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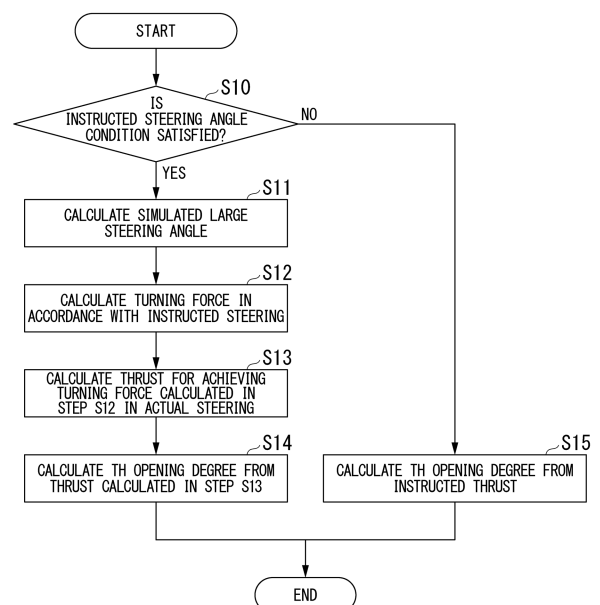
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(54) **PROPULSION SYSTEM OF BOAT**

(57) A propulsion system of a boat includes: a plurality of propulsion machines each including a power source, and a propulsor configured to generate a thrust with power transmitted from the power source, the plurality of propulsion machines being provided on left and right interposing a hull center; a thrust direction changer configured to change directions of thrusts of the plurality of propulsion machines; and a controller configured to control the thrusts and thrust directions of the plurality of propulsion machines. In a case where there is a difference between instructed steering and actual steering when the boat makes a turn, the controller conducts turning assist control for generating a thrust balance in accordance with the difference. In the turning assist control, the controller acquires an instructed steering value input into a steering angle inputter, an actual steering value at which the propulsion machine is actually steered, and an instructed thrust value input into a thrust inputter, calculates a steering thrust generated by the instructed thrust value when a steering direction of the propulsion machine reaches the instructed steering value, and calculates a compensation thrust for generating the steering thrust calculated, in the actual steering value.

FIG. 12



Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and claims the benefit of priority from Japanese Patent Application No. 2025-058870 filed in Japan on March 31, 2025, the contents of which are hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

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

Description of Related Art

[0003] In recent years, efforts to provide access to sustainable transportation systems in consideration of vulnerable people among traffic participants are becoming active. In order to develop a sustainable transportation system, research and development for further improving traffic safety and convenience through, for example, driving support for boats are in progress. Japanese Unexamined Patent Application, First Publication No. 2021-172278 discloses a boat steering system that conducts boat steering control of a boat to which two or more boat propulsion machines are attached. Japanese Unexamined Patent Application, First Publication No. 2021-172278 discloses a technique, when a turning control device malfunctions, for turning the boat by making outputs of power sources of two or more boat propulsion machines different from each other, based on a turning operation signal output from a turning operation device, without changing propulsion directions of the boat propulsion machines.

SUMMARY OF THE INVENTION

[0004] Although the principle of the above fail-safe technique exists, however, there is room for improvement in improving responsiveness while the boat is making a turn, in operating the boat propulsion machine to make a turn at the time of normal navigation and to produce a difference between the left thrust and the right thrust while the boat is making a turn.

[0005] It is an object of the present disclosure to provide a propulsion system of a boat to be capable of improving responsiveness while the boat is making a turn and to navigate the boat in accordance with a boat operator's intention in steering the boat. The present disclosure contributes to development of a sustainable transportation system, accordingly.

[0006] As a means for solving the above problem, aspects of the present disclosure include following constitutions.

(1) A propulsion system of a boat according to one aspect of the present disclosure, the propulsion system includes: a plurality of propulsion machines each including a power source, and a propulsor configured to generate a thrust with power transmitted from the power source, the plurality of propulsion machines being provided on left and right interposing a hull center; a thrust direction changer configured to change directions of thrusts of the plurality of propulsion machines; and a controller configured to control the thrusts and thrust directions of the plurality of propulsion machines, in which in a case where there is a difference between instructed steering and actual steering when the boat makes a turn, the controller conducts turning assist control for generating a thrust balance in accordance with the difference, and in the turning assist control, the controller acquires an instructed steering value input into a steering angle inputter, an actual steering value at which the propulsion machine is actually steered, and an instructed thrust value input into a thrust inputter, calculates a steering thrust generated by the instructed thrust value when a steering direction of the propulsion machine reaches the instructed steering value, and calculates a compensation thrust for generating the steering thrust calculated, in the actual steering value.

Note that a thrust balance generally means that a plurality of propulsion machines uniformly exert the thrusts, but in the present application, the thrust balance denotes adjusting the thrust of each propulsion machine so as to generate a predetermined difference mainly between the thrusts of the left and right propulsion machines.

(2) In the propulsion system of the boat described in the above (1), the controller may conduct the turning assist control in a case where an instructed steering angle to the propulsion machine based on the instructed steering value is equal to or larger than a steering angle threshold.

(3) In the propulsion system of the boat described in the above (1) or (2), the controller may conduct the turning assist control in a case where a difference between an instructed steering angle to the propulsion machine based on the instructed steering value and an actual steering angle at which the propulsion machine is actually steered is equal to or larger than an angle difference threshold.

(4) In the propulsion system of the boat described in one of the above (1) to (3), in a case where, out of the plurality of propulsion machines, a propulsion machine located on an inner side with respect to a turning direction of a hull is defined as an inner propulsion machine, and a propulsion machine located on an outer side with respect to the turning direction of the hull is defined as an outer propulsion machine, in the turning assist control, the controller may decrease a thrust of the inner propulsion machine.

chine to be smaller than a predetermined thrust, and may increase a thrust of the outer propulsion machine to be equal to or larger than the predetermined thrust.

(5) In the propulsion system of the boat described in one of the above (1) to (4), in the turning assist control, the controller may compensate the instructed steering to the propulsion machine to be larger than the instructed steering value.

(6) In the propulsion system of the boat described in one of the above (1) to (5), in the turning assist control, in a case where an actual shift position of the propulsion machine is different from a compensation shift corresponding to a shift instruction of a compensation thrust, the controller may match the actual shift corresponding to the actual shift position with the compensation shift, and then may conduct the turning assist control in accordance with the compensation thrust.

(7) In the propulsion system of the boat described in one of the above (1) to (6), in the turning assist control, the controller may calculate the steering thrust, based on an angle formed by a reference line and a straight line, the reference line being parallel to a center line of a stern and passing through a steering shaft of the propulsion machine in a plan view, the straight line connecting a steering center point of the boat with the steering shaft.

(8) In the propulsion system of the boat described in one of the above (1) to (7), in the turning assist control, the controller may calculate the steering thrust, based on either a thrust upper limit value or a thrust lower limit value when the propulsion machine is actually steered.

[0007] According to the above aspects, it becomes possible to improve responsiveness while the boat is making a turn and to navigate a boat in accordance with a boat operator's intention in steering the boat.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

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

FIG. 2 is a side view of a propulsion machine according to an embodiment;

FIG. 3 is a block diagram of a propulsion system of the boat according to an embodiment;

FIG. 4 is a view illustrating a first example of yaw control;

FIG. 5 is a view illustrating a second example of the yaw control;

FIG. 6 is a view illustrating a third example of the yaw control;

FIG. 7 is a view illustrating boat steering intended by a user while the boat is making a turn together with

relational expressions;

FIG. 8 is a view illustrating an actual boat that is delayed in steering together with relational expressions;

FIG. 9 illustrates calculation formulae of a balance thrust;

FIG. 10 is a state transition diagram of a propulsion system according to an embodiment;

FIG. 11 is an explanatory diagram of each condition of the propulsion system according to an embodiment;

FIG. 12 is a flowchart illustrating a main processing flow of turning assist control according to an embodiment;

FIG. 13 is an explanatory diagram of simulated large steering according to an embodiment;

FIG. 14 is a flowchart illustrating a processing flow for suppressing a shift shock in the turning assist control according to an embodiment;

FIG. 15 is a timing chart showing a first example of the operation of the propulsion system according to an embodiment;

FIG. 16 is a timing chart showing a second example of the operation of the propulsion system according to an embodiment; and

FIG. 17 is a view illustrating an example of a map for achieving the turning assist control according to an embodiment.

30 DETAILED DESCRIPTION OF THE INVENTION

[0009] Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. In the following description, expressions indicating relative or absolute arrangements, for example, "parallel", "orthogonal", "center", and "coaxial" not only strictly mean such arrangements but also include a state of being relatively displaced with a tolerance, or an angle or a distance at which the same function is obtainable. In addition, in the present embodiment, "face each other" is not limited to a case where the orthogonal directions (normal directions) of two surfaces coincide with each other, and includes a case where the orthogonal directions intersect each other. In the drawings for use in the following description, the scale of each member is appropriately changed in order to make each member recognizable in size.

50 Boat

[0010] FIG. 1 is a plan view of a boat 1 according to an embodiment.

[0011] As illustrated in FIG. 1, the boat 1 includes a hull 2, a plurality of propulsion machines 3, a thrust direction changer 4, and a controller 5. The plurality of propulsion machines 3, the thrust direction changer 4, and the controller 5 constitute a propulsion system 100 according to an embodiment.

[0012] It is assumed that front, rear, upper, lower, left, and right directions in the following description respectively coincide with the directions of the 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).

Propulsion Machine

[0013] A plurality of propulsion machines 3 are provided on the hull 2. The propulsion machine 3 is, for example, an outboard motor. The propulsion machines 3 include: a left propulsion machine 3L, which is provided on the left (PORT side) of the stern with respect to the center line CL; and a right propulsion machine 3R, which is provided on the right (STBD side) of the stern with respect to the center line CL. That is, the boat 1 according to the present embodiment is a so-called small-sized boat in which the two propulsion machines 3 (the left propulsion machine 3L and the right propulsion machine 3R) are provided at both left and right end portions of the stern, interposing the center line CL. Hereinafter, in a case where it is not necessary to distinguish between the propulsion machines 3L and 3R, they will be collectively described as the propulsion machine 3. Note that the left propulsion machine 3L and the right propulsion machine 3R are examples of an outer propulsion machine and an inner propulsion machine.

[0014] FIG. 2 is a side view of the propulsion machine 3 according to an embodiment. FIG. 3 is a block diagram of the propulsion system 100 of the boat 1 according to an embodiment.

[0015] Referring also to FIGS. 2 and 3, the propulsion machine 3 is, for example, an outboard motor. The propulsion machine 3 includes: a casing 11; a power source 12; a drive shaft 13; a propulsor 14; and a shift switching mechanism 15.

[0016] The casing 11 is attached to a bracket 10, which is provided at the stern, via a steering shaft (swivel shaft) 16, 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 16 in accordance with the operation of the thrust direction changer 4 (see FIG. 3).

[0017] The power source 12 is, for example, an internal combustion engine such as an engine. The power source 12 is accommodated in an upper portion of the casing 11 with a crankshaft extending in the up-down direction. Dynamic power (engine speed) of the power source 12 is set, based on an opening degree of a throttle valve. The throttle valve is driven by the operation of a throttle actuator 18.

[0018] The drive shaft 13 transmits the dynamic power generated by the power source 12 to the propulsor 14 via the shift switching mechanism 15. The drive shaft 13

extends in the up-down direction in the casing 11. An upper end portion of the drive shaft 13 is connected with the power source 12.

[0019] The propulsor 14 generates thrust with dynamic power transmitted from the power source 12. The propulsor 14 includes a propeller shaft 21 and propellers 22.

[0020] The propeller shaft 21 is provided at a lower end portion of the casing 11 so as to be rotatable around an axial line along a front-rear direction. A front end portion of the propeller shaft 21 is connected with the shift switching mechanism 15 in the casing 11.

[0021] The propellers 22 are provided projecting on the outside of the casing 11 at a rear end portion of the propeller shaft 21. The propellers 22 rotate integrally with the propeller shaft 21.

[0022] The shift switching mechanism 15 includes a drive gear 25, a forward gear 26, a reverse gear 27, and a clutch 28.

[0023] The drive gear 25 is provided at a lower end portion of the drive shaft 13. The drive gear 25 is rotatable integrally with the drive shaft 13.

[0024] The forward gear 26 and the reverse gear 27 are rotatably provided at positions that face each other in the front-rear direction interposing the drive gear 25 on the propeller shaft 21. The forward gear 26 and the reverse gear 27 mesh with the drive gear 25. The forward gear 26 and the reverse gear 27 rotate in opposite directions in accordance with the rotation of the drive gear 25.

[0025] The clutch 28 switches between a connection state and a disconnection state of the dynamic power between either the forward gear 26 or the reverse gear 27 and the propeller shaft 21. The clutch 28 is provided in a part, positioned between the forward gear 26 and the reverse gear 27, of the propeller shaft 21 so as to be rotatable integrally with the propeller shaft 21. The clutch 28 is provided to be movable in the front-rear direction along the propeller shaft 21 in accordance with the operation of a shift actuator 29.

[0026] The clutch 28 meshes with the forward gear 26, and is capable of transmitting the rotational force of the forward gear 26 to the propeller shaft 21 (a forward position F). This causes the propellers 22 to rotate in the normal rotation direction, thereby applying thrust in a forward advancing direction to the boat 1. The clutch 28 meshes with the reverse gear 27, and is capable of transmitting the rotational force of the reverse gear 27 to the propeller shaft 21 (a reverse position R). This causes the propellers 22 to rotate in the reverse rotation direction, thereby applying thrust in a rearward advancing direction to the boat 1. On the other hand, in a state in which the clutch 28 does not mesh with the forward gear 26 or the reverse gear 27, the rotational force is not transmitted to the propeller shaft 21 (a neutral position N). These positions where the clutch 28 meshes with the forward gear 26 and the reverse gear 27 (the forward position F, the reverse position R, and the neutral position N) denote shift positions (actual shift).

[0027] The thrust direction changer 4 changes the

directions of the thrusts of the plurality of propulsion machines 3. The thrust direction changer 4 may include, for example, an electric motor. Two propulsion machines 3 (the right propulsion machine 3R and the left propulsion machine 3L) are respectively attached to the stern board of the hull 2 via the brackets 10. The thrust direction changer 4 is coupled with a front end portion of the bracket 10. When the thrust direction changer 4 is driven, the propulsion machine 3 is steered around the steering shaft 16 so as to have a predetermined steering angle via a transmission mechanism such as an unillustrated gear or link. In the present embodiment, the thrust direction changer 4 is provided for every propulsion machine 3.

[0028] The propulsion machines 3 and the thrust direction changer 4 are electrically connected respectively with the controller 5 (an integrated ECU). The controller 5 controls the thrust (output) of the propulsion machine 3 and the direction (steering angle) of the thrust in accordance with the thrust direction changer 4.

Steering Angle Inputter

[0029] A steering angle inputter 6 is provided in the cockpit of the hull 2. The steering angle inputter 6 is, for example, a steering wheel provided to be rotatable clockwise and counterclockwise. The steering angle inputter 6 receives an operation of a user, when changing the course of the boat 1 (the hull 2). That is, the steering angle inputter 6 receives an operation for changing the direction (the steering angle) of the propulsion machine 3 around the steering shaft 16. 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, in a state in which the propeller shaft 21 is parallel to the center line CL in a plan view, is set as a reference value (0 degrees). An operation amount in accordance with the rotational operation on the steering angle inputter 6 is detected by a steering angle sensor 31. The steering angle sensor 31 outputs a detection signal based on an operation amount on the steering angle inputter 6 to the controller 5, as an instruction value. Note that as the steering angle inputter 6, in addition to the steering wheel, a joystick may be used, and the steering angle inputter 6 may be mounted as a switch or the like of an operation unit 9.

Thrust Inputter

[0030] A thrust inputter 7 is provided in the cockpit of the hull 2. The thrust inputter 7 is, for example, a throttle lever (an accelerator lever). The thrust inputter 7 receives the operation by a user, when changing the thrust of the propulsion machine 3 (a requested thrust) or the shift position of the propulsion machine 3 (a requested shift position). The thrust inputter 7 is constituted to be capable of reciprocating in accordance with rotation, sliding, or the like. The thrust inputter 7 is capable of reciprocating

within an operation area in which three shift areas of the forward position F, the neutral position N, and the reverse position R are aligned.

[0031] Note that in the present embodiment, the propulsion machine 3 will be described using an outboard motor as an example, but there is no limitation to this constitution. In addition to the outboard motor, the propulsion machine 3 may be an inboard motor, an inboard and outboard motor, a water jet machine, or the like as long as the propulsors are provided on the left and right interposing the hull center. For example, in a case of the inboard motor, the direction of the thrust of the propulsion machine 3 may be changed by changing the direction of a separately provided rudder. For example, in a case of the water jet machine, the direction of the thrust of the propulsion machine 3 may be changed by changing the direction of a water flow. Further, the outboard motor and a side thruster may be combined together to constitute the propulsion machine 3. In this case, the direction of the thrust of the propulsion machine 3 may be changed in accordance with a ratio between the thrust of the outboard motor and the thrust of the side thruster.

[0032] In the boat 1, it is possible to set the requested shift position in accordance with the position of the thrust inputter 7 in the operation area. That is, in a case where the thrust inputter 7 is located in the shift area of the forward position F, it is possible to request the controller 5 to set the shift position to the forward position F. In a case where the thrust inputter 7 is located in the shift area of the neutral position N, it is possible to request the controller 5 to set the shift position to the neutral position N. In a case where the thrust inputter 7 is located in the shift area of the reverse position R, it is possible to request the controller 5 to set the shift position to the reverse position R.

[0033] In the boat 1, it is possible to set the requested thrust in accordance with the position of the thrust inputter 7 in the operation area. That is, in a case where the thrust inputter 7 is located in the shift area of the neutral position N, it is possible to request the controller 5 to set the thrust to zero. In a case where the thrust inputter 7 is set in the shift area of the forward position F or the reverse position R, it is possible to request the controller 5 to increase the thrust in the corresponding advancing direction, as the thrust inputter 7 is apart from the shift area of the neutral position N. Note that the position (a lever opening rate LE) of the thrust inputter 7 is detected by a position sensor 32. The position sensor 32 outputs, to the controller 5, a detection signal based on the position (the lever opening rate LE) of the thrust inputter 7.

Boat Speed Sensor

[0034] A boat speed sensor 8 detects a speed (a boat speed) V of the boat 1. The boat speed sensor 8 receives a positioning signal from a positioning satellite such as a global positioning system (GPS), for example, measures an absolute position (latitude, longitude) of the boat 1, based on the received positioning signal, and calculates

the boat speed (the boat speed relative to the ground) V, based on time-series positioning results. Note that the boat speed sensor 8 may be an acoustic sensor or an electromagnetic sensor that detects the boat speed (the boat speed relative to the water) V of the boat 1. The boat speed sensor 8 may estimate the boat speed V, based on the engine speed.

Operation Unit

[0035] The operation unit 9 is provided in the cockpit of the hull 2. The operation unit 9 receives various operations in the boat 1. The operation unit 9 is constituted to be manually operable by a user, such as a multi-function display (MFD). Note that the operation unit 9 may be an external device such as a mobile terminal connected to the boat 1 in a wired or wireless manner.

Controller

[0036] The controller 5 integrally controls the operation of the boat 1 (the propulsion machine 3). The controller 5 is an integrated electronic control device or a plurality of electronic control devices included in the boat 1. The controller 5 is implemented by, for example, a hardware processor such as a central processing unit (CPU) executing a program (software) stored in 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.

[0037] The controller 5 includes a storage 50, an acquisitor 51, a determiner 52, and a drive processor 53.

[0038] The storage 50 includes, for example, a ROM or the like. In the storage 50, for example, programs, various data, and the like necessary for navigating the boat 1, such as a normal drive mode and a turning assist drive mode, are recorded.

[0039] The acquisitor 51 includes, for example, a RAM or the like. The acquisitor 51 acquires detection results of various sensors. The acquisitor 51 also acquires detection signals of other various sensors that detect the operation state of the propulsion machine 3, but its illustration and description will be omitted.

[0040] The determiner 52 includes, for example, a CPU or the like. The determiner 52 determines the state of the boat 1, based on information obtained by the acquisitor 51 and information stored in the storage 50.

[0041] The drive processor 53 includes, for example, a CPU or the like. The drive processor 53 controls operation of various actuators, based on a determination result of the determiner 52 and information stored in the storage 50 or the acquisitor 51.

[0042] The controller 5 controls the thrusts and the

directions of the thrusts of the plurality of propulsion machines 3. In the present embodiment, when there is a difference between instructed steering and actual steering when the boat 1 makes a turn, the controller 5 conducts turning assist control for generating a thrust balance in accordance with such a difference.

Example of Yaw Control

[0043] FIG. 4 is a view illustrating a first example of yaw control.

[0044] As illustrated in FIG. 4, in the first example of the yaw control, the rotational operation by the user on the steering angle inputter 6 (for example, the steering wheel) is not performed. The first example of the yaw control corresponds to the time when the boat 1 moves forward (advances straight).

[0045] FIG. 5 is a view illustrating a second example of the yaw control.

[0046] As illustrated in FIG. 5, the second example of the yaw control is an example of control for obtaining the thrust balance for accelerating steering effectiveness. In the second example of the yaw control, at the same time when the user starts the rotational operation on the steering angle inputter 6, the thrust balance is generated for further increasing the thrust of the propulsion machine on the outer side in making a turn than the thrust of the propulsion machine on the inner side, and thus the turning force is generated in the yaw direction from the start in making a turn. In the second example of the yaw control, while the boat 1 is making a turn, the direction of the thrust is changed while maintaining the thrust balance, so the steering angle is given as the user intends.

[0047] FIG. 6 is a view illustrating a third example of the yaw control.

[0048] As illustrated in FIG. 6, the third example of the yaw control is an example of control for obtaining the thrust balance that enables making a smaller turn than the turn in the second example of the yaw control illustrated in FIG. 5. In the third example of the yaw control, the user maintains the rotational operation on the steering angle inputter 6, and thus maintains the steering angle and maintains the turning posture of the boat 1. In the third example of the yaw control, shift handling is conducted while maintaining the steering angle. In the third example of the yaw control, as the shift handling, the shift position of the right propulsion machine 3R is continued at the forward position, and the shift position of the left propulsion machine 3L is changed to the reverse position.

Example of Turning Assist Control

[0049] FIG. 7 is a view illustrating boat 1 steering intended by a user when the boat makes a turn together with relational expressions. FIG. 8 is a view illustrating an actual boat that is delayed in steering together with relational expressions. FIG. 9 illustrates calculation formulae

of a balance thrust.

[0050] Referring also to FIGS. 7 to 9, in the turning assist control, in a case where there is a difference between instructed steering and actual steering when the boat 1 makes a turn, a thrust balance in accordance with the difference is generated. Specifically, the thrust is controlled in accordance with a difference between an instructed steering angle (see FIG. 7), which is an input from the user, and an actual steering angle (see FIG. 8), at which the propulsion machine 3 is actually steered. Thus, the steering thrust equivalent to a steering thrust theoretical value from the input from the user is obtained.

[0051] In the boat steering intended by the user in FIG. 7, a Port instructed steering angle (α) corresponds to an angle formed by a reference line parallel to the center line of the stern and passing through the steering shaft of the left propulsion machine 3L (PORT side) in a plan view and a straight line corresponding to the direction of the boat steering intended by the user. The Port thrust (F) can be estimated from the position of the thrust inputter 7 (the lever opening rate LE) although details will be described later. A gravity center position (θ) viewed from the Port corresponds to an angle formed by the reference line parallel to the center line of the stern and passing through the steering shaft of the left propulsion machine 3L in the plan view and a straight line connecting the gravity center position of the boat 1 with the steering shaft.

[0052] A Stab instructed steering angle (α) corresponds to an angle formed by a reference line parallel to the center line of the stern and passing through the steering shaft of the right propulsion machine 3R (STBD side) in a plan view and the straight line corresponding to the direction of the boat steering intended by the user. The Stab thrust (F) is proportional to the opening degree of the throttle valve (THB). A gravity center position ($-\theta$) viewed from the Stab corresponds to an angle formed by the reference line parallel to the center line of the stern and passing through the steering shaft of the right propulsion machine 3R in the plan view and a straight line connecting the gravity center position of the boat 1 with the steering shaft.

[0053] An angle formed by Port and the gravity center ($\alpha + \theta$) corresponds to the sum of the Port instructed steering angle (α) and the gravity center position (θ) viewed from the Port. An angle formed by the Stab and the gravity center ($\alpha - \theta$) corresponds to the sum of the Stab instructed steering angle (α) and the gravity center position ($-\theta$) viewed from the Stab.

[0054] Force (T_α) used for making a turn corresponds to the sum of a turning direction component of the Port thrust (F) and a turning direction component of the Stab thrust (F).

[0055] In the actual boat that is delayed in steering in FIG. 8, a Port actual steering angle (β) corresponds to an angle formed by the reference line parallel to the center line of the stern and passing through the steering shaft of the left propulsion machine 3L (PORT side) in the plan view and a straight line corresponding to the direction of

the actual boat that is delayed in steering. A Port thrust ($F_{\beta\text{-port}}$) is proportional to the opening degree of the throttle valve (THB). A gravity center position (θ) viewed from the Port corresponds to an angle formed by the reference line parallel to the center line of the stern and passing through the steering shaft of the left propulsion machine 3L in the plan view and a straight line connecting the gravity center position of the boat 1 with the steering shaft.

[0056] A Stab actual steering angle (β) corresponds to an angle formed by the reference line parallel to the center line of the stern and passing through the steering shaft of the right propulsion machine 3R (STBD side) in the plan view and the straight line corresponding to the direction of the actual boat that is delayed in steering. A Stab thrust ($F_{\beta\text{-stab}}$) is proportional to the opening degree of the throttle valve (THB). A gravity center position ($-\theta$) viewed from the Stab corresponds to an angle formed by the reference line parallel to the center line of the stern and passing through the steering shaft of the right propulsion machine 3R in the plan view and a straight line connecting the gravity center position of the boat 1 with the steering shaft.

[0057] An angle formed by the Port and the gravity center ($\beta + \theta$) corresponds to the sum of the actual port steering angle (β) and the gravity center position (θ) viewed from the Port. An angle formed by the Stab and the gravity center ($\beta - \theta$) corresponds to the sum of the Stab actual steering angle (β) and the gravity center position ($-\theta$) viewed from the Stab.

[0058] Force (T_β) used for making a turn corresponds to the sum of the turning direction component of the Port thrust ($F_{\beta\text{-port}}$) and the turning direction component of the Stab thrust ($F_{\beta\text{-stab}}$).

[0059] When restraint is exercised by a condition that total values of the left thrust and right thrust are equal to each other so that the boat speeds become equal to each other, the Port thrust ($F_{\beta\text{-port}}$) in the actual boat delayed in steering has a value obtained by adding a thrust difference (ΔF) to the Port thrust (F) in the boat steering intended by the user. In addition, the Stab thrust ($F_{\beta\text{-stab}}$) in the actual boat delayed in steering has a value obtained by subtracting the thrust difference (ΔF) from the Stab thrust (F) in the boat steering intended by the user.

[0060] The balance thrust (ΔF), when force (T_α) used for making a turn in the boat steering intended by the user and force (T_β) used for making a turn in the actual boat delayed in steering are equal to each other, is expressed by Equation (1) illustrated in FIG. 9.

[0061] The Port thrust ($F_{\beta\text{-port}}$) in the actual boat delayed in steering is expressed by Equation (2) illustrated in FIG. 9.

[0062] The Stab thrust ($F_{\beta\text{-stab}}$) in the actual boat delayed in steering is expressed by Equation (3) illustrated in FIG. 9.

[0063] Note that ΔF increases as the difference between the instructed steering and the actual steering

increases. In addition, as θ decreases, ΔF increases. In other words, ΔF increases as the gravity center position is farther (is located further forward) from the propulsion machine 3 in a plan view.

[0064] For example, in the boat steering intended by the user, turning force generated when the user fully steers the steering wheel is assumed. On the other hand, in the actual boat, the steering is delayed, and the actual boat is not steered so much. For this reason, the thrust difference (ΔF) between the left turn and the right turn is calculated in order to produce the turning force generated when the turning intended by the user is completed. When increasing the engine speed to increase the turning force, the boat speed increases. Hence, the thrust of only one of the left and right propulsion machines 3 is decreased. Alternatively, only one of the left and right propulsion machines 3 is set to reverse to increase the thrust. In the above example, while the sum of the left thrust and right thrust is not changed, the thrust difference (ΔF) is added for one, and the thrust difference (ΔF) is subtracted for the other one. Then, the thrust difference (ΔF) is obtained so that the force used for making a turn in the actual boat generates the same thrust as the turning force assumed for the full steering intended by the user.

[0065] Note that in the turning assist control, there is no limitation to calculation of the steering thrust, based on the angle formed by the reference line parallel to the center line of the stern and passing through the steering shaft of the left propulsion machine 3L in the plan view and the straight line connecting the gravity center position of the boat 1 with the steering shaft. For example, in the turning assist control, the controller 5 may calculate the steering thrust, based on an angle formed by a reference line parallel to the center line CL of the stern and passing through the steering shaft 16 of the propulsion machine 3 in the plan view and a straight line connecting a steering center point of the boat 1 with the steering shaft 16. The steering center point denotes an intersection point between the original course and the changed course in the straight traveling distance from the steering of the boat 1 to the start of the course change (in other words, an intersection point between the original course and the bow-stern line of a course change start stage).

[0066] FIG. 10 is a state transition diagram of a propulsion system 100 according to an embodiment. FIG. 11 is an explanatory diagram of each condition of the propulsion system 100 according to an embodiment.

[0067] Referring also to FIGS. 10 and 11, in the propulsion system 100, a normal drive mode (Normal DBW: drive by wire) and a turning assist drive mode (Assist Turn) are switched, based on a condition 1 and a condition 2.

[0068] The normal drive mode is a mode of navigating the boat 1 in a speed region other than a very slow speed region (a normal speed region faster than a very slow speed upper limit threshold V_{th}). The very slow speed upper limit threshold V_{th} may be set to, for example, 10

km/h.

[0069] The turning assist drive mode is a mode of navigating the boat 1 within a predetermined speed range (for example, about 2 km/h to 8 km/h) equal to or lower than the very slow speed upper limit threshold V_{th} .

[0070] The condition 1 is to satisfy all of the following conditions (1-1) to (1-3).

(1-1) The boat speed is equal to or lower than the very slow speed upper limit threshold V_{th} .

(1-2) A turning switch (TURN SW) is in a permission state.

(1-3) Initialization processing of the propulsion system is completed.

[0071] The condition 2 is to satisfy both conditions (both conditions 2A and 2B). The condition 2A is to satisfy any one of the following conditions (2-1) and (2-2), and the condition 2B is to satisfy the following condition (2-3).

(2-1) The boat speed is higher than the very slow speed upper limit threshold V_{th} .

(2-2) The turning switch (TURN SW) is in a non-permission state.

(2-3) The initialization processing of the propulsion system is not completed.

[0072] In the turning assist drive mode, the turning assist stop mode (Stop Assist Turn) and the turning assist driving mode (Active Assist Turn) are switched, based on the condition 3 and the condition 4.

[0073] The turning assist stop mode is a mode equivalent to the normal drive mode.

[0074] The turning assist driving mode is a mode including a shift control mode (Shift Control) and a rudder allocation mode (Allocation Rudder).

[0075] The condition 3 is to satisfy any one of the following conditions (3-1) and (3-2).

(3-1) The instructed steering angle is smaller than a steering angle threshold A_{th} .

(3-2) The shift instruction is the neutral position N or the reverse position R (Neutral/Reverse).

[0076] The steering angle threshold A_{th} may be set to, for example, 10 degrees. Note that the steering angle threshold A_{th} is not limited to the above one, and may be set to, for example, 5 degrees or 15 degrees. It is possible to change the steering angle threshold A_{th} in accordance with a design specification within a range in which stability at the time of advancing straight can be ensured.

[0077] The condition 4 is to satisfy both of the following conditions (4-1) and (4-2).

(4-1) The instructed steering angle is equal to or larger than the steering angle threshold A_{th} .

(4-2) The shift instruction is the forward position F

(Forward).

[0078] The shift control mode is a control mode for reducing a shift shock. The shift control mode includes a turning assist control mode (Control Assist Turn), a shift maintaining mode (Hold Shift), a shift change mode (Changing Shift), and a shift neutral position mode (Neutral Shift).

[0079] In the shift control mode, the turning assist control mode and the shift maintaining mode are switched, based on a condition 5 and a condition 8. In addition, the turning assist control mode and the shift change mode are switched, based on the condition 5. Further, the shift maintaining mode and the shift neutral position mode are switched, based on a condition 6. Further, the shift neutral position mode and the shift change mode are switched, based on a condition 7.

[0080] In the turning assist control mode, the following information calculated in the turning assist is instructed.

- Shift position
- Lever opening rate (the position of the thrust inputter 7)

[0081] In the shift maintaining mode, the following control is conducted.

- The lever opening rate instruction is gradually decreased.
- Instruct the actual shift position

[0082] In the shift neutral position mode, the following instruction (control) is conducted.

- The shift position is set to the neutral position.
- The lever opening rate is set to 0%.

[0083] In the shift change mode, the following instruction (control) is conducted.

- The shift position calculated in the turning assist is set.
- The lever opening rate is set to 0%.

[0084] The condition 5 is that the shift instruction and the actual shift position are equal to each other.

[0085] The condition 6 is that the actual engine speed is lower than a shift change allowable speed threshold.

[0086] The shift change allowable speed threshold under the condition 6 may be set to, for example, 1000 [rpm] or 1500 [rpm]. Note that the shift change allowable speed threshold is not limited to the above one, and can be changed in accordance with a design specification.

[0087] The condition 7 is that a certain period of time or more elapses from the state in which the actual shift position is the neutral position N (Neutral). The certain period of time in the condition 7 may be set to, for example, 0.1 seconds. Note that the certain period of

time in the condition 7 is not limited to the above one, and can be changed in accordance with a design specification.

[0088] The condition 8 is to satisfy both of the following conditions (8-1) and (8-2).

(8-1) A shift change is not being performed.

(8-2) A certain period of time or more elapses from a state in which the shift instruction and the actual shift position are not equal to each other.

[0089] The certain period of time in the condition 8 may be set to, for example, 0.1 seconds. Note that the certain period of time in the condition 8 is not limited to the above one, and can be changed in accordance with a design specification.

[0090] The rudder allocation mode is a mode for converting a HELM instructed steering angle into a thrust calculation steering angle (large steering). The rudder allocation mode is performed by the controller as necessary.

[0091] FIG. 12 is a flowchart illustrating a main processing flow of the turning assist control according to an embodiment. FIG. 13 is an explanatory diagram of simulated large steering according to an embodiment. Note that the condition (8-2) of the condition 8 is omitted in the flowchart of FIG. 12.

[0092] Referring also to FIGS. 12 and 13, in step S10, the controller 5 determines whether the instructed steering angle condition is satisfied. The instructed steering angle corresponds to an angle obtained by converting an operation amount on the steering wheel into a steering amount of the propulsion machine 3. The controller 5 determines whether the instructed steering angle is equal to or larger than the steering angle threshold A_{th} (for example, equal to or larger than 10 degrees) as the instructed steering angle condition. For example, in a case where the steering wheel is turned two rounds in one direction and it becomes possible to steer the propulsion machine 3 by 30 degrees, and when the steering wheel is turned equal to or larger than two-thirds round (240 degrees), "YES" is obtained in step S10. In a case where the instructed steering angle condition is satisfied in step S10 (in the case of "YES"), the processing proceeds to step S11. In a case where the instructed steering angle condition is not satisfied in step S10 (in the case of "NO"), the processing proceeds to step S15.

[0093] In step S11, the controller 5 calculates a simulated large steering angle. In the controller 5, a map as illustrated in FIG. 13 is stored beforehand. The map illustrated in FIG. 13 indicates a relationship between the instructed steering angle and the simulated large steering angle. In the turning assist control, the controller 5 may compensate the instructed steering to the propulsion machine 3 to be larger than an instructed steering value. Such compensation (including the simulated large steering) enables the large instructed steering to be promptly given to normal instructed steering. For exam-

ple, normally, in a case the steering wheel makes two rounds in one direction, and the steering wheel performs full steering, the compensation may be made by including the simulated large steering so as to perform full steering when the steering wheel makes one round in one direction.

[0094] In an example illustrated in FIG. 13, when the instructed steering angle is smaller than the steering angle threshold A_{th} , that is, until the instructed steering angle (for example, 10 degrees) at which the turning assist operates, the compensation of the simulated large steering is not made. The simulated large steering angle and the instructed steering angle are different from each other (the simulated large steering angle is not equal to the instructed steering angle) in a region equal to or larger than the instructed steering angle (for example, 10 degrees) at which the turning assist operates when the simulated large steering is included, and thus the simulated large steering angle and the actual steering angle are not equal to each other. Therefore, when the simulated large steering is included, the turning assist always operates.

[0095] After step S11, the processing proceeds to step S12. Note that it is not essential to calculate the simulated large steering angle. For example, after step S11, in the case of "YES" in step S10, the processing may proceed to step S12 without performing step S11.

[0096] In step S12, the controller 5 calculates the turning force in accordance with the instructed steering. The turning force in accordance with the instructed steering is calculated in the above relational expression (see FIGS. 7 to 9). After step S12, the processing proceeds to step S13.

[0097] In step S13, the controller 5 calculates the thrust for achieving the turning force calculated in step S12 in the actual steering. The thrust for achieving the turning force calculated in step S12 in the actual steering is calculated in the above relational expression (see FIGS. 7 to 9). The thrust calculated in step S13 is proportional to, for example, the square of the propeller rotation speed. After step S13, the processing proceeds to step S14.

[0098] In step S14, the controller 5 calculates the opening degree of the throttle valve (TH opening degree) from the thrust calculated in step S13. The controller 5 transmits the calculated TH angle information to a drive controller, not illustrated, (for example, FI-ECU) that controls the driving of each propulsion machine 3. The drive controller of each propulsion machine 3 determines, for example, a motor drive voltage, and determines the target opening degree of the throttle valve.

[0099] In step S15, the controller 5 calculates the opening degree of the throttle valve (TH opening degree) from the instructed thrust. The controller 5 transmits the calculated TH angle information to a drive controller, not illustrated, (for example, FI-ECU) that controls the driving of each propulsion machine 3.

[0100] FIG. 14 is a flowchart illustrating a processing flow for suppressing a shift shock in the turning assist

control according to an embodiment.

[0101] Referring also to FIG. 14, the control for suppressing the shift shock is conducted in the order of the condition 8, the condition 6, the condition 7, and the condition 5 in the state transition illustrated in FIG. 10, for example. The example illustrated in FIG. 14 corresponds to an example in which in a case where the compensation shift, which is a shift instruction of the compensation thrust, is different from the actual shift, which is the actual shift position of the propulsion machine 3, in the turning assist control, after the actual shift and the compensation shift are matched with each other, the controller 5 conducts the turning assist control with the compensation thrust.

[0102] In step S20, the controller 5 determines whether the actual shift is the same as the calculated shift (the compensation shift). In a case where the actual shift is the same as the calculated shift in step S20 (in the case of "YES"), the processing proceeds to step S21. In a case where the actual shift is not the same as the calculated shift in step S20 (in the case of "NO"), the processing proceeds to step S23.

[0103] In step S21, the controller 5 maintains the shift. The controller 5 performs the shift maintaining mode illustrated in FIG. 10 as the shift maintenance. After step S21, the processing proceeds to step S22.

[0104] In step S22, the controller 5 sets a TH opening degree change permission flag. This permits a change in the opening degree of the throttle valve. This permission enables an increase or a decrease in the thrust of the propulsion machine 3.

[0105] In step S23, the controller 5 determines whether the actual shift is in a gear-in state. The gear-in state means a state in which the shift position is located at the forward position F or the reverse position R. In a case where the actual shift is in the gear-in state in step S23 (in the case of "YES"), the processing proceeds to step S24. In a case where the actual shift is not in the gear-in state in step S23 (in the case of "NO"), the processing proceeds to step S27.

[0106] In step S24, the controller 5 determines whether the speed is lower than an allowable speed. As the determination in step S24, the controller 5 determines whether the condition 6 is satisfied (the actual engine speed is lower than the shift change allowable speed threshold). In a case where the condition 6 is satisfied in step S24 (in the case of "YES"), the processing proceeds to step S25. In a case where the condition 6 is not satisfied in step S24 (in the case of "NO"), the processing proceeds to step S26.

[0107] In step S25, the controller 5 performs shift change. The controller 5 changes the shift position from the forward position F or the reverse position R to the neutral position N, as the shift change.

[0108] In step S26, the controller 5 maintains the shift (maintains the state in which the shift position is located at the forward position F or the reverse position R), and reduces the actual engine speed to be equal to or smaller

than a predetermined value.

[0109] In step S27, the controller 5 determines whether a shift N state (a state in which the shift position is located at the neutral position N) has continued for a certain period of time. In a case where the shift N state has continued for a certain period of time in step S27 (in the case of "YES"), the processing proceeds to step S28. In a case where the shift N state has not continued for a certain period of time in step S27 (in the case of "NO"), the processing proceeds to step S29.

[0110] In step S28, the controller 5 changes the shift position to the calculated shift position. As a shift change in step S28, the controller 5 changes the state in which the shift position is located at the neutral position N to the forward position F or the reverse position R that is the calculated shift position.

[0111] In step S29, the controller 5 maintains the shift N (maintaining a state in which the shift position is located at the neutral position N).

[0112] Note that after step S22, step S25, step S26, step S28, and step S29, the processing proceeds to predetermined control processing.

Operation Example of Propulsion System

[0113] FIG. 15 is a timing chart showing a first example of the operation of the propulsion system 100 according to an embodiment. FIG. 16 is a timing chart showing a second example of the operation of the propulsion system 100 according to an embodiment. In FIGS. 15 and 16, the operation in a case of turning the boat 1 to the right in accordance with full steering will be described.

[0114] In FIGS. 15 and 16, the vertical axis represents, sequentially from the top, the instructed steering (the instructed steering angle), the actual steering (the actual steering angle), the thrust (the thrusts of the left and right propulsion machines), and the shift position (the shift positions of the left and right propulsion machines), and the horizontal axis represents time. In the instructed steering, Rmax represents the maximum value of steering to the right (the maximum value of the instructed steering angle in the case of steering to the right), Lmax represents the maximum value of steering to the left (the maximum value of the instructed steering angle in the case of steering to the left), Rth represents the steering angle threshold (Ath) in steering to the right, and Lth represents the steering angle threshold (Ath) in steering to the left. In the actual steering, Rmax represents the maximum value in steering to the right (the maximum value of the actual steering angle in the case of steering to the right), and Lmax represents the maximum value in steering to the left (the maximum value of the actual steering angle in the case of steering to the left). In the thrust, an alternate long and short dash line indicates the thrust before compensation, a broken line indicates the thrust of the left propulsion machine 3L, and a solid line indicates the thrust of the right propulsion machine 3R. Note that the broken line and the solid line correspond to

values obtained by adding or subtracting the thrust difference (ΔF) to or from the thrust before compensation. In the shift position, F indicates a forward position, N indicates a neutral position, and R indicates a reverse position. In the shift position, a broken line indicates the shift position of the left propulsion machine 3L, and a solid line indicates the shift position of the right propulsion machine 3R. Note that in FIGS. 15 and 16, it is assumed that the thrust instruction (that is, an instructed lever opening rate = a remote controller lever input by the user) is kept fixed at a predetermined position. Specifically, as indicated by "before compensation" in the "thrust" in FIGS. 15 and 16, in a case where the present turning assist control is not conducted (that is, in a case where the propulsion machine outputs the thrust in accordance with the thrust instruction in the normal control), the thrust instruction is set to the thrust "before compensation".

[0115] As illustrated in FIG. 15, in the instructed steering, in order to turn the boat 1 to the right in accordance with the full steering, the user starts to turn the steering wheel clockwise at time t1. Then, from time t1 to time t4, the instructed steering gradually increases toward Rmax. In the instructed steering, at time t2, the instructed steering angle is equal to or larger than the steering angle threshold Rth. In the instructed steering, time t4 corresponds to the end of turning the steering wheel (a full steering position in turning to the right).

[0116] In the instructed steering, at time t6, the user starts to return the steering wheel. Then, from time t6 to time t9, the instructed steering gradually decreases toward zero. In the instructed steering, at time t8, the instructed steering angle is smaller than the steering angle threshold Rth. In the instructed steering, time t9 corresponds to an end of returning the steering wheel (the position of ending returning to the center from the full steering in turning to the right).

[0117] In the actual steering, a following delay occurs with respect to the instructed steering. In the actual steering, at time t3, the thrust direction changer 4 starts to steer the propulsion machine 3 to the right. Then, from time t3 to time t5, the actual steering gradually increases toward Rmax. In the actual steering, time t5 corresponds to the end of steering the propulsion machine 3.

[0118] In the actual steering, at time t7, the thrust direction changer 4 starts to steer the propulsion machine 3 in a direction of returning the steering of the propulsion machine 3. Then, from time t7 to time t10, the actual steering gradually decreases toward zero. In the actual steering, time t10 corresponds to the end of returning the steering of the propulsion machine 3.

[0119] In the thrust, at time t2 when the instructed steering angle is equal to or larger than the steering angle threshold Rth, the thrust of the left propulsion machine 3L starts to increase from the thrust before compensation, and the thrust of the right propulsion machine 3R starts to decrease from the thrust before compensation. Then, from time t2 to time t3, the thrust of the left propulsion

machine 3L gradually increases, and the thrust of the right propulsion machine 3R gradually decreases toward zero. Then, the thrust of the left propulsion machine 3L gradually increases from time t3 to time t4 more gently than the thrust change from time t2 to time t3, and the thrust of the right propulsion machine 3R gradually increases toward a minus side. Then, from time t4 to time t5, the thrust of the left propulsion machine 3L decreases toward the thrust before compensation, and the thrust of the right propulsion machine 3R increases toward the thrust before compensation.

[0120] In the thrust, from time t5 to time t6, the thrust of the left propulsion machine 3L and the thrust of the right propulsion machine 3R are constant to be the same as the thrust before compensation. Then, from time t6 to time t7, the thrust of the right propulsion machine 3R starts to increase from the thrust before compensation, and the thrust of the left propulsion machine 3L starts to decrease from the thrust before compensation. Then, the thrust of the right propulsion machine 3R gradually increases from time t7 to a time before reaching time t8 more gently than the thrust change from time t6 to time t7, and the thrust of the left propulsion machine 3L gradually increases toward the minus side. Then, from time t7 to the time before reaching time t8, the thrust of the right propulsion machine 3R decreases toward the thrust before compensation, and the thrust of the left propulsion machine 3L increases toward the thrust before compensation. Then, at time t8 and later, the thrust of the left propulsion machine 3L and the thrust of the right propulsion machine 3R are constant to be the same as the thrust before compensation.

[0121] In the shift position, the shift position of the left propulsion machine 3L maintains the forward position F until time t7. Then, from time t7 to time t8, the shift position of the left propulsion machine 3L changes sequentially in the order of the neutral position N, the reverse position R, and the neutral position N. Then, at time t8 and later, the shift position of the left propulsion machine 3L maintains the forward position F.

[0122] In the shift position, the shift position of the right propulsion machine 3R maintains the forward position F until time t3. Then, from time t3 to time t4, the shift position of the right propulsion machine 3R changes sequentially in the order of the neutral position N and the reverse position R. Then, from time t4 to time t5, the shift position of the right propulsion machine 3R changes sequentially in the order of the reverse position R, the neutral position N, and the forward position F. Then, at time t5 and later, the shift position of the right propulsion machine 3R maintains the forward position F.

[0123] In the present embodiment, in a case where the instructed steering angle to the propulsion machine 3 based on the instructed steering value is equal to or larger than the steering angle threshold Ath, the controller 5 conducts the turning assist control. In the example illustrated in FIG. 15, the turning assist operates from time t2 when the instructed steering angle is equal to or larger

than the steering angle threshold Rth to time t5, and between time t6 and time t8 while the instructed steering angle is equal to or larger than the steering angle threshold Rth. In the example illustrated in FIG. 15, the turning assist does not operate before time t2 while the instructed steering angle is smaller than the steering angle threshold Rth and at time t8 and later.

[0124] In the present embodiment, in a case where the difference between the instructed steering angle to the propulsion machine 3 based on the instructed steering value and the actual steering angle at which the propulsion machine 3 is actually steered is equal to or larger than an angle difference threshold Dth, the controller 5 conducts the turning assist control. For example, the angle difference threshold Dth may be set to 10 degrees. Note that the angle difference threshold Dth is not limited to the above one, and may be set to 5 degrees or 15 degrees. The angle difference threshold Dth can be changed in accordance with a design specification.

[0125] In the example illustrated in FIG. 15, the turning assist is not operated during a period from time t5 to time t6 while the instructed steering angle is Rmax and the actual steering angle is Rmax.

[0126] In the present embodiment, out of the plurality of propulsion machines 3, the propulsion machine 3 located on the inner side with respect to the turning direction of the hull 2 is defined as an inner propulsion machine, and the propulsion machine 3 located on the outer side with respect to the turning direction of the hull 2 is defined as an outer propulsion machine. In this case, in the turning assist control, the controller 5 decreases the thrust of the inner propulsion machine to be smaller than a predetermined thrust, and increases the thrust of the outer propulsion machine to be equal to or larger than the predetermined thrust. In the example illustrated in FIG. 15, in the operation for turning the boat 1 to the right, the left propulsion machine 3L serves as the outer propulsion machine, and the right propulsion machine 3R serves as the inner propulsion machine. In the example illustrated in FIG. 15, during a period from time t2 to time t4 while in the turning assist operation, the thrust of the right propulsion machine 3R (the inner propulsion machine) is decreased to be lower than the thrust before compensation, and the thrust of the left propulsion machine 3L (the outer propulsion machine) is increased to be equal to or larger than the thrust before compensation.

[0127] In FIG. 16, description will be made with regard to the operation in a case where the instructed steering to the propulsion machine 3 is compensated to be larger than the instructed steering value, in turning the boat 1 to the right in accordance with the full steering. In FIG. 16, a thick broken line in an upper part of the vertical axis indicates the simulated large steering (the simulated large steering angle). In the description of FIG. 16, detailed description of contents similar to those in FIG. 15 will be omitted.

[0128] As illustrated in FIG. 16, in order to turn the boat 1 to the right in accordance with the full steering, the user

starts to steer the steering wheel clockwise at time t1 in the instructed steering. In the instructed steering, at time t2, the instructed steering angle is equal to or larger than the steering angle threshold Rth. In the instructed steering, at time t2, the simulated large steering operates. When the simulated large steering operates, the simulated large steering angle gradually increases more steeply than an angle change in the instructed steering from time t2 to time t4. In the simulated large steering, the simulated large steering angle is constant from time t4 when located at the full steering position of the instructed steering to time t6.

[0129] In the instructed steering, at time t6, the user starts to return the steering wheel. In the instructed steering, at time t8, the instructed steering angle is smaller than the steering angle threshold Rth. In the instructed steering, at time t8, the simulated large steering does not operate.

[0130] In the thrust, at time t2 when the instructed steering angle is equal to or larger than the steering angle threshold Rth, the thrust of the left propulsion machine 3L starts to increase from the thrust before compensation, and the thrust of the right propulsion machine 3R starts to decrease from the thrust before compensation. In accordance with the operation of the simulated large steering, the thrust of the left propulsion machine 3L increases, and the thrust of the right propulsion machine 3R decreases toward zero more steeply than the thrust change illustrated in FIG. 15 from time t2 to a time before reaching time t3. Then, the thrust of the left propulsion machine 3L gradually increases from the time before reaching time t3 to time t4 more gently than the thrust change from time t2 to the time before reaching time t3, and the thrust of the right propulsion machine 3R gradually increases toward the minus side. Then, from time t4 to time t5, the thrust of the left propulsion machine 3L gradually decreases toward the plus side of the thrust before compensation, and the thrust of the right propulsion machine 3R gradually increases toward between zero and the thrust before compensation.

[0131] In the thrust, from time t5 to time t6, the thrust of the left propulsion machine 3L and the thrust of the right propulsion machine 3R are constant to be the same as the thrust at time t5. Then, the thrust of the right propulsion machine 3R gradually increases and the thrust of the left propulsion machine 3L gradually decreases from time t6 to a time before reaching time t8. Then, from time t7 to the time before reaching time t8, the thrust of the right propulsion machine 3R decreases toward the thrust before compensation, and the thrust of the left propulsion machine 3L increases toward the thrust before compensation. Then, at time t8 and later, the thrust of the left propulsion machine 3L and the thrust of the right propulsion machine 3R are constant to be the same as the thrust before compensation.

[0132] In the shift position, the shift position of the left propulsion machine 3L always maintains the forward position F.

[0133] In the shift position, the shift position of the right propulsion machine 3R maintains the forward position F until time t3. Then, from time t3 to time t4, the shift position of the right propulsion machine 3R changes sequentially in the order of the neutral position N and the reverse position R. Then, from time t4 to time t5, the shift position of the right propulsion machine 3R changes sequentially in the order of the reverse position R, the neutral position N, and the forward position F. Then, at time t5 and later, the shift position of the right propulsion machine 3R maintains the forward position F.

[0134] In the example illustrated in FIG. 16, the simulated large steering operates at time t2 when the instructed steering angle is equal to or larger than the steering angle threshold Rth. Even though the full steering of the propulsion machine 3 ends, the actual steering does not catch up with the simulated large steering, and thus the turning assist operates while the instructed steering angle is equal to or larger than the steering angle threshold Rth. In the example illustrated in FIG. 16, the turning assist operates between time t2 when the instructed steering angle is equal to or larger than the steering angle threshold Rth and time t8. The turning assist does not operate before time t2 while the instructed steering angle is smaller than the steering angle threshold Ath and at time t8 and later.

[0135] In the present embodiment, in the turning assist control, the controller 5 calculates the steering thrust, based on a thrust upper limit value or a thrust lower limit value when the propulsion machine 3 is actually steered.

[0136] For example, the upper limit value of the thrust of the propulsion machine 3 is set to 100. Hereinafter, in the left and right propulsion machines 3, a description of (thrust, turning force in the thrust) will be used as an example.

[0137] As the thrust generated in accordance with the instructed steering, the left propulsion machine 3L (80, 40) and the right propulsion machine 3R (80, 20) are set.

[0138] With regard to the thrust achieved in the actual steering, the left propulsion machine 3L (110, 55) and the right propulsion machine 3R (50, 5) are assumed to be ideal.

[0139] In this case, the thrust of the actual steering cannot exceed 100. In the actual steering, a state in which the opening degree of the throttle valve is the maximum value and the engine speed is the maximum value corresponds to a thrust upper limit theoretical value.

[0140] Therefore, the left propulsion machine 3L (100, 50) and the right propulsion machine 3R (50, 5) are set, based on the thrust upper limit value, when the propulsion machine 3 is actually steered.

[0141] Note that in the above example, priority is given to ideal ΔF illustrated in FIG. 8, and ΔF = turning force 15. On the other hand, it is also conceivable not to change the sum of the numbers on the left side of the total thrust (xx, yy).

[0142] For example, the left propulsion machine 3L (100, 50) and the right propulsion machine 3R (60, 10)

may be set, based on the thrust upper limit value, when the propulsion machine 3 is actually steered. In this case, the total thrust 160 is maintained, and instead, ΔF is 10.

[0143] In the present embodiment, in the turning assist control, the controller 5 acquires the instructed steering value input into the steering angle inputter 6, the actual steering value at which the propulsion machine 3 is actually steered, and the instructed thrust value input into the thrust inputter 7, calculates the steering thrust generated by the instructed thrust value when the steering direction of the propulsion machine 3 reaches the instructed steering value, and calculates the compensation thrust that generates the calculated steering thrust in the actual steering value.

[0144] FIG. 17 is a view illustrating an example of a map for achieving the turning assist control according to an embodiment. In the map of FIG. 17, each axis is allocated as follows.

C_SHIFT_MAP: shift position (1 = forward position, F/2 = neutral position, N/3 = reverse position R)

Breakpoints F or Dimension 1: lever opening rate (0% to 100%)

C_to THRUST_MAP: Propeller thrust (square of rotation speed)

[0145] Referring also to FIG. 17, in order to achieve the turning assist control, for example, a map indicating a relationship between the lever opening rate and the opening degree of the throttle valve, a map indicating a relationship between the opening degree of the throttle valve and the engine speed, and a map indicating a relationship between the engine speed and the thrust may be stored in the controller 5 beforehand. In this case, the controller 5 converts the instructed lever opening rate (a remote controller lever input by the user) into the opening degree of the throttle valve, calculates the engine speed, based on the converted opening degree of the throttle valve, and calculates the current thrust, based on the calculated engine speed. Then, the controller 5 calculates the thrust in accordance with the turning assist, based on the calculated current thrust, converts the calculated thrust into the engine speed, and converts the converted engine speed into the opening degree of the throttle valve (after compensation). The controller 5 is capable of carrying out mutual conversion between the lever opening rate and the opening degree of the throttle valve, mutual conversion between the opening degree of the throttle valve and the engine speed, and mutual conversion between the engine speed and the thrust, in accordance with the above map.

[0146] Note that in the above-described timing chart, the case of steering to the right has been described as an example, but it is also possible to steer to the left using the same thresholds as the case of steering to the right. In addition, in the present embodiment, the case where the turning control is conducted on the F (forward) side has been described as an example, but the turning control

may be performed on the R (reverse) side. In the turning control on the R side, the threshold of the instructed steering and the thrust calculation method are similar to those in the turning control on the F side.

Operation and Effects

[0147] As described heretofore, the propulsion system 100 of the boat 1 according to the above embodiment includes: the plurality of propulsion machines 3 each including the power source 12 and the propulsor 14, which generates a thrust with the power transmitted from the power source 12, the plurality of propulsion machines 3 being provided on the left and right interposing the center of the hull 2; the thrust direction changer 4, which changes the directions of the thrusts of the plurality of propulsion machines 3; and the controller 5, which controls the thrusts and the thrust directions of the plurality of propulsion machines 3. In a case where there is a difference between the instructed steering and the actual steering when the boat 1 makes a turn, the controller 5 conducts turning assist control for generating a thrust balance in accordance with the difference. In the turning assist control, the controller 5 acquires the instructed steering value input into the steering angle inputter 6, the actual steering value at which the propulsion machine 3 is actually steered, and the instructed thrust value input into the thrust inputter 7, calculates the steering thrust generated by the instructed thrust value when the steering direction of the propulsion machine 3 reaches the instructed steering value, and calculates the compensation thrust for generating the calculated steering thrust in the actual steering value.

[0148] According to this constitution, in consideration of a delay in the actual steering of the propulsion machine 3 with respect to the instructed steering when the boat 1 makes a turn, the steering thrust of the propulsion machine 3 after reaching the instructed steering is achieved with the current actual steering that is delayed in steering, so that the turning force desired by the user can be promptly achieved. Therefore, it becomes possible to improve responsiveness while the boat is making a turn and to navigate the boat in accordance with a boat operator's intention in steering the boat.

[0149] In the above embodiment, the controller 5 conducts the turning assist control in a case where the instructed steering angle to the propulsion machine 3 based on the instructed steering value is equal to or larger than the steering angle threshold A_{th} .

[0150] According to this constitution, it becomes possible to suppress conducting of the turning assist control when the boat 1 advances straight.

[0151] In the above embodiment, the controller 5 conducts the turning assist control in a case where the difference between the instructed steering angle to the propulsion machine 3 based on the instructed steering value and the actual steering angle at which the propulsion machine 3 is actually steered is equal to or larger

than the angle difference threshold Dth.

[0152] According to this constitution, it becomes possible to suppress an unstable operation (hunting) due to the turning assist control.

[0153] In the above embodiment, out of the plurality of propulsion machines 3, the propulsion machine 3 located on the inner side with respect to the turning direction of the hull 2 is defined as an inner propulsion machine, and the propulsion machine 3 located on the outer side with respect to the turning direction of the hull 2 is defined as an outer propulsion machine. In this case, in the turning assist control, the controller 5 decreases the thrust of the inner propulsion machine to be smaller than a predetermined thrust, and increases the thrust of the outer propulsion machine to be equal to or larger than the predetermined thrust.

[0154] According to this constitution, in the turning assist control, responsiveness while the boat is making a turn can be improved as compared with a case where the thrust of the inner propulsion machine is increased to be equal to or larger than a predetermined thrust and the thrust of the outer propulsion machine is decreased to be smaller than the predetermined thrust.

[0155] In the above embodiment, in the turning assist control, the controller 5 compensates the instructed steering to the propulsion machine 3 to be larger than the instructed steering value.

[0156] According to this constitution, it becomes possible to promptly give large instructed steering to the normal instructed steering, so that responsiveness while the boat is making a turn can be improved.

[0157] In the above embodiment, in the turning assist control, in a case where the actual shift position of the propulsion machine 3 is different from the compensation shift corresponding to a shift instruction of the compensation thrust, the controller 5 matches the actual shift corresponding to the actual shift position with the compensation shift, and then conducts the turning assist control with the compensation thrust.

[0158] According to this constitution, it becomes possible to suppress an impact or the like (a shift shock) caused by a shift change as compared with a case where the turning assist control is conducted in accordance with the compensation thrust in a state in which the compensation shift is different from the actual shift.

[0159] In the above embodiment, in the turning assist control, the controller 5 calculates the steering thrust, based on the angle formed by the reference line parallel to the center line CL of the stern and passing through the steering shaft 16 of the propulsion machine 3 in a plan view and the straight line connecting the steering center point of the boat 1 with the steering shaft 16.

[0160] According to this constitution, it becomes possible to improve responsiveness while the boat is making a turn as compared with a case of calculating the steering thrust, based on the angle formed by the above reference line and the straight line connecting a point other than the steering center point with the steering shaft 16 in a plan

view.

[0161] In the above embodiment, in the turning assist control, the controller 5 calculates the steering thrust, based on either the thrust upper limit value or the thrust lower limit value when the propulsion machine 3 is actually steered.

[0162] According to this constitution, in the turning assist control, it is not necessary to conduct the control for calculating the thrust that exceeds the thrust upper limit value or that falls below the thrust lower limit value when the propulsion machine 3 is actually steered, so that the control can be simplified.

Modifications

[0163] In the above embodiment, description has been made with regard to an example in which the controller conducts the turning assist control in a case where the instructed steering angle to the propulsion machine based on the instructed steering value is equal to or larger than the steering angle threshold, but there is no limitation to this. For example, the controller may conduct the turning assist control in a case where the instructed steering angle to the propulsion machine based on the instructed steering value is smaller than the steering angle threshold. The mode of conducting the turning assist control based on the steering angle threshold can be changed in accordance with a design specification.

[0164] In the above embodiment, description has been made with regard to an example in which the controller conducts the turning assist control in a case where the difference between the instructed steering angle to the propulsion machine based on the instructed steering value and the actual steering angle at which the propulsion machine is actually steered is equal to or larger than the angle difference threshold, but there is no limitation to this. For example, the controller may conduct the turning assist control in a case where the difference between the instructed steering angle to the propulsion machine based on the instructed steering value and the actual steering angle at which the propulsion machine is actually steered is smaller than the angle difference threshold. The mode of conducting the turning assist control based on the angle difference threshold can be changed in accordance with a design specification.

[0165] In the above embodiment, description has been made with regard to an example in which, out of the plurality of propulsion machines, in a case where the propulsion machine located on the inner side with respect to the turning direction of the hull is defined as the inner propulsion machine and the propulsion machine located on the outer side with respect to the turning direction of the hull is defined as the outer propulsion machine, the controller decreases the thrust of the inner propulsion machine to be smaller than the predetermined thrust, and increases the thrust of the outer propulsion machine to be equal to or larger than the predetermined thrust in the

turning assist control, but there is no limitation to this. For example, in the turning assist control, the controller may increase the thrust of the inner propulsion machine to be equal to or larger than the predetermined thrust, and may decrease the thrust of the outer propulsion machine to be smaller than the predetermined thrust. The mode of increasing and decreasing the thrust of the inner propulsion machine and/or the outer propulsion machine in the turning assist control can be changed in accordance with a design specification.

[0166] In the above embodiment, description has been made with regard to an example in which the controller compensates the instructed steering to the propulsion machine to be larger than the instructed steering value in the turning assist control, but there is no intention to this. For example, in the turning assist control, the controller may not necessarily compensate the instructed steering to the propulsion machine to be larger than the instructed steering value. For example, the controller may not necessarily perform the simulated large steering in the turning assist control. The mode of compensating the instructed steering in the turning assist control can be changed in accordance with a design specification.

[0167] In the above embodiment, description has been made with regard to an example in which, in the turning assist control, in a case where the actual shift position of the propulsion machine is different from the compensation shift corresponding to the shift instruction of the compensation thrust, the controller matches the actual shift corresponding to the actual shift position with the compensation shift, and then conducts the turning assist control in accordance with the compensation thrust, but there is no limitation to this. For example, the controller may conduct the turning assist control in accordance with the compensation thrust in a state in which the compensation shift is different from the actual shift. The mode of conducting the turning assist control with the compensation thrust can be changed in accordance with a design specification.

[0168] In the above embodiment, description has been made with regard to an example in which, in the turning assist control, the controller calculates the steering thrust, based on the angle formed by the reference line parallel to the center line of the stern and passing through the steering shaft of the propulsion machine in the plan view and the straight line connecting the steering center point of the boat with the steering shaft, but there is no limitation to this. For example, in the turning assist control, the controller may calculate the steering thrust based on an angle formed by the above reference line and a straight line connecting a point other than the steering center point with the steering shaft in a plan view. The mode of calculating the steering thrust in the turning assist control can be changed in accordance with a design specification.

[0169] In the above embodiment, description has been made with regard to an example in which, in the turning assist control, the controller calculates the steering thrust

based on either the thrust upper limit value or the thrust lower limit value when the propulsion machine is actually steered, but there is no limitation to this. For example, in the turning assist control, the controller may conduct control of calculating the thrust that exceeds the thrust upper limit value or that falls below the thrust lower limit value when the propulsion machine is actually steered. The control mode of calculating the thrust in the turning assist control can be changed in accordance with a design specification.

[0170] In addition, as the type of the hull, various moving bodies on water such as a V shape hull, a pontoon boat, a center console, a runabout, a fishing boat, and a jet ski may be applicable.

[0171] In the above embodiment, the example in which the power source is the internal combustion engine has been described, but there is no limitation to this. For example, the power source may be an electric motor or the like. In a case of the electric motor, the motor rotation speed, torque, or the like corresponds to "thrust". In this case, the neutral position N is obtained by setting the motor rotation speed to zero.

[0172] In conducting automatic driving or driving assistance (for example, cruise control as autopilot or constant-speed driving), a computer may be constituted to calculate an instruction value and set a target speed or the like, instead of the user (a boat operator) inputting the thrust of the propulsion machine (the instructed thrust).

[0173] Note that a program for achieving all or some of the functions of the propulsion system in the present disclosure may be recorded in a computer-readable recording medium, and a computer system may be caused to read and execute the program recorded in such a recording medium to entirely or partially perform the processing to be performed by the propulsion system. Note that the "computer system" mentioned here includes an OS and hardware such as peripheral equipment. In addition, the "computer system" also includes a WWW system including a website providing environment (or display environment). Further, the "computer-readable recording medium" refers to a portable medium such as a flexible disk, a magneto-optical disk, a ROM, and a CD-ROM, and a memory device such as a hard disk built in a computer system. Furthermore, the "computer-readable recording medium" includes a medium that holds a program for a certain period of time, such as a volatile memory (RAM) inside a computer system that serves as a server or a client, when the program is transmitted through a network such as the Internet or a communication line such as a telephone line.

[0174] In addition, the above program may be transmitted from a computer system in which such a program is stored in a memory device or the like to another computer system through a transmission medium or on transmission waves in the transmission medium. Here, the "transmission medium" for transmitting a program refers to a medium having a function of transmitting information, such as a network (a communication net-

work) such as the Internet or a communication channel (a communication line) such as a telephone line. Further, the above program may be made for achieving some of the above-described functions. Furthermore, a program capable of achieving the above-described functions in combination with a program already recorded in the computer system, that is, a so-called differential file (a differential program) may be applicable.

[0175] Heretofore, the modes for carrying out the present invention have been described using embodiments, but the present invention is not limited to such embodiments, and various modifications and substitutions can be made without departing from the gist of the present invention.

Brief Description of the Reference Symbols

[0176]

1	Boat
2	Hull
3	Propulsion machine
3L	Left propulsion machine
3R	Right propulsion machine
4	Thrust direction changer
5	Controller
6	Steering angle inputter
7	Thrust inputter
12	Power source
14	Propulsor
16	Steering shaft
100	Propulsion system
Ath	Steering angle threshold
CL	Center line

Claims

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

a plurality of propulsion machines each including a power source, and a propulsor configured to generate a thrust with power transmitted from the power source, the plurality of propulsion machines being provided on left and right interposing a hull center;

a thrust direction changer configured to change directions of thrusts of the plurality of propulsion machines; and

a controller configured to control the thrusts and thrust directions of the plurality of propulsion machines, wherein

in a case where there is a difference between instructed steering and actual steering when the boat makes a turn, the controller conducts turning assist control for generating a thrust balance in accordance with the difference, and in the turning assist control, the controller ac-

quires an instructed steering value input into a steering angle inputter, an actual steering value at which the propulsion machine is actually steered, and an instructed thrust value input into a thrust inputter, calculates a steering thrust generated by the instructed thrust value when a steering direction of the propulsion machine reaches the instructed steering value, and calculates a compensation thrust for generating the steering thrust calculated, in the actual steering value.

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

the controller conducts the turning assist control in a case where an instructed steering angle to the propulsion machine based on the instructed steering value is equal to or larger than a steering angle threshold.

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

the controller conducts the turning assist control in a case where a difference between an instructed steering angle to the propulsion machine based on the instructed steering value and an actual steering angle at which the propulsion machine is actually steered is equal to or larger than an angle difference threshold.

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

in a case where, out of the plurality of propulsion machines, a propulsion machine located on an inner side with respect to a turning direction of a hull is defined as an inner propulsion machine, and a propulsion machine located on an outer side with respect to the turning direction of the hull is defined as an outer propulsion machine, in the turning assist control, the controller decreases a thrust of the inner propulsion machine to be smaller than a predetermined thrust, and increases a thrust of the outer propulsion machine to be equal to or larger than the predetermined thrust.

5. The propulsion system of the boat according to any one of the preceding claims, wherein in the turning assist control, the controller compensates the instructed steering to the propulsion machine to be larger than the instructed steering value.

6. The propulsion system of the boat according to any one of the preceding claims, wherein in the turning assist control, in a case where an actual shift position of the propulsion machine is different from a compensation shift corresponding to a shift

instruction of a compensation thrust, the controller matches the actual shift corresponding to the actual shift position with the compensation shift, and then conducts the turning assist control in accordance with the compensation thrust.

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7. The propulsion system of the boat according to any one of the preceding claims, wherein in the turning assist control, the controller calculates the steering thrust, based on an angle formed by a reference line and a straight line, the reference line being parallel to a center line of a stern and passing through a steering shaft of the propulsion machine in a plan view, the straight line connecting a steering center point of the boat with the steering shaft.
8. The propulsion system of the boat according to any one of the preceding claims, wherein in the turning assist control, the controller calculates the steering thrust, based on either a thrust upper limit value or a thrust lower limit value when the propulsion machine is actually steered.

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FIG. 1

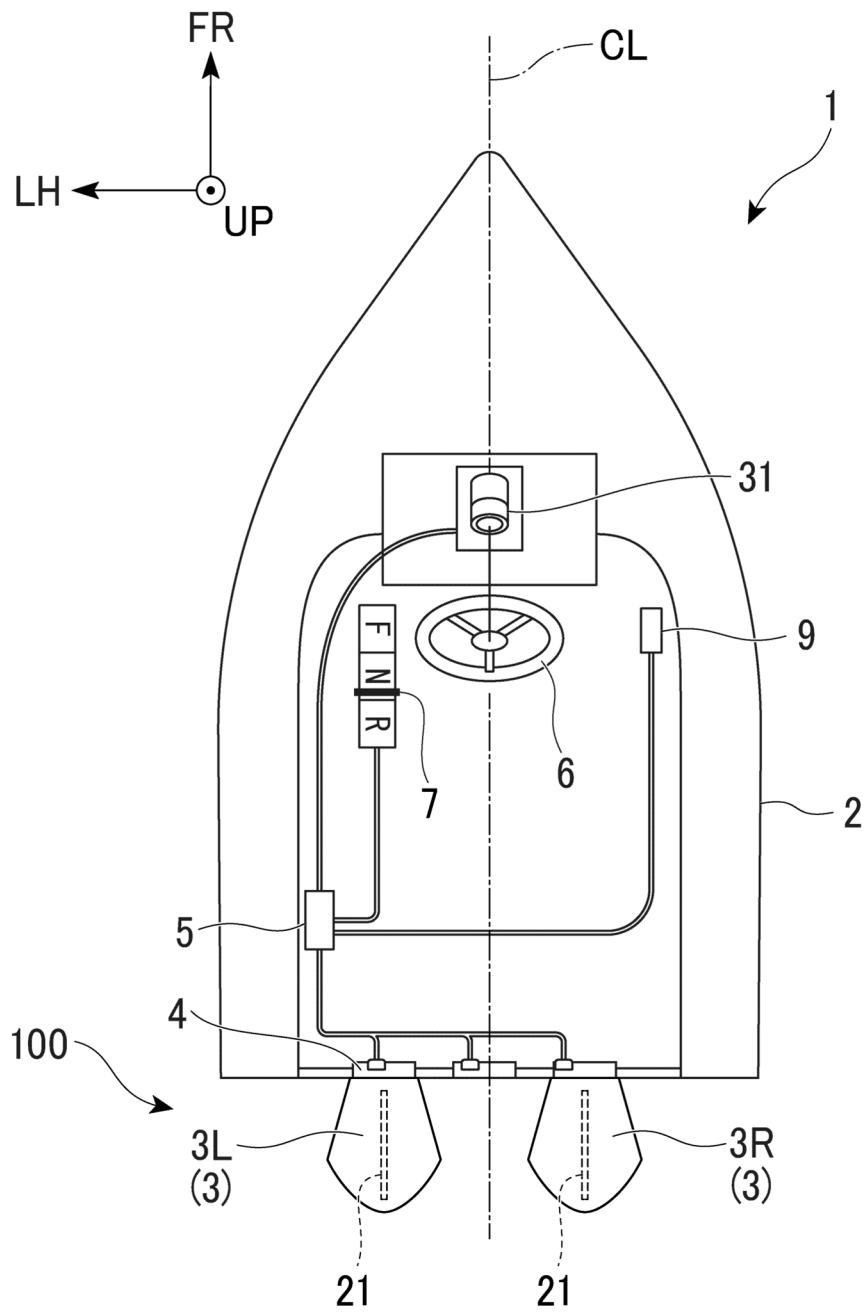


FIG. 2

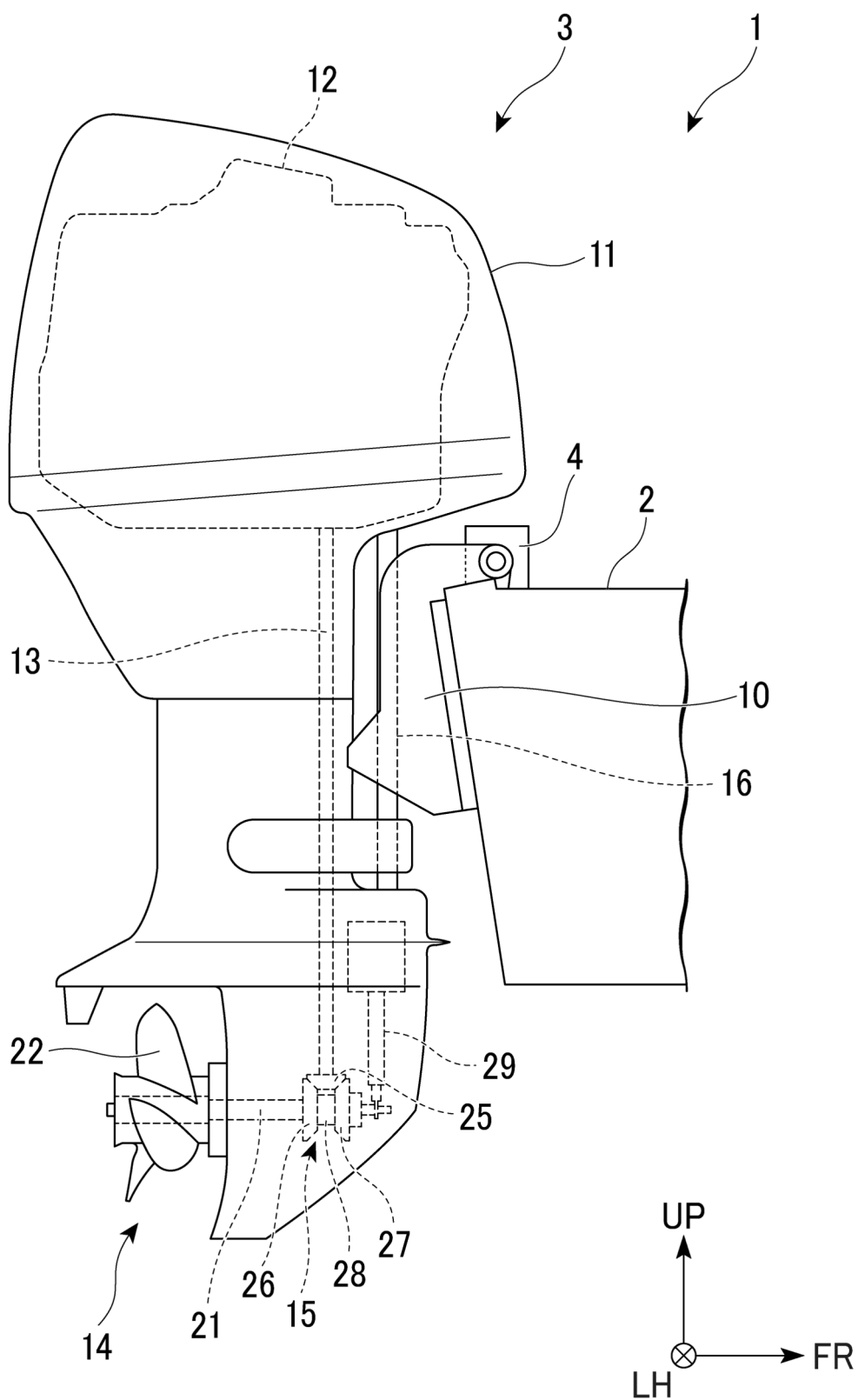


FIG. 3

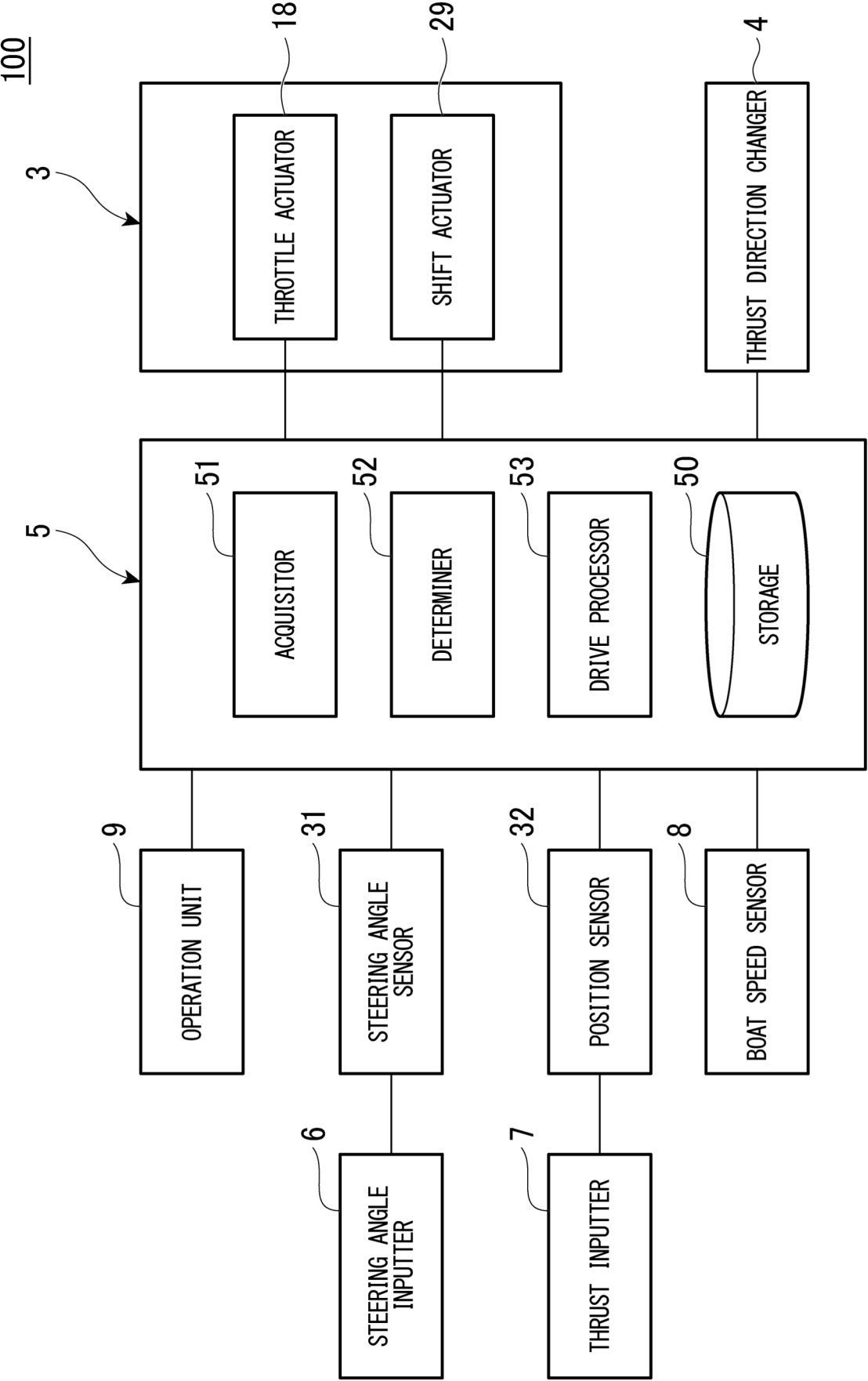


FIG. 4

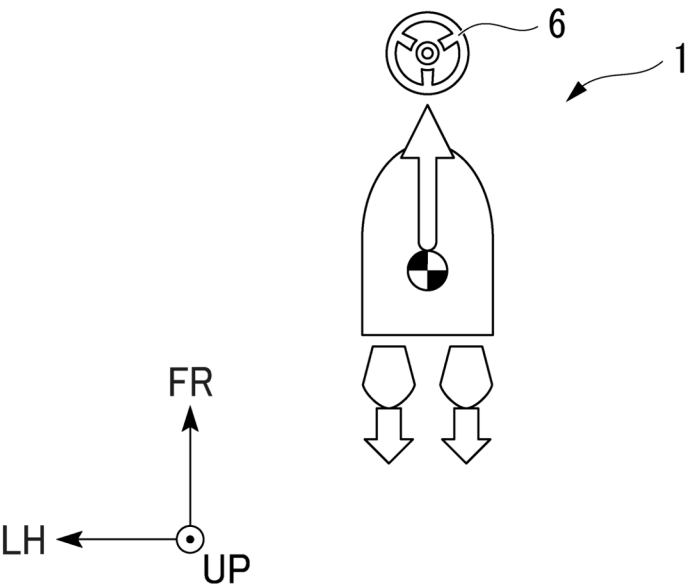


FIG. 5

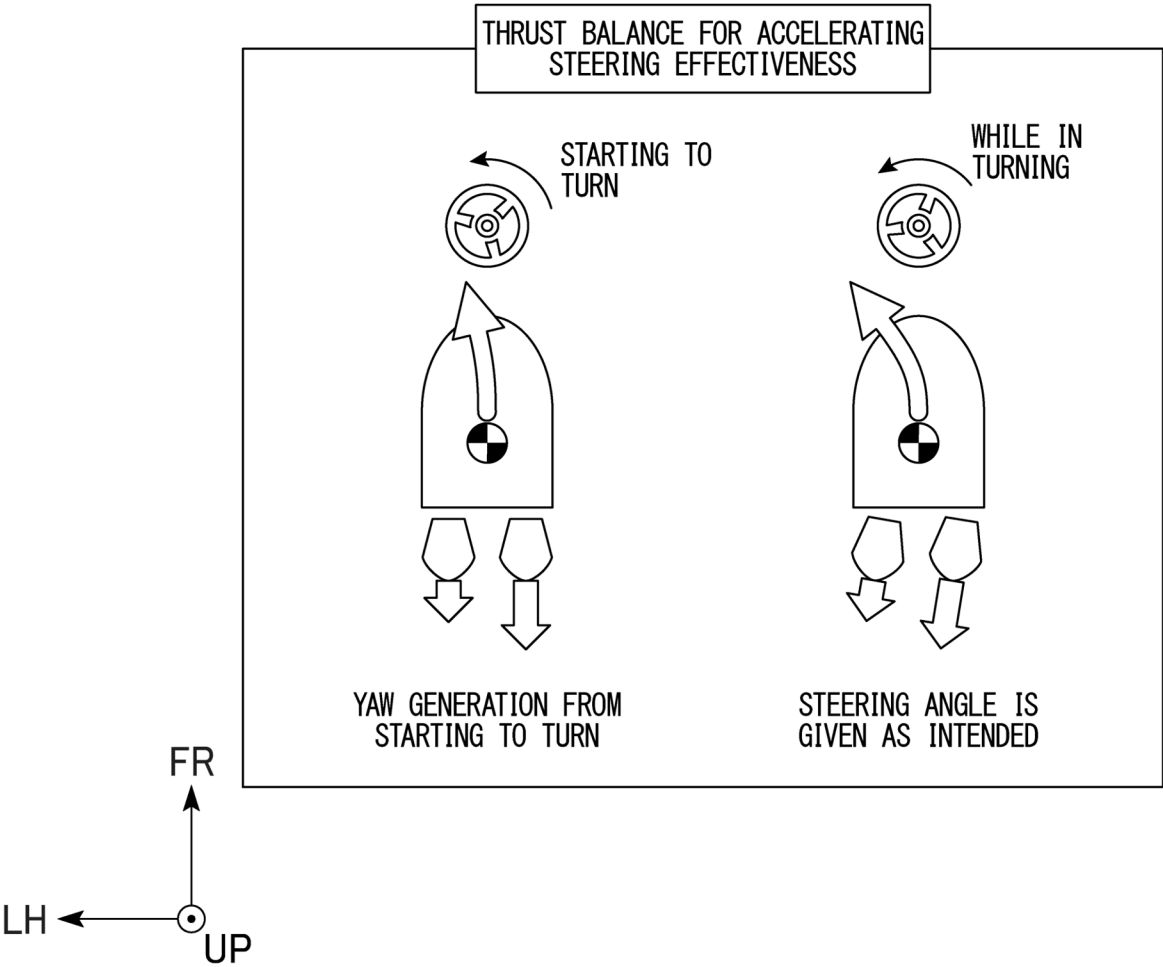


FIG. 6

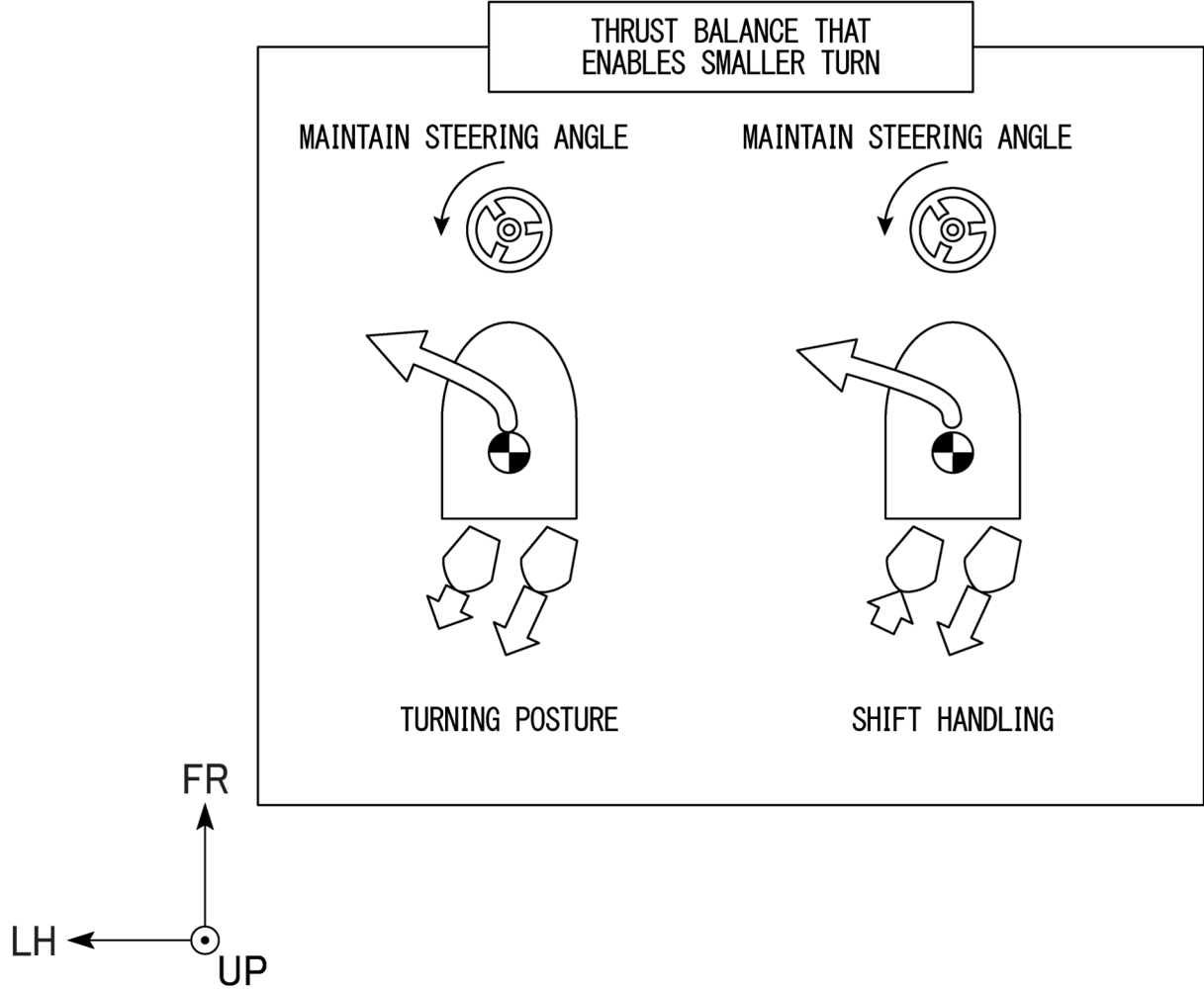


FIG. 7

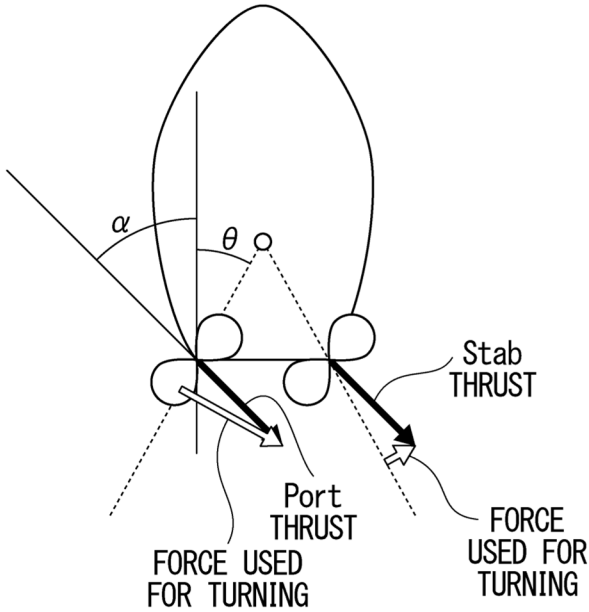
BOAT STEERING INTENDED BY USER		
	Port INSTRUCTED STEERING ANGLE= α [deg]	
	Port THRUST= $F[Nm] \propto THB$	
	GRAVITY CENTER POSITION VIEWED FROM Port= θ	
	Stab INSTRUCTED STEERING ANGLE= α [deg]	
	Stab THRUST= $F[Nm] \propto THB$	
	GRAVITY CENTER POSITION VIEWED FROM Stab= $-\theta$	
Port THRUST: F		ANGLE FORMED BY Port AND GRAVITY CENTER: $\alpha + \theta$
Stab THRUST: F		ANGLE FORMED BY Stab AND GRAVITY CENTER: $\alpha - \theta$
FORCE USED FOR TURNING: $T_{\alpha} = F \{ \sin(\alpha + \theta) + \sin(\alpha - \theta) \}$ $= 2F \sin \alpha \cos \theta$		
STEERING THRUST THEORETICAL VALUE FROM USER INPUT		

FIG. 8

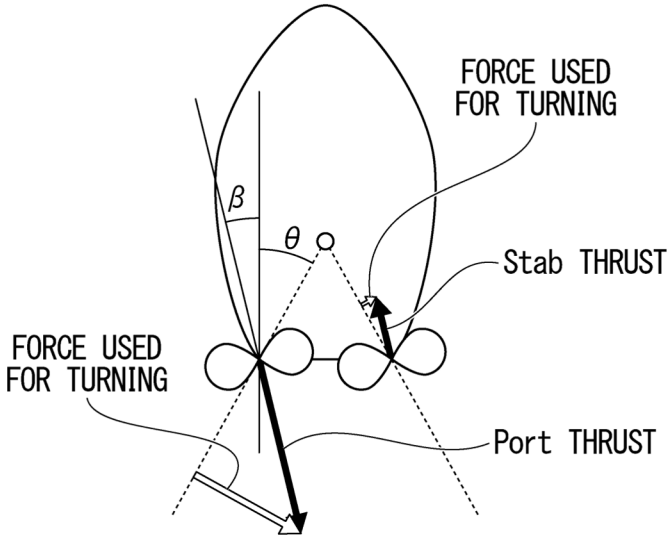
ACTUAL BOAT (DELAYED IN STEERING)	
 RESTRAINT BY CONDITION THAT TOTAL VALUES OF LEFT THRUST AND RIGHT THRUST ARE EQUAL TO EACH OTHER SO THAT BOAT SPEEDS BECOME EQUAL TO EACH OTHER	Port ACTUAL STEERING ANGLE = β [deg]
	Port THRUST = $F_{\beta\text{-port}}[\text{Nm}] \propto \text{THB}$
	GRAVITY CENTER POSITION VIEWED FROM Port = θ
	Stab ACTUAL STEERING ANGLE = β [deg]
	Stab THRUST = $F_{\beta\text{-stab}}[\text{Nm}] \propto \text{THB}$
	GRAVITY CENTER POSITION VIEWED FROM Stab = $-\theta$
Port THRUST: $F_{\beta\text{-port}} = F + \Delta F$	ANGLE FORMED BY Port AND GRAVITY CENTER: $\beta + \theta$
Stab THRUST: $F_{\beta\text{-stab}} = F - \Delta F$	ANGLE FORMED BY Stab AND GRAVITY CENTER: $\beta - \theta$
FORCE USED FOR TURNING: $T_{\beta} = F_{\beta\text{-port}} \sin(\beta + \theta) + F_{\beta\text{-stab}} \sin(\beta - \theta)$ $= 2F \sin \beta \cos \theta + \Delta F \cos \beta \sin \theta$	
STEERING THRUST	

FIG. 9

CALCULATE BALANCE THRUST ΔF WHEN “ $T_\alpha = T_\beta$ ”
 WHERE FORCES USED FOR TURNING ARE EQUAL TO EACH OTHER

$$\begin{aligned}\Delta F &= F \frac{\cos \theta}{\sin \theta} \frac{(\sin \alpha - \sin \beta)}{\cos \beta} \\ &= F \frac{1}{\tan \theta} \left(\frac{\sin \alpha}{\cos \beta} - \tan \beta \right) \cdot \cdot \cdot (1)\end{aligned}$$

$$F_{\beta-port} = F \left(1 + \frac{1}{\tan \theta} \left(\frac{\sin \alpha}{\cos \beta} - \tan \beta \right) \right) \cdot \cdot \cdot (2)$$

$$F_{\beta-stab} = F \left(1 - \frac{1}{\tan \theta} \left(\frac{\sin \alpha}{\cos \beta} - \tan \beta \right) \right) \cdot \cdot \cdot (3)$$

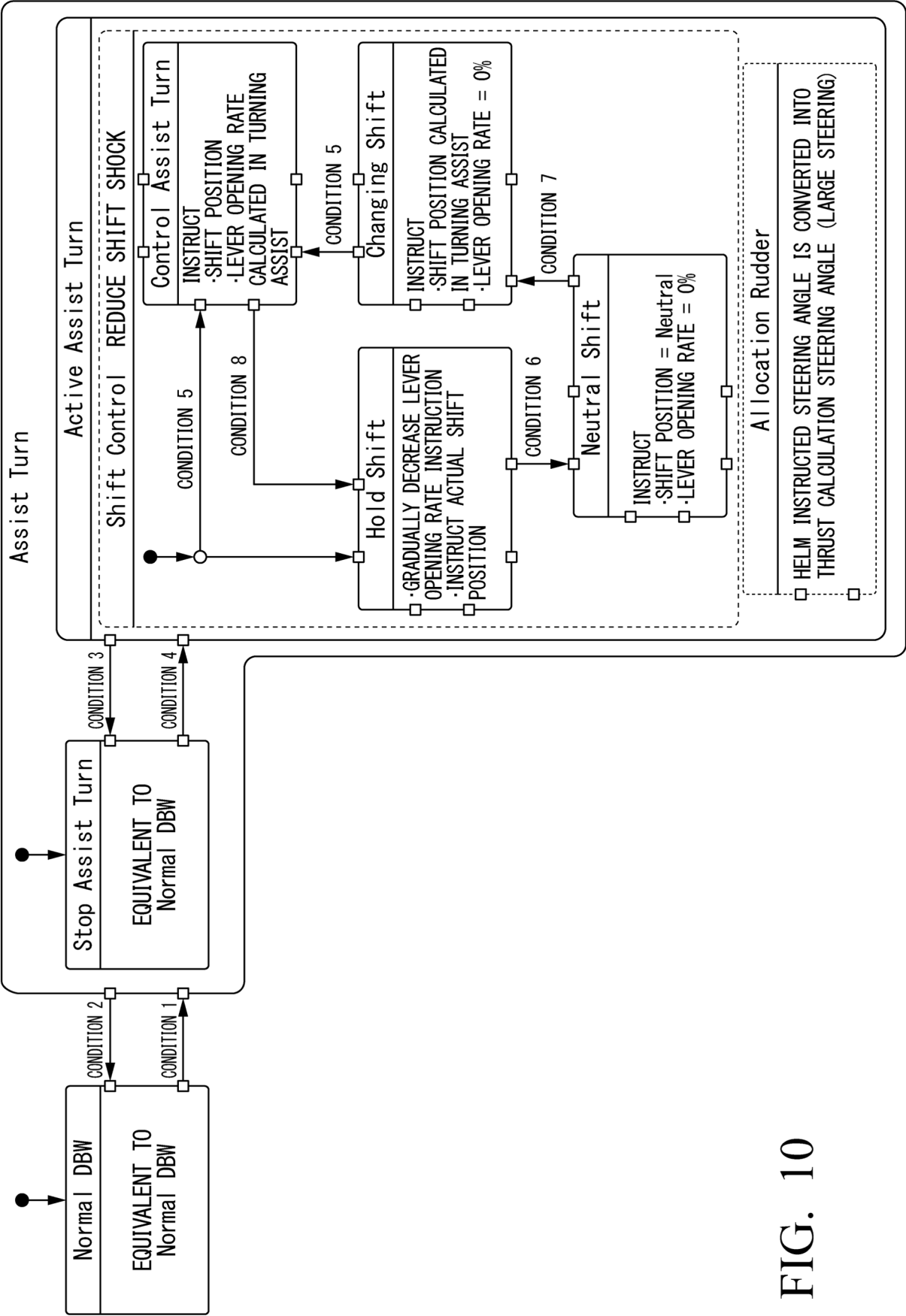


FIG. 10

FIG. 11

	ITEM
CONDITION 1	BOAT SPEED IS EQUAL TO OR LOWER THAN V_{th} && TURN SW IS IN PERMISSION STATE && INITIALIZATION PROCESSING OF SYSTEM IS COMPLETED
CONDITION 2	BOAT SPEED IS HIGHER THAN V_{th} TURN SW IS IN NON-PERMISSION STATE INITIALIZATION && PROCESSING OF SYSTEM IS NOT COMPLETED
CONDITION 3	INSTRUCTED STEERING ANGLE $< A_{th}$ SHIFT INSTRUCTION IS Neutral/Reverse
CONDITION 4	INSTRUCTED STEERING ANGLE $\geq A_{th}$ && SHIFT INSTRUCTION IS Forward
CONDITION 5	SHIFT INSTRUCTION AND ACTUAL SHIFT POSITION ARE EQUAL TO EACH OTHER
CONDITION 6	ACTUAL ENGINE SPEED IS LOWER THAN SHIFT CHANGE ALLOWABLE SPEED THRESHOLD
CONDITION 7	CERTAIN PERIOD OF TIME OR MORE ELAPSES FROM STATE IN WHICH ACTUAL SHIFT POSITION IS Neutral
CONDITION 8	SHIFT CHANGE IS NOT BEING PERFORMED && CERTAIN PERIOD OF TIME OR MORE ELAPSES FROM STATE IN WHICH SHIFT INSTRUCTION AND ACTUAL SHIFT POSITION ARE NOT EQUAL TO EACH OTHER

FIG. 12

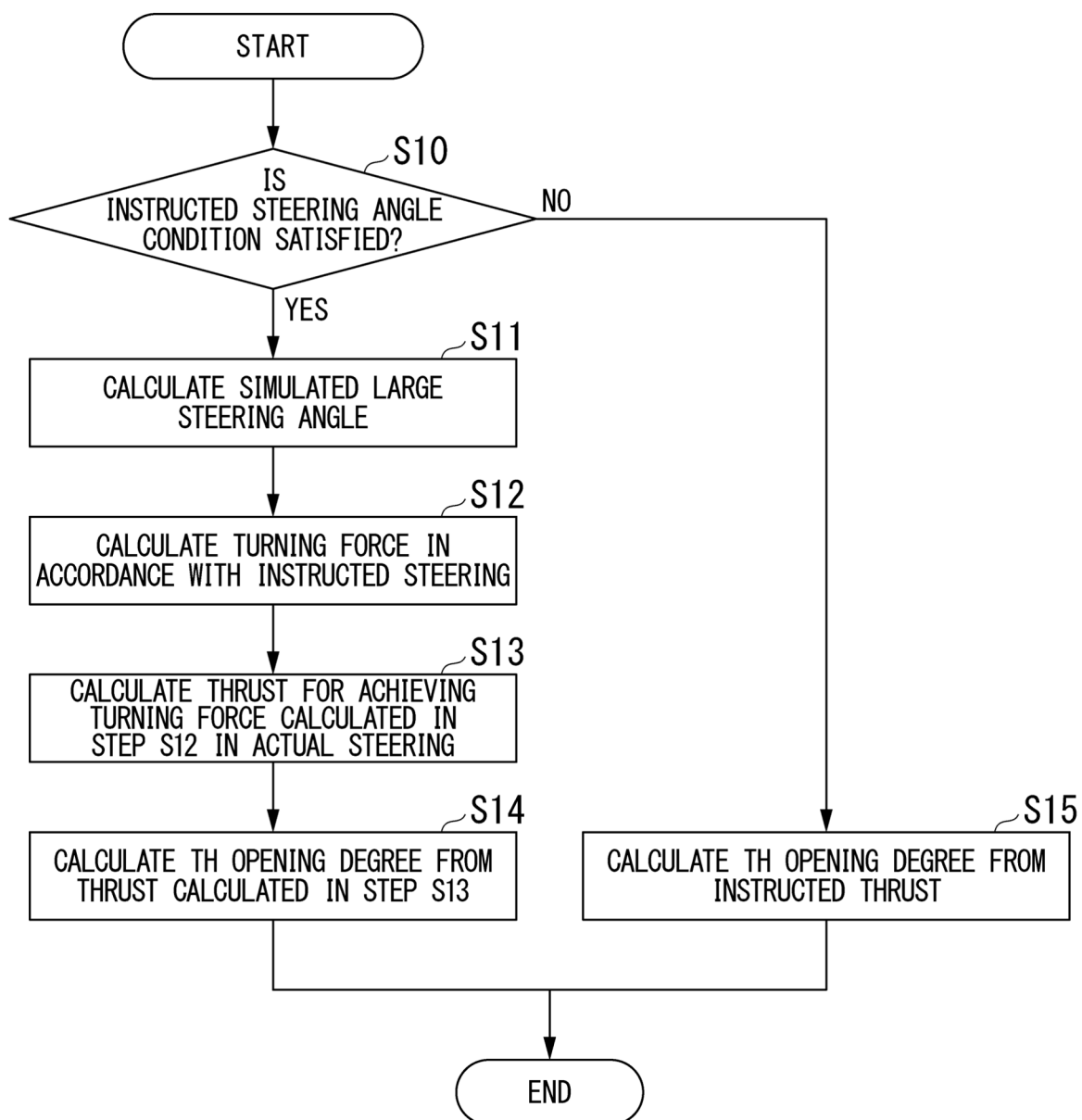


FIG. 13

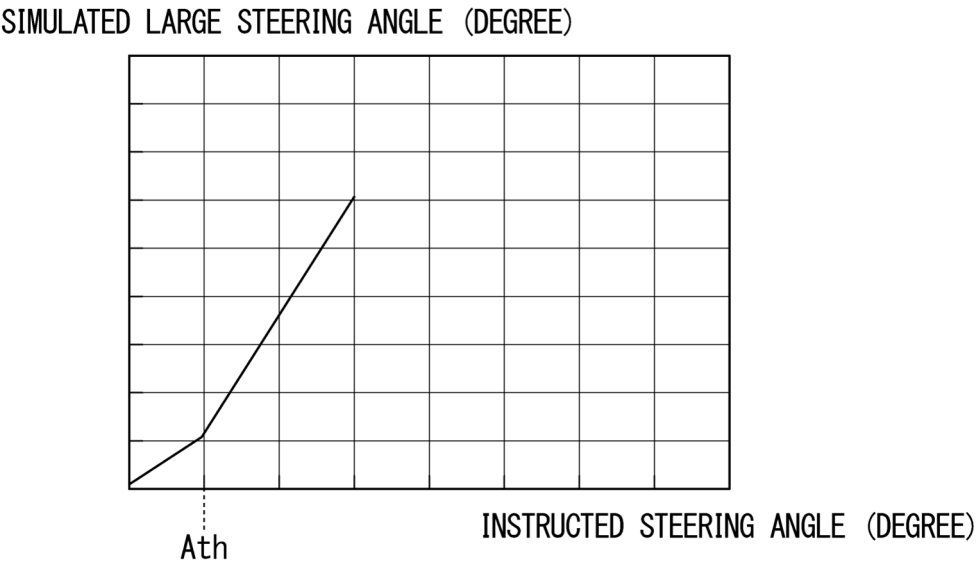


FIG. 14

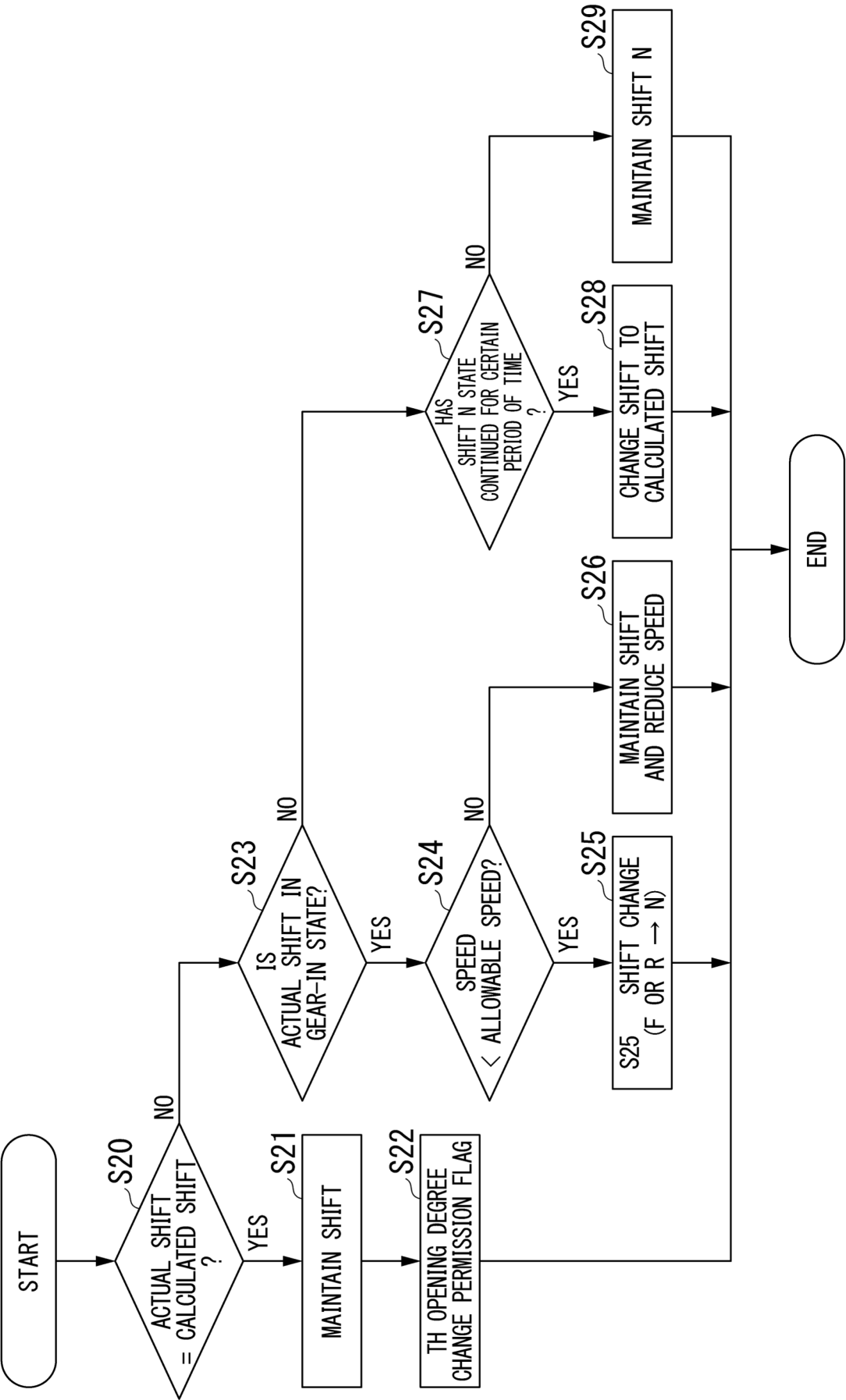


FIG. 15

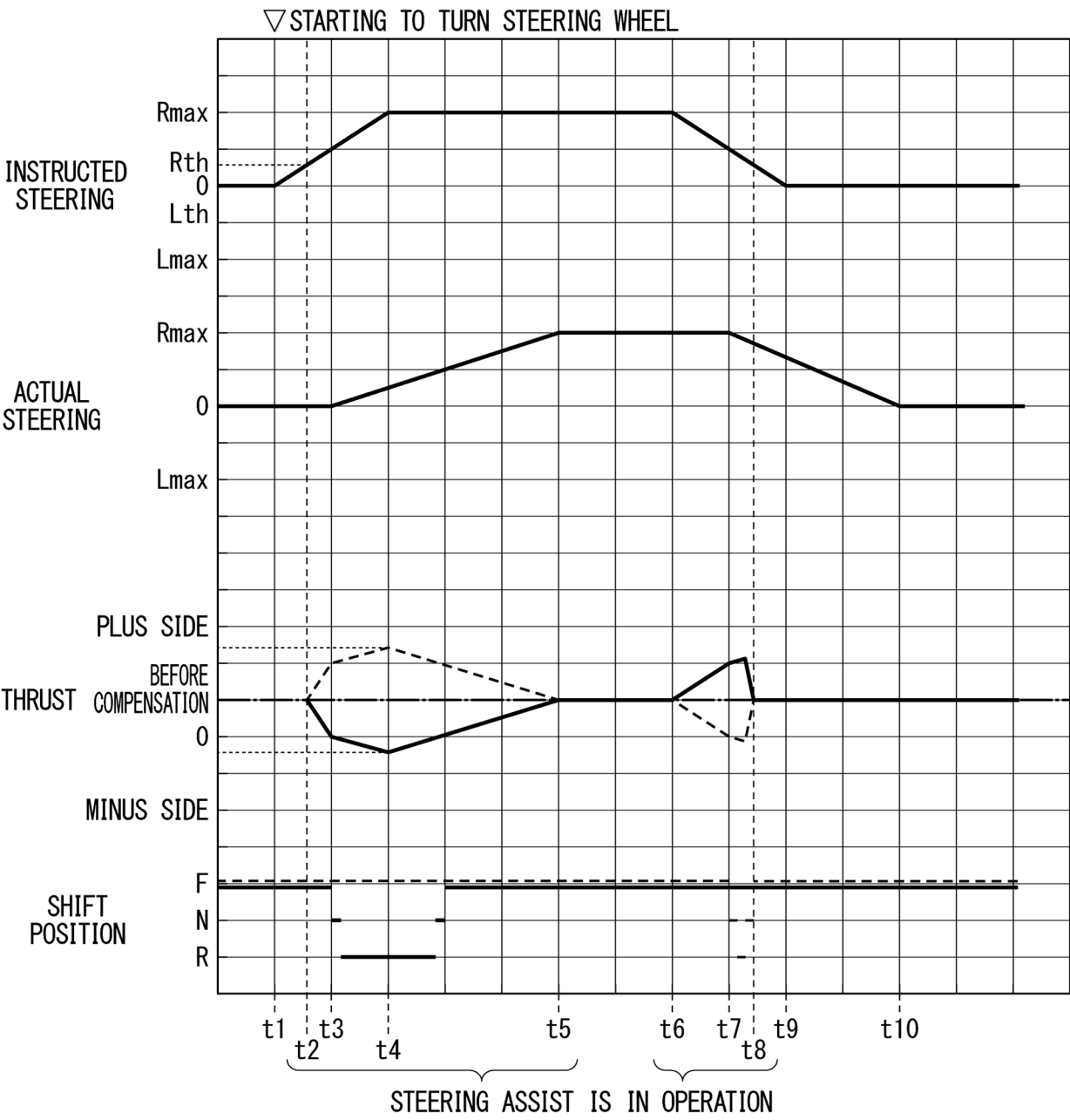


FIG. 16

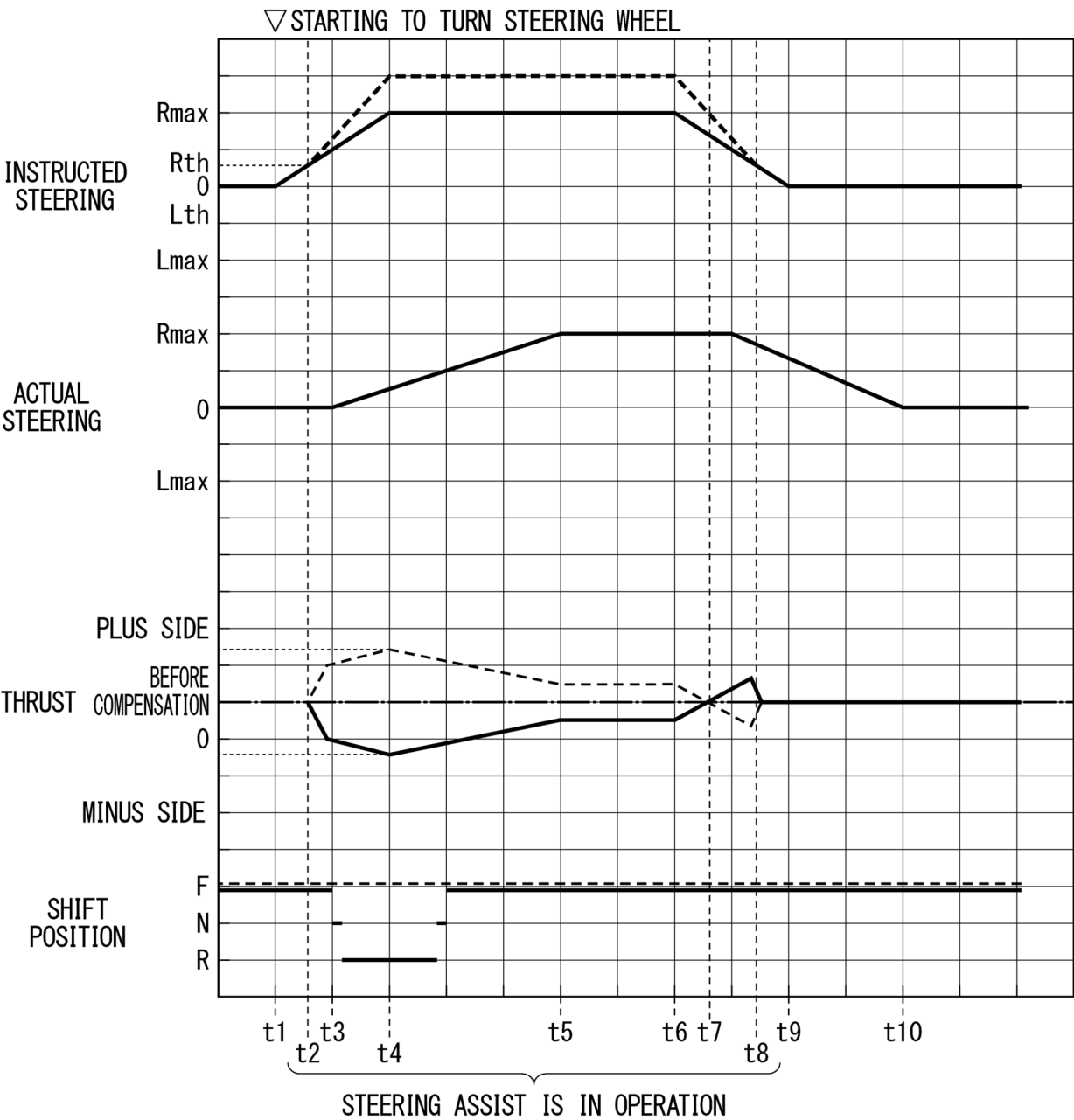
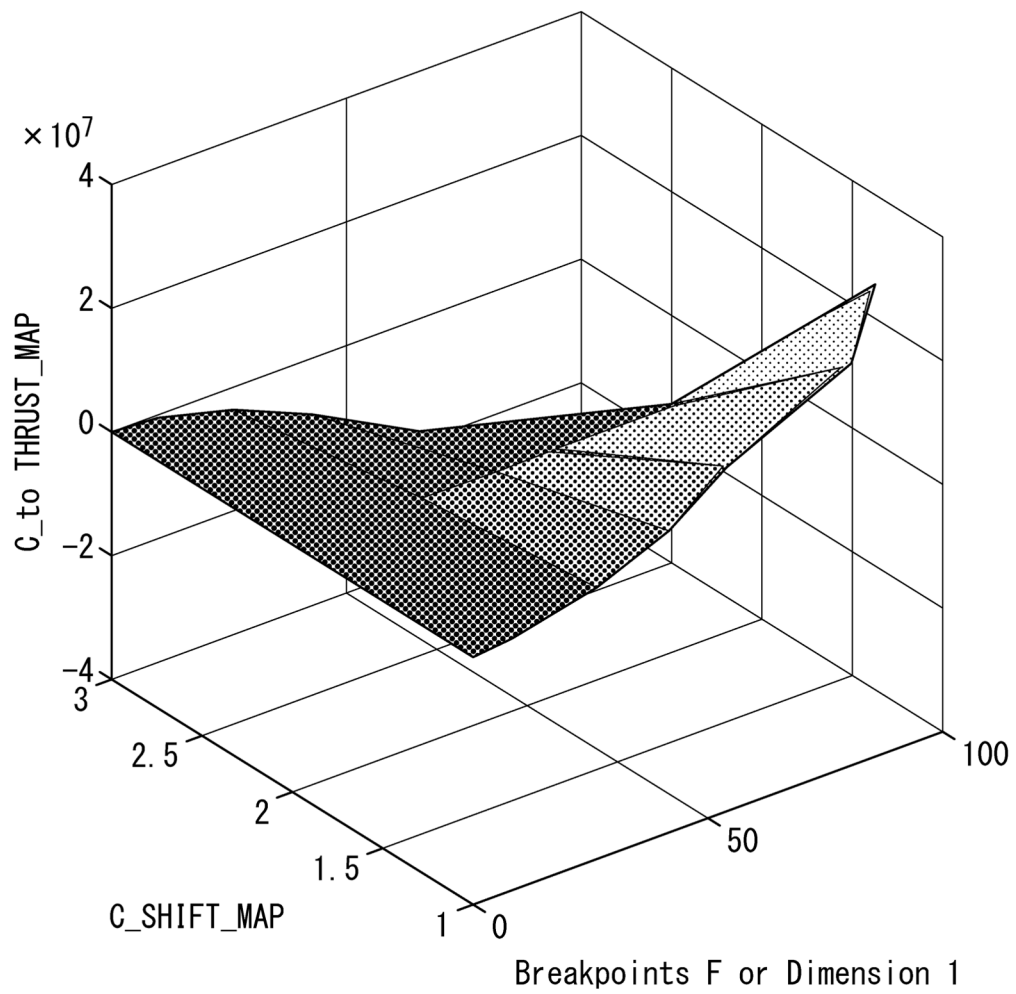


FIG. 17





EUROPEAN SEARCH REPORT

Application Number

EP 26 15 9471

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP 2022 091207 A (YAMAHA MOTOR CO LTD) 21 June 2022 (2022-06-21)	1-3,5-8	INV. B63H20/12
Y	* Machine translation; claims; figures 1,3-8B *	4	B63H25/42
Y	JP 2012 046185 A (YAMAHA MOTOR CO LTD) 8 March 2012 (2012-03-08)	4	ADD. B63H20/00
A	* Machine translation; claims; figures 1,2,4 *	1-3,5-8	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			B63H
Place of search			Examiner
The Hague			Mauriès, Laurent
Date of completion of the search			
24 August 2026			
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 26 15 9471

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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24-08-2026

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		JP 2012046185 A	08-03-2012

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EPO FORM P0459

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 2021172278 A [0003]