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(54) **STEERING SYSTEM**

(57) A steering system (1) installed in a ship includes: a hydraulic actuator (2) that turns a rudder plate (11) via a rudder stock (12) that penetrates a ship bottom; and a pump (41) that delivers hydraulic oil. A first actuating chamber (22) and a second actuating chamber (23) of the hydraulic actuator are connected to a switching valve (3) by a pair of supply/discharge lines (44, 45). The switching valve (3) is connected to the pump (41) by a pump line (42). The switching valve (3) includes a spool (31). The spool (31) is shifted by a shifting mechanism (5). The shifting mechanism (5) is configured such that a shifting speed of the spool (31) is electrically changeable.

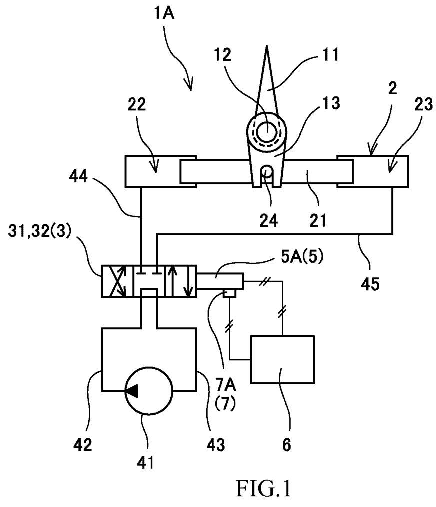

FIG.1

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Description

Technical Field

[0001] The present invention relates to a steering system installed in a ship.

Background Art

[0002] Conventionally, a steering system for hydraulically operating a rudder plate is installed in a ship. The steering system includes a hydraulic actuator that turns the rudder plate via a rudder stock that penetrates the ship's plank. The hydraulic actuator includes a first actuating chamber and a second actuating chamber. When hydraulic oil is supplied to one of the first and second actuating chambers, the hydraulic actuator turns the rudder plate in the port direction. When the hydraulic oil is supplied to the other one of the first and second actuating chambers, the hydraulic actuator turns the rudder plate in the starboard direction.

[0003] For example, Patent Literature 1 discloses a steering system that adopts, as a hydraulic actuator, a hydraulic cylinder in which a first actuating chamber and a second actuating chamber are formed on both sides of a ram, respectively. In the steering system, the first actuating chamber and the second actuating chamber of the hydraulic cylinder are connected to a switching valve by a pair of supply/discharge lines. The switching valve is connected to a pump by a pump line, and to a tank by a tank line. When the switching valve is in the neutral position, the switching valve blocks the pair of supply/discharge lines. At the time of turning the rudder plate, the switching valve brings one of the pair of supply/discharge lines into communication with the pump line, and brings the other one of the pair of supply/discharge lines into communication with the tank line.

[0004] To be more specific, the switching valve includes a spool, and the spool is driven by a pair of solenoid valves. The switching valve includes a pair of pilot chambers formed therein for applying pilot pressures to both end faces of the spool. Each of the solenoid valves switches whether or not to lead a pilot pressure to a corresponding one of the pilot chambers.

Citation List

Patent Literature

[0005] PTL 1: Japanese Laid-Open Patent Application Publication No. H09-76997

Summary of Invention

Technical Problem

[0006] However, in the steering system disclosed by Patent Literature 1, since each solenoid valve is a simple on-off valve, when the magnet coil of the solenoid valve is excited, the spool shifts instantaneously. Therefore, flexible operation of the steering system is difficult.

[0007] In view of the above, an object of the present invention is to provide a steering system capable of flexible operation.

Solution to Problem

[0008] In order to solve the above-described problems, a steering system according to the present invention is a steering system installed in a ship, and includes: a hydraulic actuator that turns a rudder plate via a rudder stock that penetrates a ship bottom, the hydraulic actuator including a first actuating chamber and a second actuating chamber; a pump that delivers hydraulic oil; a switching valve including a spool, the switching valve being connected to the first actuating chamber and the second actuating chamber by a pair of supply/discharge lines and to the pump by a pump line; and a shifting mechanism that shifts the spool, the shifting mechanism being configured such that a shifting speed of the spool is electrically changeable.

[0009] According to the above configuration, the shifting mechanism, which shifts the spool, is configured such that the shifting speed of the spool is electrically changeable. This makes flexible operation of the steering system possible.

Advantageous Effects of Invention

[0010] The present invention makes it possible to provide a steering system capable of flexible operation.

Brief Description of Drawings

[0011]

FIG. 1 shows a schematic configuration of a steering system according to Embodiment 1 of the present invention.

FIG. 2 is a sectional view of a linear motion mechanism.

FIG. 3A shows one example of steering commands, and FIG. 3B shows spool positions corresponding to the respective steering commands.

FIG. 4 is a sectional view of a part of a ship in which the steering system shown in FIG. 1 is installed.

FIG. 5 shows a schematic configuration of a steering system according to Embodiment 2 of the present invention.

FIG. 6 shows a schematic configuration of a steering system according to Embodiment 3 of the present invention.

FIG. 7 shows a schematic configuration of a steering system according to another embodiment.

Description of Embodiments

(Embodiment 1)

[0012] FIG. 1 shows a steering system 1A according to Embodiment 1 of the present invention. As shown in FIG. 4, the steering system 1A is installed in a ship.

[0013] Specifically, the steering system 1A includes a hydraulic actuator 2. The hydraulic actuator 2 turns a rudder plate 11 via a rudder stock 12, which penetrates a ship bottom 10 in the vertical direction. In the present embodiment, the hydraulic actuator 2 turns the rudder plate 11 not only via the rudder stock 12, but also via a tiller 13 disposed inside the ship.

[0014] As shown in FIG. 1, the hydraulic actuator 2 includes a first actuating chamber 22 and a second actuating chamber 23. When hydraulic oil is supplied to one of the first and second actuating chambers 22 and 23 (in the present embodiment, the second actuating chamber 23), the hydraulic actuator 2 turns the rudder plate 11 in the port direction (toward the right side in FIG. 1). When the hydraulic oil is supplied to the other one of the first and second actuating chambers 22 and 23 (in the present embodiment, the first actuating chamber 22), the hydraulic actuator 2 turns the rudder plate 11 in the starboard direction (toward the left side in FIG. 1).

[0015] In the present embodiment, the hydraulic actuator 2 is a hydraulic cylinder in which the first actuating chamber 22 and the second actuating chamber 23 are formed on both sides of a ram 21. Accordingly, a supply flow rate of the hydraulic oil to one of the first and second actuating chambers 22 and 23, and a discharge flow rate of the hydraulic oil from the other one of the first and second actuating chambers 22 and 23, are equal to each other.

[0016] The ram 21 is rod-shaped and extends in a direction orthogonal to the axial direction of the rudder stock 12. At the middle of the ram 21, a pin 24 is provided. The pin 24 engages with the tiller 13. To be more specific, the tiller 13 is provided with a groove that is open in a direction away from the rudder stock 12, and the pin 24 is inserted in the groove.

[0017] The number of hydraulic actuators 2 need not be one, but may be two such that the hydraulic cylinders are parallel to each other, with the rudder stock 12 positioned therebetween. The hydraulic actuator 2 need not be a hydraulic cylinder in which the first actuating chamber 22 and the second actuating chamber 23 are formed on both sides of the ram 21, but may be a single-rod hydraulic cylinder in which a rod extends from a piston disposed in a tube whose both ends are sealed up.

[0018] In a case where the hydraulic actuator 2 is a single-rod hydraulic cylinder, the inside of the tube is divided by the piston into the first actuating chamber 22 and the second actuating chamber 23. Further, in the case where the hydraulic actuator 2 is a single-rod hydraulic cylinder, the tube may be swingably supported, and the distal end of the rod may be coupled, by a pin, to the tiller 13.

[0019] Alternatively, the hydraulic actuator 2 may be a hydraulic motor in which the first actuating chamber 22 and the second actuating chamber 23 are divided from each other by a vane. In this case, the hydraulic actuator 2 may be provided with a plurality of first actuating chambers 22 and a plurality of second actuating chambers 23. In the case where the hydraulic actuator 2 is a hydraulic motor, the rotating shaft of the hydraulic motor is coupled to the rudder stock 12 by a coupler. Also in the case where the hydraulic actuator 2 is a hydraulic motor, a supply flow rate of the hydraulic oil to one of the first and second actuating chambers 22 and 23, and a discharge flow rate of the hydraulic oil from the other one of the first and second actuating chambers 22 and 23, are equal to each other.

[0020] The first actuating chamber 22 and the second actuating chamber 23 of the hydraulic actuator 2 are connected to a switching valve 3 by a pair of supply/discharge lines 44 and 45. The switching valve 3 is connected, by a pump line 42, to a delivery port of a pump 41, which delivers the hydraulic oil. In the present embodiment, the switching valve 3 is connected to a suction port of the pump 41 by a recovery line 43.

[0021] It should be noted that, although not illustrated, the switching valve 3 may be connected to a tank by a tank line. In this case, the suction port of the pump 41 is connected to the tank by a suction line. This configuration is often adopted in cases where the hydraulic actuator 2 is a single-rod hydraulic cylinder as described above.

[0022] In the present embodiment, the pump 41 is a fixed displacement pump. The pump 41 is driven at a constant rotation speed by an unshown electric motor. However, the rotation speed of the pump 41 need not be constant, but may be variable. The pump 41 need not be a fixed displacement pump, but may be, for example, a variable displacement pump whose tilting angle is changeable (e.g., a swash plate pump or a bent axis pump).

[0023] As shown in FIG. 1 and FIG. 2, the switching valve 3 includes a housing 32 and a spool 31. The spool 31 is slidably held by the housing 32. When the spool 31 is at the neutral position, the switching valve 3 blocks the supply/discharge lines 44 and 45, and brings the pump line 42 into communication with the recovery line 43. On the other hand, when the spool 31 shifts from the neutral position to one side or the other side in the axial direction of the spool 31, the switching valve 3 brings one of the supply/discharge lines 44 and 45 into communication with the pump line 42, and brings the other one of the supply/discharge lines 44 and 45 into communication with the recovery line 43.

[0024] The spool 31 is shifted by a shifting mechanism 5. The shifting mechanism 5 is configured such that the shifting speed of the spool 31 is electrically changeable. The shifting mechanism 5 is controlled by a controller 6.

[0025] In the present embodiment, the shifting mechanism 5 is a linear motion mechanism 5A. Specifically, the linear motion mechanism 5A includes: a rod-shaped coupling member 51, which extends in the axial direction of the spool 31; a nut 52, which is coupled to the spool 31 via the coupling member 51; a screw shaft 53, which is screwed with the nut 52; and an electric motor 54, which rotates the screw shaft 53. The coupling member 51, the nut 52, the screw shaft 53, and the electric motor 54 are arranged coaxially with the spool 31. A cylindrical casing 55 is interposed between the housing 32 and the electric motor 54. The coupling member 51, the nut 52, and the screw shaft 53 are accommodated in the casing 55.

[0026] For example, the electric motor 54 is a servomotor. When the electric motor 54 rotates the screw shaft 53 in one direction, the nut 52, the coupling member 51, and the spool 31 shift to one side in the axial direction of the spool 31, and when the electric motor 54 rotates the screw shaft 53 in the opposite direction, the nut 52, the coupling member 51, and the spool 31 shift to the other side in the axial direction of the spool 31.

[0027] Hereinafter, with reference to FIG. 2, the configuration of the linear motion mechanism 5A is described in detail. In the description below, for the sake of convenience of the description, one side in the axial direction of the spool 31 (the right side in FIG. 2) is referred to as the right side and the other side in the axial direction of the spool 31 (the left side in FIG. 2) is referred to as the left side.

[0028] In the present embodiment, the right end of the spool 31 and the left end of the coupling member 51 are coupled to each other by a ball joint. Specifically, the left end of the coupling member 51 is provided with a groove 51a, and a ball 35 is held in the groove 51a. On the other hand, the right end of the spool 31 is provided with a plate-shaped protrusion 31a, which is inserted in the groove 51a. The protrusion 31a is provided with a hole that is fitted to the ball 35.

[0029] Alternatively, conversely to the present embodiment, the right end of the spool 31 may be provided with the groove 51a, in which the ball 35 is held, and the left end of the coupling member 51 may be provided with the protrusion 31a, which is inserted in the groove 51a. Further alternatively, the right end of the spool 31 and the left end of the coupling member 51 may be coupled to each other by a joint different from a ball joint.

[0030] A hole 51b, which is open toward the right side, is provided on the center line of the coupling member 51. The nut 52 is fixed to the coupling member 51 in a state where the nut 52 is inserted in the hole 51b. The coupling member 51 is guided by an unshown guide mechanism such that the coupling member 51 is shiftable only in the left-right direction (i.e., the coupling member 51 is prevented from rotating).

[0031] The present embodiment is further provided with a mechanism between the coupling member 51 and the casing 55. The mechanism serves to keep the spool 31 at the neutral position when the electric motor 54 is not supplied with electric power. The mechanism includes: a coil spring 56 in which the coupling member 51 is inserted; and a pair of spring receivers 57 and 58, which supports both ends of the coil spring 56, respectively.

[0032] The coil spring 56 applies urging force to the spool 31 via the coupling member 51 to keep the spool 31 at the neutral position. Each of the spring receivers 57 and 58 is ringshaped and slidably fitted to the coupling member 51.

[0033] A flange 51c, which contacts the spring receiver 58, is provided on the right end of the coupling member 51. At a position that is away from the flange 51c toward the left side, a stopper 59, which contacts the spring receiver 57, is mounted to the coupling member 51.

[0034] On the inner side surface of the casing 55, a stepped portion 55b is provided at a position corresponding to the flange 51c, and a stepped portion 55a is provided at a position corresponding to the stopper 59.

[0035] With the above-described structure, when the electric motor 54 is not supplied with electric power, the urging force of the coil spring 56 causes the spring receiver 58 to contact both the flange 51c and the stepped portion 55b, and causes the spring receiver 57 to contact both the stopper 59 and the stepped portion 55a. Consequently, the spool 31 is kept at the neutral position.

[0036] In a state where the spool 31 is at the neutral position, when the coupling member 51 shifts toward the left side, the spring receiver 58 is pushed by the flange 51c to become spaced apart from the stepped portion 55b, and also, the stopper 59 becomes spaced apart from the spring receiver 57. On the other hand, in the state where the spool 31 is at the neutral position, when the coupling member 51 shifts toward the right side, the flange 51c becomes spaced apart from the spring receiver 58, and also, the spring receiver 57 is pushed by the stopper 59 to become spaced apart from the stepped portion 55a.

[0037] Alternatively, the coil spring 56, which applies the urging force to the spool 31 to keep the spool 31 at the neutral position, may be provided at the opposite side of the spool 31 from the linear motion mechanism 5A.

[0038] Next, control performed by the controller 6 is described in detail. For example, the controller 6 is a computer including memories such as a ROM and RAM, a storage such as a HDD or SSD, and a CPU. The CPU executes a program stored in the ROM or the storage.

[0039] As shown in FIG. 3A, steering commands are inputted to the controller 6. The steering commands are: a port direction steering command to turn the rudder plate 11 in the port direction; a steering stop command to stop the rudder plate 11; and a starboard direction steering command to turn the rudder plate 11 in the starboard direction. However, the steering commands are not limited to these three commands, but may include steering commands that are in between these three commands. That is, the waveform of a steering command need not be a rectangular pulse waveform, but may be a smooth curved waveform.

[0040] When the controller 6 receives the port direction steering command, i.e., when the steering command changes from the steering stop command into the port direction steering command, the controller 6 controls the linear motion mechanism 5A to cause the shifting speed of the spool 31 to transition on a curve C1 as shown in FIG. 3B. Consequently, the spool 31 shifts from the neutral position to a maximum opening position where the opening area between the pump line 42 and the supply/discharge line 45 is maximum. The curve C1 is an S-shaped curve indicating that the shifting speed of the spool 31 increases gradually and then decreases gradually.

[0041] Thereafter, when the steering command changes from the port direction steering command into the steering stop command, the controller 6 controls the linear motion mechanism 5A to cause the shifting speed of the spool 31 to transition on a curve C2. Consequently, the spool 31 shifts from the maximum opening position to the neutral position. The curve C2 is an S-shaped curve indicating that the shifting speed of the spool 31 increases gradually and then decreases gradually.

[0042] On the other hand, when the controller 6 receives the starboard direction steering command, i.e., when the steering command changes from the steering stop command into the starboard direction steering command, the controller 6 controls the linear motion mechanism 5A to cause the shifting speed of the spool 31 to transition on a curve C3. Consequently, the spool 31 shifts from the neutral position to a maximum opening position where the opening area between the pump line 42 and the supply/discharge line 44 is maximum. The curve C3 is an S-shaped curve indicating that the shifting speed of the spool 31 increases gradually and then decreases gradually.

[0043] Thereafter, when the steering command changes from the starboard direction steering command into the steering stop command, the controller 6 controls the linear motion mechanism 5A to cause the shifting speed of the spool 31 to transition on a curve C4. Consequently, the spool 31 shifts from the maximum opening position to the neutral position. The curve C4 is an S-shaped curve indicating that the shifting speed of the spool 31 increases gradually and then decreases gradually.

[0044] The controller 6 is electrically connected to a position detector 7, which detects the position of the spool 31. In the present embodiment, the position detector 7 is a rotary encoder 7A, which detects the amount of rotation of the electric motor 54 as the position of the spool 31.

[0045] When the controller 6 receives the port direction steering command or the starboard direction steering command, the controller 6 determines whether or not the spool 31 is stuck based on the position of the spool 31 detected by the position detector 7 (in the present embodiment, the amount of rotation of the electric motor 54, which is detected by the rotary encoder 7A) and the electric current of the electric motor 54. In this manner, sticking of the spool 31 can be detected without using a special sensor, because usually in the linear motion mechanism 5A, the rotary encoder 7A is used for controlling the electric motor 54.

[0046] At a normal time when the spool 31 is not stuck, an electric current corresponding to necessary thrust for shifting the spool 31 to a target position flows to the electric motor 54. On the other hand, when the spool 31 is stuck, since the spool 31 does not reach the target position, the controller 6 maximizes the electric current flowing to the electric motor 54 to cause the spool 31 to reach the target position (i.e., brings and keeps the electric current value of the electric motor 54 to the upper limit value). Therefore, in a case where the position of the spool 31 does not change and the electric current value of the electric motor 54 is kept to the upper limit value for about one second, the controller 6 determines that the spool 31 is stuck. On the other hand, in a case where these conditions are not met, the controller 6 determines that the spool 31 is not stuck.

[0047] When the controller 6 determines that the spool 31 is stuck, the controller 6 may output an error signal. For example, the controller 6 may output the error signal to an unshown display device disposed in a wheelhouse to indicate on a screen of the display device that the spool 31 is stuck. In this manner, a ship operator can be notified of the sticking of the spool 31.

[0048] Alternatively, when the controller 6 determines that the spool 31 is stuck, in a case where the controller 6 receives the port direction steering command, the controller 6 may control the linear motion mechanism 5A such that the spool 31 shifts in a direction corresponding to the starboard direction steering command and then shifts in a direction corresponding to the port direction steering command, whereas in a case where the controller 6 receives the starboard direction steering command, the controller 6 may control the linear motion mechanism 5A such that the spool 31 shifts in a direction corresponding to the port direction steering command and then shifts in a direction corresponding to the starboard direction steering command. By performing such control, the sticking of the spool 31 may be releasable. The spool 31 may be shifted in regular and reverse directions multiple times such that the spool 31 oscillates.

[0049] As described above, in the steering system 1A of the present embodiment, the shifting mechanism 5, which shifts the spool 31, is configured such that the shifting speed of the spool 31 is electrically changeable. This makes flexible operation of the steering system 1A possible.

[0050] In a case where the spool 31 is shifted instantaneously by excitation of the magnet coil of a solenoid valve as in a conventional steering system, rapid change occurs in the motion of the rudder stock 12 and the rudder plate 11, and thereby a great impact shock occurs. On the other hand, in a case where the shifting speed of the spool 31 transitions on such a curve that the shifting speed increases gradually and then decreases gradually (i.e., transitions on the curve C1 or C3) as in the present embodiment, such an impact shock can be reduced.

[0051] The controller 6 may calculate a supply flow rate of the hydraulic oil to the first actuating chamber 22 or the second actuating chamber 23 based on the position of the spool 31 detected by the position detector 7, and may calculate the angle of the rudder plate 11 based on the calculated supply flow rate. In this manner, the angle of the rudder plate 11 can be known without using an angle sensor. For example, the controller 6 may integrate the calculated supply flow rate to calculate a total supply amount of the hydraulic oil to the first actuating chamber 22 or the second actuating chamber 23, and may calculate the angle of the rudder plate 11 based on the calculated total supply amount.

[0052] Further, the controller 6 may output an error signal when the calculated angle of the rudder plate 11 is out of an allowable range. For example, the controller 6 may output the error signal to the unshown display device disposed in the wheelhouse to indicate on the screen of the display device that the rudder plate is not turning in accordance with steering. In this manner, the ship operator can be notified that the rudder plate 11 is not turning in accordance with steering.

[0053] The aforementioned allowable range can be calculated, for example, from a target rudder angle. The target rudder angle can be calculated from a time during which the controller 6 receives the port direction operation command or the starboard direction operation command. For example, the lower limit of the allowable range may be calculated by subtracting a predetermined value from the target rudder angle, or may be calculated by multiplying the target rudder angle by a predetermined percentage (e.g., 50 to 90%). The upper limit of the allowable range may be calculated by adding a predetermined value to the target rudder angle, or may be calculated by multiplying the target rudder angle by a predetermined percentage (e.g., 110 to 150%).

(Embodiment 2)

[0054] FIG. 5 shows a steering system 1B according to Embodiment 2 of the present invention. In the present embodiment and the following Embodiment 3, the same components as those described in Embodiment 1 are denoted by the same reference signs as those used in Embodiment 1, and repeating the same descriptions is avoided.

[0055] In the present embodiment, a pressure sensor 8, which detects the pressure of the second actuating chamber 23, is provided on the supply/discharge line 45, which connects to the second actuating chamber 23. Alternatively, the pressure sensor 8 may be provided on the second actuating chamber 23. Further alternatively, the pressure sensor 8 may be provided on the first actuating chamber 22 or the supply/discharge line 44, and may detect the pressure of the first actuating chamber 22.

[0056] Similar to Embodiment 1, when the controller 6 receives the port direction steering command or the starboard direction steering command, the controller 6 controls the linear motion mechanism 5A to cause the shifting speed of the spool 31 to transition on the curve C1 or C3 shown in FIG. 3B. Further, in the present embodiment, the controller 6 corrects the curves C1 and C3 in accordance with the pressure detected by the pressure sensor 8.

[0057] For example, in a case where the pressure detected by the pressure sensor 8 is lower than a specified value, the controller 6 increases the slopes of the respective curves C1 and C3 (i.e., makes the curves C1 and C3 steep), whereas in a case where the pressure detected by the pressure sensor 8 is higher than the specified value, the controller 6 decreases the slopes of the respective curves C1 and C3 (i.e., makes the curves C1 and C3 smooth). In this manner, the range of flow velocity fluctuation of the hydraulic oil that is caused by pressure fluctuation can be kept small.

[0058] In the steering system 1B of the present embodiment, the curves C1 and C3 are corrected in accordance with the pressure. Therefore, compared to a case where the curves C1 and C3 are constant, the relationship between the position of the spool 31 and the flow velocity of the hydraulic oil passing through the switching valve 3 can be made more stable.

[0059] At the time of stopping the rudder plate 11 from turning, the controller 6 may correct the curves C2 and C4 shown in FIG. 3B in accordance with the pressure detected by the pressure sensor 8.

(Embodiment 3)

[0060] FIG. 6 shows a steering system 1C according to Embodiment 3 of the present invention. The steering system 1C includes a first circuit and a second circuit. The first circuit includes the pump 41, the pump line 42, the recovery line 43, the switching valve 3, and the supply/discharge lines 44 and 45, which are described in Embodiment 1. The second circuit is configured in the same manner as the first circuit.

[0061] Specifically, in the present embodiment, the pump 41, the switching valve 3, the shifting mechanism 5, the position detector 7, and the controller 6, which are described in Embodiment 1, are a first pump 41, a first switching valve 3, a first shifting mechanism 5, a first position detector 7, and a first controller 6, respectively. Also, in the present embodiment, the housing 32 and the spool 31 of the switching valve 3 described in Embodiment 1 are a first housing 32 and a first spool 31, respectively.

[0062] Similar to the first circuit, the second circuit includes a second pump 41', a pump line 42', a recovery line 43', a second switching valve 3', and a pair of supply/discharge lines 44' and 45'. The second switching valve 3' is connected to the first actuating chamber 22 and the second actuating chamber 23 of the hydraulic actuator 2 by the supply/discharge lines 44' and 45', respectively. The second switching valve 3' is connected to the second pump 41' by the pump line 42' and the recovery line 43'.

[0063] Similar to the first pump 41, the second pump 41' is a fixed displacement pump, and is driven at a constant rotation speed by an unshown electric motor. The variations of the first pump 41, which are described in Embodiment 1, are applicable also to the second pump 41'.

[0064] Similar to the first switching valve 3, the second switching valve 3' includes a second housing 32' and a second spool 31'. The second spool 31' is slidably held by the second housing 32'. The second spool 31' is shifted by a second shifting mechanism 5'.

[0065] Similar to the first shifting mechanism 5, the second shifting mechanism 5' is configured such that the shifting speed of the second spool 31' is electrically changeable. The second shifting mechanism 5' is controlled by the controller 6. In the present embodiment, similar to the first shifting mechanism 5, the second shifting mechanism 5' is a linear motion mechanism 5A.

[0066] The second controller 6' is electrically connected to a second position detector 7', which detects the position of the second spool 31'. In the present embodiment, similar to the first position detector 7, the second position detector 7' is the rotary encoder 7A, which detects the amount of rotation of the electric motor 54 of the linear motion mechanism 5A as the position of the second spool 31'.

[0067] The second controller 6' is configured in the same manner as the first controller 6. The second controller 6' is configured to communicate with the first controller 6.

[0068] In the present embodiment, the first controller 6 or the second controller 6' outputs an error signal when an inconsistency occurs in a positional relationship between the position of the first spool 31 detected by the first position detector 7 (in the present embodiment, the amount of rotation, detected by the rotary encoder 7A, of the electric motor 54 of the linear motion mechanism 5A serving as the first shifting mechanism 5) and the position of the second spool 31' detected by the second position detector 7' (in the present embodiment, the amount of rotation, detected by the rotary encoder 7A, of the electric motor 54 of the linear motion mechanism 5A serving as the second shifting mechanism 5'). In this manner, a situation where the first spool 31 of the first switching valve 3 and the second spool 31' of the second switching valve 3' are moving differently from each other can be detected.

[0069] For example, the first controller 6 or the second controller 6' may output an error signal to the unshown display device disposed in the wheelhouse to indicate on the screen of the display device that the first spool 31 of the first switching valve 3 and the second spool 31' of the second switching valve 3' are moving differently from each other.

[0070] Examples of a case where an inconsistency occurs in the positional relationship between the position of the first spool 31 and the position of the second spool 31' include: a case where the position of the first spool 31 and the position of the second spool 31' are different from each other; and a case where the first spool 31 and the second spool 31' shift in opposite directions to each other. Specifically, if the error signal is outputted in the case where the first spool 31 and the second spool 31' shift in opposite directions to each other, a situation where the first shifting mechanism 5 and the second shifting mechanism 5' are receiving different commands, respectively, from the controller 6 can be detected.

[0071] Accordingly, in the case where the position of the first spool 31 and the position of the second spool 31' are different from each other, or in the case where the shifting direction of the first spool 31 and the shifting direction of the second spool 31' are different from each other (including a case where either one of the first spool 31 or the second spool 31' has shifted, but the other has not), the first controller 6 or the second controller 6' determines that an inconsistency has occurred in the positional relationship between the position of the first spool 31 and the position of the second spool 31'.

[0072] Alternatively, in a case where the steering command received by the first controller 6 and the steering command received by the second controller 6' are different from each other, the first controller 6 or the second controller 6' may output an error signal. This configuration makes it possible to prevent erroneous motion of the first spool 31 or the second spool 31'.

[0073] The controller 6 may control the first circuit in the same manner as in Embodiment 1 and Embodiment 2. Further, the controller 6 may control the second circuit in the same manner as in Embodiment 1 and Embodiment 2.

(Other Embodiments)

[0074] The present invention is not limited to the above-described embodiments. Various modifications can be made without departing from the scope of the present invention.

[0075] For example, the shifting mechanism 5 in Embodiments 1 to 3 (as well as the second shifting mechanism 5' in Embodiment 3) need not be the linear motion mechanism 5A, but may be a pair of solenoid proportional valves 61 and 62 as in a steering system 1D according to a variation shown in FIG. 7. In this case, a pair of pilot chambers 33 and 34 is formed in the switching valve 3, and the solenoid proportional valves 61 and 62 are connected to the pilot chambers 33 and 34, respectively. Further, the solenoid proportional valves 61 and 62 are connected to a sub pump 64 by a primary pressure line 63.

[0076] Each of the solenoid proportional valves 61 and 66 is fed with a command current from the controller 6. Each of the solenoid proportional valves 61 and 62 outputs a secondary pressure to a corresponding one of the pilot chambers 33 and 34 in accordance with the command current. In the illustrated example, each of the solenoid proportional valves 61 and 62 is a direct proportional valve whose output secondary pressure and the command current fed thereto indicate a positive correlation. Alternatively, each of the solenoid proportional valves 61 and 62 may be an inverse proportional valve whose output secondary pressure and the command current fed thereto indicate a negative correlation.

[0077] As shown in FIG. 7, in a case where the shifting mechanism 5 is the pair of solenoid proportional valves 61 and 62, the switching valve 3 needs to be provided with, for example, a stroke sensor 7B as the position detector 7, which detects the position of the spool 31. On the other hand, in a case where the shifting mechanism 5 is the linear motion mechanism 5A and the position detector 7 is the rotary encoder 7A, which detects the amount of rotation of the electric motor 54 included in the linear motion mechanism 5A, the switching valve 3 need not be provided with a sensor.

(Summary)

[0078] A steering system according to the present invention is a steering system installed in a ship, and includes: a hydraulic actuator that turns a rudder plate via a rudder stock that penetrates a ship bottom, the hydraulic actuator including a first actuating chamber and a second actuating chamber; a pump that delivers hydraulic oil; a switching valve including a spool, the switching valve being connected to the first actuating chamber and the second actuating chamber by a pair of supply/discharge lines and to the pump by a pump line; and a shifting mechanism that shifts the spool, the shifting mechanism being configured such that a shifting speed of the spool is electrically changeable.

[0079] According to the above configuration, the shifting mechanism, which shifts the spool, is configured such that the shifting speed of the spool is electrically changeable. This makes flexible operation of the steering system possible.

[0080] The above steering system may include a controller that controls the shifting mechanism. When the controller receives a steering command to turn the rudder plate, the controller may control the shifting mechanism to cause the shifting speed of the spool to transition on such a curve that the shifting speed increases gradually and then decreases gradually. In a case where the spool is shifted instantaneously by excitation of the magnet coil of a solenoid valve as in a conventional steering system, rapid change occurs in the motion of the rudder stock and the rudder plate, and thereby a great impact shock occurs. On the other hand, in a case where the shifting speed of the spool transitions on such a curve that the shifting speed increases gradually and then decreases gradually as in the above configuration, such an impact shock can be reduced.

[0081] The above steering system may include a pressure sensor that detects a pressure of the first actuating chamber or the second actuating chamber. The controller may correct the curve in accordance with the pressure detected by the pressure sensor. According to this configuration, compared to a case where the curve is constant, the relationship between the position of the spool and the flow velocity of the hydraulic oil passing through the switching valve can be made more stable.

[0082] For example, the above steering system may include: a controller that controls the shifting mechanism; and a position detector that detects a position of the spool.

[0083] The shifting mechanism may be a linear motion mechanism including: a nut that is coupled to the spool; a screw shaft that is screwed with the nut; and an electric motor that rotates the screw shaft. The position detector may be a rotary encoder that detects an amount of rotation of the electric motor as the position of the spool. In a case where the shifting mechanism is a pair of solenoid proportional valves, the switching valve needs to be provided with, for example, a stroke sensor as the position detector, which detects the position of the spool. On the other hand, in a case where the shifting mechanism is the linear motion mechanism and the position detector is the rotary encoder that detects the amount of rotation of the electric motor included in the linear motion mechanism, the switching valve need not be provided with a sensor.

[0084] When the controller receives a steering command to turn the rudder plate, the controller may determine whether or not the spool is stuck based on the detected position of the spool and an electric current of the electric motor. According to this configuration, sticking of the spool can be detected without using a special sensor.

[0085] The controller may output an error signal when the controller determines that the spool is stuck. According to this configuration, a ship operator can be notified of the sticking of the spool.

[0086] When the controller determines that the spool is stuck, the controller may control the shifting mechanism such that the spool shifts in a direction opposite to a direction corresponding to the steering command, and then shifts in the direction corresponding to the steering command. According to this configuration, the sticking of the spool may be releasable.

[0087] The controller may calculate a supply flow rate of the hydraulic oil to the first actuating chamber or the second actuating chamber based on the detected position of the spool, and calculate an angle of the rudder plate based on the calculated supply flow rate. According to this configuration, the angle of the rudder plate can be known without using an angle sensor.

[0088] The controller may output an error signal when the calculated angle of the rudder plate is out of an allowable range. According to this configuration, the ship operator can be notified that the rudder plate is not turning in accordance with steering.

[0089] The pump may be a first pump. The spool may be a first spool. The switching valve may be a first switching valve. The shifting mechanism may be a first shifting mechanism. The position detector may be a first position detector. The controller may be a first controller. The steering system may include: a second pump that delivers the hydraulic oil; a second switching valve including a second spool, the second switching valve being connected to the first actuating chamber and the second actuating chamber by a pair of supply/discharge lines and to the second pump by a pump line; a second shifting mechanism that shifts the second spool, the second shifting mechanism being configured such that a shifting speed of the second spool is electrically changeable; a second controller that controls the second shifting mechanism and that is configured to communicate with the first controller; and a second position detector that detects a position of the second spool. The first controller or the second controller may output an error signal when an inconsistency occurs in a positional relationship between the position of the first spool detected by the first position detector and the position of the second spool detected by the second position detector. According to this configuration, a situation where the first spool of the first switching valve and the second spool of the second switching valve are moving differently from each other can be detected.

[0090] The pump may be a first pump. The spool may be a first spool. The switching valve may be a first switching valve. The shifting mechanism may be a first shifting mechanism. The steering system may include: a first controller that controls the first shifting mechanism; a second pump that delivers the hydraulic oil; a second switching valve including a second spool, the second switching valve being connected to the first actuating chamber and the second actuating chamber by a pair of supply/discharge lines and to the second pump by a pump line; a second shifting mechanism that shifts the second spool, the second shifting mechanism being configured such that a shifting speed of the second spool is electrically changeable; and a second controller that controls the second shifting mechanism and that is configured to communicate with the first controller. The first controller or the second controller may output an error signal when a steering command received by the first controller and a steering command received by the second controller are different from each other. This configuration makes it possible to prevent erroneous motion of the first spool or the second spool.

[0091] For example, the switching valve may be connected to the pump by a recovery line.

Reference Signs List

[0092]

1A to 1D steering system
10 ship bottom
11 rudder plate
2 hydraulic actuator
22 first actuating chamber
23 second actuating chamber
3 switching valve
31 spool (first spool)
31' second spool
41 pump (first pump)
41' second pump
42, 42' pump line
43, 43' recovery line
44, 45, 44', 45' supply/discharge line
5 shifting mechanism (first shifting mechanism)
5' second shifting mechanism
5A linear motion mechanism
52 nut
53 screw shaft
54 electric motor
6 controller (first controller)
6' second controller
7 position detector (first position detector)
7' second position detector
7A rotary encoder
8 pressure sensor

Claims

1. A steering system installed in a ship, comprising:

a hydraulic actuator that turns a rudder plate via a rudder stock that penetrates a ship bottom, the hydraulic actuator including a first actuating chamber and a second actuating chamber;
a pump that delivers hydraulic oil;
a switching valve including a spool, the switching valve being connected to the first actuating chamber and the second actuating chamber by a pair of supply/discharge lines and to the pump by a pump line; and
a shifting mechanism that shifts the spool, the shifting mechanism being configured such that a shifting speed of the spool is electrically changeable.

2. The steering system according to claim 1, comprising a controller that controls the shifting mechanism, wherein
when the controller receives a steering command to turn the rudder plate, the controller controls the shifting mechanism to cause the shifting speed of the spool to transition on such a curve that the shifting speed increases gradually and then decreases gradually.

3. The steering system according to claim 2, comprising a pressure sensor that detects a pressure of the first actuating chamber or the second actuating chamber, wherein
the controller corrects the curve in accordance with

the pressure detected by the pressure sensor.

4. The steering system according to any one of claims 1 to 3, comprising:

a controller that controls the shifting mechanism; and
a position detector that detects a position of the spool.

5. The steering system according to claim 4, wherein

the shifting mechanism is a linear motion mechanism including:

a nut that is coupled to the spool;
a screw shaft that is screwed with the nut; and
an electric motor that rotates the screw shaft, and

the position detector is a rotary encoder that detects an amount of rotation of the electric motor as the position of the spool.

6. The steering system according to claim 5, wherein when the controller receives a steering command to turn the rudder plate, the controller determines whether or not the spool is stuck based on the detected position of the spool and an electric current of the electric motor.

7. The steering system according to claim 6, wherein the controller outputs an error signal when the controller determines that the spool is stuck.

8. The steering system according to claim 6 or 7, wherein
when the controller determines that the spool is stuck, the controller controls the shifting mechanism such that the spool shifts in a direction opposite to a direction corresponding to the steering command, and then shifts in the direction corresponding to the steering command.

9. The steering system according to any one of claims 4 to 8, wherein
the controller calculates a supply flow rate of the hydraulic oil to the first actuating chamber or the second actuating chamber based on the detected position of the spool, and calculates an angle of the rudder plate based on the calculated supply flow rate.

10. The steering system according to claim 9, wherein the controller outputs an error signal when the calculated angle of the rudder plate is out of an allowable range.

11. The steering system according to any one of claims 4 to 10, wherein

the pump is a first pump,
the spool is a first spool,
the switching valve is a first switching valve,
the shifting mechanism is a first shifting mechanism,
the position detector is a first position detector,
the controller is a first controller,
the steering system comprises:

a second pump that delivers the hydraulic oil;
a second switching valve including a second spool, the second switching valve being connected to the first actuating chamber and the second actuating chamber by a pair of supply/discharge lines and to the second pump by a pump line;
a second shifting mechanism that shifts the second spool, the second shifting mechanism being configured such that a shifting speed of the second spool is electrically changeable;
a second controller that controls the second shifting mechanism and that is configured to communicate with the first controller; and
a second position detector that detects a position of the second spool, and

the first controller or the second controller outputs an error signal when an inconsistency occurs in a positional relationship between the position of the first spool detected by the first position detector and the position of the second spool detected by the second position detector.

12. The steering system according to any one of claims 1 to 11, wherein

the pump is a first pump,
the spool is a first spool,
the switching valve is a first switching valve,
the shifting mechanism is a first shifting mechanism,
the steering system comprises:

a first controller that controls the first shifting mechanism;
a second pump that delivers the hydraulic oil;
a second switching valve including a second spool, the second switching valve being connected to the first actuating chamber and the second actuating chamber by a pair of supply/discharge lines and to the second pump by a pump line;

a second shifting mechanism that shifts the second spool, the second shifting mechanism being configured such that a shifting speed of the second spool is electrically changeable; and

a second controller that controls the second shifting mechanism and that is configured to communicate with the first controller, and

the first controller or the second controller outputs an error signal when a steering command received by the first controller and a steering command received by the second controller are different from each other.

13. The steering system according to any one of claims 1 to 10, wherein
the switching valve is connected to the pump by a recovery line.

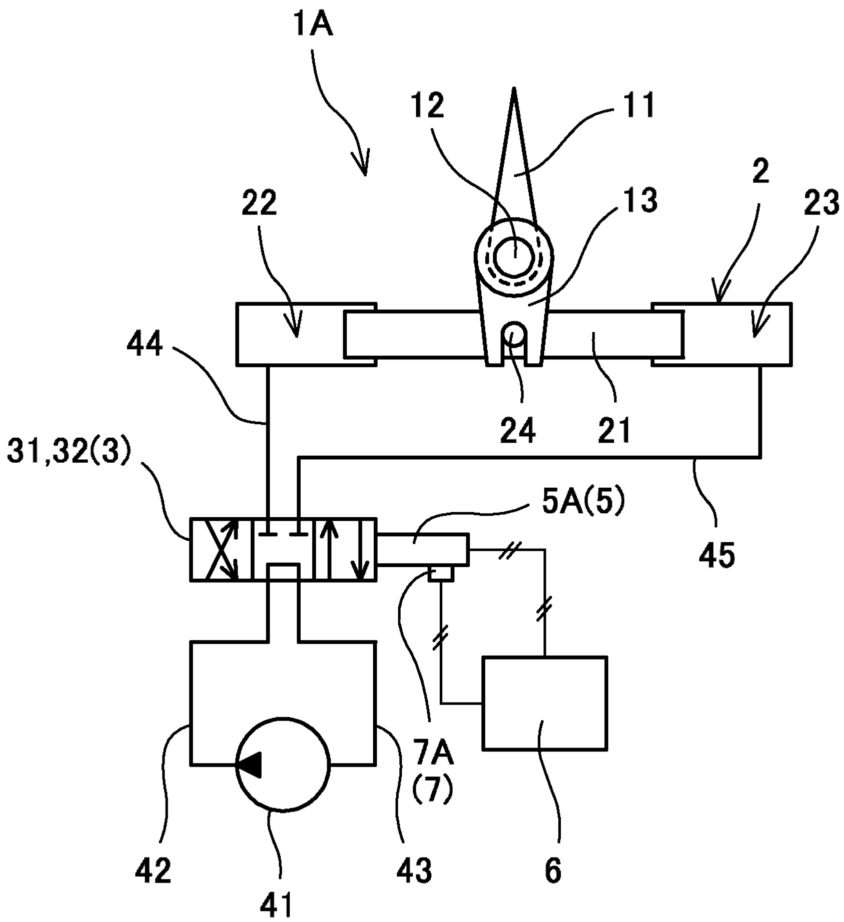


FIG.1

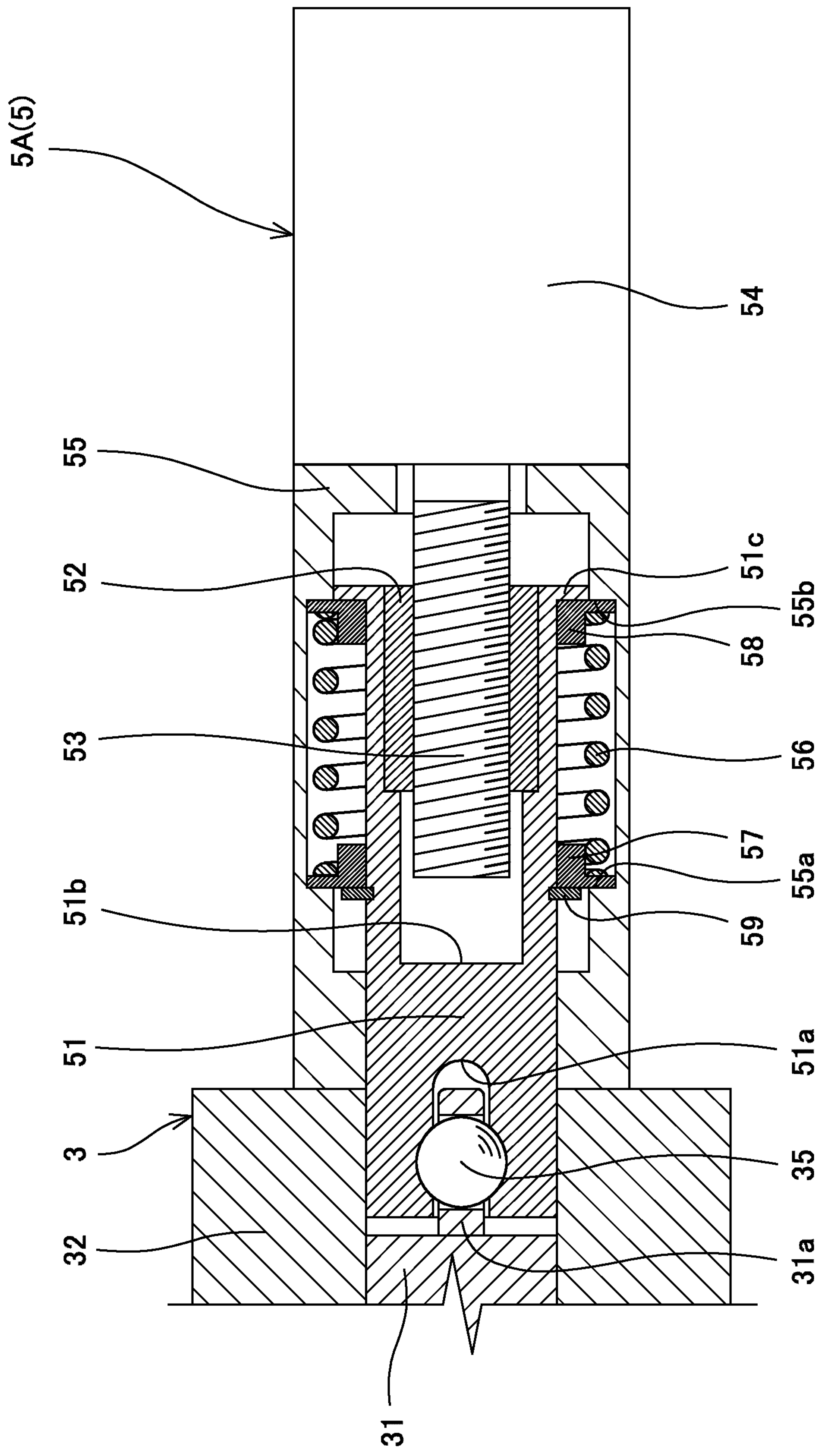


FIG.2

FIG.3A

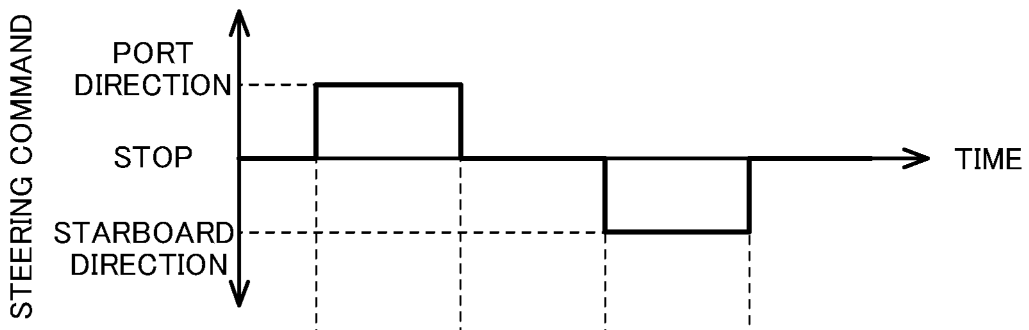
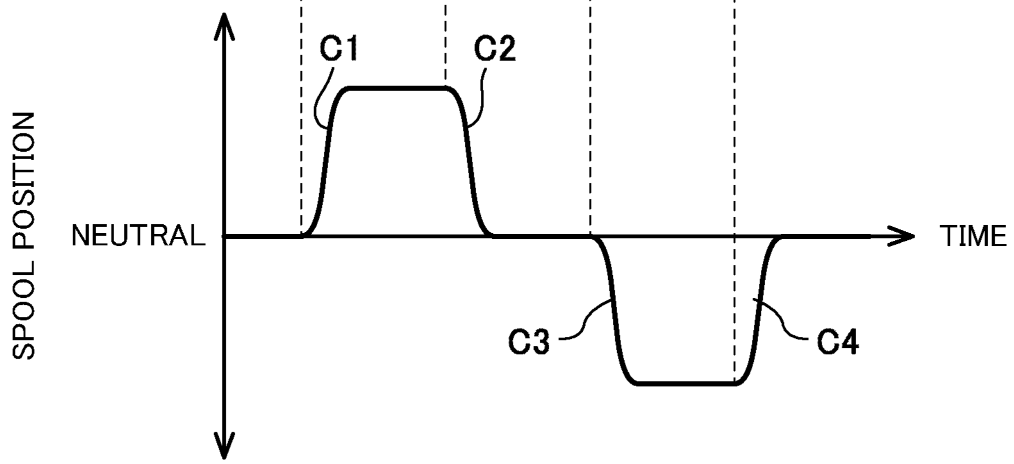

STEERING COMMAND
PORT DIRECTION
STOP
STARBOARD DIRECTION
TIME

FIG.3B


SPOOL POSITION
C1
C2
NEUTRAL
TIME
C3
C4

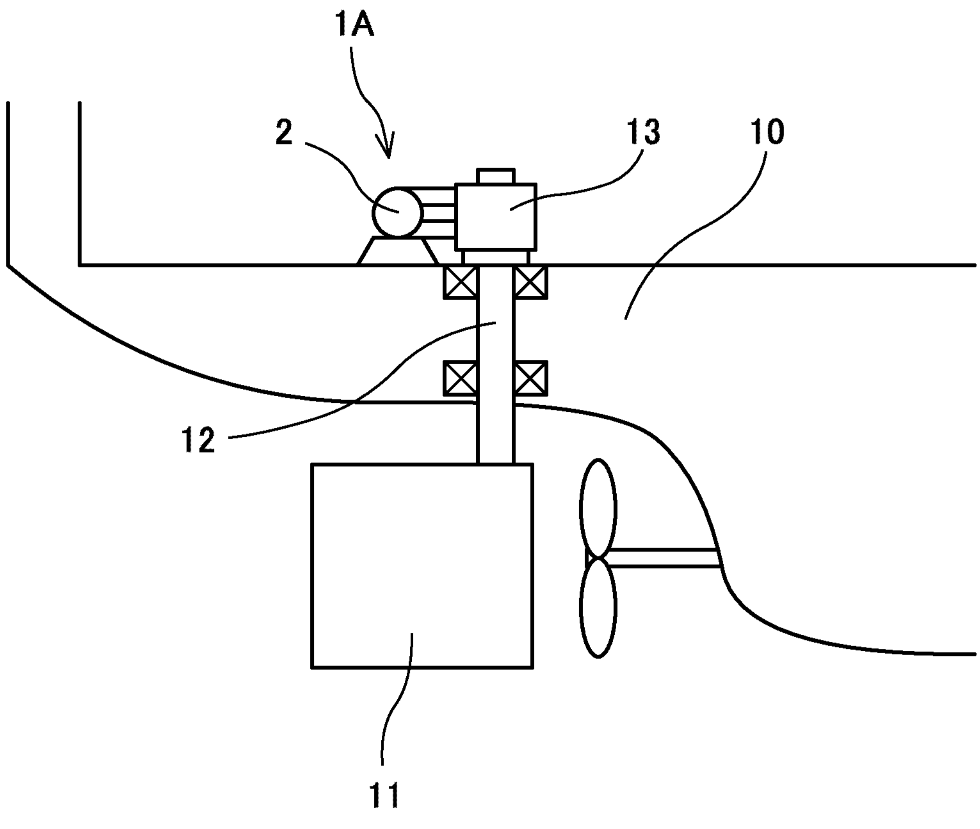


FIG.4

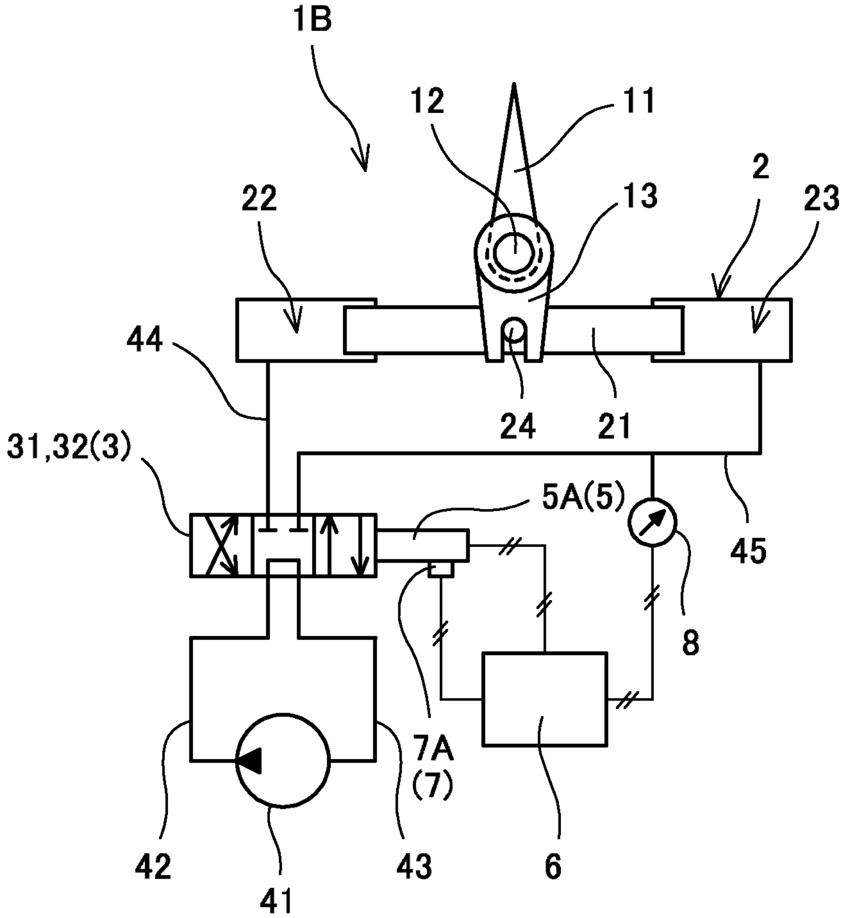
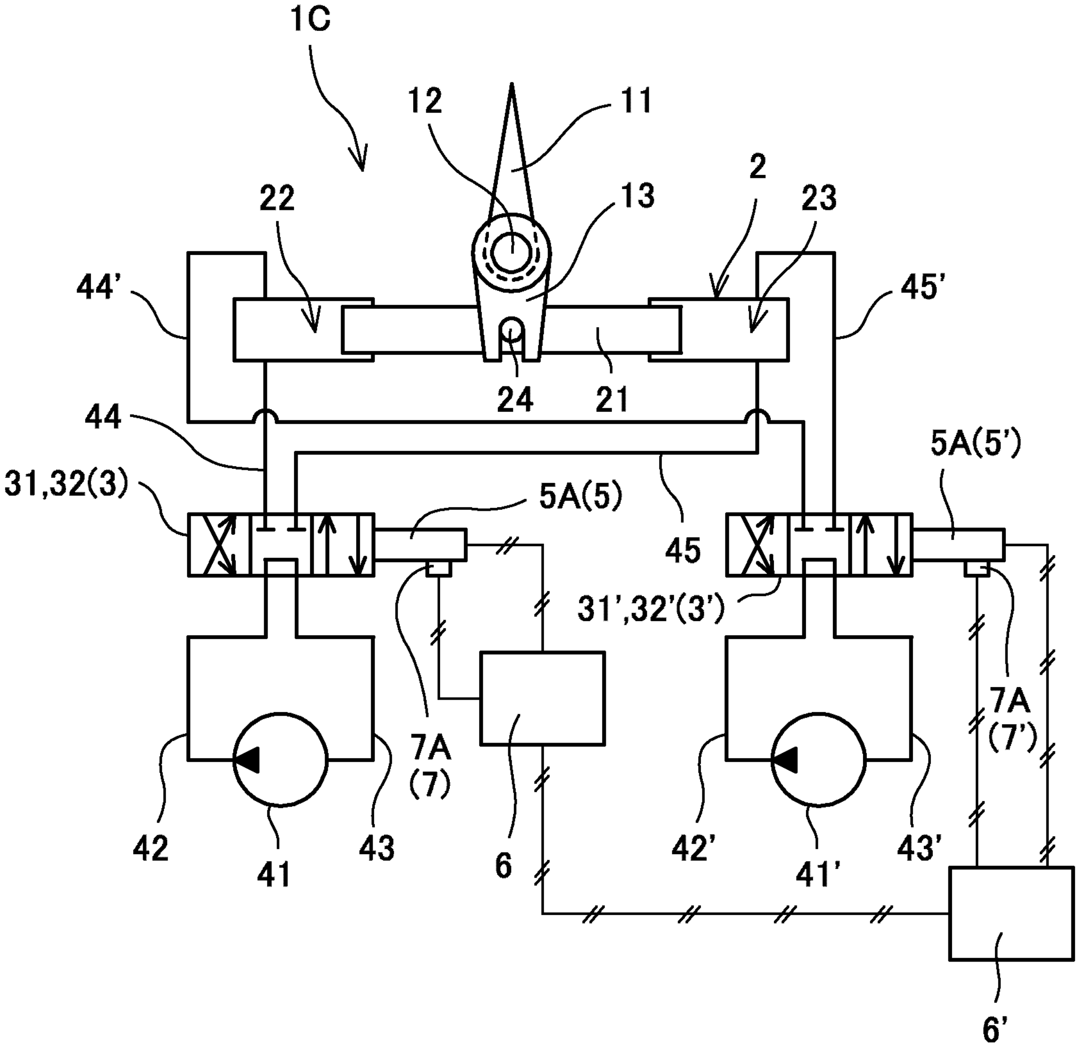


FIG.5


1C
12
11
2
22
13
23
44'
45'
24
21
44
5A(5')
31,32(3)
5A(5)
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31',32'(3')
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(7)
6
7A
(7')
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41
43
42'
41'
43'
6'

FIG.6

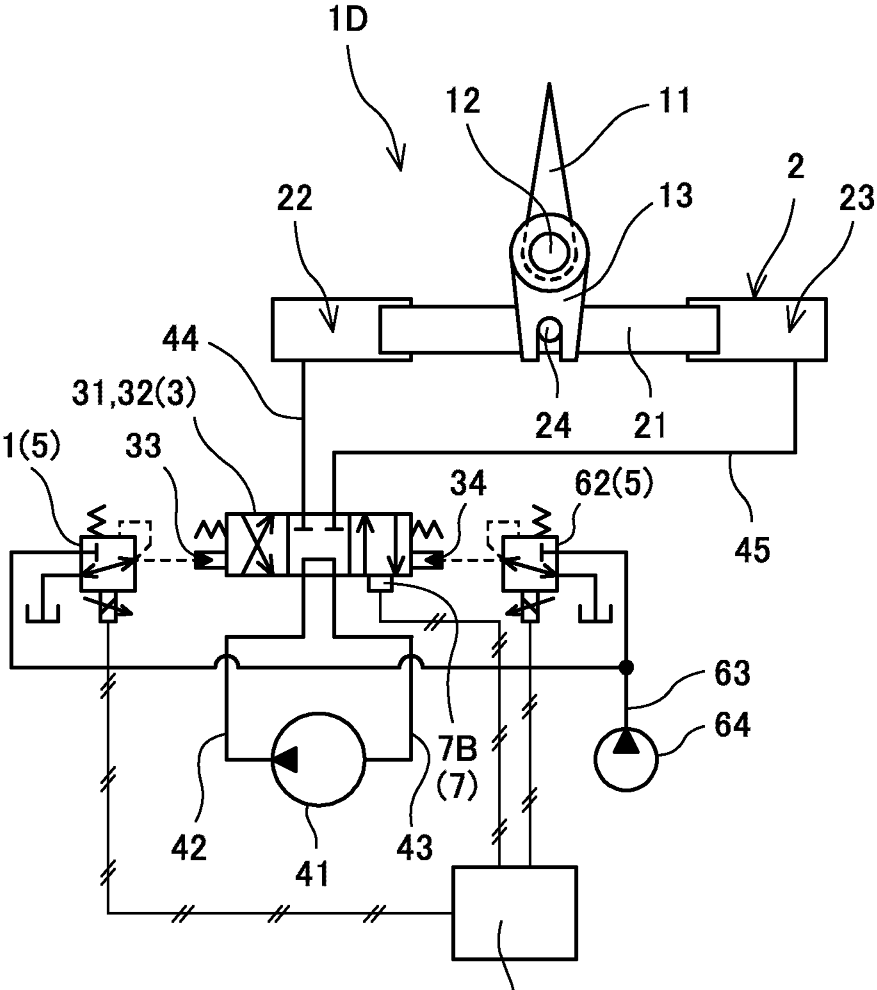
1D
12
11
2
22
13
23
44
31,32(3)
24
21
61(5)
33
34
62(5)
45
63
64
7B
(7)
42
41
43
6

FIG.7

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2021/004064

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. B63H25/08(2006.01)i, B63H25/24(2006.01)i, B63H25/30(2006.01)i
FI: B63H25/24Z, B63H25/30, B63H25/08

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)
Int.Cl. B63H25/08, B63H25/24, B63H25/30

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	CN 203372387 U (YANG, G. G.) 01 January 2014 (2014-01-01), paragraphs [0016]-[0023], fig. 1, 2	1, 13 4-5 2-3, 6-12
Y	JP 2005-90732 A (KOREA MACH RES INST) 07 April 2005 (2005-04-07), paragraphs [0016]-[0025], fig. 3, 4	4-5
A	JP 2013-107447 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 06 June 2013 (2013-06-06)	1-13
A	JP 6-156386 A (SHOWA CORPORATION) 03 June 1994 (1994-06-03)	1-13
A	US 5857488 A (KOBELT, J.) 12 January 1999 (1999-01-12)	1-13

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

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 01 April 2021	Date of mailing of the international search report 20 April 2021
Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/004064

CN 203372387 U	01 January 2014	(Family: none)
JP 2005-90732 A	07 April 2005	US 2005/0062003 A1 paragraphs [0022]-[0032], fig. 3, 4
JP 2013-107447 A	06 June 2013	CN 103764496 A
JP 6-156386 A	03 June 1994	(Family: none)
US 5857488 A	12 January 1999	(Family: none)

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H0976997 A **[0005]**