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(54) **ANTI-CAVITATION HYDRAULIC CIRCUIT**

(57) An anti-cavitation hydraulic circuit capable of effectively reducing cavitation with a simple configuration is provided. An anti-cavitation hydraulic circuit which enables to easily add a cavitation reduction function to an existing circuit is provided. An anti-cavitation valve (50) includes an anti-cavitation spool (51) which is connected to the first supply-discharge passage (21) via a first communication passage (61) and is connected to the second supply-discharge passage (22) via a second communication passage (62), and a slide position of the anti-cavitation spool (51) is determined according to pressure of the hydraulic fluid from the first and second supply-discharge passages (21, 22). While the anti-cavitation spool (51) is positioned in at least a part between a neutral position and a stroke end position, the anti-cavitation valve (50) is placed in a communication passage communicating state in which the first and second communication passages (61, 62) are communicated with each other.

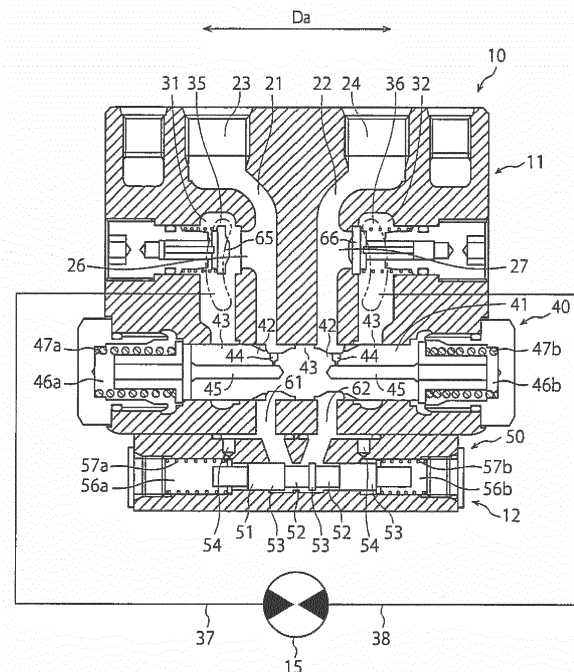


FIG. 4

Description

TECHNICAL FIELD

[0001] The present invention relates to an anti-cavitation hydraulic circuit connected to a hydraulic actuator such as a hydraulic motor, and more particularly, to an anti-cavitation hydraulic circuit that reduces cavitation that may occur during a stop operation of a hydraulic actuator.

BACKGROUND ART

[0002] Various circuits adapted to various purposes have been proposed as hydraulic circuits for supplying hydraulic fluid (which may also be referred to as "hydraulic oil") to a hydraulic motor for running or turning. For example, since cavitation occurring when a hydraulic motor is stopped is accompanied by unpleasant noise or vibration, it is preferable to suppress such cavitation as much as possible. Japanese patent application publications Nos. 2001-214901 and 2006-17263 disclose hydraulic circuits aiming to prevent such cavitation from occurring.

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0003] The above-described hydraulic circuits disclosed in Japanese patent application publications Nos. 2001-214901 and 2006-17263 do not necessarily have a simple configuration, and sufficient cavitation suppression effect may not be necessarily attained.

[0004] For example, in the hydraulic circuit disclosed in Japanese patent application publication No. 2001-214901, return circuits are connected to two main circuits respectively, a check valve is provided in each return circuit, a bypass circuit is connected to an intermediate point between these return circuits, and two branch passages are selectively opened and closed with respect to the bypass circuit. In the hydraulic circuit in Japanese patent application publication No. 2001-214901, the occurrence of cavitation is prevented by supplying the hydraulic fluid of the main circuit on the return side to the main circuit on the supply side when the pump operation is stopped, but the circuit configuration is complicated and it is also necessary to install check valves at various positions. Therefore, the hydraulic circuit disclosed in Japanese patent application publication No. 2001-214901 tends to increase in cost.

[0005] Further, in the hydraulic circuit disclosed in Japanese patent application publication No. 2006-17263, when the hydraulic motor is braked, the oil suction performance from the suction-side supply-discharge passage to the hydraulic motor is improved by connecting the suction-side supply-discharge passage to the hydraulic motor via the counterbalance valve. However,

when the hydraulic motor is braked, the supply of oil to this suction-side supply-discharge passage is stopped, or the amount of oil supplied to this suction-side supply-discharge passage is reduced. Therefore, it is not always possible for the hydraulic circuit in Japanese patent application publication No. 2006-17263 to supply a sufficient oil amount to the hydraulic motor, and cavitation cannot be sufficiently suppressed in some circumstances.

[0006] As described above, a hydraulic circuit having a simple structure and high cavitation suppression effect has not been proposed, and there is room for further improvement in terms of cost reduction. Further, in the context of increasing in diversity of needs, while there are users desiring a hydraulic circuit capable of effectively reducing cavitation even as the cost somewhat increases, there are users desiring a hydraulic circuit with a reduced cost by omitting the cavitation reduction function. In order to be able to respond to any of these demands, it is also desired to be able to easily add a cavitation reduction function to an existing circuit as necessary.

[0007] The present invention has been made in view of the above circumstances, and an object thereof is to provide a hydraulic circuit capable of effectively reducing cavitation with a simple configuration. It is another object of the present invention to provide a hydraulic circuit which enables to easily add a cavitation reduction function to an existing circuit.

SOLUTION TO PROBLEM

[0008] One aspect of the present invention is directed to an anti-cavitation hydraulic circuit comprising: a first supply-discharge passage and a second supply-discharge passage connected to a hydraulic actuator, a hydraulic fluid being supplied to the hydraulic actuator from one of the first and second supply-discharge passages and the hydraulic fluid being discharged from the hydraulic actuator to the other of the first and second supply-discharge passages; and an anti-cavitation valve including an anti-cavitation spool which is connected to the first supply-discharge passage via a first communication passage and is connected to the second supply-discharge passage via a second communication passage, a slide position of the anti-cavitation spool being determined according to a pressure of the hydraulic fluid from the first supply-discharge passage and a pressure of the hydraulic fluid from the second supply-discharge passage, wherein when the anti-cavitation spool is positioned in at least a part between a neutral position and a stroke end position, the anti-cavitation valve is placed in a communication passage communicating state in which the first communication passage and the second communication are communicated with each other.

[0009] The anti-cavitation hydraulic circuit may further comprises: a first block body which has the first supply-discharge passage and the second supply-discharge passage; and a second block body which is attached to

the first block body and has the anti-cavitation valve.

[0010] The anti-cavitation hydraulic circuit may further comprises: a first relay passage provided between the first supply-discharge passage and the hydraulic actuator; a second relay passage provided between the second supply-discharge passage and the hydraulic actuator; a first check valve which operates in accordance with a differential pressure between a pressure of the hydraulic fluid in the first supply-discharge passage and a pressure of the hydraulic fluid in the first relay passage, and allows the hydraulic fluid flowing from the first supply-discharge passage toward the first relay passage to pass through the first check valve but does not allow the hydraulic fluid flowing from the first relay passage toward the first supply-discharge passage to pass through the first check valve; and a second check valve which operates in accordance with a differential pressure between a pressure of the hydraulic fluid in the second supply-discharge passage and a pressure of the hydraulic fluid in the second relay passage, and allows the hydraulic fluid flowing from the second supply-discharge passage toward the second relay passage to pass through the second check valve but does not allow the hydraulic fluid flowing from the second relay passage toward the second supply-discharge passage to pass through the second check valve.

[0011] The anti-cavitation hydraulic circuit may further comprises a counterbalance valve including a counterbalance spool which is connected to the first supply-discharge passage and the second supply-discharge passage, a slide position of the counterbalance spool being determined according to the pressure of the hydraulic fluid from the first supply-discharge passage and the pressure of the hydraulic fluid from the second supply-discharge passage, a connection state of the first supply-discharge passage with respect to the hydraulic actuator and a connection state of the second supply-discharge passage with respect to the hydraulic actuator being changed according to the slide position of the counterbalance spool.

[0012] The counterbalance valve may further include a first elastic body applying elastic force to the counterbalance spool so as to dispose the counterbalance spool at a neutral position, the anti-cavitation valve may further include a second elastic body applying elastic force to the anti-cavitation spool so as to dispose the anti-cavitation spool at the neutral position, and an elastic modulus of the second elastic body may be smaller than an elastic modulus of the first elastic body.

[0013] The anti-cavitation hydraulic circuit may further comprises: a first slow return check valve which brings about resistance applied to the hydraulic fluid in such a manner that the resistance applied to the hydraulic fluid flowing from the anti-cavitation spool toward the first supply-discharge passage is higher than the resistance applied to the hydraulic fluid flowing from the first supply-discharge passage toward the anti-cavitation spool; and a second slow return check valve which brings about

resistance applied to the hydraulic fluid in such a manner that the resistance applied to the hydraulic fluid flowing from the anti-cavitation spool toward the second supply-discharge passage is higher than the resistance applied to the hydraulic fluid flowing from the second supply-discharge passage toward the anti-cavitation spool.

[0014] According to the present invention, cavitation can be effectively reduced with a simple configuration. In addition, by including the anti-cavitation valve in the second block body attached to the first block body, it is possible to easily add a function of reducing cavitation to a circuit included in the first block body.

BRIEF DESCRIPTION OF DRAWINGS

[0015]

Fig. 1 is a diagram illustrating a cross-sectional state of an anti-cavitation hydraulic circuit according to one embodiment of the present invention.

Fig. 2 is a diagram illustrating a cross-sectional state of an anti-cavitation hydraulic circuit according to said one embodiment of the present invention.

Fig. 3 is a diagram illustrating a cross-sectional state of an anti-cavitation hydraulic circuit according to said one embodiment of the present invention.

Fig. 4 is a diagram illustrating a cross-sectional state of an anti-cavitation hydraulic circuit according to said one embodiment of the present invention.

Fig. 5 is a circuit diagram illustrating an example of a hydraulic circuit according to an embodiment of the present invention.

Fig. 6 is a circuit diagram illustrating an example of a hydraulic circuit including an anti-cavitation hydraulic circuit according to a modified example of the present invention.

Fig. 7 is a conceptual diagram illustrating the relation between the state of an anti-cavitation valve and the difference ΔP between the pressure of the hydraulic fluid in a first supply-discharge passage and the pressure of the hydraulic fluid in a second supply-discharge passage.

DESCRIPTION OF EMBODIMENTS

[0016] Embodiment of the present invention will be described with reference to the drawings. It should be noted that, in order to facilitate understanding, the elements shown in each drawing may include an element whose size, scale and the like are shown different from the actual ones.

[0017] The hydraulic circuits described below can be applied to, for example, a construction machine, and can effectively reduce cavitation that can occur at the time of operation for stopping a hydraulic motor for a travel motion and a hydraulic motor for a turning motion. However, an apparatus to which the following hydraulic circuits can be applied is not particularly limited, and in cases where

reduction of cavitation is desired in an arbitrary apparatus using a hydraulic actuator such as a hydraulic motor, the following hydraulic circuits can be suitably used.

[0018] Figs. 1 to 4 are diagrams illustrating cross-sectional states of an anti-cavitation hydraulic circuit 10 according to one embodiment of the present invention, and show connection states of the anti-cavitation hydraulic circuit 10 and a hydraulic motor 15 in a simplified manner.

[Structure]

[0019] The anti-cavitation hydraulic circuit 10 comprises a first supply-discharge passage 21, a second supply-discharge passage 22, a counterbalance valve 40, and an anti-cavitation valve 50. The first supply-discharge passage 21, the second supply-discharge passage 22, and the counterbalance valve 40 are included in a first block body 11, while the anti-cavitation valve 50 is included in a second block body 12. The second block body 12 is fixedly attached to the first block body 11 via an arbitrary fixture (not shown) such as a screw.

[0020] The first supply-discharge passage 21 and the second supply-discharge passage 22 are connected to the hydraulic motor 15, a hydraulic fluid is supplied to the hydraulic motor 15 from one of the first and second supply-discharge passages 21, 22 and the hydraulic fluid is discharged from the hydraulic motor 15 to the other, so that the forward rotation driving and the reverse rotation driving of the hydraulic motor 15 are performed. Figs. 1 to 4 shows states in which the first supply-discharge passage 21 is connected to a hydraulic pump P, the second supply-discharge passage 22 is connected to a discharge tank T, and the hydraulic fluid is supplied from the first supply-discharge passage 21 to the hydraulic motor 15 and the hydraulic fluid is discharged from the hydraulic motor 15 to the second supply-discharge passage 22, so that the forward rotation driving of the hydraulic motor 15 is performed.

[0021] A main circuit (oil passage) connected to each of a first connection port 23 and a second connection port 24 is connected to a control changeover valve (not shown), and by means of the control changeover valve, it is possible to change the connections modes of the first and second supply-discharge passages 21, 22 with respect to the hydraulic pump P and the discharge tank T. Specifically, by using the control changeover valve operable by the user, the oil passage configuration on the upstream side of the anti-cavitation hydraulic circuit 10 can be changed to the forward rotation driving mode in which the hydraulic pump P is connected to the first supply-discharge passage 21 while the discharge tank T is connected to the second supply-discharge passage 22 or to the reverse rotation driving mode in which the hydraulic pump P is connected to the second supply-discharge passage 22 while the discharge tank T is connected to the first supply-discharge passage 21.

[0022] The counterbalance valve 40 is connected to the first supply-discharge passage 21 and the second

supply-discharge passage 22 and includes a first spool (counterbalance spool) 41, and the slide position in the axial direction Da of the first spool 41 is determined according to the pressure of the hydraulic fluid from the first supply-discharge passage 21 and the pressure of the hydraulic fluid from the second supply-discharge passage 22. A plurality of cutout sections (notches) 42 and a plurality of land sections 43 are formed in the first spool 41, and the connection states of the first and second supply-discharge passages 21, 22 with respect to the hydraulic motor 15 are changed depending on the slide position of the first spool 41. Both end portions of the first spool 41 receive elastic forces in the axial direction Da from first springs 47a, 47b accommodated in first spring chambers 46a, 46b. The first spring chambers 46a, 46b are connected to and communicated with the first supply-discharge passage 21 and the second supply-discharge passage 22 respectively, via fixed throttle sections 44 formed in the cutout sections 42 of the first spool 41 and through passages 45 formed inside the first spool 41. While the first springs 47a, 47b apply the elastic force to the first spool 41 so as to dispose the first spool 41 at the neutral position, the hydraulic fluid flowing into the first spring chambers 46a, 46b applies the hydraulic pressure to the first spool 41 so as to move the first spool 41 toward the stroke end positions. Accordingly, the slide position of the first spool 41 is determined according to the pressure of the hydraulic fluid flowing into the first spring chamber 46a from the first supply-discharge passage 21, the elastic force of the first spring 47a, the pressure of the hydraulic fluid flowing into the first spring chamber 46b from the second supply-discharge passage 22 and the elastic force of the first spring 47b.

[0023] The anti-cavitation valve 50 is connected to the first supply-discharge passage 21 via the counterbalance valve 40 and a first communication passage 61, and is connected to the second supply-discharge passage 22 via the counterbalance valve 40 and a second communication passage 62. The anti-cavitation valve 50 includes a second spool (anti-cavitation spool) 51, and the slide position of the second spool 51 is determined according to the pressure of the hydraulic fluid from the first supply-discharge passage 21 and the second supply-discharge passage 22. Each of the first communication passage 61 and the second communication passage 62 is constituted by holes formed in the first block body 11 and the second block body 12, and connects a spool hole in which the first spool 41 is slidably disposed, with a spool hole in which the second spool 51 is slidably disposed. Further, the first communication passage 61 and the second communication passage 62 are connected to and communicated with corresponding fixed throttle sections 54 respectively.

[0024] A plurality of cutout sections 52 and a plurality of land sections 53 are formed in the second spool 51. Depending on the slide position of the second spool 51, the anti-cavitation valve 50 is placed in a communication passage shut-off state in which the communication be-

tween the first communication passage 61 and the second communication passage 62 is blocked by a land section 53, or is placed in a communication passage communicating state in which the first communication passage 61 is communicated with the second communication passage 62 via a cutout section 52. Both end portions of the second spool 51 receive the elastic forces in the axial direction Da from the second springs 57a, 57b accommodated in the second spring chambers 56a, 56b. The second spring chambers 56a, 56b are connected to and communicated with the first communication passage 61 and the second communication passage 62 respectively, via the fixed throttle sections 54 formed in the second block body 12. The second springs 57a, 57b apply the elastic force to the second spool 51 so as to dispose the second spool 51 at the neutral position whereas the hydraulic fluid flowing into the second spring chambers 56a, 56b applies the hydraulic pressure to the second spool 51 so as to move the second spool 51 towards the stroke end positions. Therefore, the slide position of the second spool 51 is determined according to the pressure of the hydraulic fluid flowing into the second spring chamber 56a from the first supply-discharge passage 21 via the counterbalance valve 40, the first communication passage 61 and the fixed throttle section 54, the elastic force of the second spring 57a, the pressure of the hydraulic fluid flowing into the second spring chamber 56b from the second supply-discharge passage 22 via the counterbalance valve 40, the second communication passage 62 and the fixed throttle section 54, and the elastic force of the second spring 57b.

[0025] Regardless of the slide position of the first spool 41, the plurality of cutout sections 42 (in particular, the plurality of cutout sections 42 in which the fixed throttle sections 44 are formed) of the first spool 41 are positioned between the first supply-discharge passage 21 and the first communication passage 61, and between the second supply-discharge passage 22 and the second communication passage 62. Accordingly, regardless of the slide position of the first spool 41, the hydraulic fluid in the first supply-discharge passage 21 and the hydraulic fluid in the second supply-discharge passage 22 flow into the fixed throttle sections 44, the through passages 45 and the first spring chambers 46a, 46b and act on the first spool 41, and flow into the cutout sections 42, the first communication passage 61, the second communication passage 62, the fixed throttle sections 54 and the second spring chambers 56a, 56b, and act on the second spool 51.

[0026] The anti-cavitation hydraulic circuit 10 further comprises a first relay passage 31, a second relay passage 32, a first check valve 65 and a second check valve 66. The first relay passage 31 is provided between the first supply-discharge passage 21 and the hydraulic motor 15, and the second relay passage 32 is provided between the second supply-discharge passage 22 and the hydraulic motor 15. The first relay passage 31 is provided with a first communication port 35 which is connected to

and communicated with the hydraulic motor 15 via a first communication oil passage 37, and the second relay passage 32 is provided with a second communication port 36 which is connected to and communicated with the hydraulic motor 15 via a second communication oil passage 38. The first check valve 65 opens and closes a first check through passage 26 provided between the first supply-discharge passage 21 and the first relay passage 31 according to the differential pressure between the pressure of the hydraulic fluid in the first supply-discharge passage 21 and the pressure of the hydraulic fluid in the first relay passage 31, and allows the hydraulic fluid to flow from the first supply-discharge passage 21 towards the first relay passage 31 while does not allow the hydraulic fluid to flow from the first relay passage 31 towards the first supply-discharge passage 21. The second check valve 66 opens and closes a second check through passage 27 provided between the second supply-discharge passage 22 and the second relay passage 32 according to the differential pressure between the pressure of the hydraulic fluid in the second supply-discharge passage 22 and the pressure of the hydraulic fluid in the second relay passage 32, and allows the hydraulic fluid to flow from the second supply-discharge passage 22 towards the second relay passage 32 while does not allow the hydraulic fluid to flow from the second relay passage 32 towards the second supply-discharge passage 22.

[0027] When the second spool 51 is positioned at least at the neutral position and the stroke end positions, the anti-cavitation valve 50 having the above-described configuration is placed in the communication passage shut-off state in which the communication between the first supply-discharge passage 21 and the second supply-discharge passage 22 is blocked; and when the second spool 51 is disposed in at least a part between the neutral position and the stroke end positions, the anti-cavitation valve 50 is placed in the communication passage communicating state in which the first supply-discharge passage 21 is communicated with the second supply-discharge passage 22. Accordingly, while the second spool 51 moves from the neutral position to the stroke end position, and while the second spool 51 moves from the stroke end position to the neutral position, the communication passage communicating state in which the first supply-discharge passage 21 and the second supply-discharge passage 22 are communicated with each other is achieved.

[0028] It should be noted that the neutral position referred to here means, for example, the position where the spool is disposed in a state in which no force is applied from the hydraulic fluid to the spool, or in a state in which the force applied from the hydraulic fluid in the first supply-discharge passage 21 to the spool is equal to the force applied from the hydraulic fluid in the second supply-discharge passage 22 to the spool, and the neutral position is a position determined according to the elastic force of the springs disposed in the both end portions. In addition, the stroke end positions are the positions at the

extreme end positions in terms of the axial direction Da (the left and right end positions in Fig. 1) among the positions where the spool is slidable.

[0029] At the initial stage of the stop operation of the hydraulic motor 15, the hydraulic motor 15 continues the rotation operation under the influence of inertia, in such a manner that the hydraulic motor 15 exerts the vacuum action and sucks the hydraulic fluid from the first supply-discharge passage 21 while the supply of the hydraulic fluid from the hydraulic pump 15 to the first supply-discharge passage 21 is stopped or reduced. Therefore, an imbalance occurs between the amount of hydraulic fluid that the hydraulic motor 15 intends to draw in and the amount of hydraulic fluid that can be supplied from the first supply-discharge passage 21 to the hydraulic motor 15. Due to this imbalance, cavitation can occur during the stop operation of the hydraulic motor 15. In the anti-cavitation hydraulic circuit 10 of the present embodiment described above, in the initial stage of the stop operation of the hydraulic motor 15, the anti-cavitation valve 50 is placed in the above-described communication passage communicating state in at least a part of the time period when the second spool 51 moves from the stroke end position to the neutral position. As a result, the hydraulic fluid discharged once from the hydraulic motor 15 is guided to the first supply-discharge passage 21 and can be supplied again to the hydraulic motor 15, so that the aforementioned imbalance is suppressed and the cavitation can be effectively reduced.

[Operation]

[0030] Hereinafter, specific operations of the counterbalance valve 40 and the anti-cavitation valve 50 will be described.

[0031] When the supply of the hydraulic fluid to the first supply-discharge passage 21 and the second supply-discharge passage 22 is stopped, the first spool 41 and the second spool 51 are arranged at the neutral position as shown in Fig. 1. In this situation, the oil passage between the first supply-discharge passage 21 and the second supply-discharge passage 22 (that is, the spool hole of the counterbalance valve 40 and the spool hole of the anti-cavitation valve 50) is blocked by a land section 43 of the first spool 41 and a land section 53 of the second spool 51. Further, each of the oil passages between the first supply-discharge passage 21 and the first relay passage 31 and between the second supply-discharge passage 22 and the second relay passage 32 (that is, the spool hole of the counterbalance valve 40) is also blocked by a land section 43 of the first spool 41. Moreover, the first check valve 65 blocks the first check through passage 26, and the second check valve 66 blocks the second check through passage 27. Thus, the supply and discharge of the hydraulic fluid are not performed in the hydraulic motor 15, and the hydraulic motor 15 is placed in a stopped state.

[0032] On the other hand, when the control changeo-

ver valve (not shown) performs control in such a manner that the first supply-discharge passage 21 is communicated with the hydraulic pump P and the second supply-discharge passage 22 is communicated with the discharge tank T, the hydraulic fluid is supplied from the hydraulic pump P to the first supply-discharge passage 21 so as to increase the pressure of the hydraulic fluid in the first supply-discharge passage 21. As a result, as shown in Figs. 2 and 3, the first check valve 65 opens the first check through passage 26, so that the hydraulic fluid is supplied from the first supply-discharge passage 21 to the hydraulic motor 15 via the first relay passage 31, the first communication port 35 and first communication oil passage 37. Further, the pressure of the hydraulic fluid flowing into the first spring chamber 46a from the first supply-discharge passage 21 via the fixed throttle section 44 and the through passage 45 increases, and the pressure of the hydraulic fluid flowing into the second spring chamber 56a from the first supply-discharge passage 21 via the cutout section 42, the first communication passage 61 and the fixed throttle section 54 increases. As a result, the first spool 41 and the second spool 51 move toward one stroke end position (toward the stroke end position on the right side in Fig. 2). In this situation, as shown in Figs. 2 and 3, the second relay passage 32 is communicated with the second supply-discharge passage 22 via a cutout section 42 of the first spool 41, and the hydraulic fluid is discharged from the hydraulic motor 15 to the second supply-discharge passage 22 via the second communication oil passage 38, the second communication port 36, the second relay passage 32 and the cutout section 42. In this way, the hydraulic motor 15 is driven to rotate forward.

[0033] In the state shown in Figs. 2 and 3, the second spool 51 is disposed at the right stroke end position, and the oil passage between the first communication passage 61 and the second communication passage 62 (that is, a spool hole of the anti-cavitation valve 50) is blocked by a land section 53 of the second spool 51. In this state, hydraulic fluid does not directly flow from the first supply-discharge passage 21 to the second supply-discharge passage 22 via the first communication passage 61 and the second communication passage 62 without passing through the hydraulic motor 15, and therefore the hydraulic motor 15 can be driven with energy efficiency.

[0034] However, in the middle of the movement of the second spool 51 from the neutral position to the stroke end position, there is a state in which the first communication passage 61 and the second communication passage 62 is communicated with each other via a cutout section 52 of the second spool 51 and the hydraulic fluid directly flows from the first supply-discharge passage 21 to the second supply-discharge passage 22 without passing through the hydraulic motor 15. From the viewpoint of reducing the time when this state is maintained as much as possible, it is preferable to set the spring constant (elastic modulus) of the second springs 57a, 57b of the anti-cavitation valve 50 to be sufficiently small

so as to keep the elastic force applied from the second spool 57a, 57b to the second spool 51 low. In this case, it is possible to cause the second spool 51 to reach the stroke end position from the neutral position in a very short time in accordance with the rise in the pressure of the hydraulic fluid in the first supply-discharge passage 21, and it is also possible to reduce the energy loss due to the direct outflow of the hydraulic fluid from the supply-discharge passage 21 to the second supply-discharge passage 22 to a substantially negligible level. In addition, when the spring constants of the second springs 57a, 57b are very small, the force with which the second springs 57a, 57b return the second spool 51 to the neutral position weakens. Thanks to the combination of the low restoring force (low elastic force) of the second springs 57a, 57b and the throttling effect of the fixed throttle sections 54, the second spool 51 can be slowly returned from the stroke end position toward the neutral position and it is possible to obtain the cavitation reduction effect over a long period of time.

[0035] In the present embodiment, the elastic modulus (for example, the spring constant) of the second springs 57a, 57b (second elastic body) of the anti-cavitation valve 50 is set to be smaller than the elastic modulus of the first springs 47a, 47b (first elastic body) of the counterbalance valve 40. In this case, as shown in Fig. 2, before the first spool 41 reaches the stroke end position, the second spool 51 reaches the stroke end position ahead, and after a certain time has elapsed since that time, as shown in Fig. 3, the first spool 41 also reaches the stroke end position.

[0036] On the other hand, when the stop operation of the hydraulic motor 15 is performed by the control changeover valve (not shown), the first spool 41 and the second spool 51 gradually move from the stroke end position toward the neutral position (toward the left side in Fig. 4), and eventually are disposed at the neutral position shown in Fig. 1, so that the supply and discharge of the hydraulic fluid in the hydraulic motor 15 are halted. Specifically, when the stop operation of the hydraulic motor 15 is carried out, the supply of the hydraulic fluid from the hydraulic pump P to the first supply-discharge passage 21 is stopped, whereas the pressure of the hydraulic fluid in the first supply-discharge passage 21 drops gradually over time. Thus, the first spool 41 and the second spool 51 gradually move from the stroke end position toward the neutral position in accordance with the decrease in the pressure of the hydraulic fluid in the first supply-discharge passage 21 and the decrease in the elastic force from the first springs 47a, 47b and the second springs 57a, 57b. In this way, while the second spool 51 returns from the stroke end position to the neutral position, the first communication passage 61 and the second communication passage 62 are communicated with each other via a cutout section 52 of the second spool 51, and the hydraulic fluid is sent from the second communication passage 62 to the first communication passage 61, so that the cavitation is reduced.

[0037] Specifically, for a while even after the stop operation of the hydraulic motor 15, the hydraulic motor 15 continues to rotate by inertia while being decelerated, and tries to continue sucking hydraulic fluid from the first supply-discharge passage 21. On the other hand, the hydraulic fluid discharged from the hydraulic motor 15 flows into the second supply-discharge passage 22 and the second communication passage 62 from the second relay passage 32 via a cutout section 42 of the first spool 41 while the communication passage area of the cutout section 42 gradually decreases. The hydraulic fluid that has flowed into the second communication passage 62 flows into the first communication passage 61 via a cutout section 52 of the second spool 51 of the anti-cavitation valve 50, and after that, flows into the first supply-discharge passage 21 via a cutout section 42 of the counterbalance valve 40. This can suppress the imbalance between the amount of hydraulic fluid that the hydraulic motor 15 intends to draw from the first supply-discharge passage 21 and the amount of hydraulic fluid that can be supplied from the first supply-discharge passage 21 to the hydraulic motor 15, and can reduce the cavitation.

[0038] Although the above explanation is mainly directed to the forward rotation driving mode, those skilled in the art can understand that operation and effect similar to the above can be provided even in the case of the reverse rotation driving mode. Specifically, when the hydraulic fluid from the hydraulic pump P is supplied to the second supply-discharge passage 22 and the hydraulic fluid from the first supply-discharge passage 21 is discharged to the discharge tank T, the flow of the hydraulic fluid, the rotation direction of the hydraulic motor 15, the action direction of the counterbalance valve 40 and the anti-cavitation valve 50, and the behavior of the first check through passage 26 and the second check through passage 27 are opposite to those in the forward rotation driving mode described above, but similar behavior to that in the forward rotation driving mode is basically performed.

[Circuit diagram]

[0039] Fig. 5 is a circuit diagram illustrating an example of a hydraulic circuit 90 according to one embodiment of the present invention. Fig. 5 shows a state in which the behavior aspect of the anti-cavitation hydraulic circuit 10 shown in Figs. 1 to 4 is mainly reflected, and the anti-cavitation hydraulic circuit 10 shown in Fig. 5 and the anti-cavitation hydraulic circuit 10 shown in Figs. 1 to 4 are not necessarily consistent with each other in structural terms.

[0040] Fig. 5 shows a state in which the first spool 41 of the counterbalance valve 40 and the second spool 51 of the anti-cavitation valve 50 are disposed in the neutral position (see Fig. 1), the block indicated by the reference character of "40b" is selected in the counterbalance valve 40, and the block indicated by the reference character of "50c" is selected in the anti-cavitation valve 50.

[0041] On the other hand, when the first spool 41 is disposed at a slide position other than the neutral position, the block indicated by the reference character of "40a" is selected in the forward rotation driving mode, and the block indicated by the reference character of "40c" is selected in the reverse rotation driving mode. Further, in the anti-cavitation valve 50, a block indicated by the reference character of "50a" is selected when the second spool 51 is disposed at the stroke end position in the forward rotation drive mode; a block indicated by the reference character of "50b" is selected when the second spool 51 is disposed between the stroke end position and the neutral position (in particular, during the above-described communication passage communicating state) in the forward rotation drive mode; a block indicated by the reference character of "50e" is selected when the second spool 51 is disposed at the stroke end position in the reverse rotation drive mode; a block indicated by the reference character of "50d" is selected when the second spool 51 is disposed between the stroke end position and the neutral position (in particular, during the above-described communication passage communicating state) in the reverse rotation drive mode.

[0042] The hydraulic circuit 90 shown in Fig. 5 further includes a high-pressure selection valve 91, a brake device 92, a switching valve 93, and a switching cylinder 94, in addition to the anti-cavitation hydraulic circuit 10. The high-pressure selection valve 91 selects the high-pressure side oil passage of the first supply-discharge passage 21 and the second supply-discharge passage 22, and flows the hydraulic fluid toward the switching valve 93. The switching valve 93 switches the oil passage in accordance with the pilot pressure oil from the pilot pressure source P and performs switching between the state in which the hydraulic fluid is supplied from the high-pressure selection valve 91 to the switching cylinder 94 and the state in which the hydraulic fluid is not supplied from the high-pressure selection valve 91 to the switching cylinder 94. The switching cylinder 94 switches the hydraulic motor 15 to the high speed mode or the low speed mode according to whether or not the hydraulic fluid is supplied from the switching valve 93. Further, the brake device 92 working when the hydraulic motor 15 is stopped is connected to the hydraulic motor 15. The hydraulic motor 15 is connected to the drains D1, D2.

[0043] As described above, according to the present embodiment, cavitation can be effectively reduced by the anti-cavitation valve 50 having a simple configuration. Further, while the first supply-discharge passage 21, the second supply-discharge passage 22 and the counter-balance valve 40 are formed in the first block body 11, the anti-cavitation valve 50 is formed in the second block body 12. Thus, it is possible to add a cavitation reduction function to the hydraulic circuit included in the first block body 11 by simply applying relatively simple processing, such as forming the first communication passage 61 and the second communication passage 62, to the first block body 11 and attaching the second block body 12 to the

first block body 11. Therefore, it is possible for the user to easily select, in the manufacturing process of the hydraulic circuit, whether or not to add a cavitation reduction function to the hydraulic circuit included in the first block body 11.

[First Modification Example]

[0044] Fig. 6 is a circuit diagram illustrating an example of a hydraulic circuit 90 including an anti-cavitation hydraulic circuit 10 according to a modified example of the present invention. The hydraulic circuit 90 of the present modification example has basically the same circuit configuration as the hydraulic circuit 90 shown in Fig. 5 described above, but includes the first slow return check valve 71 and the second slow return check valve 72, instead of the fixed throttle sections 54. The first slow return check valve 71 brings about resistance applied to the hydraulic fluid in such a manner that the resistance applied to the hydraulic fluid flowing from the second spool 51 toward the first supply-discharge passage 21 is higher than the resistance applied to the hydraulic fluid flowing from the first supply-discharge passage 21 toward the second spool 51. On the other hand, the second slow return check valve 72 brings about resistance applied to the hydraulic fluid in such a manner that the resistance applied to the hydraulic fluid flowing from the second spool 51 toward the second supply-discharge passage 22 is higher than the resistance applied to the hydraulic fluid flowing from the second supply-discharge passage 22 toward the second spool 51.

[0045] According to the present modification example, when the second spool 51 is moved from the neutral position to the stroke end position, the resistance applied to the hydraulic fluid by the first slow return check valve 71 and the second slow return check valve 72 is relatively low, and thus the second spool 51 moves quickly. On the other hand, when the second spool 51 is moved from the stroke end position to the neutral position, the resistance applied to the hydraulic fluid by the first slow return check valve 71 and the second slow return check valve 72 is relatively high, and thus the second spool 51 moves slowly. According to the anti-cavitation hydraulic circuit 10 having this configuration, it is possible to keep the effect of reducing the cavitation over a long period of time while it is possible to reduce the energy loss caused by the direct communication between the first supply-discharge passage 21 and the second supply-discharge passage 22 in the communication passage communicating state.

[0046] The specific configurations of the first slow return check valve 71 and the second slow return check valve 72 are not particularly limited, and it is also possible to use a known slow return check valve for them. Also, the installation positions of the first slow return check valve 71 and the second slow return check valve 72 are not particularly limited, and it is possible to install the first slow return check valve 71 at a proper position of the oil passage extending from the first supply-discharge pas-

sage 21 to the second spool 51 (for example, the second spring chamber 56a) and to install the second slow return check valve 72 at a proper position of the oil passage extending from the second supply-discharge passage 22 to the second spool 51 (for example, the second spring chamber 56b).

[Other Modification Examples]

[0047] For example, the properties of the cutout sections 42 and the land sections 43 of the first spool 41, such as the positions, the widths and shapes, may be appropriately changed, and the properties of the cutout sections 52 and the land sections 53 of the second spool 51, such as the positions, the widths and shapes, may be appropriately changed. In particular, by changing the position, width, shape, etc. of the cutout sections 52 and the land sections 53 of the second spool 51, it is also possible to adjust the state of communication between the first communication passage 61 and the second communication passage 62 (that is, the state of communication between the first supply-discharge passage 21 and the second supply-discharge passage 22). Further, it is possible to adjust the elastic characteristics of the first springs 47a, 47b of the counterbalance valve 40 and the elastic characteristics of the second springs 57a, 57b of the anti-cavitation valve 50.

[0048] Fig. 7 is a conceptual diagram showing the relation between the state of the anti-cavitation valve 50 and the difference $\Delta P (= P_1 - P_2)$ between the pressure P_1 of the hydraulic fluid in the first supply-discharge passage 21 and the pressure P_2 of the hydraulic fluid in the second supply-discharge passage 22. In Fig. 7, the horizontal axis represents ΔP , the right side of the position denoted by "0" (i.e., the neutral position) indicates that ΔP is a positive value (+), and the left side of the position denoted by "0" indicates that ΔP is a negative value (-). As shown in Fig. 7, when ΔP is positive and more than a first differential pressure value d_1 , the anti-cavitation valve 50 is placed in the communication passage shut-off state. Further, when ΔP is positive and is equal to or smaller than the first differential pressure value d_1 and more than a second differential pressure value d_2 , the anti-cavitation valve 50 is placed in the communication passage communicating state. Further, when ΔP is negative and smaller than the fourth differential pressure value d_4 , the anti-cavitation valve 50 is placed in the communication passage shut-off state. Further, when ΔP is negative and is equal to or more than the fourth differential pressure value d_4 and smaller than the third differential pressure value d_3 , the anti-cavitation valve 50 is placed in the communication passage communicating state. Moreover, when ΔP is equal to or less than the second differential pressure value d_2 and is equal to or more than the third differential pressure value d_3 , the anti-cavitation valve 50 is placed in the communication passage shut-off state.

[0049] Specific numerical values of the first to fourth

differential pressure values d_1 to d_4 shown in Fig. 7 may be appropriately set by adjusting the shape of the second spool 51 and the spring constants of the second springs 57a, 57b. For example, it is possible to set the absolute value of the second differential pressure value d_2 to be the same as or be different from the absolute value of the third differential pressure value d_3 , and in particular, the second differential pressure value d_2 and the third differential pressure value d_3 may be set to "0" (zero) or a value close to "0". Further, it is also possible to set the absolute value of the first differential pressure value d_1 to be the same as or be different from the absolute value of the fourth differential pressure value d_4 .

[0050] The embodiments of the present invention may include embodiments having components other than the above-described components. Further, embodiments in which a part of the above-described components is not included may also be included in the embodiments of the present invention. In addition, embodiments including a part of the components included in a certain embodiment of the present invention and a part of the components included in another embodiment of the present invention may also be included in the embodiments of the present invention. Therefore, components included in the above-described embodiments and modification examples and other embodiments of the present invention which are not described above may be combined with one another, and embodiments based on such combination may be included in the embodiments of the present invention. Further, the effects brought about by the present invention are not limited to the above-described effects, and specific effects based on the specific configuration of each embodiment can be exerted. As described above, various additions, modifications and partial deletions can be made to each element described in the claims, description, abstract and drawings without departing from the technical idea and gist of the present invention.

Claims

1. An anti-cavitation hydraulic circuit (10) comprising:

a first supply-discharge passage (21) and a second supply-discharge passage (22) connected to a hydraulic actuator (15), a hydraulic fluid being supplied to the hydraulic actuator (15) from one of the first and second supply-discharge passages (21, 22) and the hydraulic fluid being discharged from the hydraulic actuator (15) to the other of the first and second supply-discharge passages (21, 22); and
an anti-cavitation valve (50) including an anti-cavitation spool (51) which is connected to the first supply-discharge passage (21) via a first communication passage (61) and is connected to the second supply-discharge passage (22) via a second communication passage (62), a

- slide position of the anti-cavitation spool (51) being determined according to a pressure of the hydraulic fluid from the first supply-discharge passage (21) and a pressure of the hydraulic fluid from the second supply-discharge passage (22), wherein
when the anti-cavitation spool (51) is positioned in at least a part between a neutral position and a stroke end position, the anti-cavitation valve (50) is placed in a communication passage communicating state in which the first communication passage (61) and the second communication (62) are communicated with each other.
2. The anti-cavitation hydraulic circuit (10) according to claim 1, further comprising:
- a first block body (11) which has the first supply-discharge passage (21) and the second supply-discharge passage (22); and
a second block body (12) which is attached to the first block body (11) and has the anti-cavitation valve (50).
3. The anti-cavitation hydraulic circuit (10) according to claim 1 or 2, further comprising:
- a first relay passage (31) provided between the first supply-discharge passage (21) and the hydraulic actuator (15);
a second relay passage (32) provided between the second supply-discharge passage (22) and the hydraulic actuator (15);
a first check valve (65) which operates in accordance with a differential pressure between a pressure of the hydraulic fluid in the first supply-discharge passage (21) and a pressure of the hydraulic fluid in the first relay passage (31), and allows the hydraulic fluid flowing from the first supply-discharge passage (21) toward the first relay passage (31) to pass through the first check valve (65) but does not allow the hydraulic fluid flowing from the first relay passage (31) toward the first supply-discharge passage (21) to pass through the first check valve (65); and
a second check valve (66) which operates in accordance with a differential pressure between a pressure of the hydraulic fluid in the second supply-discharge passage (22) and a pressure of the hydraulic fluid in the second relay passage (32), and allows the hydraulic fluid flowing from the second supply-discharge passage (22) toward the second relay passage (32) to pass through the second check valve (66) but does not allow the hydraulic fluid flowing from the second relay passage (32) toward the second supply-discharge passage (22) to pass through the second check valve (66).
4. The anti-cavitation hydraulic circuit (10) according to any one of claims 1 to 3, further comprising a counterbalance valve (40) including a counterbalance spool (41) which is connected to the first supply-discharge passage (21) and the second supply-discharge passage (22), a slide position of the counterbalance spool (41) being determined according to the pressure of the hydraulic fluid from the first supply-discharge passage (21) and the pressure of the hydraulic fluid from the second supply-discharge passage (22), a connection state of the first supply-discharge passage (21) with respect to the hydraulic actuator (15) and a connection state of the second supply-discharge passage (22) with respect to the hydraulic actuator (15) being changed according to the slide position of the counterbalance spool (41).
5. The anti-cavitation hydraulic circuit (10) according to claim 4, wherein:
- the counterbalance valve (40) further includes a first elastic body (47a, 47b) applying elastic force to the counterbalance spool (41) so as to dispose the counterbalance spool (41) at a neutral position,
the anti-cavitation valve (50) further includes a second elastic body (57a, 57b) applying elastic force to the anti-cavitation spool (51) so as to dispose the anti-cavitation spool (51) at the neutral position, and
an elastic modulus of the second elastic body (57a, 57b) is smaller than an elastic modulus of the first elastic body (47a, 47b).
6. The anti-cavitation hydraulic circuit (10) according to any one of claims 1 to 5, further comprising:
- a first slow return check valve (71) which brings about resistance applied to the hydraulic fluid in such a manner that the resistance applied to the hydraulic fluid flowing from the anti-cavitation spool (51) toward the first supply-discharge passage (21) is higher than the resistance applied to the hydraulic fluid flowing from the first supply-discharge passage (21) toward the anti-cavitation spool (51); and
a second slow return check valve (72) which brings about resistance applied to the hydraulic fluid in such a manner that the resistance applied to the hydraulic fluid flowing from the anti-cavitation spool (51) toward the second supply-discharge passage (22) is higher than the resistance applied to the hydraulic fluid flowing from the second supply-discharge passage (22) toward the anti-cavitation spool (51).

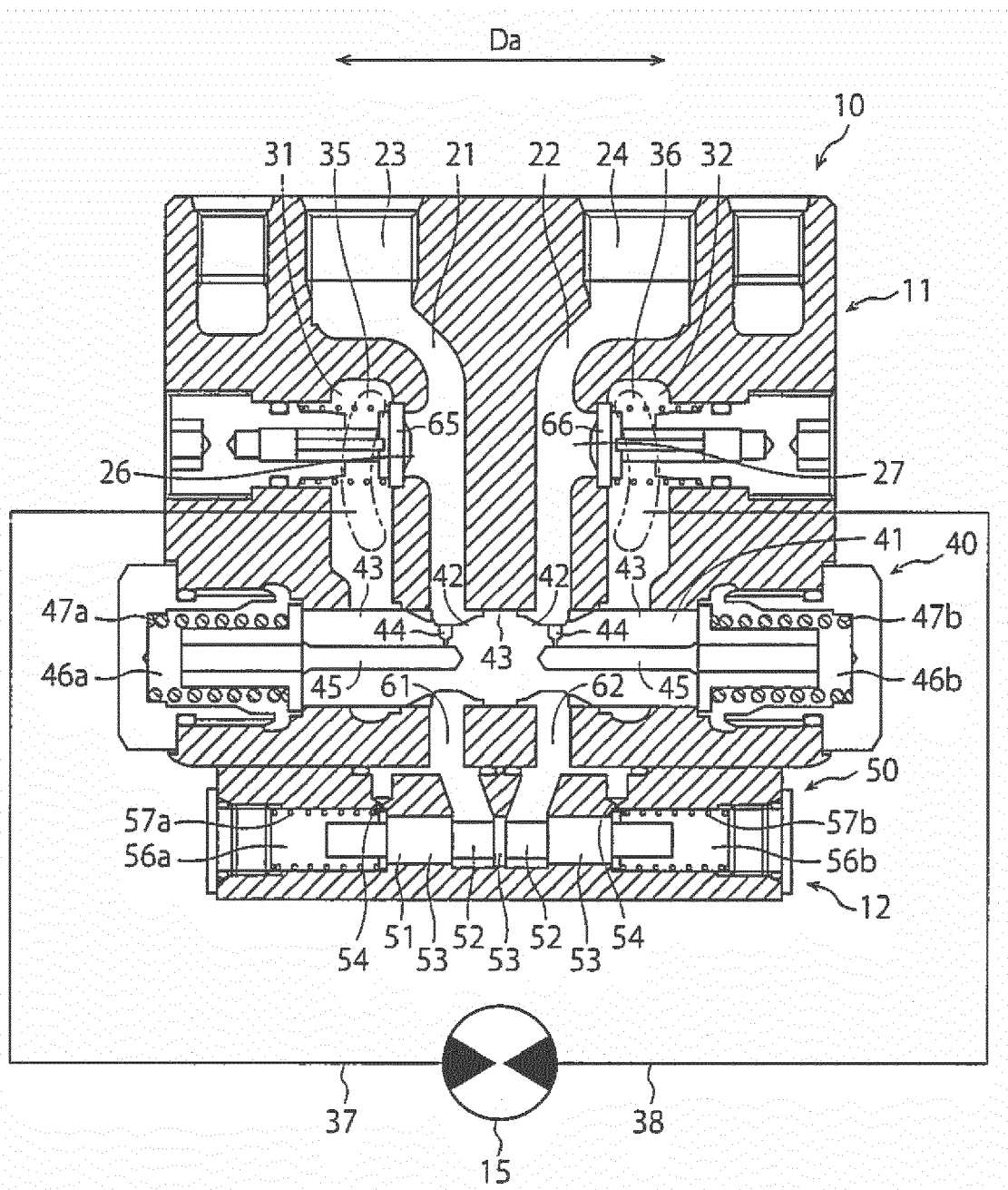


FIG. 1

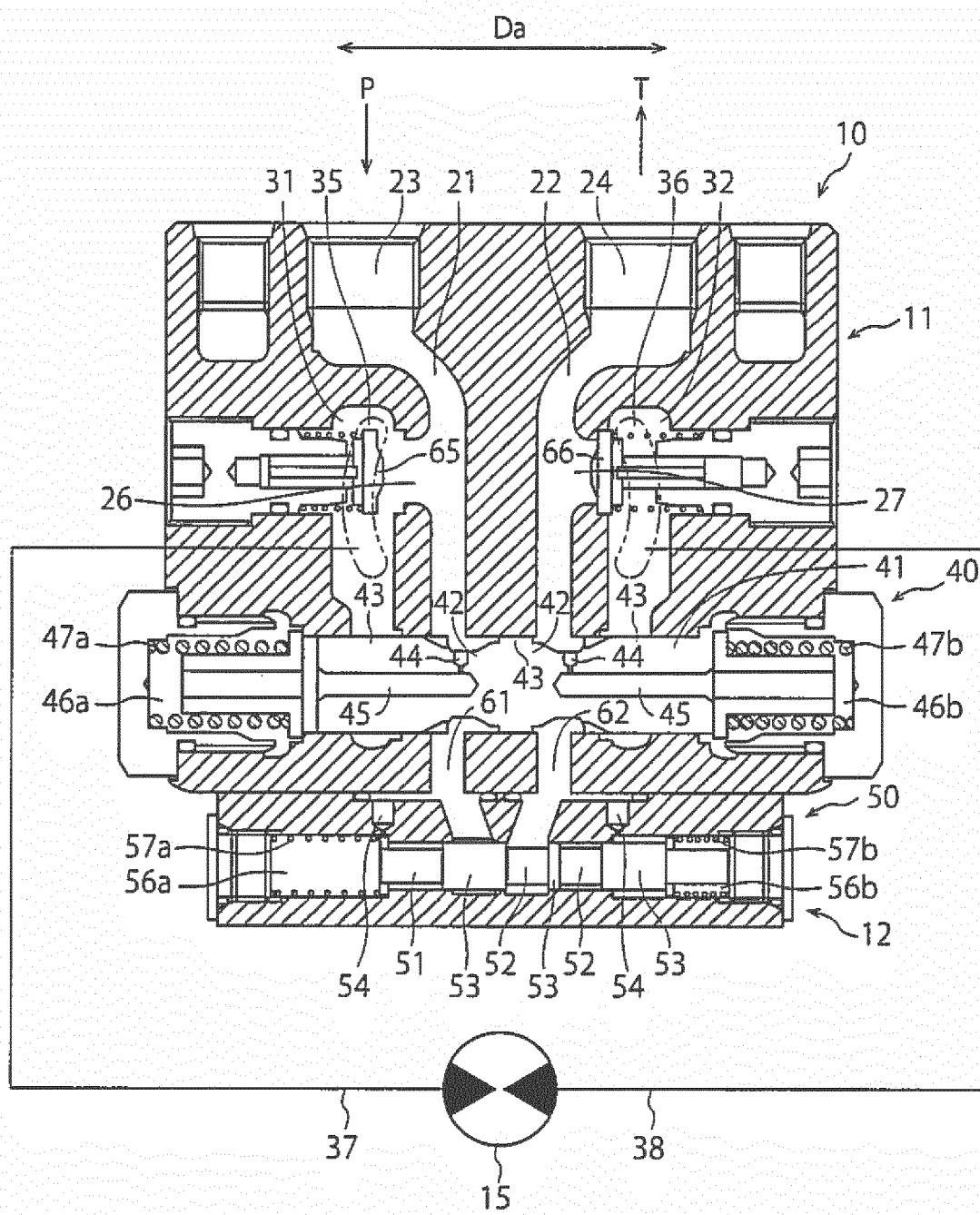


FIG. 2

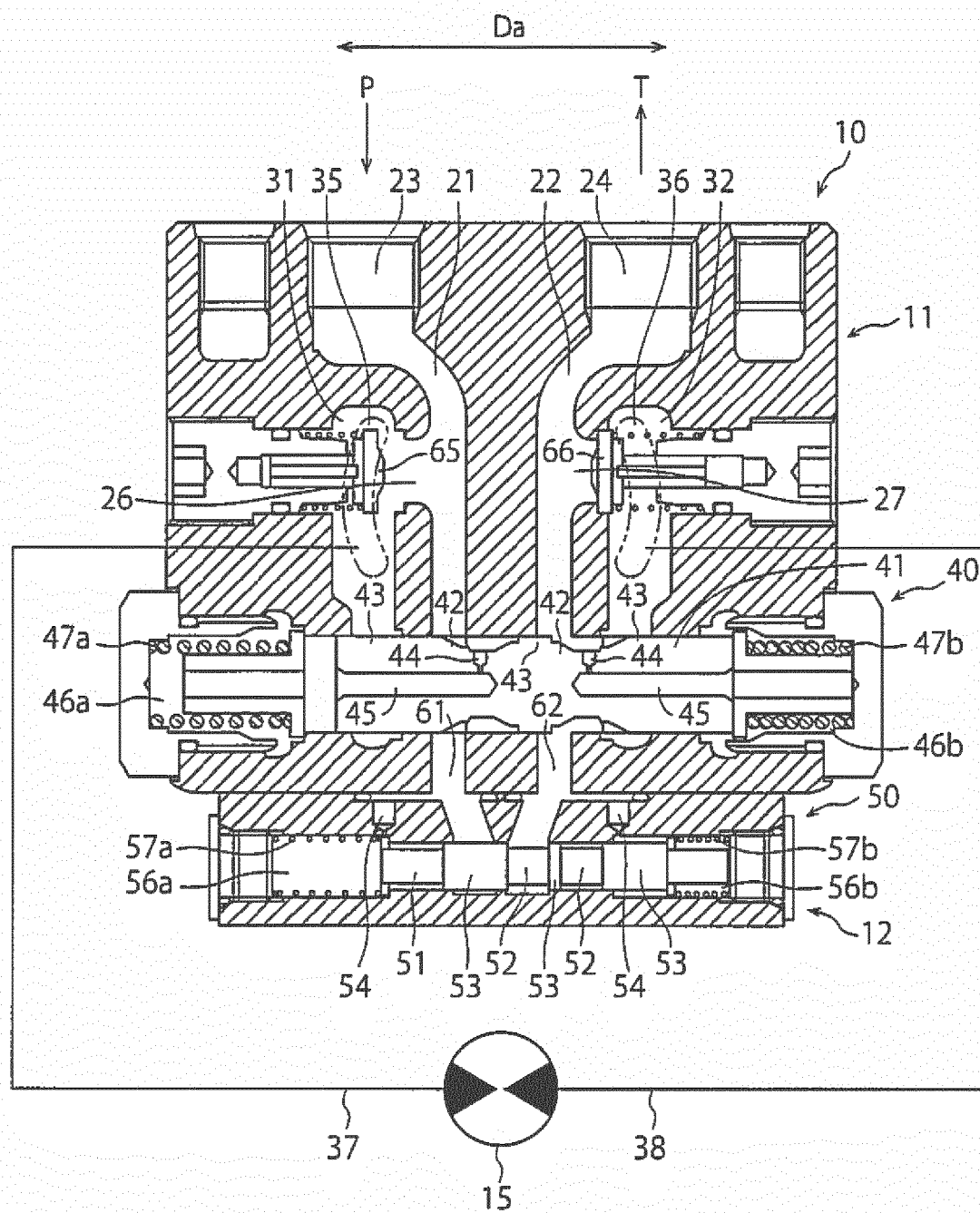


FIG. 3

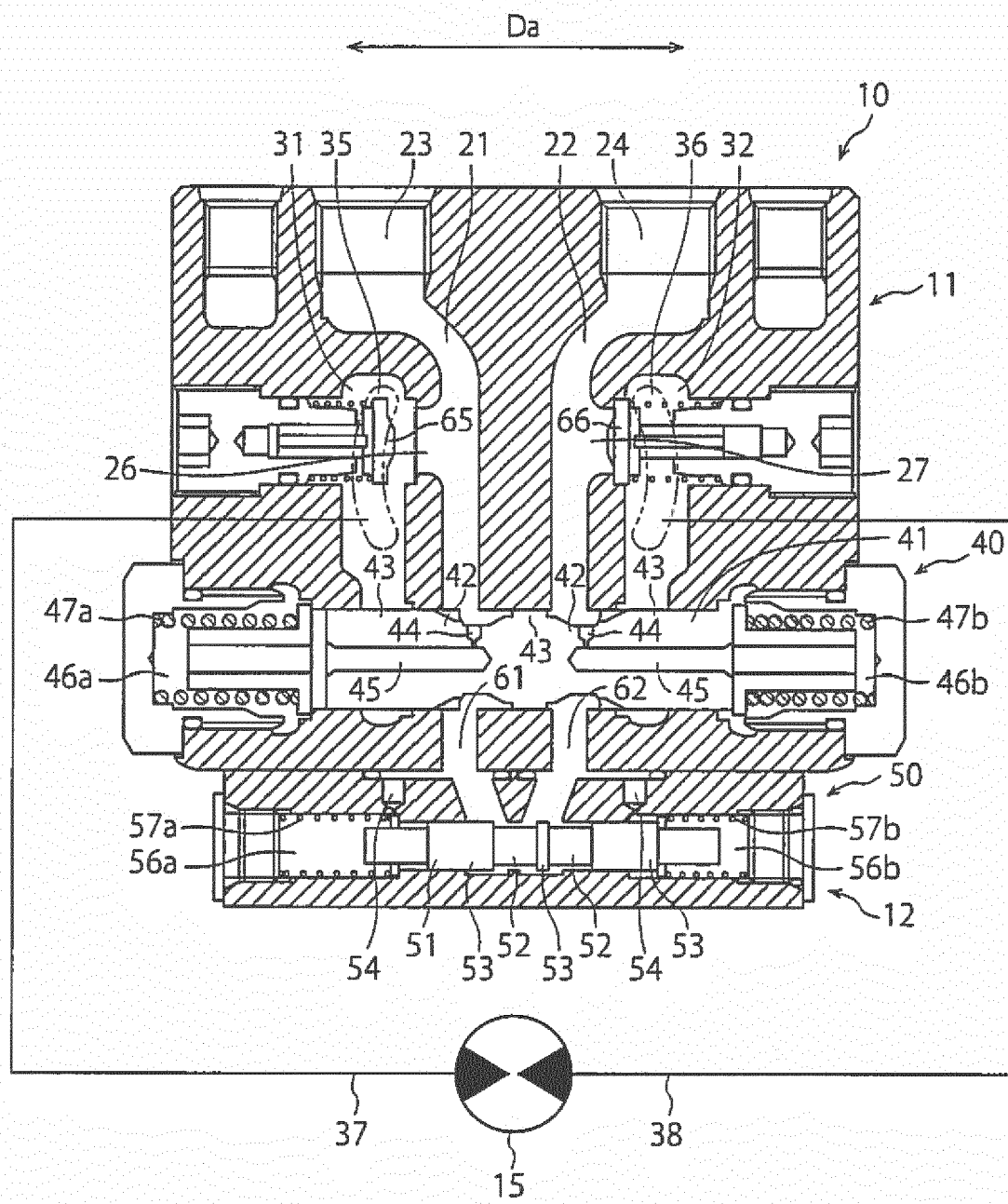


FIG. 4

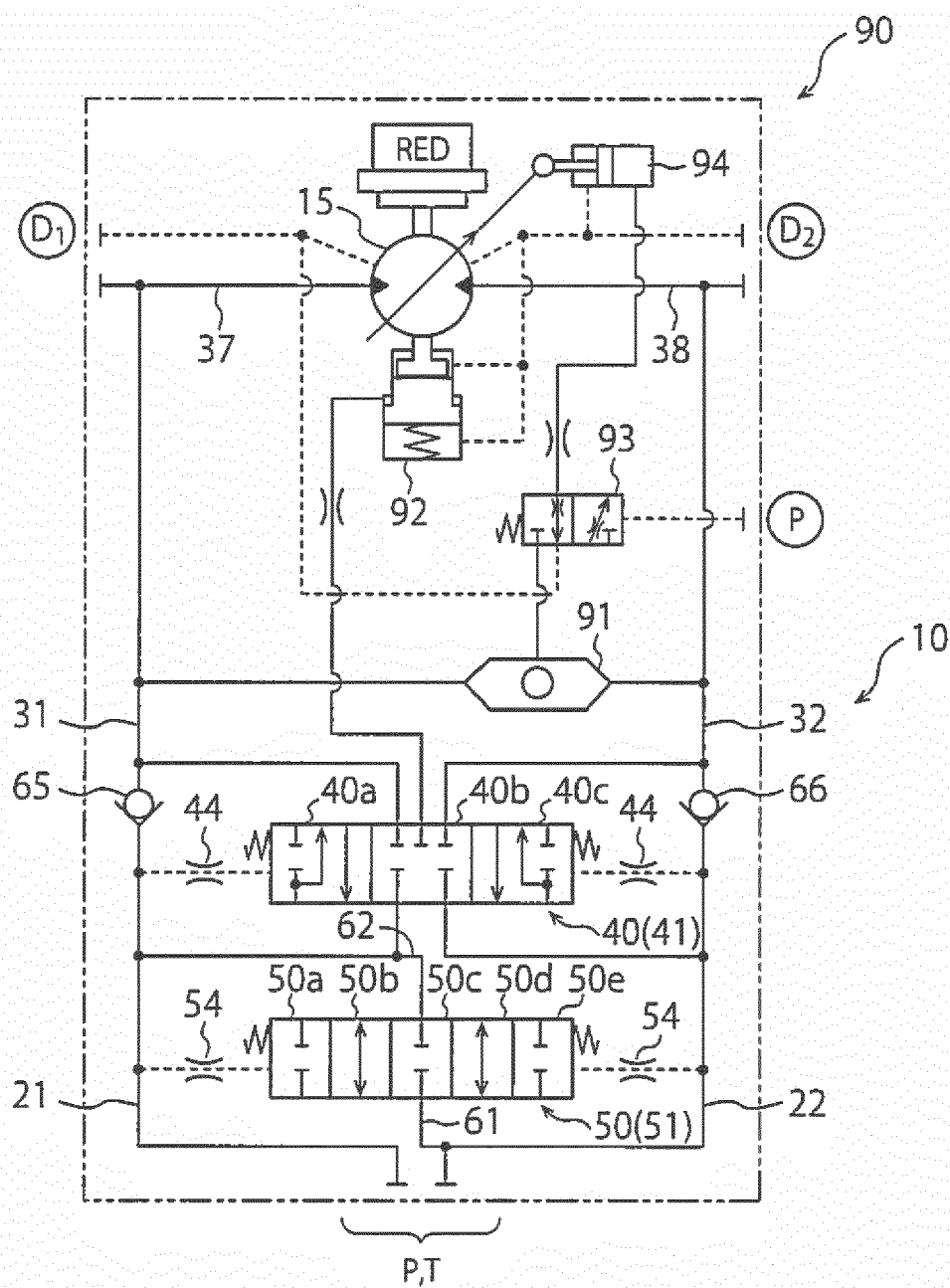


FIG. 5

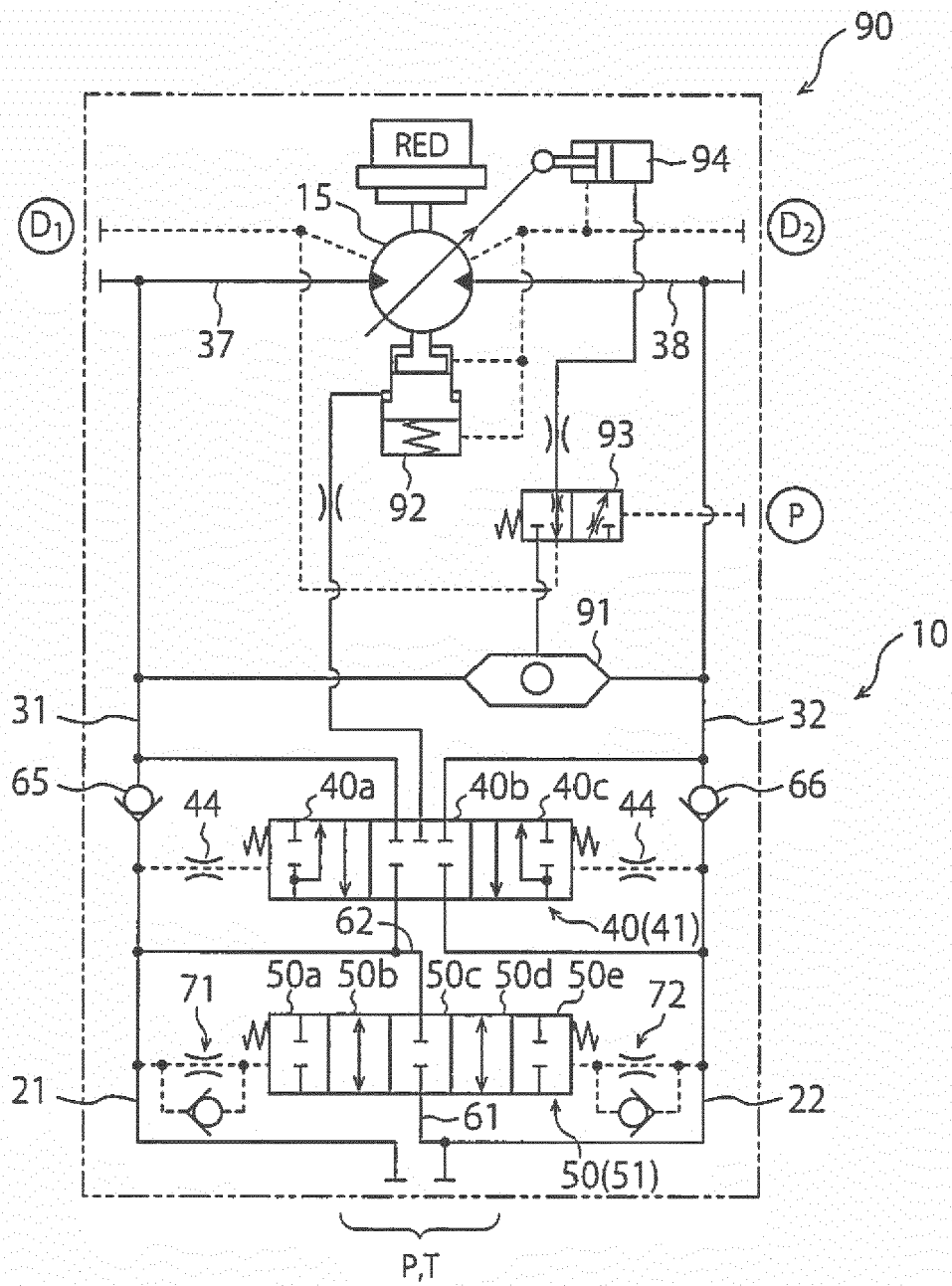
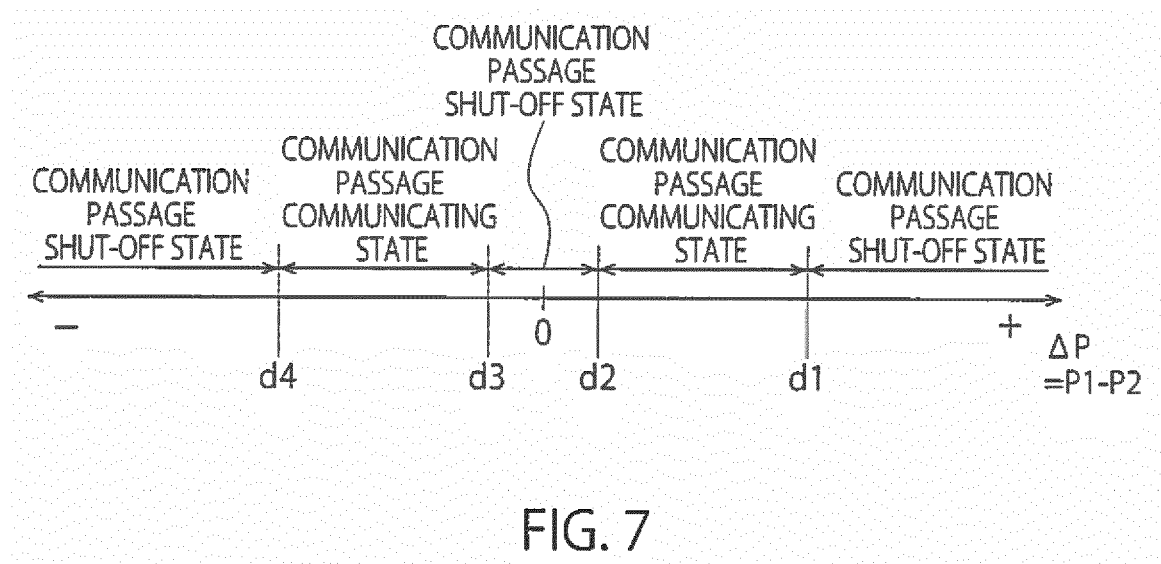


FIG. 6





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