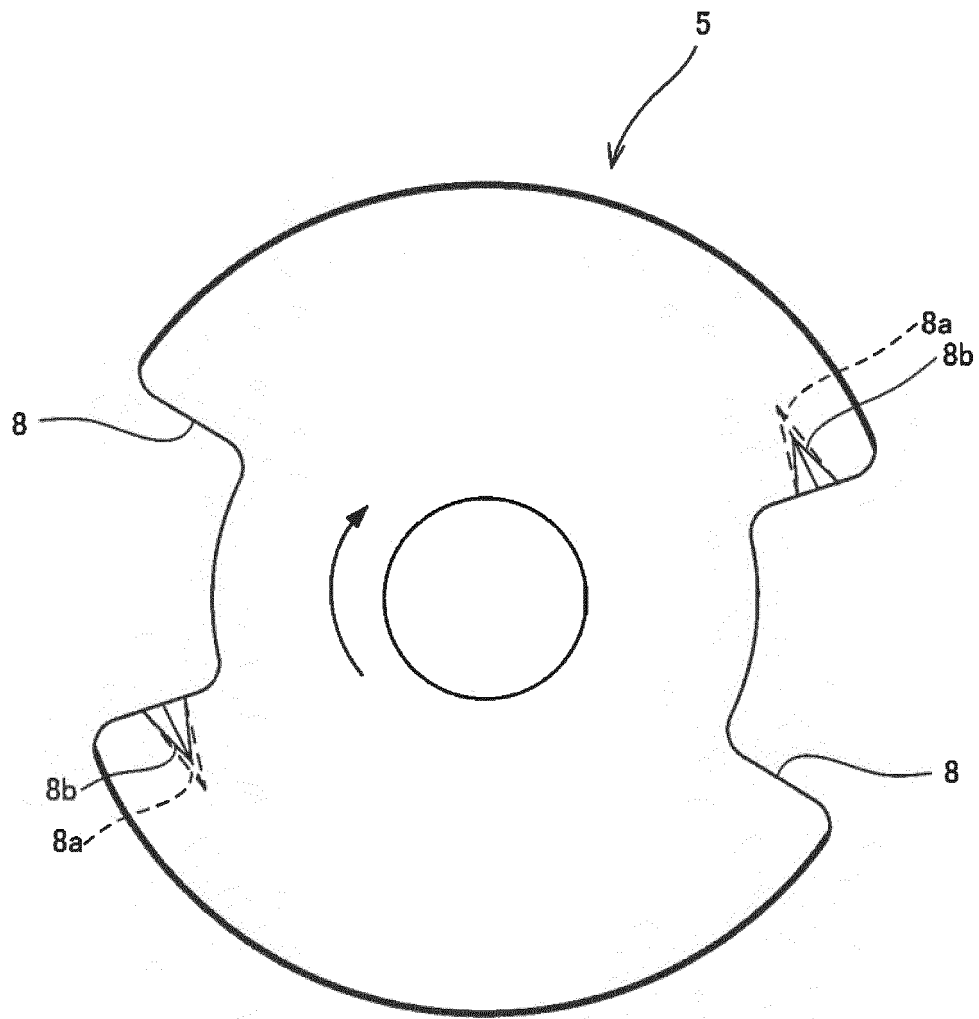


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/066137

A. CLASSIFICATION OF SUBJECT MATTER

F04C11/00(2006.01)*i*, *F04C2/344*(2006.01)*i*, *F04C14/26*(2006.01)*i*, *F04C15/06*(2006.01)*i*

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F04C11/00, *F04C2/344*, *F04C14/26*, *F04C15/06*

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2010-14101 A (Kayaba Industry Co., Ltd.), 21 January 2010 (21.01.2010), paragraphs [0010] to [0040]; fig. 1 to 4 (Family: none)	1-4
Y	JP 11-303773 A (Jidosha Kiki Co., Ltd.), 02 November 1999 (02.11.1999), paragraphs [0009] to [0055], [0062]; fig. 1 to 10 & US 6120256 A column 2, line 50 to column 11, line 42; fig. 1 to 10	1-4

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

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"&" document member of the same patent family

Date of the actual completion of the international search
19 August 2016 (19.08.16)

Date of mailing of the international search report
30 August 2016 (30.08.16)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
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Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/066137

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-184759 A (Unisia JKC Steering Systems Co., Ltd.), 03 July 2003 (03.07.2003), paragraph [0003] (Family: none)	1-4

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2010014101 A [0002]
- JP 2015112566 A [0068]