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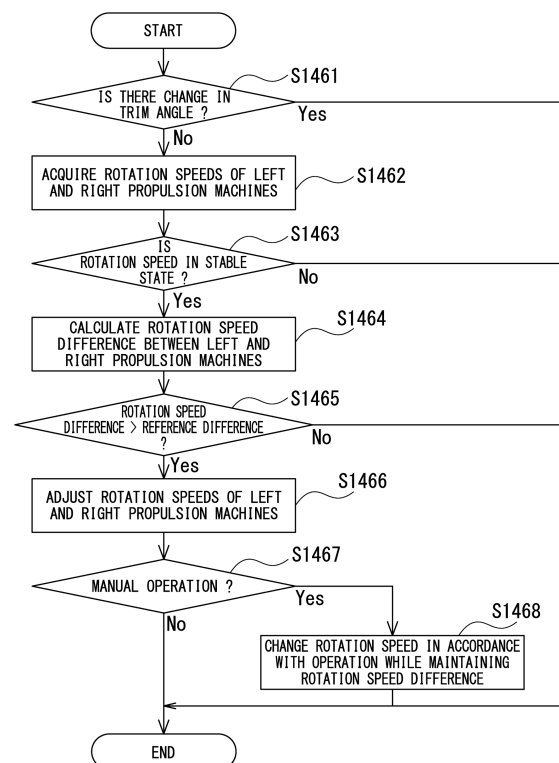
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(54) **PROPULSION SYSTEM OF BOAT**

(57) A propulsion system of a boat includes: at least one propulsion machine provided on each of both sides in a left-right direction with respect to a center of a hull; a rotation speed sensor configured to detect a rotation speed of a propulsor of the propulsion machine; a trim angle adjuster configured to adjust a trim angle of each of the propulsion machines on the both sides in the left-right direction with respect to the hull; and a controller configured to control the trim angle adjuster, in which while conducting the heel control, in a case where a difference in rotation speed between the propulsion machines on the both sides in the left-right direction detected by the rotation speed sensor is equal to or larger than a preset reference difference, the controller adjusts rotation speeds of the propulsion machines to reduce the difference in the rotation speed between the propulsion machines on the both sides in the left-right direction.

FIG. 10



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Description

BACKGROUND OF THE INVENTION

[0001] Priority is claimed on Japanese Patent Application No. 2025-057496, filed March 31, 2025, the content of which is incorporated herein by reference.

Field of the Invention

[0002] The present invention relates to a propulsion system of a boat.

Description of Related Art

[0003] Various techniques for automatically controlling a propulsion system of a boat have been conventionally proposed in order to improve stability, acceleration, a maximum speed, energy efficiency, and the like, in navigating the boat.

[0004] For example, Japanese Patent No. 5059392 discloses a constitution related to heel control of controlling a heel angle of a boat. In this constitution, in a case where it is determined that the boat is not in a turning state in accordance with the steering angle of the steering mechanism of the boat, the heel angle of the boat is increased in a direction corresponding to the steering angle of the steering mechanism by generating a difference between left lift force and right lift force of the boat.

SUMMARY OF THE INVENTION

[0005] In conducting the heel control, by the way, the plurality of propulsion machines provided on the left and right of the hull are made to have different trim angles with respect to the hull. In this situation, the operation resistances of the propulsors such as the propellers provided in the propulsion machines may be different between the left and right propulsion machines depending on the magnitude of the trim angle.

[0006] For example, when the propulsion machine is inclined rearward in a propulsion direction of the boat with respect to the hull, the thrust generated by the propulsion machine works obliquely downward and rearward in the propulsion direction. Then, the operation resistance of the propulsion machine increases as compared with a case where the thrust is applied rearward in the propulsion direction of the boat without inclining the propulsion machine rearward in the propulsion direction.

[0007] In addition, for example, when the propulsion machine is inclined forward in the propulsion direction of the boat with respect to the hull, the thrust generated by the propulsion machine works obliquely upward and rearward in the propulsion direction. Then, the distance to the water surface is shorter than that of a case where the thrust is applied rearward in the propulsion direction of the boat without inclining the propulsion machine rearward in the propulsion direction. Hence, the operation

resistance of the propulsion machine becomes small.

[0008] When the operation resistances received by the propulsors are different between the left and right propulsion machines, a difference in the rotation speed between the left and right propulsion machines may occur. Then, the operation sounds generated by the left and right propulsion machines will be different. Further, in the rotation speed meter for displaying the rotation speeds of the left and right propulsion machines, the difference in the rotation speed between the left and right propulsion machines is displayed. As a result, the boat operator may recognize that there is the difference in rotation speed between the right and left propulsion machines, and may have an uneasy feeling.

[0009] The present invention has been made in view of the above circumstances, and it is an object of the present invention to provide a propulsion system of a boat capable of suppressing an uneasy feeling of a boat operator, while conducting heel control.

[0010] In order to solve the above problems, the present disclosure adopts the following aspects.

(1) A propulsion system of a boat according to one aspect of the present disclosure, includes:

at least one propulsion machine including a drive source, and a propulsor configured to generate thrust with dynamic power transmitted from the drive source, the at least one propulsion machine being provided on each of both sides in a left-right direction with respect to a center of a hull;

a rotation speed sensor configured to detect a rotation speed of the propulsor of the propulsion machine;

a trim angle adjuster configured to adjust a trim angle of each of the propulsion machines on the both sides in the left-right direction with respect to the hull; and

a controller configured to control the trim angle adjuster, in which

the controller is capable of conducting heel control of causing the trim angle adjuster to adjust the trim angle to a heel suppression angle set in accordance with an inclination in a roll direction of the hull to suppress the inclination in the roll direction of the hull, and

while conducting the heel control, in a case where a difference in rotation speed between the propulsion machines on the both sides in the left-right direction detected by the rotation speed sensor is equal to or larger than a preset reference difference, the controller adjusts rotation speeds of the propulsion machines to reduce the difference in the rotation speed between the propulsion machines on the both sides in the left-right direction.

(2) In the propulsion system of the boat according to the above aspect (1), the controller may decrease the rotation speed of one of the propulsion machines having a higher rotation speed, out of the propulsion machines on the both sides in the left-right direction, to approach the rotation speed of the other one of the propulsion machines having a lower rotation speed.

(3) In the propulsion system of the boat according to the above aspect (1) or (2), in a case where it is determined that the rotation speeds of the propulsion machines on the both sides in the left-right direction each are in a stable state, the controller may adjust the rotation speeds of the propulsion machines on the both sides in the left-right direction.

(4) In the propulsion system of the boat according to the above aspect (3), in each of the propulsion machines on the both sides in the left-right direction, in a case where a fluctuation range of the rotation speed within a predetermined period of time is smaller than a preset reference fluctuation range, the controller may determine that the rotation speeds of the propulsion machines on the both sides in the left-right direction each are in the stable state.

(5) The propulsion system of the boat according to one of the above aspects (1) to (4) may further include a throttle operation inputter configured to adjust the rotation speeds of the propulsion machines in accordance with an external input, in which upon receipt of an operation input from the throttle operation inputter, while adjusting the rotation speeds of the propulsion machines to reduce the difference in the rotation speed between the propulsion machines on the both sides in the left-right direction, the controller may adjust the rotation speeds of the propulsion machines in accordance with the operation input from the throttle operation inputter while maintaining the difference in the rotation speed between the propulsion machines at a time of receiving the operation input.

(6) In the propulsion system of the boat according to one of the above aspects (1) to (5), in a case where it is determined that the hull is advancing straight, the controller may enable conducting the heel control.

(7) The propulsion system of the boat according to the above aspect (6) may further include a heel angle detector configured to detect a heel angle serving as an inclination in a roll direction of the hull, in which in a case where the heel angle is equal to or larger than a preset heel angle reference value, the controller may conduct the heel control.

(8) In the propulsion system of the boat according to one of the above aspects (1) to (7), in a case where it is determined that the hull is in a turning state while conducting the heel control, the controller may stop conducting the heel control.

(9) In the propulsion system of the boat according to one of the above aspects (1) to (8), the controller may be capable of conducting trim support control of

causing the trim angle adjuster to adjust the trim angle to a trim support angle set in accordance with either a preset boat speed or the rotation speed of the propulsion machine, and in a case where a preset condition is satisfied, the controller may conduct, in addition to the trim support control, the heel control of causing the trim angle adjuster to adjust the propulsion machine to the heel suppression angle set with reference to the trim support angle of the propulsion machine.

[0011] According to the aspect (1), while conducting the heel control, in a case where the difference in the rotation speed between the propulsion machines on both sides in the left-right direction is equal to or larger than the preset reference difference, the rotation speed of the propulsion machine is adjusted to reduce the difference in the rotation speed between the propulsion machines on both sides in the left-right direction. Thus, in a case where the difference in the rotation speed between the propulsion machines on both sides in the left-right direction increases, it becomes possible to reduce the difference in the rotation speed by conducting the heel control. Therefore, it becomes possible to suppress an uneasy feeling of the boat operator due to the difference in the rotation speed between the propulsion machines on both sides in the left-right direction.

[0012] According to the aspect (2), the rotation speed of one propulsion machine having a higher rotation speed, out of the propulsion machines on both sides in the left-right direction, is decreased to approach the rotation speed of the other propulsion machine having a lower rotation speed. Thus, the thrust generated by one propulsion machine having a higher rotation speed decreases, so that the influence on the behavior of the hull can be suppressed by the heel control, and in addition, an increase in the rotation speed that is not intended by the boat operator can be prevented. As a result, an uneasy feeling of the boat operator can be suppressed.

[0013] According to the aspect (3), in a case where it is determined that the rotation speeds of the propulsion machines on both sides in the left-right direction each are in a stable state, the rotation speed of the propulsion machine is adjusted. Thus, it becomes possible to adjust the rotation speeds of the propulsion machines in a state in which the behavior of the hull is stable, so that an uneasy feeling of the boat operator can be suppressed.

[0014] According to the aspect (4), in each of the propulsion machines on both sides in the left-right direction, in a case where the fluctuation range of the rotation speed of the propulsion machine within a predetermined period of time is smaller than a preset reference fluctuation range, it is determined that the rotation speed of the propulsion machine is in the stable state. Thus, it becomes possible to easily determine whether the rotation speeds of the propulsion machines on both sides in the left-right direction each are in the stable state, so that the rotation speeds of the propulsion machines can be ad-

justed smoothly.

[0015] According to the aspect (5), while the rotation speed of the propulsion machine is being adjusted, upon receipt of the operation input from the throttle operation inputter, the rotation speed of the propulsion machine is adjusted in accordance with the operation input from the throttle operation inputter while maintaining the difference in the rotation speed between the propulsion machines at the time of receiving the operation input. Thus, it becomes possible to continue an adjustment state of the rotation speed of the propulsion machine in accordance with the operation input intended by the boat operator. Therefore, it becomes possible to satisfactorily adjust the imbalance in the rotation speed between the propulsion machines while suppressing an uneasy feeling of the boat operator.

[0016] According to the aspect (6), conducting the heel control is enabled in a case where it is determined that the boat is advancing straight. Thus, while the boat is advancing straight, it becomes possible to smoothly conduct the heel control, so that the stability, the acceleration, the maximum speed, the energy efficiency, and the like can be improved.

[0017] According to the aspect (7), the heel control is conducted in a case where the heel angle is equal to or larger than the preset heel angle reference value. Thus, as the preset conditions, while the boat is advancing straight and in the case where the heel angle is large, it becomes possible to suppress the heel angle, so that the stability, the acceleration, the maximum speed, the energy efficiency, and the like of the boat can be improved.

[0018] According to the aspect (8), conducting the heel control is stopped in a case where it is determined that the boat is in the turning state, based on the input value of the steering angle. Accordingly, in the case where the boat is in the turning state, it becomes possible to suppress inhibition of the turning property due to the heel control.

[0019] According to the aspect (9), in the case where the preset condition is satisfied, the heel control is conducted in addition to the trim support control, and the trim angle adjuster is caused to adjust the propulsion machine to the heel suppression angle set with reference to the trim support angle of the propulsion machine. Accordingly, in the case where the preset condition is satisfied, the heel control is conducted in addition to the trim support control, and thus it becomes possible to suppress the heel angle of the boat while automatically adjusting the trim angle. Therefore, the stability, the acceleration, the maximum speed, the energy efficiency, and the like of the boat can be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

FIG. 1 is a plan view of a boat according to an embodiment;

FIG. 2 is a functional block diagram of a propulsion system of the above boat;

FIG. 3 is a side view of a propulsion machine of the above propulsion system;

FIG. 4 is a diagram illustrating an example of trim support control, heel control, hump control, and bogen control to be conducted in accordance with a boat speed in the above propulsion system;

FIG. 5 is a diagram illustrating an example of a set value of a trim support angle in the trim support control, the heel control, and the hump control to be conducted in accordance with the boat speed in above the propulsion system;

FIG. 6 is a view illustrating a state in which the trim support control is being conducted in the above propulsion system;

FIG. 7 is a view illustrating a state of conducting the heel control in a state in which the above boat is inclined to a port side;

FIG. 8 is a view illustrating a state of conducting the heel control in a state in which the above boat is inclined to a starboard side;

FIG. 9 is a flowchart illustrating a method for conducting the heel control while conducting the trim support control;

FIG. 10 is a flowchart illustrating a processing flow of rotation speed adjustment control for the propulsion machines to be conducted while the heel control is being conducted in the above propulsion system;

FIG. 11 is a timing chart illustrating an example of the operation of the above propulsion system; and

FIG. 12 is a timing chart illustrating another example of the operation of the above propulsion system.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Hereinafter, embodiments of the present invention will be described with reference to the drawings. Note that it is assumed that front, rear, upper, lower, left, and right directions in the following description respectively coincide with the directions of a boat 1. In this case, an arrow FR in the drawing indicates a forward side of the boat 1, an arrow UP in the drawing indicates an upper side of the boat 1, and an arrow LH in the drawing indicates a leftward side of the boat 1. In addition, a center line CL indicates the center position of the boat 1 in a left-right direction (a width direction).

[0022] FIG. 1 is a plan view of the boat according to an embodiment. FIG. 2 is a functional block diagram of a propulsion system of the boat.

[0023] As illustrated in FIG. 1, the boat 1 includes: a hull 2; and a propulsion system 20, which is provided on the hull 2.

[0024] As illustrated in FIGS. 1 and 2, the propulsion system 20 includes a plurality of propulsion machines 3, an operation unit 7, a detector 6 (see FIG. 2), and a controller 8 (see FIG. 2).

(Propulsion Machine)

[0025] As illustrated in FIG. 1, the propulsion machine 3 includes: a right propulsion machine 3a, which is provided on the right of a stern 2b with respect to the center line CL; and a left propulsion machine 3b, which is provided on the left of the stern 2b, with respect to the center line CL. The two propulsion machines 3 (the right propulsion machine 3a and the left propulsion machine 3b) are respectively provided on the stern 2b of the hull 2 on both sides in the left-right direction of the stern 2b, interposing the center line CL between them. That is, the boat 1 in the present embodiment is a so-called small-sized boat in which the two propulsion machines are provided. Hereinafter, in a case where it is not necessary to distinguish between the propulsion machines 3a and 3b, they will be collectively described as the propulsion machine 3.

[0026] FIG. 3 is a side view of a propulsion machine of the propulsion system.

[0027] As illustrated in FIG. 3, the propulsion machine 3 is, for example, an outboard motor. The propulsion machine 3 includes: a casing 31; a drive source 32; a drive shaft 33; a propulsor 34; and a shift switching mechanism 35.

[0028] The casing 31 is attached to a bracket 22, which is provided on the stern 2b, via a steering shaft (a swivel shaft) 36, which extends in an up-down direction. The propulsion machine 3 is attached to the hull 2 so as to be rotatable around the steering shaft 36 in accordance with the operation of a steering actuator 41 (see FIG. 2).

[0029] The drive source 32 is, for example, an internal combustion engine such as an engine. The drive source 32 is accommodated in an upper portion of the casing 31 with a crankshaft extending in the up-down direction. Dynamic power (an engine speed) of the drive source 32 is set, based on an opening degree of a throttle valve. The throttle valve is driven by the operation of a throttle actuator 42 (see FIG. 2). Note that the drive source 32 may be an electric motor.

[0030] The drive shaft 33 transmits the dynamic power generated by the drive source 32 to the propulsor 34 via the shift switching mechanism 35. The drive shaft 33 extends in the up-down direction in the casing 31. An upper end portion of the drive shaft 33 is connected with the drive source 32.

[0031] The propulsor 34 includes a propeller shaft 341 and propellers 342.

[0032] The propeller shaft 341 is provided at a lower end portion of the casing 31 so as to be rotatable around an axis along a front-rear direction. A front end portion of the propeller shaft 341 is connected with the shift switching mechanism 35 in the casing 31.

[0033] The propellers 342 are provided projecting outside of the casing 31 at a rear end portion of the propeller shaft 341. The propellers 342 rotate integrally with the propeller shaft 341.

[0034] The shift switching mechanism 35 includes a

drive gear 351, a forward gear 352, a reverse gear 353, and a clutch 354.

[0035] The drive gear 351 is provided at a lower end portion of the drive shaft 33. The drive gear 351 is rotatable integrally with the drive shaft 33.

[0036] The forward gear 352 and the reverse gear 353 are rotatably provided at positions facing each other in the front-rear direction, interposing the drive gear 351 between them on the propeller shaft 341. The forward gear 352 and the reverse gear 353 are capable of meshing with the drive gear 351. The forward gear 352 and the reverse gear 353 rotate in opposite directions to each other in accordance with the rotation of the drive gear 351.

[0037] The clutch 354 switches between a connection state and a disconnection state of the dynamic power between either the forward gear 352 or the reverse gear 353 and the propeller shaft 341. The clutch 354 is provided to be rotatable integrally with the propeller shaft 341. The clutch 354 is provided to be movable in the front-rear direction along the propeller shaft 341 in accordance with the operation of a shift actuator 43. The clutch 354 alternatively meshes with the forward gear 352 and the reverse gear 353 to switch the rotation directions of the propeller shaft 341 and the propellers 342, and is capable of switching the propulsion direction of the boat 1.

[0038] The propulsion machine 3 is supported by the bracket 22, which is attached to the stern 2b of the hull 2, so as to be rotatable around a support shaft 38, which extends in the left-right direction. This enables the propulsion machine 3 to be rotatable (swingable) around the support shaft 38 with respect to a reference plane Fv. Here, the reference plane Fv denotes a virtual plane along a vertical plane that passes through the center axis of the support shaft 38 when the hull 2 is simply floated on the water surface.

[0039] Here, a trim angle θ_t is defined as an angle at which the direction in which the steering shaft 36 of the propulsion machine 3 extends is inclined in the front-rear direction around the support shaft 38 with respect to the reference plane Fv. In the present embodiment, with regard to the trim angle θ_t , a positive (plus) direction represents a direction in which a lower end portion of the propulsion machine 3 is apart rearward from the stern 2b, and a negative (minus) direction represents a direction in which the lower end portion of the propulsion machine 3 approaches the stern 2b.

[0040] The trim angle θ_t of the propulsion machine 3 is adjustable by a trim angle adjuster 45. The trim angle adjuster 45 uses an actuator, not illustrated, to rotate the propulsion machine 3 around the support shaft 38 within a preset angle range. The rotation of the propulsion machine 3 in the positive direction and the negative direction is restricted by hitting a stopper, not illustrated, or the like provided on the bracket 22.

[0041] In the present embodiment, the bracket 22 is attached to an attachment surface 2f, which is formed on the stern 2b, via an intermediate member 37. The inter-

mediate member 37 is sandwiched between the bracket 22 and the attachment surface 2f. The intermediate member 37 is formed in a wedge shape having a thickness in the front-rear direction gradually decreasing from the top to the bottom. Thus, the bracket 22 is provided to be further inclined rearward than a case of being directly attached to the attachment surface 2f without the use of the intermediate member 37. This constitution enables setting of a larger rotation angle (rotation range) of the propulsion machine 3 in the negative direction.

[0042] In the present embodiment, the propulsion machine 3 is rotatable within a range between about 20 degrees at maximum in the positive direction and about -10 degrees at maximum in the negative direction with respect to the reference plane Fv, for example.

(Operation Unit)

[0043] As illustrated in FIGS. 1 and 2, the operation unit 7 is provided to allow a boat operator to perform an operation input in order to navigate the boat 1. In the present embodiment, in the operation unit 7, for example, a steering angle inputter 71, a thrust inputter (a throttle operation inputter) 72, a trim angle operation unit 73 (see FIGS. 2 and 3), and an operation inputter 74 are provided.

[0044] The steering angle inputter 71 is provided in a cockpit of the hull 2. The steering angle inputter 71 is, for example, a steering wheel provided to be rotatable clockwise and counterclockwise. The steering angle inputter 71 receives an operation input by the boat operator from the outside, in changing the course of the boat 1 (the hull 2). That is, the steering angle inputter 71 receives an operation, by the boat operator, for changing the direction (the steering angle) of the propulsion machine 3 around the steering shaft 36. The steering angle denotes an inclination angle of the propulsion machine 3 with respect to the center line CL in a plan view. In the present embodiment, the steering angle of the propulsion machine 3 when the course of the boat 1 is the straight advancing direction is set as the reference value (0 degrees). Note that as the steering angle inputter 71, in addition to the steering wheel, a joystick may be used, and the steering angle inputter 71 may be mounted as a switch or the like of the operation inputter 74.

[0045] The thrust inputter 72 is provided in the cockpit of the hull 2. The thrust inputter 72 is, for example, a throttle lever. In changing the thrust of the propulsion machine 3 or the shift position of the propulsion machine 3, the thrust inputter 72 receives an operation input from the outside by the boat operator. The thrust inputter 72 is constituted to be displaceable by rotation, sliding, or the like. The thrust inputter 72 is capable of reciprocating within an operation region in which three shift regions of the forward position F, the neutral position N, and the reverse position R are aligned. When the thrust inputter 72 is located at the forward position F, the propulsion machine 3 exerts thrust for moving the boat 1 forward. When the thrust inputter 72 is located at the reverse

position R, the propulsion machine 3 exerts thrust for moving the boat 1 rearward.

[0046] The thrust inputter 72 adjusts the rotation speed of the propulsor 34 in accordance with its displacement amount, and is capable of adjusting the thrust generated by the propulsion machine 3, in moving the boat 1 forward or rearward.

[0047] When the thrust inputter 72 is located at the neutral position N, the drive gear 351, which is illustrated in FIG. 3, is disconnected from the forward gear 352 and the reverse gear 353, and the propulsion machine 3 does not exert thrust for propelling the boat 1.

[0048] As illustrated in FIG. 1, a trim angle operation switch is provided as the trim angle operation unit 73 in the vicinity of the thrust inputter 72. The boat operator of the boat 1 is able to change the trim angle θ_t of the propulsion machine 3 by manually operating the trim angle operation switch (the trim angle operation unit 73).

[0049] The operation inputter 74 receives various operations on the boat 1. The operation inputter 74 is constituted to be manually operable by the boat operator, such as a multi-function display (MFD). Note that the operation inputter 74 may be an external device such as a mobile terminal connected to the boat 1 in a wired or wireless manner.

(Detector)

[0050] The detector 6 illustrated in FIG. 2 detects a state (a navigation state) of the boat 1. In the present embodiment, the detector 6 includes a position sensor 61, a boat speed sensor 62, a steering angle sensor 63, an inertial sensor (a heel angle detector) 64, a trim operation sensor 65, a trim angle sensor 66, an actual steering angle sensor 67, and a rotation speed sensor 68.

[0051] The position sensor 61 detects the position of the thrust inputter 72. The position sensor 61 outputs, to the controller 8, a detection signal based on the position of the thrust inputter 72.

[0052] The boat speed sensor 62 detects a boat speed V of the boat 1. The boat speed sensor 62 is, for example, a global positioning system (GPS) or the like, and calculates the boat speed V, based on a positioning signal from a positioning satellite. Note that the boat speed sensor 62 may be an acoustic sensor or an electromagnetic sensor that detects the boat speed (a boat speed relative to the water) V of the boat 1. The boat speed sensor 62 may estimate the boat speed V, based on the engine speed. The boat speed sensor 62 outputs a signal indicating the detected boat speed V to the controller 8.

[0053] The steering angle sensor 63 detects an operation amount (a steering instruction angle) in accordance with the rotation operation on the steering angle inputter 71. The steering angle sensor 63 outputs, to the controller 8, a detection signal based on the steering instruction angle on the steering angle inputter 71.

[0054] The inertial sensor 64 detects the inclination in the roll direction of the hull 2, that is, a heel angle θ_h . The

inertial sensor 64 is also capable of detecting an inclination or the like in the pitch direction of the hull 2. The inertial sensor 64 outputs, to the controller 8, detection signals based on the detected inclinations in the roll direction and the pitch direction of the hull 2.

[0055] The trim operation sensor 65 detects whether an operation input from the outside has been made on the trim angle operation switch, which serves as the trim angle operation unit 73. The trim operation sensor 65 outputs, to the controller 8, a detection signal indicating the presence or absence of the detected operation input.

[0056] The trim angle sensor 66 is provided in the trim angle adjuster 45. The trim angle sensor 66 detects an actual trim angle θ_t to be adjusted by the trim angle adjuster 45. The trim angle sensor 66 outputs, to the controller 8, a detection signal indicating the detected trim angle θ_t .

[0057] The actual steering angle sensor 67 is provided on the steering actuator 41. The actual steering angle sensor 67 detects the actual steering angle of the propulsion machine 3, and outputs the actual steering angle to the controller 8.

[0058] The rotation speed sensor 68 detects the rotation speed of the propulsor 34 in each of the plurality of propulsion machines 3. The rotation speed sensor 68 outputs, to the controller 8, a detection signal indicating the detected rotation speed of the propulsor 34.

(Controller)

[0059] The controller 8 integrally controls the operation of the boat 1 (the propulsion machine 3). The controller 8 is an integrated electronic control device or a plurality of electronic control devices included in the boat 1. The controller 8 is implemented by, for example, a hardware processor such as a central processing unit (CPU) executing a program (software) stored in a storage 80 such as a read only memory (ROM), a random access memory (RAM), or the like. Some or all of these constituent elements may be implemented by a hardware (a circuit part; including circuitry) such as a large scale integration (LSI), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a graphics processing unit (GPU), or system on chip (SOC), or may be implemented by software and hardware in cooperation.

[0060] The controller 8 includes a storage 80, an acquirer 81, a determiner 82, and a drive processor 83.

[0061] The storage 80 records programs, various data, and the like necessary for navigation of the boat 1, such as the trim support control, the heel control, the hump control, and the bogen control.

[0062] The acquirer 81 acquires detection results of various sensors of the detector 6.

[0063] The determiner 82 determines the state of the boat 1, based on information obtained by the acquirer 81 and information stored in the storage 80.

[0064] The drive processor 83 controls operations of various actuators, based on a determination result by the

determiner 82 and the information stored in the storage 80 or the acquirer 81. In the present embodiment, when the determiner 82 determines that a predetermined control conducting condition is satisfied, the drive processor 83 controls the operations of the trim angle adjuster 45, the steering actuator 41, and the like to conduct the trim support control, the heel control, the hump control, and the bogen control. In the present embodiment, when the boat 1 is in a straight advancing state, the drive processor 83 conducts the trim support control, the heel control, the hump control, and the bogen control. In the present embodiment, the drive processor 83 does not conduct the bogen control, when the boat 1 is not in the straight advancing state.

(Trim Support Control)

[0065] FIG. 4 is a diagram illustrating an example of the trim support control, the heel control, the hump control, and the bogen control to be conducted in accordance with the boat speed in the propulsion system.

[0066] As illustrated in FIG. 4, when the boat 1 is in the straight advancing state, the drive processor 83 conducts the trim support control in the regions of the heel control, the hump control, and the bogen control, for example, in accordance with a setting of the boat operator through the input from the trim angle operation unit 73 and the operation inputter 74.

[0067] FIG. 5 is a diagram illustrating an example of set values of the trim support angles in the trim support control, the heel control, and the hump control to be conducted in accordance with the boat speed in the propulsion system.

[0068] As illustrated in FIG. 5, in the trim support control, the trim angle adjuster 45 is caused to adjust a trim angle θ_t to be a trim support angle θ_{sp} , which is set in accordance with a preset boat speed V (or rotation speed of the propulsion machine). In the present embodiment, in conducting the trim support control, the trim support angle θ_{sp} is set in accordance with the boat speed V to optimize stability, acceleration, a maximum speed, energy efficiency, and the like. The trim support angle θ_{sp} may be set in accordance with the rotation speed of the propulsion machine. Therefore, in the storage 80, the boat speed V (or the rotation speed of the propulsion machine) and the trim support angle θ_{sp} , at which the stability, the acceleration, the maximum speed, the energy efficiency, and the like are optimized, are stored beforehand in association with each other. In the example of FIG. 5, the trim support angle θ_{sp} is set in a stepwise manner with respect to the boat speed V (or the rotation speed of the propulsion machine).

[0069] The drive processor 83 acquires, from the storage 80, the trim support angle θ_{sp} , which is associated with the boat speed acquired by the acquirer 81.

[0070] The drive processor 83 controls the trim angle adjuster 45 so that the trim angle θ_t of the propulsion machine 3 approaches the acquired trim support angle

θ_{sp} .

[0071] FIG. 6 is a view illustrating a state in which the trim support control is being conducted in the propulsion system.

[0072] As illustrated in FIG. 6, in conducting the trim support control, the drive processor 83 sets the trim support angles θ_{sp} of the propulsion machines 3a and 3b on both sides in the left-right direction to the same value.

(Heel Control)

[0073] As illustrated in FIG. 4, when the boat 1 is in the straight advancing state and the boat speed V is equal to or higher than a second threshold V2, while the trim support control is being conducted, and in a case where the determiner 82 determines that a preset first condition (a preset condition) is satisfied, the drive processor 83 conducts the heel control in addition to the trim support control. Specifically, when the boat 1 is in the straight advancing state, while the trim support control is being conducted, and when the boat speed becomes equal to or higher than the second threshold V2, the drive processor 83 conducts the heel control in addition to the trim support control, that is, both the trim support control and the heel control.

[0074] In this case, the drive processor 83 conducts the heel control, in a case where the heel angle θ_h , which is detected by the inertial sensor 64, and which is the inclination in the roll direction of the hull 2, is equal to or larger than a preset heel angle reference value θ_{hs} (for example, several degrees). That is, in a case where the heel angle θ_h is smaller than the heel angle reference value θ_{hs} , the drive processor 83 continuously conducts the trim support control without conducting the heel control.

[0075] In conducting the heel control, the drive processor 83 sets a heel suppression angle θ_d as a target value in accordance with the heel angle θ_h of the hull 2. Here, the heel suppression angle θ_d denotes a trim angle of the propulsion machines 3 on both sides in the left-right direction for suppressing the inclination in the roll direction of the hull 2. The drive processor 83 calculates a heel suppression angle θ_d , which is capable of effectively suppressing the inclination in the roll direction of the hull 2, in accordance with the heel angle θ_h of the hull 2 in a preset calculation formula.

[0076] The drive processor 83 sets the heel suppression angle θ_d with reference to the trim support angle θ_{sp} of the propulsion machine 3 at such a timing. With regard to the trim support angle θ_{sp} , the drive processor 83 sets the heel suppression angle θ_d of the propulsion machine 3 on one side in the left-right direction to a value larger than the trim support angle θ_{sp} , and also sets the heel suppression angle θ_d of the propulsion machine 3 on the other side in the left-right direction to a value smaller than the trim support angle θ_{sp} .

[0077] FIG. 7 is a view illustrating a state of conducting

the heel control in a state in which the boat is inclined to the port side. FIG. 8 is a view illustrating a state of conducting the heel control in a state in which the boat is inclined to the starboard side.

[0078] For example, as illustrated in FIG. 7, when the hull 2 is inclined to the port side, the drive processor 83 sets a heel suppression angle θ_{d2} of the right propulsion machine 3a to a value larger than the trim support angle θ_{sp} , and sets a heel suppression angle θ_{d1} of the left propulsion machine 3b to a value smaller than the trim support angle θ_{sp} . For example, as illustrated in FIG. 8, when the hull 2 is inclined to the starboard side, the drive processor 83 sets the heel suppression angle θ_{d1} of the left propulsion machine 3b to a value larger than the trim support angle θ_{sp} , and sets the heel suppression angle θ_{d2} of the right propulsion machine 3a to a value smaller than the trim support angle θ_{sp} .

[0079] The drive processor 83 calculates the heel suppression angles θ_{d1} and θ_{d2} with reference to the trim support angle θ_{sp} set at such a timing, based on the heel angle θ_h of the hull 2 at such a timing that has been acquired by the acquirer 81. The drive processor 83 calculates, in a preset calculation formula, a trim angle addition value $\Delta\theta_{t1}$ to be added to the trim support angle θ_{sp} as a reference for the propulsion machine 3 on one side in the left-right direction and a trim angle subtraction value $\Delta\theta_{t2}$ to be subtracted from the trim support angle θ_{sp} as a reference for the propulsion machine 3 on the other side in the left-right direction. Here, the absolute value of the trim angle addition value $\Delta\theta_{t1}$ and the absolute value of the trim angle subtraction value $\Delta\theta_{t2}$ are preferably identical to each other. Here, the absolute value of the trim angle addition value $\Delta\theta_{t1}$ and the absolute value of the trim angle subtraction value $\Delta\theta_{t2}$ are set to be equal to or smaller than a preset value. Note that the absolute value of the trim angle addition value $\Delta\theta_{t1}$ and the absolute value of the trim angle subtraction value $\Delta\theta_{t2}$ may be different from each other.

[0080] When the hull 2 is inclined to the port side, the drive processor 83 calculates the heel suppression angle θ_{d1} of the left propulsion machine 3b in the following equation (1), and calculates the heel suppression angle θ_{d2} of the right propulsion machine 3a in the following equation (2).

$$\theta_{d1} = \theta_{sp} - \Delta\theta_{t2} \dots (1)$$

$$\theta_{d2} = \theta_{sp} + \Delta\theta_{t1} \dots (2)$$

[0081] When the hull 2 is inclined to the starboard side, the drive processor 83 calculates the heel suppression angle θ_{d1} of the left propulsion machine 3b in the following equation (3), and calculates the heel suppression angle θ_{d2} of the right propulsion machine 3a in the following equation (4).

$$\theta d1 = \theta sp + \Delta \theta t1 \dots (3)$$

$$\theta d2 = \theta sp - \Delta \theta t2 \dots (4)$$

[0082] The drive processor 83 sets the heel suppression angles $\theta d1$ and $\theta d2$ that have been calculated to the target values, and causes the trim angle adjuster 45 to adjust the trim angles θt of the propulsion machines 3 (3a, 3b) so as to approach the heel suppression angles $\theta d1$ and $\theta d2$.

[0083] While conducting the heel control, in a case where the determiner 82 determines that the boat speed V becomes equal to or lower than a preset third threshold V3, the drive processor 83 stops conducting the heel control. Here, the third threshold V3 is set to be lower than the second threshold V2.

[0084] While conducting the heel control, in a case where there is a large difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction, the controller 8 adjusts the rotation speeds of the propulsion machines 3 so that the difference in the rotation speed between both propulsion machines 3 becomes smaller (hereinafter, referred to as rotation speed adjustment control for the propulsion machines 3, in some cases).

[0085] Thus, while conducting the heel control, upon receipt of an input of the detection signal indicating the rotation speed of the propulsor 34 from the rotation speed sensor 68, the determiner 82 calculates an absolute value of the difference between the rotation speed of the propulsor 34 of the right propulsion machine 3a and the rotation speed of the propulsor 34 of the left propulsion machine 3b (hereinafter, simply referred to as a rotation speed difference, in some cases).

[0086] The determiner 82 determines whether a preset start condition of the rotation speed adjustment control for the propulsion machines 3 is satisfied.

[0087] Here, as the start condition of the rotation speed adjustment control for the propulsion machines 3, for example, the following conditions A to C can be presented.

[0088] Condition A: The rotation speed difference that has been calculated is equal to or larger than a preset reference difference.

[0089] Condition B: The rotation speeds of the propulsion machines 3 on both sides in the left-right direction each are in a stable state.

[0090] Condition C: There is no change in the trim angles θt of the propulsion machines 3 on both sides in the left-right direction.

[0091] In a case where all the conditions A to C are satisfied, the determiner 82 determines that the start condition of the rotation speed adjustment control for the propulsion machines 3 is satisfied. Note that as the start condition of the rotation speed adjustment control for the propulsion machines 3, any condition other than the above conditions A to C may be adopted.

[0092] Upon determination that the start condition of the rotation speed adjustment control for the propulsion machines 3 is satisfied, the drive processor 83 adjusts the rotation speeds of the propulsion machines 3 so as to reduce the difference between the rotation speed of the propulsor 34 of the right propulsion machine 3a and the rotation speed of the propulsor 34 of the left propulsion machine 3b. In the present embodiment, out of the propulsor 34 of the right propulsion machine 3a and the propulsor 34 of the left propulsion machine 3b, the rotation speed of one propulsion machine 3 having a higher rotation speed is decreased to approach the rotation speed of the other propulsion machine 3 having a lower rotation speed. The controller 8 preferably sets the rotation speed of the right propulsion machine 3a and the rotation speed of the left propulsion machine 3b to be identical to each other.

[0093] For example, in a case where the rotation speed of the right propulsion machine 3a is higher, the controller 8 decreases the rotation speed of the right propulsion machine 3a to approach the rotation speed of the left propulsion machine 3b. In a case where the rotation speed of the left propulsion machine 3b is higher, the controller 8 decreases the rotation speed of the left propulsion machine 3b to approach the rotation speed of the right propulsion machine 3a.

[0094] As described above, while the rotation speeds of the propulsion machines 3 are being adjusted to reduce the difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction (the propulsion machines 3a and 3b), upon receipt of the operation input by the boat operator from the thrust inputter 72, the controller 8 adjusts the rotation speeds of the propulsion machines 3 in accordance with the operation input from the thrust inputter 72.

[0095] Specifically, the controller 8 adjusts the rotation speeds of the propulsion machines 3 in accordance with the operation input from the thrust inputter 72 while maintaining the difference in the rotation speed between the propulsion machines 3 at the time of receiving the operation input.

[0096] In addition, while conducting the heel control, upon receipt of the input of the steering angle on the steering angle inputter 71 from the steering angle sensor 63, the determiner 82 determines whether the boat 1 is in a turning state, based on the received input value of the steering angle. Upon determination that the boat 1 is in the turning state, the drive processor 83 stops conducting the trim support control and the heel control. In addition, while conducting the heel control, in a case where the determiner 82 determines that the operation input by the boat operator is received from the trim angle operation unit 73, the drive processor 83 stops conducting the heel control.

(Hump Control)

[0097] In addition, as illustrated in FIG. 4, when the

boat 1 is in the straight advancing state and the boat speed V is equal to or higher than the first threshold $V1$, and in a case where the determiner 82 determines that a preset second condition is satisfied, the drive processor 83 conducts the hump control. The drive processor 83 conducts the hump control, when the boat 1 is in the straight advancing state and the boat speed V is equal to or higher than the first threshold $V1$, and in a case where the boat speed V is lower than the second threshold $V2$.
[0098] The hump control is conducted to suppress excessive lifting of a bow 2a when the bow 2a is largely lifted with respect to the stern 2b. In conducting the hump control, the drive processor 83 sets the trim angles θt of the propulsion machines 3a and 3b on both sides in the left-right direction to the same value.

(Bogen Control)

[0099] In addition, in a case where the boat speed V is lower than the first threshold $V1$, the drive processor 83 conducts the bogen control. In the bogen control, the plurality of propulsion machines 3 are steered in a direction intersecting the front-rear direction of the hull 2 in a yaw direction. When the boat 1 is in the straight advancing state and the boat speed V is lower than the first threshold $V1$, the left and right propulsion machines 3 are rotated in directions opposite to each other around the swivel axis and at almost the same steering angle in the bogen control. In the bogen control, it becomes possible to reduce the forward propulsion force that works on the entirety of the hull 2 and to navigate the hull 2 at a low speed or an extremely low speed, as compared with a case where the propulsion machines 3 are disposed in parallel with the front-rear direction of the hull 2. Note that in the present embodiment, there is no limitation to the specific content of the bogen control.

(Control Method of Propulsion System)

[0100] Next, a control method of the propulsion system will be described. Processing to be described below is repeatedly performed, for example, at a predetermined control cycle (for example, several tens of milliseconds).

[0101] Here, the trim support control is conducted at an appropriate timing in accordance with a setting of the boat operator. In the trim support control, the controller 8 sets the trim support angle θ_{sp} , at which the stability, the acceleration, the maximum speed, the energy efficiency, and the like are optimized, as the target value in accordance with the boat speed V . The controller 8 controls the trim angle adjuster 45 so that the trim angles θt of the propulsion machines 3 on both sides in the left-right direction approach the trim support angles θ_{sp} , which are set as the target values.

[0102] FIG. 9 is a flowchart illustrating a method for conducting the heel control while conducting the trim support control.

[0103] While conducting the trim support control, the

controller 8 causes the acquirer 81 to acquire a detection result of the boat speed in the boat speed sensor 62 at a predetermined control cycle, in step S141.

[0104] In step S142, the controller 8 determines whether the boat speed V is equal to or higher than the second threshold $V2$, based on the detection result of the boat speed sensor 62.

[0105] In a case where the determination result in step S142 is "No" ($V < V2$), the processing ends. The processing from step S141 is repeated at every predetermined control cycle, and the trim support control is continuously conducted. In a case where the determination result in step S142 is "Yes" ($V \geq V2$), the processing proceeds to step S143, and the controller 8 enables conducting the heel control. In other words, the controller 8 sets the heel control to a standby state.

[0106] Next, in step S144, the acquirer 81 acquires a detection result of the heel angle θh of the hull 2 in the inertial sensor 64.

[0107] In step S145, the controller 8 determines whether the heel angle θh is equal to or larger than the heel angle reference value θ_{hs} , based on the detection result of the inertial sensor 64.

[0108] In a case where the determination result in step S145 is "No" ($\theta h < \theta_{hs}$), the processing returns to step S144. After a predetermined control cycle elapses, step S144 is repeatedly performed.

[0109] In a case where the determination result in step S145 is "Yes" ($\theta h \geq \theta_{hs}$), the processing proceeds to step S146.

[0110] In step S146, the controller 8 conducts the heel control in addition to the trim support control. In step S146, the controller 8 sets the heel suppression angle θd in accordance with the heel angle θh of the hull 2. The controller 8 sets the heel suppression angle θd with reference to the trim support angle θ_{sp} of the propulsion machine 3 at such a timing. The drive processor 83 calculates the trim angle addition value $\Delta\theta t1$ to be added to the trim support angle θ_{sp} as a reference for the propulsion machine 3 on one side in the left-right direction and the trim angle subtraction value $\Delta\theta t2$ to be subtracted from the trim support angle θ_{sp} as a reference for the propulsion machine 3 on the other side in the left-right direction in a preset calculation formula, based on the heel angle θh of the hull 2 at such a timing that has been acquired by the acquirer 81.

[0111] In a case where the hull 2 is inclined to the port side, the drive processor 83 calculates the heel suppression angle $\theta d1$ of the left propulsion machine 3b in the above equation (1), and calculates the heel suppression angle $\theta d2$ of the right propulsion machine 3a in the above equation (2). In a case where the hull 2 is inclined to the starboard side, the drive processor 83 calculates the heel suppression angle $\theta d1$ of the left propulsion machine 3b in the above equation (3), and calculates the heel suppression angle $\theta d2$ of the right propulsion machine 3a in the above equation (4).

[0112] The drive processor 83 sets the heel suppres-

sion angles θ_{d1} and θ_{d2} that have been calculated to the target values, and causes the trim angle adjuster 45 to adjust the trim angles θ_t of the propulsion machines 3 (3a and 3b).

[0113] In step S147, while conducting the heel control, it is determined whether a predetermined stop condition for stopping the heel control is satisfied. In the present embodiment, as the predetermined stop condition for stopping the heel control, examples include

Condition 1: While conducting the heel control, a case where the boat speed V becomes equal to or lower than the preset third threshold $V3$, and

Condition 2: A case of receiving an operation input by the boat operator from the trim angle operation unit 73.

[0114] In a case where the determination result in step S147 is "No" (in a case where neither the condition 1 nor the condition 2 is satisfied), the processing proceeds to step S149.

[0115] In a case where the determination result in step S147 is "Yes" (in a case where at least one of the conditions 1 and 2 is satisfied), the processing proceeds to step S148, conducting the heel control is stopped, and only the trim support control is continuously conducted.

[0116] In step S149, the controller 8 determines whether the boat 1 is turning. In this case, the controller 8 causes the steering angle sensor 63 to determine whether the boat 1 is turning, based on the input value of the steering angle from the steering angle inputter 71.

[0117] In a case where the determination result in step S149 is "No" (when the boat 1 is not turning, that is, when the boat 1 is advancing straight), the processing ends. After a predetermined control cycle elapses, the above processing is repeatedly performed.

[0118] In a case where the determination result in step S149 is "Yes" (when the boat 1 is turning), the processing proceeds to step S150, and conducting the trim support control and the heel control is stopped.

[0119] FIG. 10 is a flowchart illustrating a processing flow of the rotation speed adjustment control for the propulsion machines to be conducted while the heel control is being conducted in the propulsion system.

[0120] While the heel control is being conducted in step S146, the controller 8 conducts the rotation speed adjustment control for the propulsion machines as illustrated in FIG. 10.

[0121] In step S1461, the controller 8 determines whether a change in the trim angle θ_t is occurring in at least one of the propulsion machines 3 on both sides in the left-right direction, as one of the start conditions of the rotation speed adjustment control for the propulsion machines 3.

[0122] In a case where the determination result in step S1461 is "Yes" (in a case where the change in the trim angle θ_t is occurring), the processing ends. The processing from step S1461 is repeated at every predetermined

control cycle. In a case where the determination result in step S1461 is "No" (in a case where there is no change in the trim angle θ_t), the processing proceeds to step S1462.

[0123] In step S1462, the controller 8 acquires the rotation speeds of the propulsors 34 of the propulsion machines 3 (the propulsion machines 3a and 3b) on both sides in the left-right direction detected by the rotation speed sensor 68 at a predetermined control cycle.

[0124] In step S1463, the controller 8 determines whether the rotation speeds of the propulsion machines 3 on both sides each are in a stable state, as one of the start conditions of the rotation speed adjustment control for the propulsion machines 3 (the condition B). Thus, in a case where a fluctuation range of the rotation speeds of the propulsion machines 3 within a predetermined period of time is smaller than a present reference fluctuation range, the determiner 82 determines that the rotation speeds of the propulsion machines 3 on both sides each are in the stable state. As a specific example, in a case where the fluctuation ranges of the rotation speeds are smaller than 100 rpm in two seconds in both propulsion machines 3 on both sides in the left-right direction, the determiner 82 determines that the rotation speeds of the propulsion machines 3 on both the sides each are in the stable state.

[0125] In a case where the determination result in step S1463 is "No" (in a case where the rotation speed is not in the stable state), the processing ends. The processing from step S1461 is repeated at every predetermined control cycle.

[0126] In a case where the determination result in step S1463 is "Yes" (in a case where the rotation speeds each are in the stable state), the processing proceeds to step S1464.

[0127] In step S1464, the controller 8 calculates a difference in the rotation speed between the propulsor 34 of the right propulsion machine 3a and the propulsor 34 of the left propulsion machine 3b.

[0128] In step S1465, the controller 8 determines whether the calculated difference in the rotation speed is equal to or larger than a preset reference difference, as one of the start conditions of the rotation speed adjustment control for the propulsion machines 3 (the condition A).

[0129] In a case where the determination result in step S1465 is "No" (in a case where the difference in the rotation speed is smaller than the reference difference), the processing ends. The processing from step S1461 is repeated at every predetermined control cycle.

[0130] In a case where the determination result in step S1465 is "Yes" (in a case where the difference in the rotation speed is equal to or larger than the reference difference), the processing proceeds to step S1466.

[0131] In step S1466, the controller 8 adjusts the rotation speeds of the propulsion machines 3 to reduce the difference in the rotation speed between the right propulsion machine 3a and the left propulsion machine 3b. Out of the propulsor 34 of the right propulsion machine 3a and

the propulsor 34 of the left propulsion machine 3b, the controller 8 decreases the rotation speed of one propulsion machine 3 having a higher rotation speed to approach the rotation speed of the other propulsion machine 3 having a lower rotation speed.

[0132] In step S1467, while the rotation speed of the propulsion machine 3 is being adjusted to reduce the difference in the rotation speed between the propulsion machines 3 (the propulsion machines 3a and 3b) on both sides in the left-right direction, the controller 8 determines whether an operation input in accordance with a manual operation by the boat operator is received from the thrust inputter 72.

[0133] In a case where the determination result in step S1467 is "No" (in a case where the operation input is not received and manual operation is not performed), the processing ends. The processing from step S1461 is repeated at every predetermined control cycle.

[0134] In a case where the determination result in step S1467 is "Yes" (in a case where the operation input is received and manual operation is performed), the processing proceeds to step S1468.

[0135] In step S1468, the controller 8 adjusts the rotation speeds of the propulsion machines 3 in accordance with the operation input from the thrust inputter 72. The controller 8 adjusts the rotation speeds of the propulsion machines 3 in accordance with the operation input from the thrust inputter 72 while maintaining the difference in the rotation speed between the propulsion machines 3 at the time of receiving the operation input. After step S1468 is completed, the processing returns to step S1467, and the processing is repeated until the operation input in accordance with the manual operation by the boat operator is completed from the thrust inputter 72.

[0136] FIG. 11 is a timing chart illustrating an example of the operation of the propulsion system.

[0137] In FIG. 11, "0" indicates that the determination result of the controller 8 is "No", and "1" indicates that the determination result of the controller 8 is "Yes" in each a "boat speed determination flag", a "straight advancing determination flag", and a "heel control conducting determination flag".

[0138] As illustrated in FIG. 11, for example, when the boat speed V is increased in accordance with the operation by the boat operator on the thrust inputter 72, and exceeds the second threshold V2 (time t1), the boat speed determination flag of the controller 8 in the above step S142 changes from "0" to "1". In the example of FIG. 11, at this timing, the straight advancing determination flag in the above step S149 is "0", and it is determined that the boat 1 is not in the straight advancing state in accordance with the steering angle of the steering angle inputter 71. Thus, in the above step S150, the heel control conducting determination flag becomes "0", and the heel control (and the trim support control) is not performed.

[0139] Then, when the boat speed V is decreased in accordance with the operation by the boat operator on the thrust inputter 72, and becomes equal to or lower than the

third threshold V3 (time t2), the boat speed determination flag in the above step S142 changes from "1" to "0". Also at this timing, the straight advancing determination flag is "0" in accordance with the steering angle of the steering angle inputter 71. Thus, the heel control conducting determination flag remains "0", and the heel control is not conducted.

[0140] Subsequently, when the leftward steering angle becomes smaller than a predetermined leftward steering angle threshold (time t3) in accordance with the steering operation by the boat operator on the steering angle inputter 71, the straight advancing determination flag changes from "0" to "1". Furthermore, when the steering angle is switched from the left direction to the right direction in accordance with the steering operation by the boat operator on the steering angle inputter 71 and the rightward steering angle becomes equal to or larger than a predetermined rightward steering angle threshold (time t4), the straight advancing determination flag returns from "1" to "0". At this timing, the boat speed V is lower than the second threshold V2. Thus, the boat speed determination flag remains at "0", and the heel control conducting determination flag also remains at "0".

[0141] Next, when the rightward steering angle becomes smaller than the rightward steering angle threshold (time t5) in accordance with the steering operation by the boat operator on the steering angle inputter 71, the straight advancing determination flag changes from "0" to "1". Furthermore, when the steering angle is switched from the right direction to the left direction in accordance with the steering operation by the boat operator on the steering angle inputter 71 and the leftward steering angle becomes equal to or larger than the leftward steering angle threshold (time t6), the straight advancing determination flag returns from "1" to "0". At this timing, the boat speed V is lower than the second threshold V2. Thus, the boat speed determination flag remains at "0", and the heel control conducting determination flag also remains at "0".

[0142] Then, when the leftward steering angle becomes smaller than the leftward steering angle threshold (time t7) in accordance with the steering operation by the boat operator on the steering angle inputter 71, the straight advancing determination flag changes from "0" to "1".

[0143] Then, when the boat speed V is increased in accordance with the operation by the boat operator on the thrust inputter 72 and exceeds the second threshold V2 (time t8), the boat speed determination flag changes from "0" to "1". Thus, the boat 1 is in the straight advancing state and the boat speed V is equal to or higher than the second threshold V2. Thus, the heel control conducting determination flag changes from "0" to "1", and the heel control (and the trim support control) is conducted.

[0144] FIG. 12 is a timing chart illustrating another example of the operation of the propulsion system.

[0145] In FIG. 12, "0" indicates that the determination result of the controller 8 is "No", and "1" indicates that the

determination result of the controller 8 is "Yes" in each an "operation input determination flag", a "rotation speed stability determination flag", and a "trim angle change determination flag". In addition, in a "rotation speed matching determination flag", "0" indicates a standby state, "1" indicates a stable state, "2" indicates a change state, and "3" indicates a state in which an instructed lever opening rate is matched with the actual lever opening rate.

[0146] As illustrated in FIG. 12, when the opening rate of the thrust inputter 72 is increased in accordance with the operation by the boat operator (time t11 to time t12), the operation input determination flag indicating that the operation input has been made changes from "0" to "1" in the controller 8. With such a change, the signal value of the instructed lever opening rate for changing the rotation speed of the propulsor 34 output from the controller 8 to each propulsion machine 3 corresponds to an operation amount on the thrust inputter 72.

[0147] The rotation speed of each propulsion machine 3 increases from time t11 to time t12 in accordance with the change in the signal value of the instructed lever opening rate. While the rotation speed of the propulsion machine 3 is changing, the rotation speed stability determination flag indicating the stable state of the rotation speed of the propulsion machine 3 changes from "1" to "0". In addition, in the example of FIG. 12, while the rotation speed of the propulsion machine 3 is changing from time t11 to time t12, the trim angles θ_t of the propulsion machines 3 on both sides in the left-right direction during the trim support control are the same as each other. Thus, the rotation speed matching determination flag changes from "1", which indicates that the difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction is smaller than the reference difference and is stable, to "2", which indicates that the rotation speed of the propulsion machine 3 is changing while maintaining the state in which the difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction is smaller than the reference difference.

[0148] When the change in the opening rate of the thrust inputter 72 in accordance with the operation by the boat operator ends (time t12), the change in the rotation speed of the propulsion machine 3 stops with a response delay of the propulsion machine 3 (time t13). Then, when a state in which the fluctuation range of the rotation speed of the propulsion machine 3 is smaller than the reference fluctuation range continues for a predetermined period of time (time t13 to time t14), the rotation speed stability determination flag changes from "0" to "1", and it is determined that the rotation speed of the propulsion machine 3 is in the stable state. The rotation speed matching determination flag returns from "2" to "1".

[0149] Then, when the heel control is started at time t15 and the trim angle θ_t of the left propulsion machine 3b and the trim angle θ_r of the right propulsion machine 3a are different from each other, a difference in operation resis-

tance received by the propulsors 34 in the water causes a difference between the rotation speed of the left propulsion machine 3b (a solid line in FIG. 12) and the rotation speed of the right propulsion machine 3a (a dotted line in FIG. 12) (time t15 to time t16).

[0150] At time t15, when the heel control is started, the rotation speed stability determination flag changes from "1" to "0". In addition, the rotation speed matching determination flag changes from "1" to "3", and the instructed lever opening rate is matched with the actual lever opening rate. In the above step S1461, since the trim angle θ_t changes from time t15 to time t16, the change determination flag of the trim angle changes from "0" to "1".

[0151] In this case, since the trim angle θ_t changes in the above step S1461, the rotation speed adjustment for the propulsion machines in step S1466 is not made.

[0152] When the trim angles θ_t of the propulsion machines 3 on both sides in the left-right direction in the heel control stop changing at time t16, the trim angle change determination flag changes from "1" to "0" in the above step S1461. The trim angles θ_t stop changing, and thus the rotation speed matching determination flag changes from "3" to "0", and the controller 8 stands by until the rotation speed is stable.

[0153] At the time t16 and later, when a state in which the fluctuation range of the rotation speed of the propulsion machine 3 is smaller than the reference fluctuation range continues for a predetermined period of time (time t17), the rotation speed stability determination flag changes from "0" to "1" in the above step S1463. Accordingly, in the above step S1465, the rotation speed matching determination flag changes from "0" to "1", and the rotation speed adjustment for the propulsion machines 3 in step S1466 is made. The controller 8 outputs a signal value of the instructed lever opening rate for changing the rotation speeds of the propulsion machines 3a and 3b on both sides in the left-right direction. Specifically, by decreasing the instructed lever opening rate of the left propulsion machine 3b while maintaining the instructed lever opening rate of the right propulsion machine 3a, the rotation speed of the left propulsion machine 3b is decreased to approach the rotation speed of the right propulsion machine 3a.

[0154] Then, when the opening rate of the thrust inputter 72 is decreased in accordance with the operation by the boat operator at time t18 (time t18 to time t19), the operation input determination flag indicating that the operation input has been made changes from "0" to "1" in step S1467. Thus, for each propulsion machine 3, while the controller 8 is maintaining the difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction at such a timing, the controller 8 changes the rotation speeds of the propulsion machines 3 on both sides in the left-right direction in accordance with the operation input into the thrust inputter 72.

[0155] In this manner, while conducting the heel con-

trol, in a case where the difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction is equal to or larger than the preset reference difference, the propulsion system 20 according to the present embodiment adjusts the rotation speed of the propulsion machine 3 to reduce the difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction. Thus, in a case where the difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction increases, it becomes possible to reduce the difference in the rotation speed by conducting the heel control. Therefore, it becomes possible to suppress an uneasy feeling of the boat operator due to the difference in the rotation speed between the propulsion machines 3 on both sides in the left-right direction.

[0156] In addition, the propulsion system 20 according to the present embodiment decreases the rotation speed of one propulsion machine 3 having a higher rotation speed, out of the propulsion machines 3 on both sides in the left-right direction, to approach the rotation speed of the other propulsion machine 3 having a lower rotation speed. Thus, the thrust generated by one propulsion machine 3 having a higher rotation speed decreases, so that the influence on the behavior of the hull 2 can be suppressed by the heel control, and in addition, an increase in the rotation speed that is not intended by the boat operator can be prevented. As a result, an uneasy feeling of the boat operator can be suppressed.

[0157] In addition, the propulsion system 20 according to the present embodiment adjusts the rotation speeds of the propulsion machines 3 in a case where it is determined that the rotation speeds of the propulsion machines 3 on both sides in the left-right direction each are in a stable state. Thus, it becomes possible to adjust the rotation speed of the propulsion machine 3 in a state in which the behavior of the hull 2 is stable, so that an uneasy feeling of the boat operator can be suppressed.

[0158] In addition, in each of the propulsion machines 3 on both sides in the left-right direction, in a case where the fluctuation range of the rotation speed of the propulsion machine 3 within a predetermined period of time is smaller than a preset reference fluctuation range, the propulsion system 20 according to the present embodiment determines that the rotation speed of the propulsion machine 3 is in the stable state. Thus, it becomes possible to easily determine whether the rotation speeds of the propulsion machines 3 on both sides in the left-right direction each are in the stable state, so that the rotation speeds of the propulsion machines 3 can be adjusted smoothly.

[0159] In addition, while adjusting the rotation speeds of the propulsion machines 3, upon receipt of the operation input from the thrust inputter 72, the propulsion system 20 according to the present embodiment adjusts the rotation speeds of the propulsion machines 3 in accordance with the operation input from the thrust inputter 72 while maintaining the difference in the rotation

speed between the propulsion machines 3 at the time of receiving the operation input. Thus, it becomes possible to continue an adjustment state of the rotation speed of the propulsion machine 3 in accordance with the operation input intended by the boat operator. Therefore, it becomes possible to satisfactorily adjust the imbalance in the rotation speed between the propulsion machines 3 while suppressing an uneasy feeling of the boat operator.

[0160] In addition, the propulsion system 20 according to the present embodiment enables conducting the heel control in a case where it is determined that the boat 1 is advancing straight. Thus, while the boat 1 is advancing straight, it becomes possible to smoothly conduct the heel control, so that the stability, the acceleration, the maximum speed, the energy efficiency, and the like can be improved.

[0161] In addition, the propulsion system 20 according to the present embodiment conducts the heel control in the case where the heel angle θ_h is equal to or larger than the preset heel angle reference value θ_{hs} . Thus, as the preset conditions, while the boat 1 is advancing straight and in the case where the heel angle θ_h is large, it becomes possible to suppress the heel angle θ_h , so that the stability, the acceleration, the maximum speed, the energy efficiency, and the like of the boat 1 can be improved.

[0162] Further, the propulsion system 20 according to the present embodiment stops conducting the heel control, in the case where it is determined that the boat 1 is in the turning state. Accordingly, in the case where the boat 1 is in the turning state, it becomes possible to suppress inhibition of the turning property due to the heel control.

[0163] In addition, in the case where the preset condition is satisfied, the propulsion system 20 according to the present embodiment conducts the heel control in addition to the trim support control, and causes the trim angle adjuster 45 to adjust the propulsion machine 3 to the heel suppression angle θ_d set with reference to the trim support angle θ_{sp} of the propulsion machine 3.

Accordingly, in the case where the preset condition is satisfied, the heel control is conducted in addition to the trim support control, and thus it becomes possible to suppress the heel angle θ_h of the boat 1 while automatically adjusting the trim angle θ_t . Therefore, in transitioning from the state of conducting the heel control to another state, it becomes possible to smoothly transition the state so as not to impair the stability, the acceleration, the maximum speed, the energy efficiency, or the like of the boat 1, and so as not to make the boat operator feel uneasy.

[0164] Note that the present invention is not limited to the above-described embodiments with reference to the drawings, and various modifications are conceivable within the technical scope.

[0165] For example, in the above embodiment, the trim support control, the heel control, and the like are conducted, based on the boat speed V . However, the trim support control, the heel control, and the like may be

conducted, based on the rotation speed of the propulsion machine 3 instead of the boat speed V.

[0166] In addition, in the above embodiment, while the boat 1 is advancing straight, the case of conducting only the trim support control and the case of conducting both the trim support control and the heel control in accordance with the boat speed V have been given as examples. However, while the boat 1 is advancing straight, it is also possible to conduct only the heel control in accordance with the boat speed V.

[0167] Further, in the above embodiment, one propulsion machine 3 is provided on each of both sides in the left-right direction, but a plurality of propulsion machines 3 may be provided on each of both sides in the left-right direction.

[0168] In addition, the procedure and contents of the control conducted by the controller 8 can be changed as appropriate.

[0169] Then, the constitution in the above embodiment is an example of the present invention, and various changes can be made without departing from the gist of the present invention.

[0170] While preferred embodiments of the invention have been described and illustrated above, it should be understood that these are exemplary of the invention and are not to be considered as limiting. Additions, omissions, substitutions, and other modifications can be made without departing from the scope of the present invention. Accordingly, the invention is not to be considered as being limited by the foregoing description, and is only limited by the scope of the appended claims.

Reference Signs List

[0171]

1	Boat	
2	Hull	
3	Propulsion Machine	
3a	Right propulsion machine (propulsion machine)	40
3b	Left propulsion machine (propulsion machine)	
6	Detector	
8	Controller	
20	Propulsion system	
32	Drive source	45
34	Propulsor	
45	Trim angle adjuster	
64	Inertial sensor (heel angle detector)	
68	Rotation speed sensor	
72	Thrust inputter (throttle operation inputter)	50

Claims

1. A propulsion system of a boat, the propulsion system comprising:

at least one propulsion machine including a drive source, and a propulsor configured to gen-

erate thrust with dynamic power transmitted from the drive source, the at least one propulsion machine being provided on each of both sides in a left-right direction with respect to a center of a hull;

a rotation speed sensor configured to detect a rotation speed of the propulsor of the propulsion machine;

a trim angle adjuster configured to adjust a trim angle of each of the propulsion machines on the both sides in the left-right direction with respect to the hull; and

a controller configured to control the trim angle adjuster, wherein

the controller is capable of conducting heel control of causing the trim angle adjuster to adjust the trim angle to a heel suppression angle set in accordance with an inclination in a roll direction of the hull to suppress the inclination in the roll direction of the hull, and

while conducting the heel control, in a case where a difference in rotation speed between the propulsion machines on the both sides in the left-right direction detected by the rotation speed sensor is equal to or larger than a preset reference difference, the controller adjusts rotation speeds of the propulsion machines to reduce the difference in the rotation speed between the propulsion machines on the both sides in the left-right direction.

2. The propulsion system of the boat according to claim 1, wherein

the controller decreases the rotation speed of one of the propulsion machines having a higher rotation speed, out of the propulsion machines on the both sides in the left-right direction, to approach the rotation speed of the other one of the propulsion machines having a lower rotation speed.

3. The propulsion system of the boat according to claim 1 or 2, wherein

in a case where it is determined that the rotation speeds of the propulsion machines on the both sides in the left-right direction each are in a stable state, the controller adjusts the rotation speeds of the propulsion machines on the both sides in the left-right direction.

4. The propulsion system of the boat according to claim 3, wherein

in each of the propulsion machines on the both sides in the left-right direction, in a case where a fluctuation range of the rotation speed within a predetermined period of time is smaller than a preset reference fluctuation range, the controller determines that the rotation speeds of the propulsion machines on the both sides in the left-right direction each are in the

stable state.

5. The propulsion system of the boat according to any one of the preceding claims, further comprising a throttle operation inputter configured to adjust the rotation speeds of the propulsion machines in accordance with an external input, wherein upon receipt of an operation input from the throttle operation inputter, while adjusting the rotation speeds of the propulsion machines to reduce the difference in the rotation speed between the propulsion machines on the both sides in the left-right direction, the controller adjusts the rotation speeds of the propulsion machines in accordance with the operation input from the throttle operation inputter while maintaining the difference in the rotation speed between the propulsion machines at a time of receiving the operation input.

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6. The propulsion system of the boat according to any one of the preceding claims, wherein in a case where it is determined that the hull is advancing straight, the controller enables conducting the heel control.

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7. The propulsion system of the boat according to claim 6, further comprising a heel angle detector configured to detect a heel angle serving as an inclination in a roll direction of the hull, wherein in a case where the heel angle is equal to or larger than a preset heel angle reference value, the controller conducts the heel control.

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8. The propulsion system of the boat according to any one of the preceding claims, wherein while conducting the heel control, in a case where it is determined that the hull is in a turning state, the controller stops conducting the heel control.

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9. The propulsion system of the boat according to any one of the preceding claims, wherein

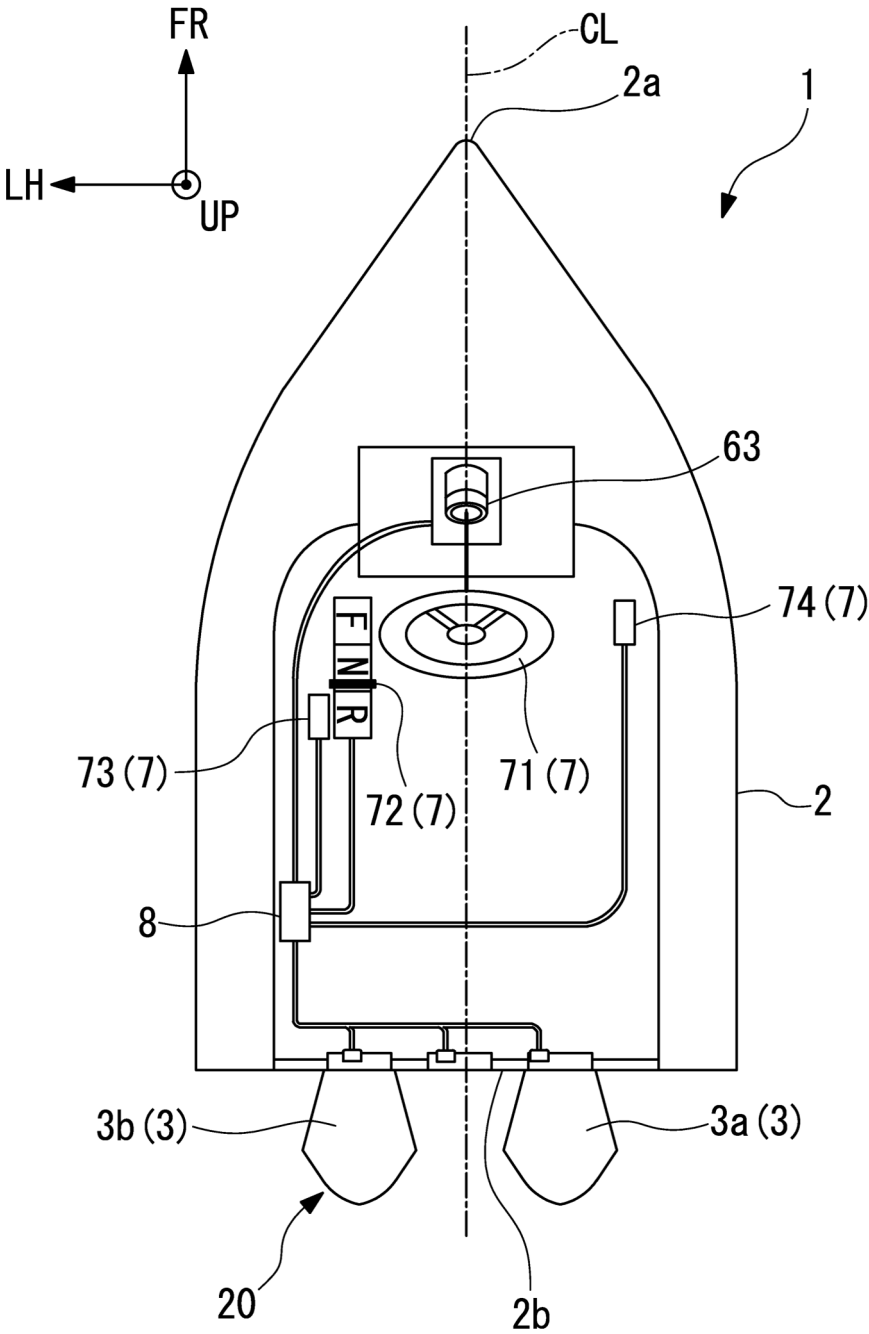
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the controller is capable of conducting trim support control of causing the trim angle adjuster to adjust the trim angle to a trim support angle set in accordance with either a preset boat speed or the rotation speed of the propulsion machine, and

in a case where a preset condition is satisfied, the controller conducts, in addition to the trim support control, the heel control of causing the trim angle adjuster to adjust the propulsion machine to the heel suppression angle set with reference to the trim support angle of the propulsion machine.

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FIG. 1



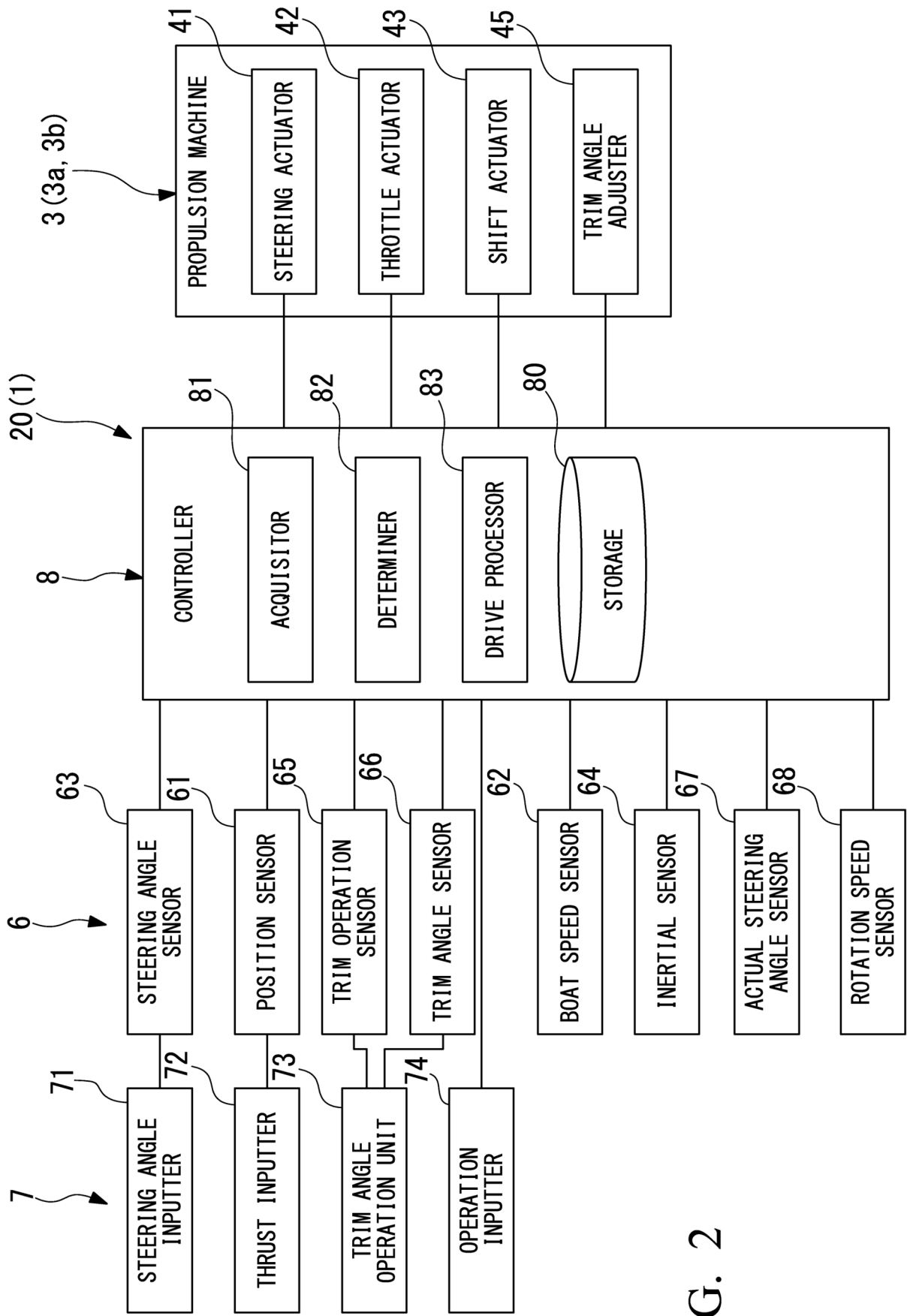


FIG. 2

FIG. 3

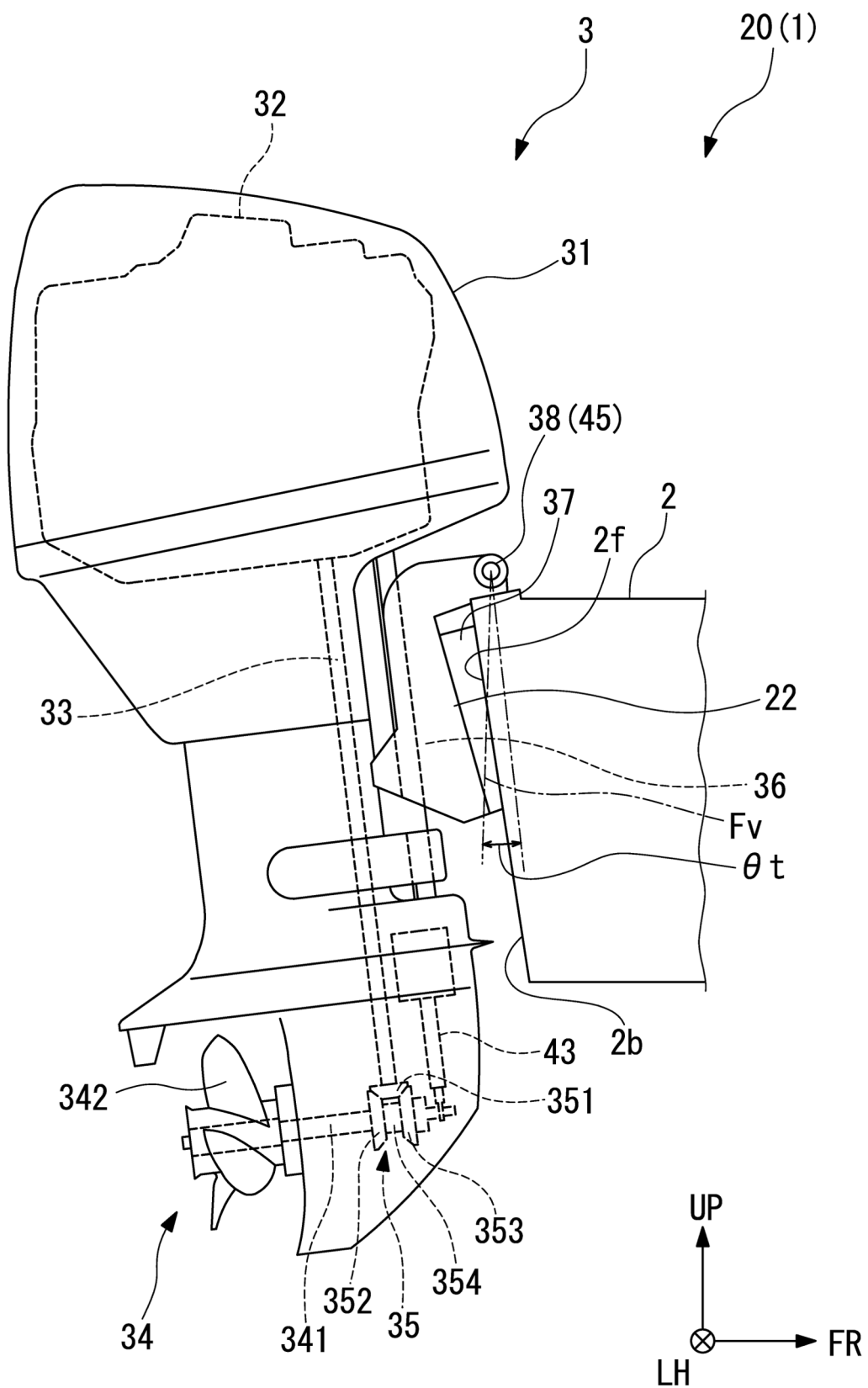


FIG. 4

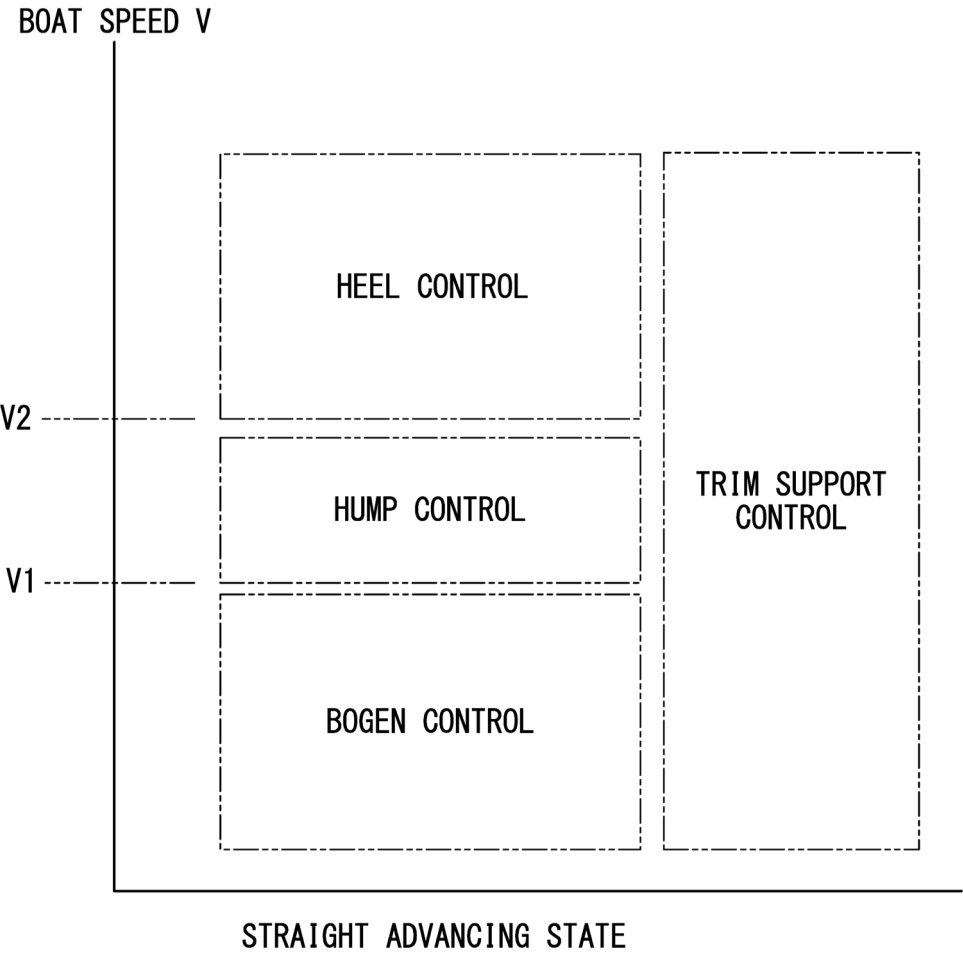


FIG. 5

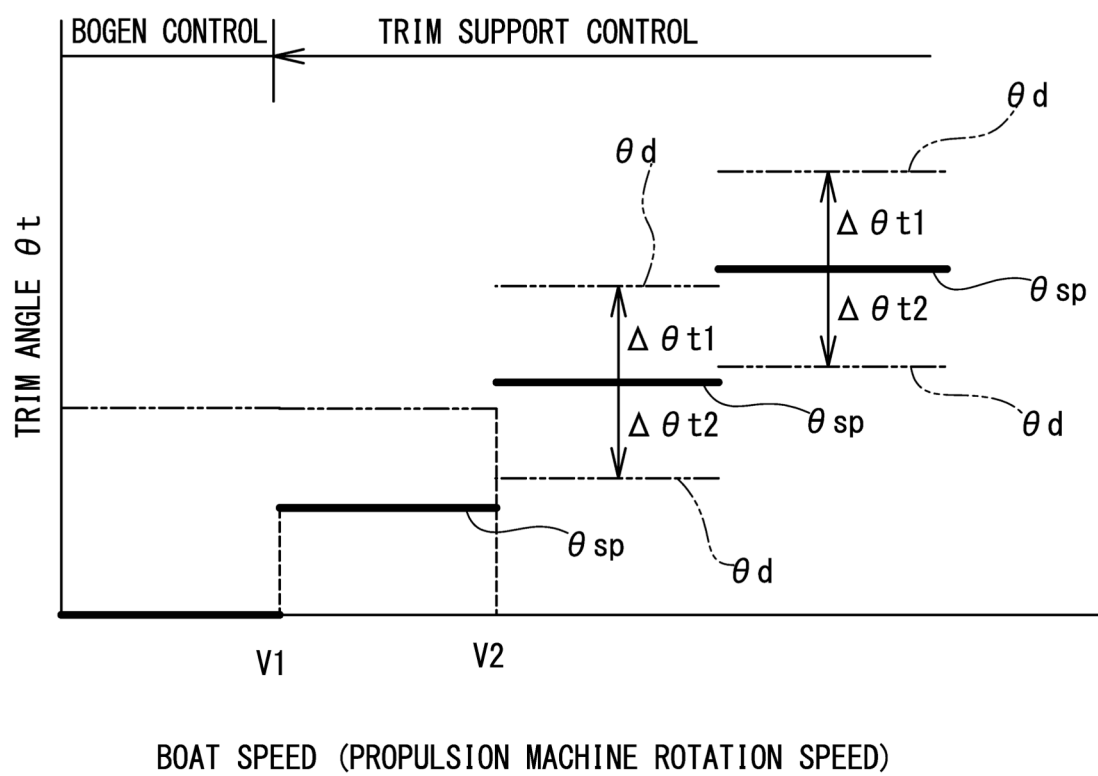


FIG. 6

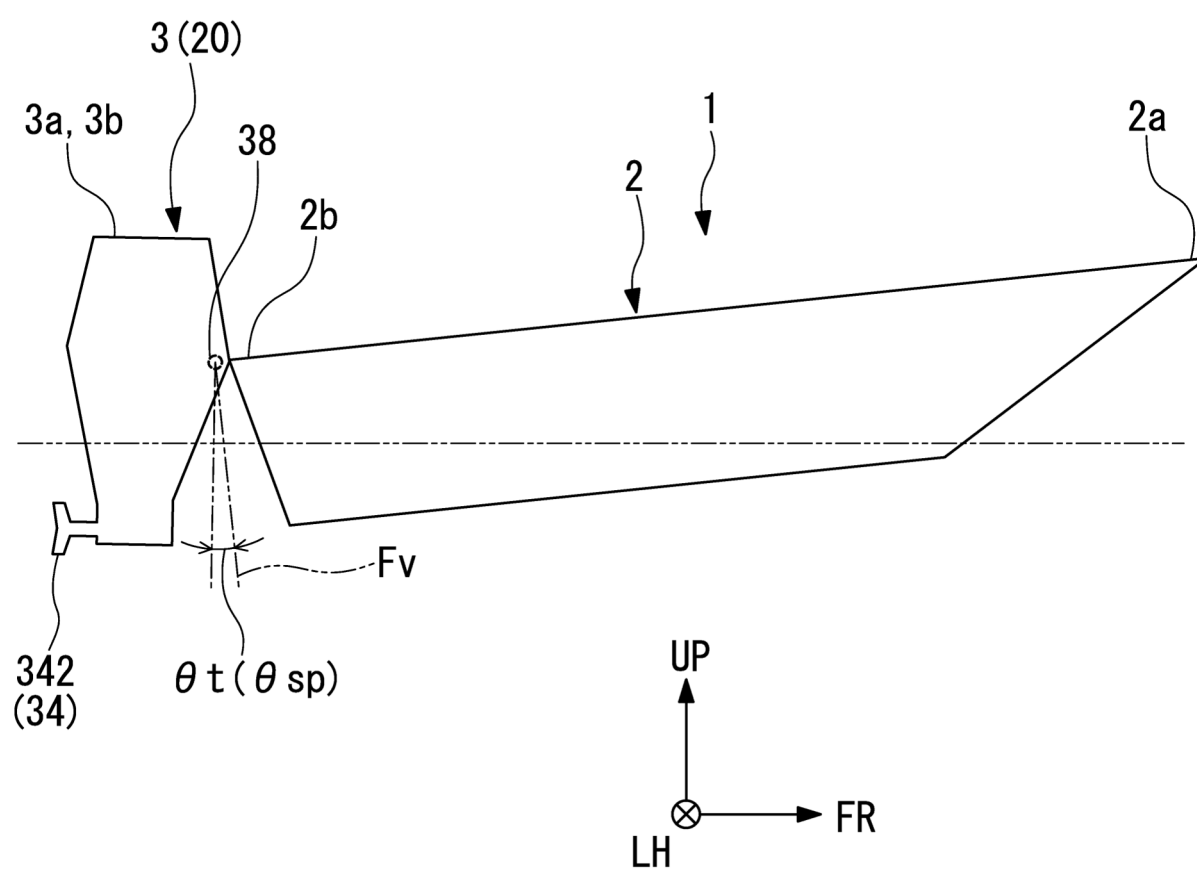


FIG. 7

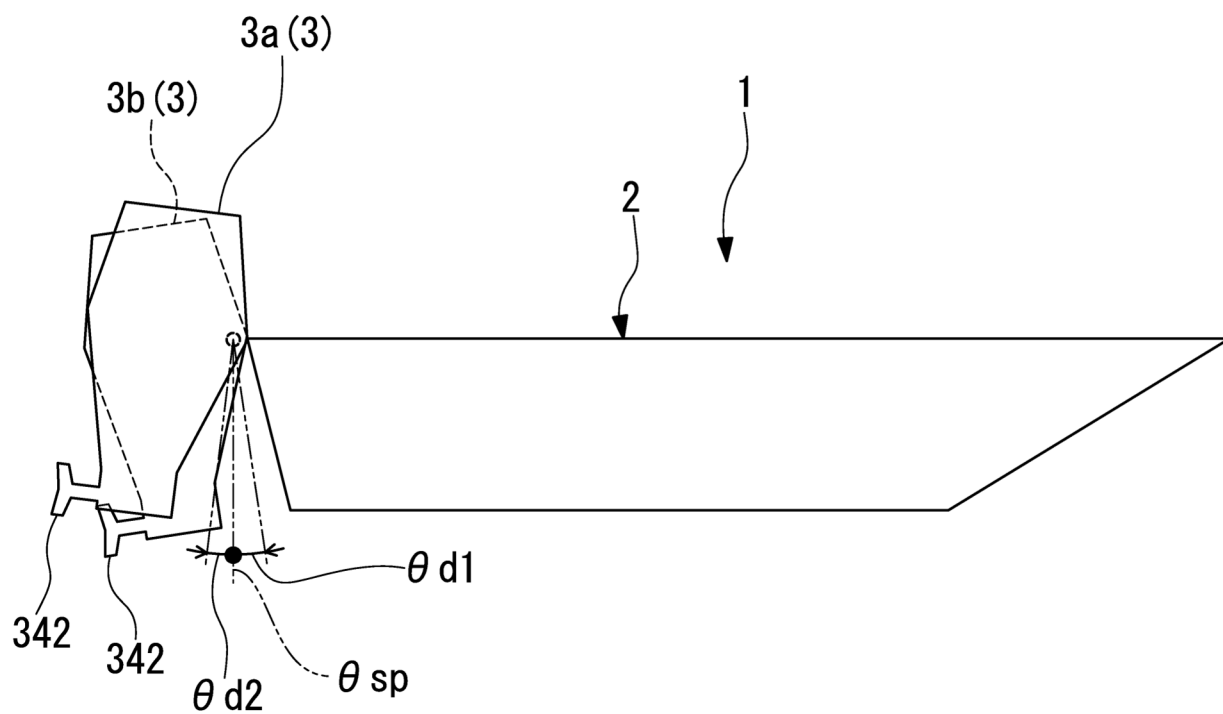


FIG. 8

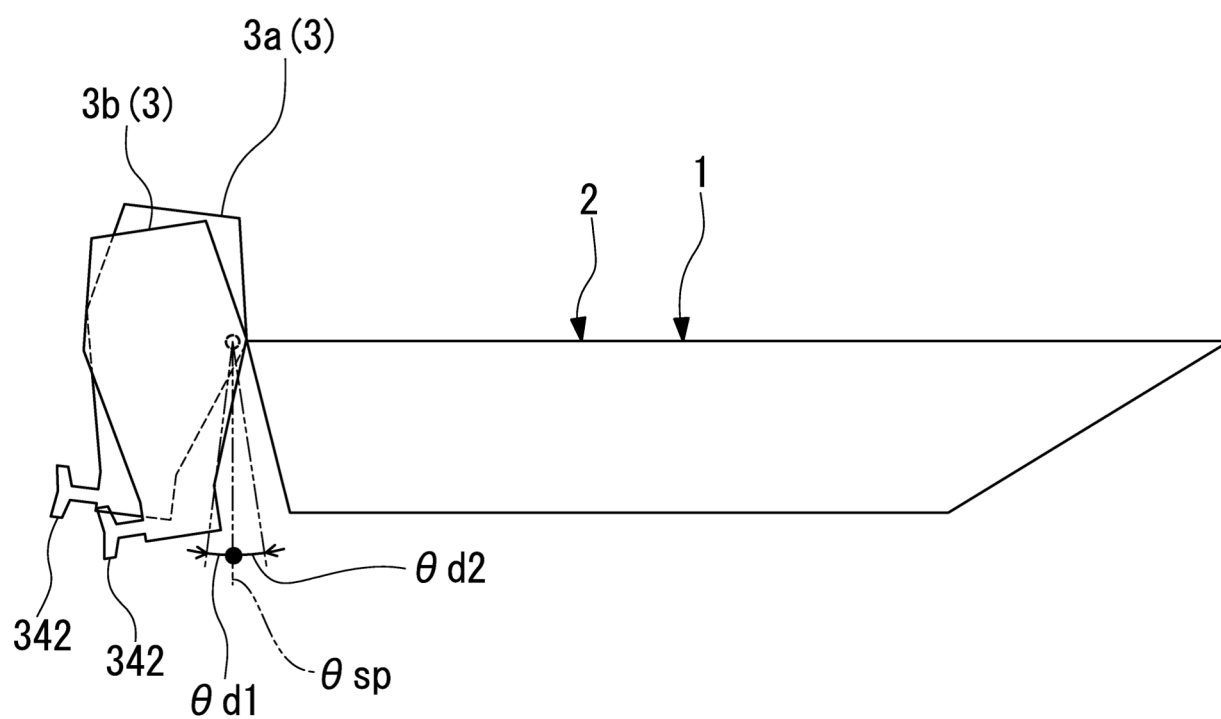


FIG. 9

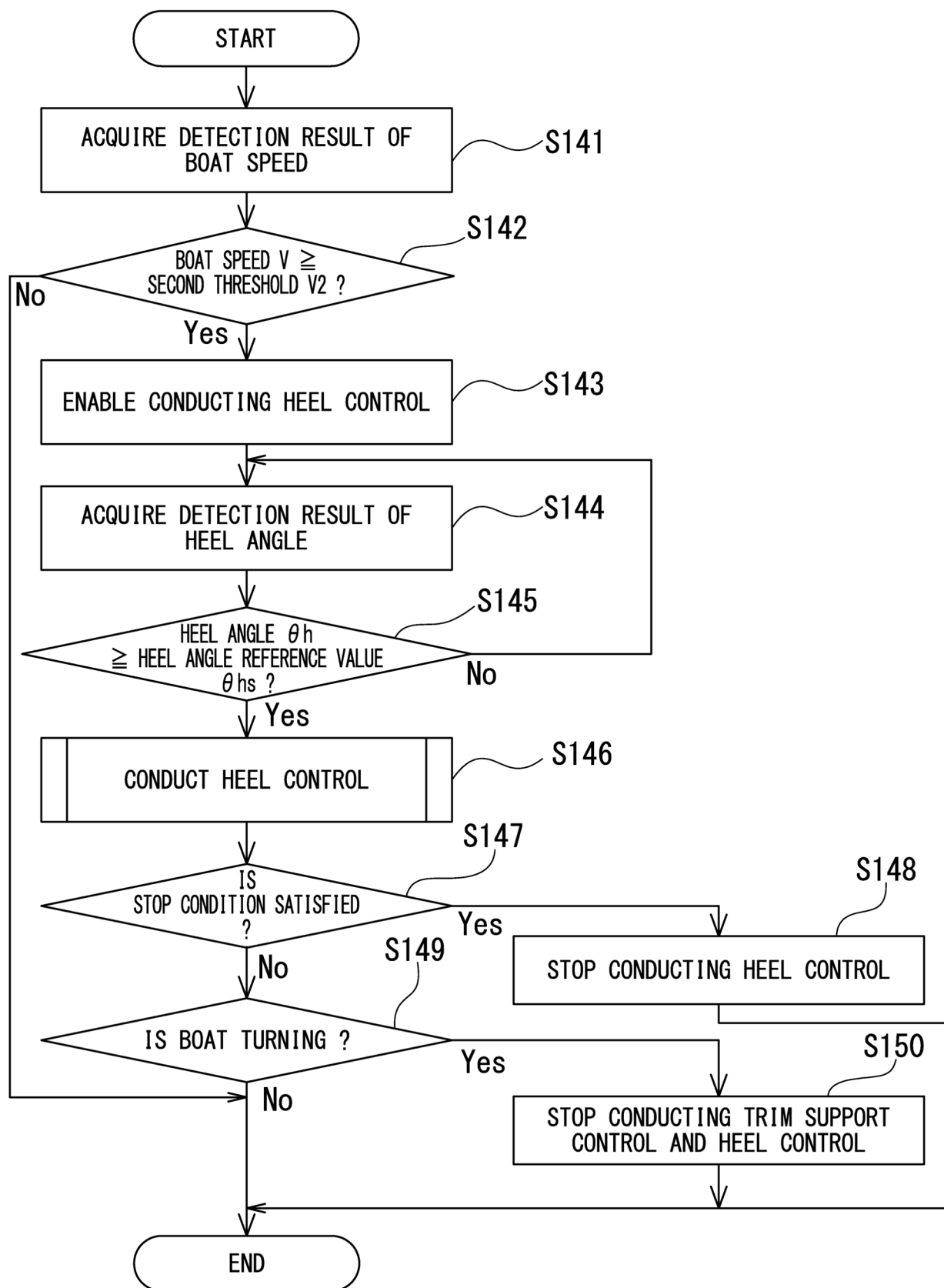


FIG. 10

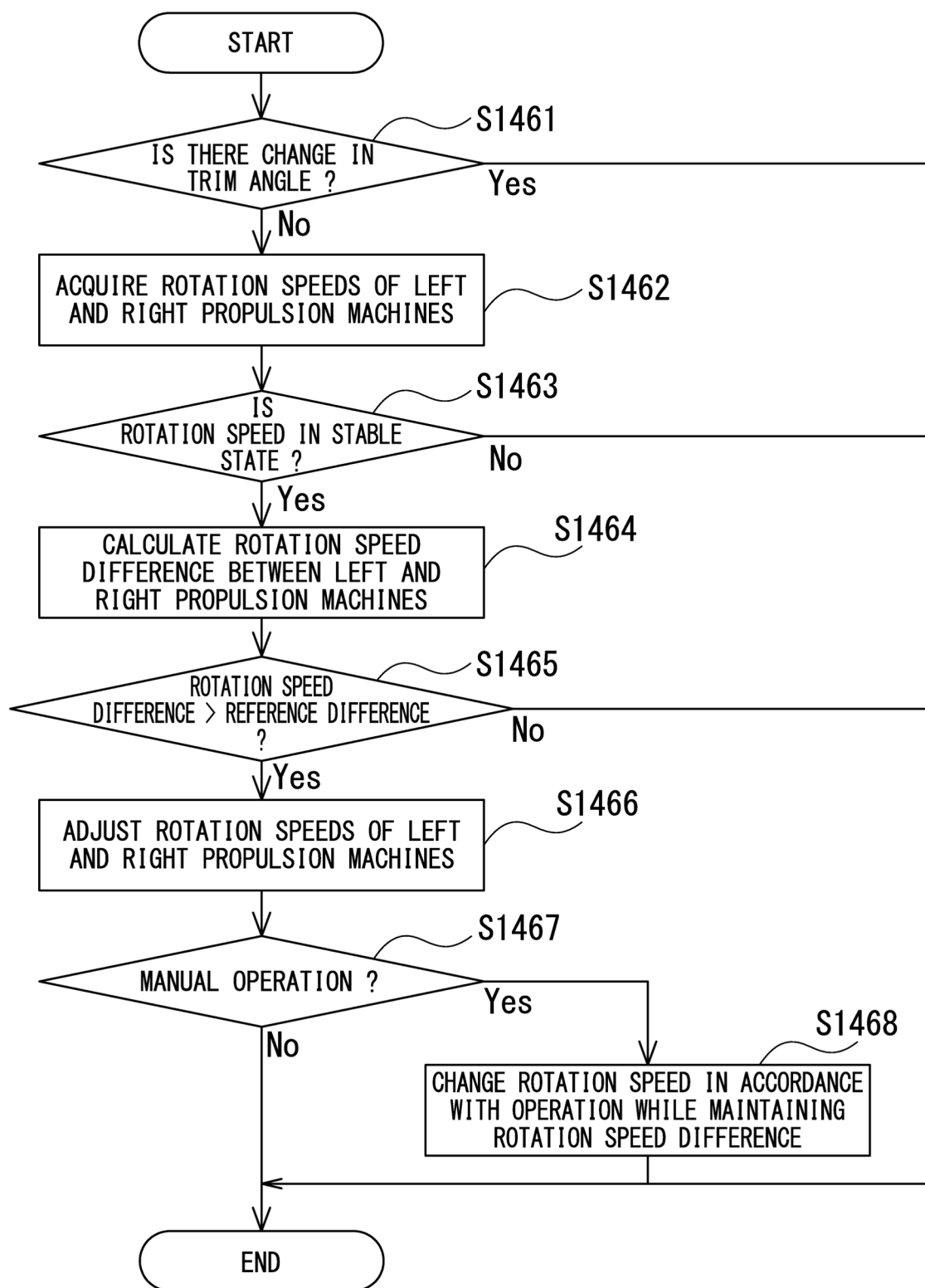


FIG. 11

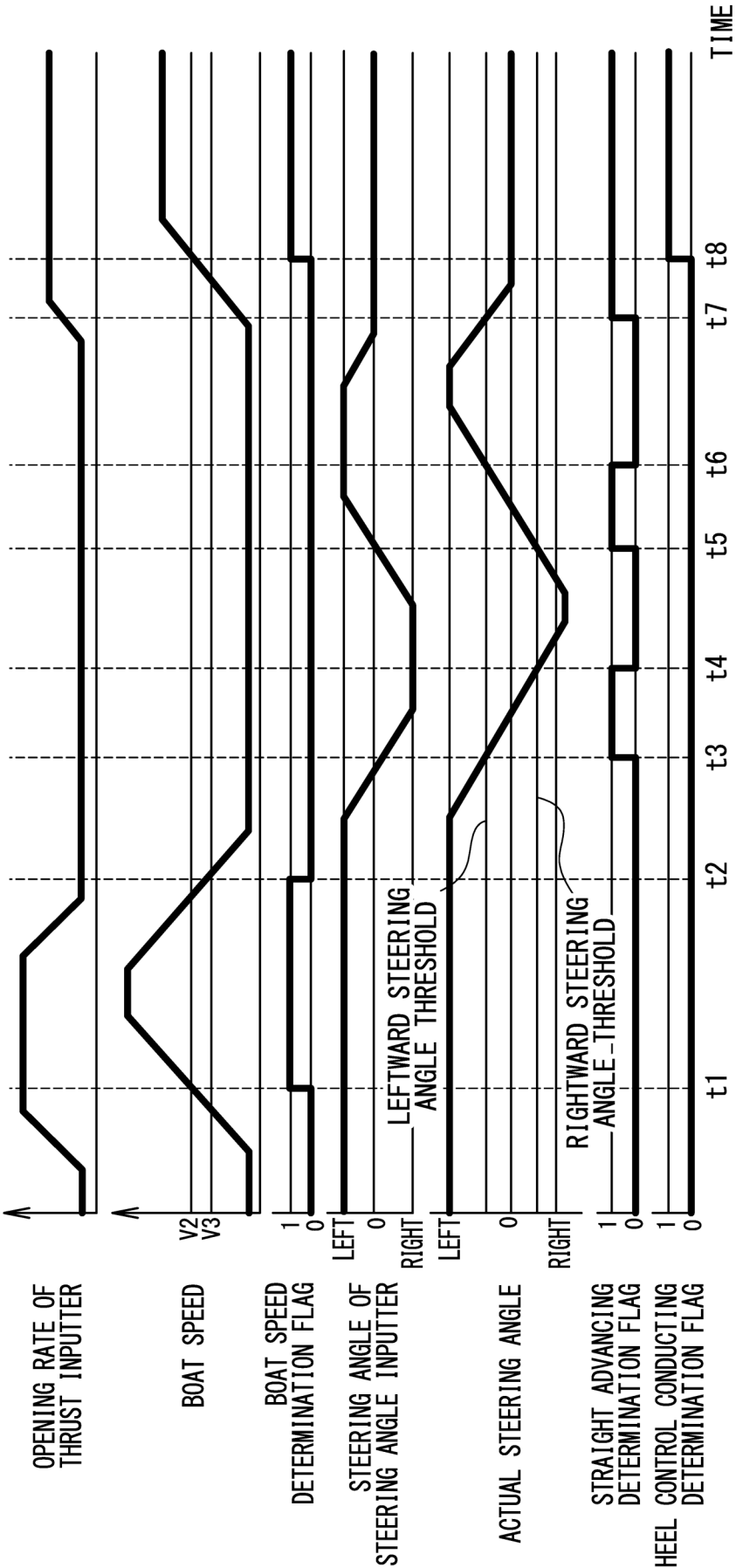
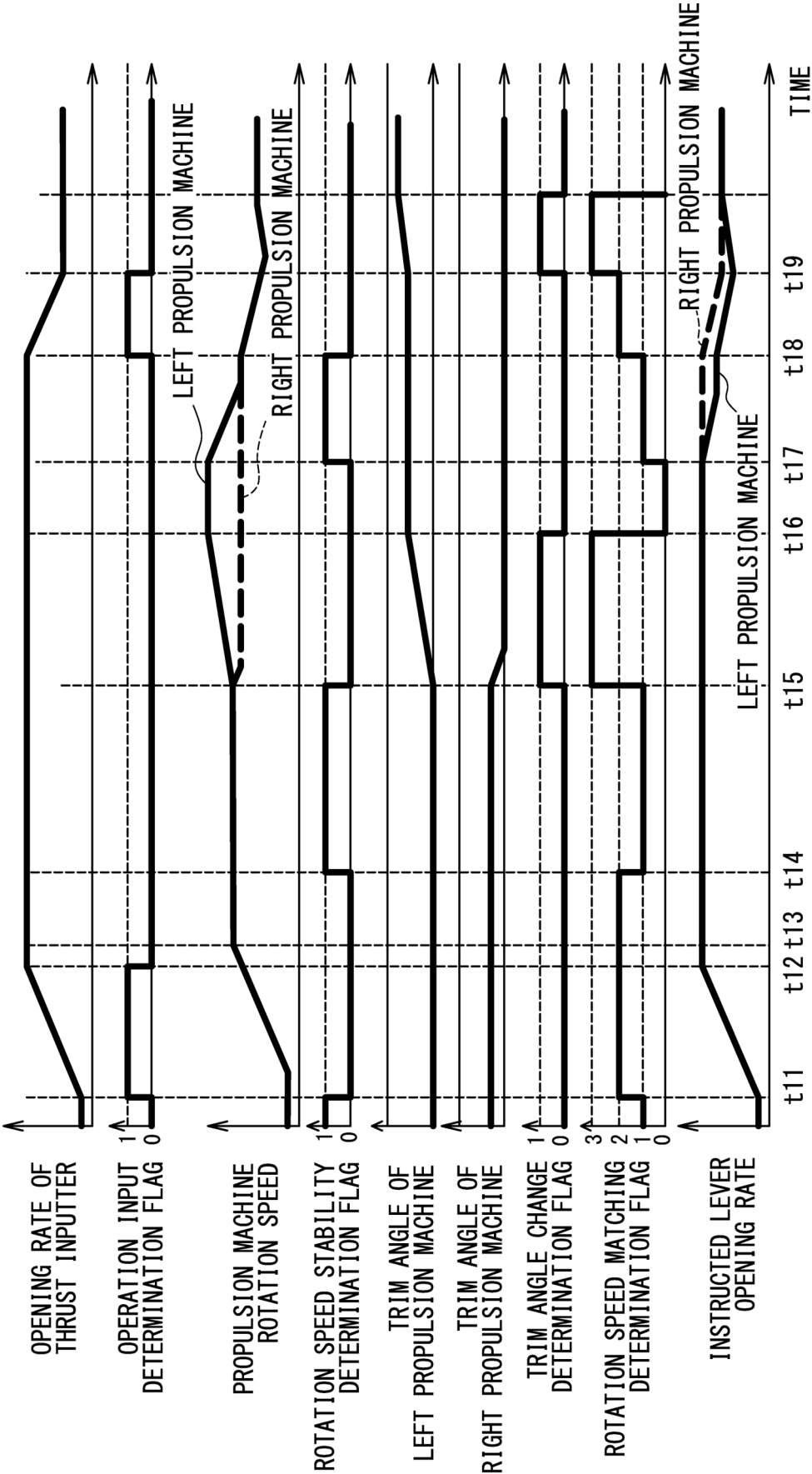


FIG. 12





EUROPEAN SEARCH REPORT

Application Number

EP 26 15 7547

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	* claim 1; figures * * paragraph [0028] * * paragraph [0058] * * paragraph [0060] - paragraph [0062] * * paragraph [0064] * * paragraph [0085] - paragraph [0094] * * paragraph [0097] *	3,4	ADD. B63B79/40 B63H20/00 G05D109/30
A	----- US 2007/276563 A1 (KAJI HIROTAKA [JP]) 29 November 2007 (2007-11-29) * paragraph [0059] * * paragraph [0063] * * abstract; figures 1-7 * -----	1,6,7	
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			B63H G05D B63B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		30 July 2026	Buron, Emmanuel
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X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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30-07-2026

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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