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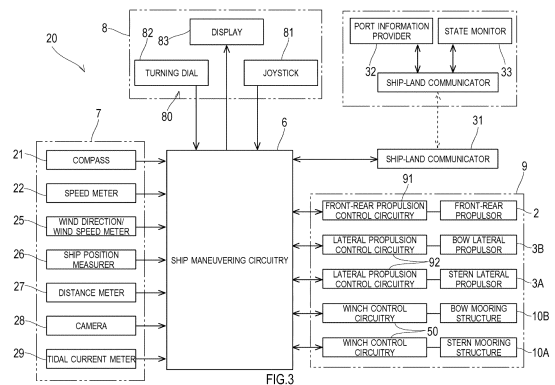
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(54) **SHIP STEERING SYSTEM AND SHIP STEERING METHOD**

(57) A ship maneuvering system includes: a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull; a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull; at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope; and ship maneuvering circuitry configured to control operations of the front-rear propulsor, the lateral propulsor, and the mooring structures. When making the hull reach a quay, with the mooring ropes locked to mooring posts located at the quay, the ship maneuvering circuitry makes the mooring structures wind the mooring ropes, and at the same time, makes at least one of the front-rear propulsor and the lateral propulsor output the thrust by which tension of each mooring rope is reduced.



Description**Technical Field**

[0001] The present disclosure relates to a ship maneuvering system and a ship maneuvering method which are used when a ship arrives at and is moored to a quay.

Background Art

[0002] A series of steps performed from when a ship enters into a port until the ship arrives at and is moored at a berth include: ship maneuver which causes large mental load of ship pilots; and work which causes large workload of ship crews. For these reasons, the automation and manpower-saving of the above series of steps are desired in order to reduce the load and improve safety. However, appropriate actions need to be taken with respect to changes in weather and marine conditions at a port, and superb cooperation between the ship crews and the workers at the port is necessary. Therefore, currently, most of the work is performed based on experiences of the ship pilots and the workers in the ships and at the ports.

[0003] PTL 1 discloses an automatic arriving/mooring structure that automates ship maneuver performed from when a ship arrives at a quay until the ship is moored to the quay. The ship of PTL 1 includes: a front-rear thrust engine that outputs front-rear thrust of a hull; a bow side thruster and a stern pod propulsor which can output lateral thrust in directions toward both sides of the hull; a bow mooring structure and a stern mooring structure each of which can wind and unwind a mooring rope; a distance meter that measures a distance to the quay; and a controller that controls the bow side thruster, the stern pod propulsor, the bow mooring structure, and the stern mooring structure based on a measured value of the distance meter. The controller performs arriving and mooring operations of the ship in order of an arriving mode and a mooring mode. In the arriving mode, the controller stops the front-rear thrust engine, the bow mooring structure, and the stern mooring structure, and laterally moves the hull by the bow side thruster and the stern pod propulsor to a mooring start position that is away from the quay by one meter. In the mooring mode, the controller stops the front-rear thrust engine, the bow side thruster, and the stern pod propulsor, and moors the hull to the quay in such a manner that the bow mooring structure and the stern mooring structure pull the mooring ropes.

Citation List**Patent Literature**

[0004] PTL 1: Japanese Laid-Open Patent Application Publication No. 2005-255058

Summary of Invention**Technical Problem**

[0005] The ship of PTL 1 consecutively performs the lateral movement of the hull by the bow side thruster and the stern pod propulsor and the adjusting and maintaining of a moored position of the hull by the bow mooring structure and the stern mooring structure. However, the ship of PTL 1 does not simultaneously generate the thrust by the propulsors and the tension by the mooring structures.

[0006] The present disclosure was made under these circumstances, and an object of the present disclosure is to perform ship maneuver in which a hull is made to efficiently reach a quay by cooperation between propulsors and mooring structures.

Solution to Problem

[0007] A ship maneuvering system according to one aspect of the present disclosure includes: a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull; a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull; at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope; and ship maneuvering circuitry configured to control operations of the front-rear propulsor, the lateral propulsor, and the mooring structures. When making the hull reach a quay, with the mooring ropes locked to mooring posts located at the quay, the ship maneuvering circuitry makes the mooring structures wind the mooring ropes, and at the same time, makes at least one of the front-rear propulsor and the lateral propulsor output the thrust by which tension of each mooring rope is reduced.

[0008] A ship maneuvering method according to one aspect of the present disclosure is a ship maneuvering method of a ship. The ship includes: a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull; a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull; and at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope. The ship maneuvering method includes, when making the hull reach a quay, with the mooring ropes locked to mooring posts located at the quay, making the mooring structures wind the mooring ropes, and at the same time, making at least one of the front-rear propulsor and the lateral propulsor output the thrust by which tension of each mooring rope is reduced.

[0009] A ship maneuvering system according to another aspect of the present disclosure includes: a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull; a lateral propulsor that outputs

lateral thrust toward both sides in a lateral direction of the hull; at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope; and ship maneuvering circuitry configured to control operations of propulsion structures including the front-rear propulsor, the lateral propulsor, and the mooring structures, the mooring structures being regarded as the propulsion structures each of which outputs thrust corresponding to the tension of the mooring rope. The ship maneuvering circuitry acquires a command vector defined such that a direction and magnitude of the command vector represent a command thrust acting on the hull, distributes thrust corresponding to the command vector to the propulsion structures, and controls the propulsion structures such that the propulsion structures output the distributed thrust.

[0010] A ship maneuvering method according to another aspect of the present disclosure is a ship maneuvering method of a ship. The ship includes: a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull; a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull; and at least mooring structure located close to a stern of the hull and at least mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope. The ship maneuvering method includes: acquiring a command vector defined such that a direction and magnitude of the command vector represent a command thrust acting on the hull; distributing thrust corresponding to the command vector to propulsion structures including the front-rear propulsor, the lateral propulsor, and the mooring structures, the mooring structures being regarded as the propulsion structures each of which outputs thrust corresponding to tension of the mooring rope; and controlling the propulsion structures such that the propulsion structures output the distributed thrust.

[0011] Moreover, a ship maneuvering system according to the present disclosure includes: a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull; a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull; at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope; and ship maneuvering circuitry configured to control operations of the front-rear propulsor, the lateral propulsor, and the mooring structures. When making the hull reach a quay, with the mooring ropes locked to mooring posts located at the quay, the ship maneuvering circuitry makes the mooring structures wind the mooring ropes, and at the same time, makes at least one of the front-rear propulsor and the lateral propulsor output the thrust by which tension of each mooring rope becomes a predetermined threshold or less.

Advantageous Effects of Invention

[0012] According to the ship maneuvering system and the ship maneuvering method in the present disclosure, the hull can efficiently reach the quay by cooperation between the propulsors and the mooring structures.

Brief Description of Drawings

[0013]

FIG. 1 is a diagram showing a schematic configuration of a ship to which a ship maneuvering system according to one embodiment of the present disclosure is applied.

FIG. 2 is a diagram showing a schematic configuration of a mooring structure.

FIG. 3 is a diagram showing the configuration of the ship maneuvering system.

FIG. 4 is a diagram showing functional parts of ship maneuvering circuitry.

FIG. 5 is a diagram for explaining processing of a ship maneuvering equipment control part.

FIG. 6 is a diagram for explaining a ship maneuvering method performed when the ship arrives at and is moored to a quay.

FIG. 7 is a diagram for explaining a hull kinetic model showing that the ship is moored to the quay.

Description of Embodiments

[0014] Next, an embodiment of the present disclosure will be described with reference to the drawings. FIG. 1 is a diagram showing a schematic configuration of a ship S to which a ship maneuvering system 20 according to one embodiment of the present disclosure is applied.

Schematic Configuration of Ship S

[0015] As shown in FIG. 1, based on the ship S, a horizontal direction connecting a bow and stern of the ship S is referred to as a "front-rear direction," and a horizontal direction (left-right direction) orthogonal to the front-rear direction is referred to as a "lateral direction." The ship S includes: a hull 5; at least one front-rear propulsor 2 that outputs thrust in the front-rear direction relative to the hull 5; and at least one lateral propulsor 3 that outputs thrust in the lateral direction relative to the hull 5.

[0016] In the present embodiment, the front-rear propulsor 2 includes a combination of a variable pitch propeller, which is a main propulsor, and a rudder. The variable pitch propeller and the rudder are located close to the stern of the hull 5. However, the front-rear propulsor 2 is not limited to the above and may be a turning thruster or may be a combination of variable pitch propellers and rudders.

[0017] The lateral propulsor 3 desirably includes at least one bow lateral propulsor 3B and at least one stern

lateral propulsor 3A. In the present embodiment, the bow lateral propulsor 3B is a side thruster (bow thruster) located close to the bow. Moreover, in the present embodiment, the combination of the variable pitch propeller and the rudder which are located close to the stern can output both of the thrust in the front-rear direction and the thrust in the lateral direction in accordance with the direction of the rudder, and therefore, also serves as the stern lateral propulsor 3A. However, the lateral propulsor 3 included in the ship S is not limited to the above. Side thrusters may be respectively located close to the bow and stern of the hull 5, or a turning thruster may be located close to at least one of the bow and stern of the hull 5.

[0018] Moreover, the ship S includes: at least one bow mooring structure 10B located on a deck and close to the bow; and at least one stern mooring structure 10A located on the deck and close to the stern.

[0019] In the present embodiment, the bow mooring structure 10B includes a headline mooring structure and a forward spring line mooring structure. The bow mooring structure 10B may further include a forward breast mooring structure. Moreover, in the present embodiment, the stern mooring structure 10A includes a stern line mooring structure and an aft spring mooring structure. The stern mooring structure 10A may further include an aft breast mooring structure. The mooring structures 10 (a reference sign 10 is used when the bow mooring structure 10B and the stern mooring structure 10A are not distinguished from each other) that should be included in the ship S are determined based on an equipment number and the like.

[0020] The mooring structures 10 that are the bow mooring structure 10B and the stern mooring structure 10A are substantially the same in structure as each other. As shown in FIG. 2, each of the mooring structures 10 includes a mooring rope R and a winch W that can wind and unwind the mooring rope R. The winch W is of an electric hydraulic type. The winch W includes: a winding drum 11 around which the mooring rope R is wound; a motor 12 that rotates the winding drum 11; a hydraulic clutch 13 that switches connection and disconnection of power transmission from the motor 12 to the winding drum 11; a reducer 14 located on a power transmitting path extending from the motor 12 to the winding drum 11; and a hydraulic release brake 15 that applies braking force at all times. However, the structure of the winch W is not limited to the above, and the winch W may be of an electric type.

[0021] The mooring structure 10 includes a rotational position sensor 51, a tension meter 52, a rope length meter 53, and winch control circuitry 50 that controls an operation of the winch W based on detected values of the rotational position sensor 51, the tension meter 52, and the rope length meter 53. The rotational position sensor 51 detects a rotational position and rotational frequency of the motor 12 or the winding drum 11. The rope length meter 53 measures the length of the mooring rope R unwound from the winding drum 11. The winch control

circuitry 50 measures the rotation of the motor 12 or the winding drum 11 and estimates the length of the wound mooring rope R and the length of the unwound mooring rope R based on a detection signal of the rotational position sensor 51 and/or a measured value of the rope length meter 53. The tension meter 52 may directly or indirectly detect tension (load) acting on the mooring rope R. For example, the tension meter 52 may be a load cell located at the brake 15 and may estimate the tension of the mooring rope R based on the load detected by the load cell. For example, the tension meter 52 may be a torque sensor that detects output torque of the motor 12 and may estimate the tension of the mooring rope R based on the torque detected by the torque sensor. The winch control circuitry 50 can control the rotation of the winding drum 11 based on the detected value of the tension meter 52 such that the tension acting on the mooring rope R is maintained at a predetermined value that is not more than a predetermined upper limit.

[0022] When winding the mooring rope R around the winding drum 11, the power transmitting path extending from the motor 12 to the winding drum 11 is established by the clutch 13, and the winding drum 11 is rotated in a winding direction. When unwinding the mooring rope R from the winding drum 11, the clutch 13 is disengaged, and therefore, the power transmitting path extending from the motor 12 to the winding drum 11 is cut. Thus, the winding drum 11 is set to such a state as to be able to idle and can rotate in an unwinding direction. Or, when unwinding the mooring rope R, the power transmitting path extending from the motor 12 to the winding drum 11 may be established by the clutch 13, and the winding drum 11 may be rotated in the unwinding direction.

[0023] Referring back to FIG. 1, a tip of the mooring rope R is locked to a mooring post 35 located at a quay. The mooring rope R pulled out from the winding drum 11 is protected and guided by suitable guides 36, such as a chock (mooring hole), a fair-leader, a deck end roller, and a stand roller.

Configuration of Ship Maneuvering System 20

[0024] FIG. 3 is a diagram showing the configuration of the ship maneuvering system 20. As shown in FIG. 3, the ship maneuvering system 20 of the ship S includes: ship maneuvering circuitry 6; an instrument group 7 that is electrically connected to the ship maneuvering circuitry 6 with a cable or wirelessly; a user interface 8; and a ship maneuvering equipment group 9.

[0025] The ship maneuvering circuitry 6 includes a processor, a memory such as a ROM and a RAM, and an I/O part (all of these are not shown). The instrument group 7, the user interface 8, and the ship maneuvering equipment group 9 are connected to the ship maneuvering circuitry 6 through the I/O part. A storage (not shown) may be connected to the ship maneuvering circuitry 6 through the I/O part. The ship maneuvering circuitry 6 may include a single processor that performs centralized

control or may include processors that perform distributed control. The memory and the storage means store a basic program, an application program, and the like executed by the processor. The application program is configured to make the processor perform processing of the functional parts. The processor reads and executes the program to serve as the ship maneuvering circuitry 6. The ship maneuvering circuitry 6 may include at least one of a computer, a personal computer, a microcontroller, a microprocessor, a PLD (programmable logic device) such as a FPGA (field-programmable gate array), a PLC (programmable logic controller), and a logic circuit or may include a combination of two or more of these.

[0026] A ship-land communicator 31 is connected to the ship maneuvering circuitry 6. The ship maneuvering circuitry 6 uses the ship-land communicator 31 to transmit ship maneuvering information to a state monitor 33 located at a land terminal. The ship maneuvering information includes a sailing state in a port, equipment operation data, and the like.

[0027] The instrument group 7 includes a distance meter 27, a camera 28, and various nautical instruments.

[0028] The distance meter 27 includes: a bow-quay distance meter that measures a bow-quay distance that is a distance from the bow to the quay; and a stern-quay distance meter that measures a distance from the stern to the quay. The distance meter 27 may be a known non-contact distance meter, such as a laser distance meter. Based on the information acquired from the distance meter 27, the ship maneuvering circuitry 6 can obtain a distance (hull-quay distance) from the hull 5 (especially, the bow and the stern) to the quay that the ship 5 is about to reach.

[0029] The camera 28 includes: a bow camera that is located on the deck and close to the bow and continuously or intermittently takes images of the quay from the bow; and a stern camera that is located on the deck and close to the stern and continuously or intermittently takes images of the quay from the stern. It is desirable that an imaging field of the bow camera include, in addition to the quay, the bow mooring structure 10B and/or the mooring rope R unwound from the bow mooring structure 10B. Moreover, it is desirable that an imaging field of the stern camera include the stern mooring structure 10A and/or the mooring rope R unwound from the stern mooring structure 10A. To secure such wide viewing field, an around view camera system may be adopted as the camera 28.

[0030] Examples of such various nautical instruments include a compass 21 that detects a bow azimuth, a speed (log speed) meter 22, a wind direction/wind speed meter 25 (a wind vane and an anemometer), a ship position measurer 26, a tidal current meter 29, a sounder, a radar, a chronometer, and a draft gauge. The ship position measurer 26 is a GPS position measurer using satellites, a radio wave position measurer using radio wave from a reference station, and/or a light wave position measurer using light from the reference station.

Based on the information acquired from such various nautical instruments, the ship maneuvering circuitry 6 can obtain sailing state information including the position, course, bow azimuth, ship speed, and the like of the hull 5.

[0031] The ship maneuvering circuitry 6 uses the ship-land communicator 31 to timely acquire port information from a port information provider 32 located at a land terminal. The port information includes weather/marine information in a port, port environmental information, and the like. The weather/marine information includes a wind speed, a wind direction, a tidal current, a tide level, weather, a climate, and the like in the port. The port environmental information includes the degree of congestion and a berth state in the port. Together with the information from the instrument group 7, the ship maneuvering circuitry 6 utilizes, for calculation, the information transmitted from the port information provider 32 through the ship-land communicator 31.

[0032] The user interface 8 includes an operator 80 and a display 83. The user interface 8 may further include: setters and indicators for ship maneuvering equipment, such as individual propellers and rudders; a display that displays signals of a direction, a ship speed, and the like output from the instrument group 7; a function changing switch; a display lamp; and the like.

[0033] In the present embodiment, the operator 80 includes a joystick 81 and a turning dial 82. The ship pilot operates the joystick 81 to input a command regarding the direction and magnitude of the thrust by which the parallel displacement of the hull 5 is performed. The joystick 81 receives the command and inputs the command to the ship maneuvering circuitry 6. Moreover, the ship pilot operates the turning dial 82 to input a command regarding the direction and magnitude of a turning moment by which the turning displacement of the hull 5 is performed. The turning dial 82 receives the command and inputs the command to the ship maneuvering circuitry 6. However, the operator 80 is not limited to the above, and a known operator may be adopted.

[0034] As the display 83, at least one of known displays, such as a touch panel display and a head mount display, is adopted. The display 83 may include: ship maneuvering support information output from the ship maneuvering circuitry 6; the image taken by the camera 28; the operation states of the equipment; the sailing state information; the environmental information (marine/weather information) of the hull 5; and the like. The ship maneuvering support information includes at least one of: an own ship position, a recommended route, a danger line, a remaining distance, a marine area facility, and a target position on a nautical chart; a movement speed vector of the hull 5; the speed of an arbitrary position of the bow; the speed of an arbitrary position of the stern; the remaining distance between the bow and the quay; the remaining distance between the stern and the quay; and the like.

[0035] The ship maneuvering equipment group 9 includes: the winch control circuitry 50 that controls the

winch W of the mooring structure 10; front-rear propulsion control circuitry 91 that controls the front-rear propulsor 2; and lateral propulsion control circuitry 92 that controls the lateral propulsor 3. The winch control circuitry 50, the front-rear propulsion control circuitry 91, and the lateral propulsion control circuitry 92 are included in accordance with the numbers of winches W, front-rear propulsors 2, and lateral propulsors 3 mounted on the ship S. In FIG. 3, one winch control circuitry 50, one front-rear propulsion control circuitry 91, and one lateral propulsion control circuitry 92 are shown, and the others are not shown. The ship maneuvering circuitry 6 outputs operation commands to the respective pieces of ship maneuvering equipment of the ship maneuvering equipment group 9, and the ship maneuvering equipment group 9 operates the corresponding pieces of ship maneuvering equipment based on the operation commands.

[0036] As shown in FIG. 4, the ship maneuvering circuitry 6 includes functional parts that are a ship maneuvering support information generating part 65, a display control part 66, a route planning part 67, a command generating part 68, and a ship maneuvering equipment control part 69. The ship maneuvering support information generating part 65 generates the ship maneuvering support information based on the information acquired from the instrument group 7 and the port information provider 32. The display control part 66 makes the display 83 display the generated ship maneuvering support information. Based on the information acquired from the instrument group 7 and the port information provider 32 and the like, the route planning part 67 searches an optimal route which is from a departure place to a destination and in which a predetermined evaluation index is optimized, and generates the optimal route as a planned route. During automatic ship maneuver, the command generating part 68 generates commands in place of the ship pilot. The ship maneuvering equipment control part 69 controls the operation of the ship maneuvering equipment group 9.

[0037] FIG. 5 is a diagram for explaining processing of the ship maneuvering equipment control part 69. As shown in FIG. 5, the ship maneuvering equipment control part 69 of the ship maneuvering circuitry 6 includes an acquiring part 61, a thrust distribution calculating part 62, and an output part 63.

[0038] The acquiring part 61 acquires the information detected or measured by the instrument group 7 and the command received by the operator 80 of the user interface 8 and subjects the acquired information (signal) to A/D conversion, scaling processing, signal abnormality determination, and the like.

[0039] The thrust distribution calculating part 62 generates a "command vector" based on the command received by the joystick 81 (i.e., a tilt angle and tilt direction of the joystick 81). The command vector is defined such that the direction and magnitude of the command vector represent command thrust acting on the hull 5. The di-

rection of the command vector corresponds to the tilt direction of the joystick 81, and the magnitude of the command vector corresponds to the tilt angle of the joystick 81.

[0040] The thrust distribution calculating part 62 acquires disturbance information including: the tidal current detected by the tidal current meter 29; the wind direction and wind speed detected by the wind direction/wind speed meter 25; and/or the tidal current, the wind direction, and the wind speed in the port which are acquired from the port information provider 32. The thrust distribution calculating part 62 estimates disturbance force acting on the ship S based on the disturbance information and corrects the command vector by adding force against the disturbance force to the command vector. The thrust distribution calculating part 62 performs calculation to distribute thrust to the propulsion structures (the mooring structure 10, the front-rear propulsor 2, and the lateral propulsor 3) such that the corrected command vector corresponds to a thrust vector. Herein, the mooring structure 10 is regarded as one type of propulsion structure, and the "thrust vector" is defined such that the direction and magnitude of the thrust vector represent resultant force of the thrust output from the propulsion structures (the mooring structure 10, the front-rear propulsor 2, and the lateral propulsor 3). A thrust distribution calculating method performed by the thrust distribution calculating part 62 will be described later in detail.

[0041] The output part 63 subjects the thrust, calculated by the thrust distribution calculating part 62 and distributed to the propulsion structures 2, 3, and 10, to scaling, D/A conversion, abnormality processing, and the like, and outputs the thrust as the operation commands to the corresponding winch control circuitry 50, the corresponding front-rear propulsion control circuitry 91, and the corresponding lateral propulsion control circuitry 92. With this, the thrust which has magnitude corresponding to the tilt angle of the joystick 81 and acts in the tilt direction is applied to the hull 5.

Ship Maneuvering Method

[0042] A ship maneuvering method performed by using the ship maneuvering system 20 configured as above when the ship S arrives at and is moored to the quay will be described with reference to FIG. 6.

[0043] When the ship S enters into the port, the ship maneuvering circuitry 6 starts approach maneuver. In the approach maneuver, the ship maneuvering circuitry 6 generates approach maneuver support information by using the information acquired from the instrument group 7 and the port information provider 32 and displays the approach maneuver support information on a screen image of the display 83. Here, the ship maneuvering circuitry 6 sets a predetermined arrival start position P2 as the target position and calculates an optimal route from a port entrance P1 to the arrival start position P2 as the planned route by using the information acquired from the

instrument group 7 and the port information provider 32. As the approach maneuver support information, the screen image of the display 83 graphically displays: a port nautical chart on which the planned route including way points, the target position, and the own ship position are overlaid; and sailing information, such as the bow azimuth and the ship speed. The arrival start position P2 is a position away from the quay of the berth by a predetermined distance (about 30 meters, for example). The front-rear direction of the hull 5 of the ship S which has reached the arrival start position P2 is substantially parallel to an extending direction of the quay, and the speed of the hull 5 in the front-rear direction is substantially zero.

[0044] The ship pilot operates the joystick 81 and the turning dial 82 based on the approach maneuver support information displayed on the display 83. The ship maneuvering circuitry 6 calculates the command vector based on the tilt angle and tilt direction of the joystick 81. However, the approach maneuver of the ship S may be automatically performed. In this case, the ship maneuvering circuitry 6 may generate the command vector based on the information acquired from the instrument group 7 and the port information provider 32 and the planned route.

[0045] The ship maneuvering circuitry 6 calculates the corrected command vector by adding the force against the disturbance force to the command vector, and distributes the thrust to the front-rear propulsor 2 such that the thrust vector corresponding to the corrected command vector is obtained by the resultant of the thrust output from the front-rear propulsor 2. In the approach maneuver, the thrust distributed to the lateral propulsor 3 and the thrust distributed to the mooring structure 10 are zero. The ship maneuvering circuitry 6 generates a thrust target value by which the distributed thrust is output, and outputs the thrust target value to the front-rear propulsion control circuitry 91. The front-rear propulsion control circuitry 91 controls the front-rear propulsor 2 such that the front-rear propulsor 2 outputs the thrust corresponding to the thrust target value. As a result, the ship S obtains the thrust corresponding to the command vector and sails along the planned route.

[0046] When the ship S reaches the arrival start position P2, the ship maneuvering circuitry 6 starts arrival maneuver. In the arrival maneuver, the ship maneuvering circuitry 6 generates arrival maneuver support information by using the information acquired from the instrument group 7 and the port information provider 32 and displays the arrival maneuver support information on the screen image of the display 83. In the arrival maneuver, the ship S moves from the arrival start position P2 to a predetermined mooring start position P3. The mooring start position P3 is a position away from the quay of the berth by about several meters. The front-rear direction of the hull 5 of the ship S which has reached the mooring start position P3 is substantially parallel to the extending direction of the quay. The speeds of the hull 5 in the bow direction and the lateral direction are substantially zero. As the arrival maneuver support information, the screen

image of the display 83 displays: a port nautical chart on which the target position and the own ship position are overlaid; the sailing information, such as the bow azimuth and the ship speed; the hull-quay distance; the image taken by the camera 28; and the like.

[0047] The ship pilot operates the joystick 81 and the turning dial 82 based on the arrival maneuver support information displayed on the display 83. The ship maneuvering circuitry 6 calculates the command vector based on the tilt angle and tilt direction of the joystick 81. However, the arrival maneuver of the ship S may be automatically performed. In this case, the ship maneuvering circuitry 6 may generate the command vector based on the information acquired from the instrument group 7 and the port information provider 32.

[0048] The ship maneuvering circuitry 6 calculates the corrected command vector by adding the force against the disturbance force to the command vector, and distributes the thrust to the front-rear propulsor 2 and the lateral propulsor 3 such that the thrust vector corresponding to the corrected command vector is obtained by the resultant of the thrust output from the front-rear propulsor 2 and the thrust output from the lateral propulsor 3. In the arrival maneuver, the thrust distributed to the mooring structure 10 is zero. The ship maneuvering circuitry 6 generates thrust target values by which the thrust distributed to the front-rear propulsion control circuitry 91 and the thrust distributed to the lateral propulsion control circuitry 92 are output, and outputs the thrust target values to the front-rear propulsion control circuitry 91 and the lateral propulsion control circuitry 92. The front-rear propulsion control circuitry 91 controls the front-rear propulsor 2 such that the front-rear propulsor 2 outputs the thrust corresponding to the given thrust target value. Moreover, the lateral propulsion control circuitry 92 controls the lateral propulsor 3 such that the lateral propulsor 3 outputs the thrust corresponding to the given thrust target value. As a result, the ship S obtains the thrust corresponding to the command vector and mainly performs lateral movement to the mooring start position P3.

[0049] When the ship S reaches the mooring start position P3, the mooring ropes R are unwound from the stern mooring structure 10A and the bow mooring structure 10B, and tip portions of the mooring ropes R are locked to the mooring posts 35 located at the quay. During this, the ship maneuvering circuitry 6 maintains the position of the ship S at the mooring start position P3 by an automatic direction maintaining function. The automatic direction maintaining function of the ship maneuvering circuitry 6 performs, for example, PID calculation of a deviation between a set bow azimuth and the bow azimuth from the compass 21 and gives the deviation as a turning moment command to thrust distributing calculation instead of the turning dial 82. With this, the front-rear propulsor 2 and the lateral propulsor 3 are operated such that the direction of the bow is maintained.

[0050] After the tip portions of all the mooring ropes R are locked to the mooring posts 35 located at the quay,

the ship maneuvering circuitry 6 starts mooring maneuver. The ship maneuvering circuitry 6 generates mooring maneuver support information by using the information acquired from the instrument group 7 and the port information provider 32 and displays the mooring maneuver support information on the screen image of the display 83. As the arrival maneuver support information, the screen image of the display 83 displays: a port nautical chart on which the target position and the own ship position are overlaid; the sailing information, such as the bow azimuth and the ship speed; the hull-quay distance; the image taken by the camera 28; and the like.

[0051] The mooring maneuver is automatically performed, and the ship maneuvering circuitry 6 generates the command vector based on the information acquired from the instrument group 7 and the port information provider 32. However, the ship pilot may visually confirm the mooring maneuver support information displayed on the display 83 and operate the joystick 81 and the turning dial 82 according to need. In this case, the operations received by the joystick 81 and the turning dial 82 may be prioritized over the command generated by the ship maneuvering circuitry 6.

[0052] The ship maneuvering circuitry 6 calculates the corrected command vector by adding the force against the disturbance force to the command vector, and distributes the thrust to the mooring structure 10, the front-rear propulsor 2, and the lateral propulsor 3 such that the thrust vector corresponding to the corrected command vector is obtained by the resultant of the thrust output from the mooring structure 10, the thrust output from the front-rear propulsor 2, and the thrust output from the lateral propulsor 3. The ship maneuvering circuitry 6 generates thrust target values by which the thrust distributed to the winch control circuitry 50, the thrust distributed to the front-rear propulsion control circuitry 91, and the thrust distributed to the lateral propulsion control circuitry 92 are output, and outputs the thrust target values to the winch control circuitry 50, the front-rear propulsion control circuitry 91, and the lateral propulsion control circuitry 92. The winch control circuitry 50 controls the mooring structure 10 such that the mooring structure 10 outputs the thrust corresponding to the given thrust target value. Specifically, the winch control circuitry 50 controls the operation of the winch W to achieve the thrust target value in such a manner that the tension and the rope length are adjusted by winding or unwinding the mooring rope R. The front-rear propulsion control circuitry 91 controls the front-rear propulsor 2 such that the front-rear propulsor 2 outputs the thrust corresponding to the given thrust target value. The lateral propulsion control circuitry 92 controls the lateral propulsor 3 such that the lateral propulsor 3 outputs the thrust corresponding to the given thrust target value. As a result, the ship S obtains the thrust corresponding to the command vector and mainly performs lateral movement to reach the quay.

[0053] In the thrust distribution of the mooring maneuver, the distribution of the thrust to the mooring structure

10 is prioritized. An allowable range of the tension of the mooring rope R is set for each mooring structure 10. After the mooring maneuver starts, and the looseness of the mooring rope R is eliminated by the winding operation performed by the mooring structure 10, the thrust is distributed to the mooring structure 10 such that the tension of the mooring rope R which is measured by the tension meter 52 is maintained within the allowable range. Here, the allowable range of the tension is not more than a predetermined threshold that is larger than zero and smaller than maximum winding force of the mooring structure 10A, 10B. The maximum winding force of the mooring structure 10A is a known value specific to the mooring structure 10A, and the maximum winding force of the mooring structure 10B is a known value specific to the mooring structure 10B. The threshold (allowable range) regarding the tension of the mooring rope R may be set individually for each of the mooring structures 10A and 10B. Or, the same threshold (allowable range) regarding the tension of the mooring rope R may be set for all the mooring structures 10A and 10B.

[0054] In the thrust distribution of the mooring maneuver, first, the thrust is distributed to each mooring structure 10 such that the tension of the mooring rope R is maintained within the allowable range. Then, a resultant vector (mooring structure thrust vector) of the thrust output from all the mooring structures 10 is calculated, and a shortage calculated by subtracting the mooring structure thrust vector from the command vector is compensated by the thrust output from the front-rear propulsor 2 and the lateral propulsor 3. When there is no shortage, the thrust output from the front-rear propulsor 2 and the lateral propulsor 3 may be zero. By the above distribution of the thrust, the ship maneuvering circuitry 6 controls the propulsion structures in at least a part of the mooring maneuver such that the bow mooring structure 10B and the stern mooring structure 10A wind the mooring ropes R, and at the same time, at least one of the front-rear propulsor 2 and the lateral propulsor 3 outputs the thrust by which the tension of the mooring rope R is reduced.

[0055] Here, the thrust distribution calculating method (First Example and Second Example) performed by the thrust distribution calculating part 62 of the ship maneuvering circuitry 6 will be described in detail.

Thrust Distribution Calculating Method: First Example

[0056] The ship maneuvering circuitry 6 includes a hull kinetic model configured to estimate the thrust output from the bow mooring structure 10B and the thrust output from the stern mooring structure 10A based on the tension of the mooring rope R of the bow mooring structure 10B and the tension of the mooring rope R of the stern mooring structure 10A. As shown in FIG. 7, regarding each mooring rope R, the hull kinetic model includes coordinates of an input point 78 that is the position of the guide 36 located at a most tip side when viewed from the

winch W based on the hull 5. The ship maneuvering circuitry 6 can estimate components of the thrust acting on the input point 78 in three directions (the front-rear direction, the lateral direction, and the vertical direction) by inputting the draft of the hull 5, the position of the hull 5, coordinates of a quay mooring point 77 that is a position where the mooring rope R is locked to the mooring post 35, and the tension of the mooring rope R to the hull kinetic model. Moreover, by simulation using the hull kinetic model, the ship maneuvering circuitry 6 can estimate the behavior of the hull 5 that behaves by the thrust acting on the input point 78. Based on a calculation result using the hull kinetic model, the ship maneuvering circuitry 6 can determine the thrust distributed to the bow mooring structure 10B and the stern mooring structure 10A.

[0057] The winch control circuitry 50 operates the winch W so as to generate the tension used in the simulation in the ship maneuvering circuitry 6. Then, the ship maneuvering circuitry 6 performs feedback of a difference between the movement of the hull 5 which is obtained by the simulation and the actual movement of the hull 5 and moves the hull 5 in an arbitrary direction to perform the mooring maneuver. Here, when the tension that exceeds the predetermined threshold is measured, the ship maneuvering circuitry 6 outputs a command to the winch control circuitry 50 to lower a winding speed. Then, the thrust is distributed to the front-rear propulsor 2 and/or the lateral propulsor 3 such that the shortage of the thrust which is caused by a reduction in the winding speed is compensated by the front-rear propulsor 2 and/or the lateral propulsor 3. With this, an overload of the mooring rope R is prevented.

Thrust Distribution Calculating Method: Second Example

[0058] To simplify calculation, the hull 5 is regarded as being controlled in a horizontal plane and is considered based on three degrees of freedom (x, y, z). Thrust commands received by the joystick 81 and the turning dial 82 regarding the three degrees of freedom are assigned to a front-rear direction thrust command (xd), a lateral direction thrust command (yd), and a turning moment command (φd). A command vector Xd is represented by Formula 1 below. In the above embodiment, since the thrust vector is calculated from the corrected command vector, the command vector Xd below is regarded as the corrected command vector. In Formulas 1 to 4, each of X, Xd, A, A*, and Xk is a vector or a matrix.

Formula 1

$$X_d = \begin{bmatrix} x_d \\ y_d \\ \phi_d \end{bmatrix} \quad \dots \text{(Formula 1)}$$

[0059] Herein, Tp denotes the thrust of the front-rear propulsor 2, Tr denotes rudder thrust, Ts denotes the thrust of the lateral propulsor 3, Tb denotes the thrust of the bow mooring structure 10B, and Ta denotes the thrust of the stern mooring structure 10A. When the ship S includes n front-rear propulsors 2, the thrust of the front-rear propulsors 2 is shown by Tp1, ..., Tpn. When the ship S includes m lateral propulsors 3, the thrust of the lateral propulsors 3 is shown by Ts1, ..., Tsm. When the ship S includes k bow mooring structures 10B, each bow mooring structure 10B is regarded as generating the thrust (resultant force of the front-rear thrust and the lateral thrust) corresponding to the tension, and the thrust of the bow mooring structures 10B is shown by Tb1, ..., Tbk. When the ship S includes k stern mooring structures 10A, each stern mooring structure 10A is regarded as generating the thrust (the front-rear thrust and the lateral thrust) corresponding to the tension, and the thrust of the stern mooring structure 10A is shown by Ta1, ..., Tak. A thrust vector X that is a combination of these is shown by Formula 2 below.

Formula 2

$$X = \begin{bmatrix} T_s \\ T_p \\ T_r \\ T_b \\ T_a \end{bmatrix} \quad \dots \text{(Formula 2)}$$

[0060] The thrust vector X and the command vector Xd satisfy Formula 3 below.

$$X_d = A \cdot X \quad \dots \text{(Formula 3)}$$

[0061] Herein, a matrix A is an arrangement matrix. The thrust vector X is shown by Formula 4 below by using a general inverse matrix A* of the arrangement matrix A.

$$X = A^* \cdot X_d + X_k \quad \dots \text{(Formula 4)}$$

[0062] Herein, Xk satisfies Formula 5 below. A* denotes a thrust distribution matrix.

$$A^* \cdot X_k = 0 \quad \dots \text{(Formula 5)}$$

[0063] Although there are various general inverse matrices, for example, a general inverse matrix that minimizes the sum of squares of each component of the thrust vector X may be adopted. To obtain necessary thrust, such as rudder lateral force, a constraint condition is given in addition to the rudder angle. The constraint condi-

tion is, for example, a condition of minimum necessary thrust of the variable pitch propeller. The ship maneuvering circuitry 6 prestores the thrust distribution matrix A^* . The ship maneuvering circuitry 6 uses the thrust distribution matrix A^* to derive the thrust vector from the command vector X_d (in the above embodiment, the corrected command vector).

Conclusion

[0064] As described above, the ship maneuvering system 20 according to the present embodiment includes:

- at least one front-rear propulsor 2 that can output the thrust toward both sides in the front-rear direction of the hull 5;
- at least one lateral propulsor 3 that can output the thrust toward both sides in the lateral direction of the hull 5;
- at least one mooring structure 10A located close to the stern of the hull 5 and at least one mooring structure 10B located close to the bow of the hull 5, each of the mooring structures 10A and 10B being able to wind and unwind the mooring rope R; and
- the ship maneuvering circuitry 6 configured to control the operations of the front-rear propulsor 2, the lateral propulsor 3, and the mooring structures 10A and 10B.

[0065] Then, when making the hull 5 reach the quay, with the mooring ropes R locked to the mooring posts 35 located at the quay, the ship maneuvering circuitry 6 makes the mooring structures 10A and 10B wind the mooring ropes R, and at the same time, makes at least one of the front-rear propulsor 2 and the lateral propulsor 3 output the thrust by which the tension of each mooring rope R is reduced.

[0066] Similarly, the ship maneuvering method of the ship S according to the present embodiment is a ship maneuvering method of the ship S. The ship S includes: at least one front-rear propulsor 2 that can output the thrust toward both sides in the front-rear direction of the hull 5; at least one lateral propulsor 3 that can output the thrust toward both sides in the lateral direction of the hull 5; and at least one mooring structure 10A located close to the stern of the hull 5 and at least one mooring structure 10B located close to the bow of the hull 5, each of the mooring structures 10A and 10B being able to wind and unwind the mooring rope R.

[0067] The ship maneuvering method includes, when making the hull 5 reach the quay, with the mooring ropes R locked to the mooring posts 35 located at the quay, making the mooring structures 10A and 10B wind the mooring ropes R, and at the same time, making at least one of the front-rear propulsor 2 and the lateral propulsor 3 output the thrust by which the tension of each mooring rope R is reduced.

[0068] According to the ship maneuvering system 20

and the ship maneuvering method, while the mooring structures 10A and 10B wind the mooring ropes R in order to make the hull 5 reach the quay, the thrust by which the tension of each mooring rope R is reduced acts on the hull 5. As above, by the cooperation between the propulsors 2 and 3 and the mooring structures 10A and 10B, an overload is prevented from being applied to the mooring ropes R. Generally, if the overload is applied to the mooring rope while the mooring structure winds the mooring rope, the mooring structure is made to unwind the mooring rope, and this eliminates the overload. However, according to the ship maneuvering system 20 and the ship maneuvering method, while the mooring structures 10A and 10B wind the mooring ropes R, the overload is prevented from being applied to the mooring ropes R. Therefore, the length of the unwound mooring rope R continuously decreases, i.e., the decrease in the length of the unwound mooring rope R does not stop, or the length of the unwound mooring rope R does not increase. On this account, the hull 5 can be made to reach the quay more efficiently than when only the mooring structures 10A and 10B are used.

[0069] The above ship maneuvering system 20 further includes the tension meter 52 that measures the tension of each mooring rope R. The ship maneuvering circuitry 6 makes at least one of the front-rear propulsor 2 and the lateral propulsor 3 output the thrust by which the tension of each mooring rope R is reduced, such that the tension of the mooring rope R which is measured by the tension meter 52 is maintained within a range of not more than a predetermined threshold that is larger than zero and smaller than the maximum winding force of the mooring structure 10A, 10B.

[0070] Similarly, at least one of the front-rear propulsor 2 and the lateral propulsor 3 is made to output the thrust by which the tension of each mooring rope R is reduced, such that the tension of the mooring rope R is maintained within a range of not more than a predetermined threshold that is larger than zero and smaller than the maximum winding force of the mooring structure 10A, 10B.

[0071] As above, while the mooring structures 10A and 10B wind the mooring ropes R in order to make the hull 5 reach the quay, the tension of each mooring rope R is maintained within the above range, and therefore, the overload is prevented from being applied to the mooring rope R.

[0072] Moreover, the ship maneuvering system 20 according to the above embodiment includes:

- at least one front-rear propulsor 2 that can output the thrust toward both sides in the front-rear direction of the hull 5;
- at least one lateral propulsor 3 that can output the thrust toward both sides in the lateral direction of the hull 5;
- at least one mooring structure 10A located close to the stern of the hull 5 and at least one mooring structure 10B located close to the bow of the hull 5, each

of the mooring structures 10A and 10B being able to wind and unwind the mooring rope R; and the ship maneuvering circuitry 6 configured to control operations of the propulsion structures 2, 3, 10A, and 10B including the front-rear propulsor 2, the lateral propulsor 3, and the mooring structures 10A and 10B, the mooring structures 10A and 10B being regarded as the propulsion structures each of which outputs the thrust corresponding to the tension of the mooring rope R.

[0073] Then, the ship maneuvering circuitry 6 acquires the command vector defined such that the direction and magnitude of the command vector represent the command thrust acting on the hull 5, distributes the thrust corresponding to the command vector to the propulsion structures 2, 3, 10A, and 10B, and controls the propulsion structures 2, 3, 10A, and 10B such that the propulsion structures 2, 3, 10A, and 10B output the distributed thrust. Herein, the ship maneuvering circuitry 6 may distribute the thrust to the propulsion structures 2, 3, 10A, and 10B such that the thrust vector corresponds to the command vector, the thrust vector being defined such that the direction and magnitude of the thrust vector represent the resultant force of the thrust output from the propulsion structures 2, 3, 10A, and 10B.

[0074] Similarly, the ship maneuvering method of the ship S according to the above embodiment is a ship maneuvering method of the ship S. The ship S includes: at least one front-rear propulsor 2 that can output the thrust toward both sides in the front-rear direction of the hull 5; at least one lateral propulsor 3 that can output the thrust toward both sides in the lateral direction of the hull 5; and at least one mooring structure 10A located close to the stern of the hull 5 and at least one mooring structure 10B located close to the bow of the hull 5, each of the mooring structures 10A and 10B being able to wind and unwind the mooring rope R.

[0075] The ship maneuvering method includes: acquiring the command vector defined such that the direction and magnitude of the command vector represent the command thrust acting on the hull 5; distributing the thrust corresponding to the command vector to the propulsion structures 2, 3, 10A, and 10B including the front-rear propulsor 2, the lateral propulsor 3, and the mooring structures 10A and 10B, the mooring structures 10A and 10B being regarded as the propulsion structures each of which outputs the thrust corresponding to the tension of the mooring rope R; and controlling the propulsion structures 2, 3, 10A, and 10B such that the propulsion structures 2, 3, 10A, and 10B output the distributed thrust. Herein, the above distributing step may include distributing the thrust to the propulsion structures 2, 3, 10A, and 10B such that the thrust vector corresponds to the command vector, the thrust vector being defined such that the direction and magnitude of the thrust vector represent the resultant force of the thrust output from the propulsion structures 2, 3, 10A, and 10B.

[0076] According to the ship maneuvering system 20 and the ship maneuvering method, each of the mooring structures 10A and 10B is regarded as one type of propulsion structure, and the thrust acting on the hull 5 is distributed to the propulsion structures 2, 3, 10A, and 10B including the mooring structures 10A and 10B, the front-rear propulsor 2, and the lateral propulsor 3. As above, since the propulsors 2 and 3 and the mooring structures 10A and 10B are collectively controlled, it is unnecessary to individually operate the propulsors 2 and 3 and the mooring structures 10A and 10B, and therefore, the work efficiency can be improved, and the manpower can be saved. Moreover, fluid force near the quay is irregular. However, the propulsion structures 2, 3, 10A, and 10B including the propulsors 2 and 3 and the mooring structures 10A and 10B generate the thrust in cooperation, and therefore, the hull 5 can reach the target position more stably than when the hull 5 is moved only by the mooring structures 10A and 10B.

[0077] Moreover, the ship maneuvering system 20 according to the above embodiment includes the joystick 81 that receives an operation and inputs the operation to the ship maneuvering circuitry 6. The tilt angle of the joystick 81 corresponds to the magnitude of the command vector. The tilt direction of the joystick 81 corresponds to the direction of the command vector. The ship maneuvering circuitry 6 acquires the command vector corresponding to the operation received by the joystick 81.

[0078] Similarly, in the above ship maneuvering method, the step of acquiring the command vector includes acquiring the command vector corresponding to the operation received by the joystick 81, the tilt angle of the joystick 81 corresponding to the magnitude of the command vector, the tilt direction of the joystick 81 corresponding to the direction of the command vector.

[0079] By operating the joystick 81 as above, the propulsion structures 2, 3, 10A, and 10B including the mooring structures 10A and 10B and the lateral propulsor 3 can be collectively operated. Therefore, it is unnecessary to individually operate the propulsors 2 and 3 and the mooring structures 10A and 10B, and therefore, the work efficiency can be improved, and the manpower can be saved.

[0080] Moreover, the ship maneuvering system 20 according to the above embodiment includes: the distance meter 27 that measures the hull-quay distance of the hull 5; and the ship position measurer 26 that measures the ship position of the hull 5. The ship maneuvering circuitry 6 generates the command vector based on the hull-quay distance and the ship position.

[0081] Similarly, in the ship maneuvering method according to the above embodiment, the step of acquiring the command vector includes: measuring the hull-quay distance of the hull 5; measuring the ship position of the hull 5; and generating the command vector based on the hull-quay distance and the ship position.

[0082] As above, since the command vector is auto-

matically generated, the automatic ship maneuver of the ship S can be performed.

[0083] Moreover, in the ship maneuvering system 20 according to the above embodiment, the ship maneuvering circuitry 6 acquires the disturbance information including the wind direction, the wind speed, the tidal current in the environment around the hull 5, estimates the disturbance force acting on the hull 5 based on the disturbance information, and corrects the command vector by the disturbance force.

[0084] Similarly, in the ship maneuvering method according to the above embodiment, the step of acquiring the command vector includes: acquiring the disturbance information including the wind direction, the wind speed, and the tidal current in the environment around the hull 5; estimating the disturbance force acting on the hull 5 based on the disturbance information; and correcting the command vector by the disturbance force.

[0085] As above, since the command vector is corrected such that the disturbance force acting on the hull 5 is canceled, the command vector that has not been corrected yet does not have to be prepared in consideration of the disturbance force. Therefore, the ship pilot can give a command without depending on experience.

[0086] Moreover, in the ship maneuvering system 20 according to the above embodiment, when the hull 5 arrives at and is moored to the quay, the ship maneuvering circuitry 6 performs: the arrival maneuver in which the hull 5 is moved from the predetermined arrival start position P2 to the mooring start position P3 closer to the quay than the arrival start position P2; and the mooring maneuver in which the hull 5 is moved from the mooring start position P3 and is made to reach the quay. In the arrival maneuver, the ship maneuvering circuitry distributes the thrust to the propulsion structures 2, 3, 10A, and 10B such that the thrust distributed to the mooring structures 10A and 10B becomes zero. Moreover, in the mooring maneuver, the ship maneuvering circuitry 6 distributes the thrust to the propulsion structures 2, 3, 10A, and 10B such that among the propulsion structures 2, 3, 10A, and 10B, the thrust is distributed to the mooring structures 10A and 10B more preferentially than the propulsion structures 2 and 3.

[0087] Similarly, the ship maneuvering method according to the above embodiment includes, when the hull 5 arrives at and is moored to the quay, performing: the arrival maneuver in which the hull 5 is moved from the predetermined arrival start position P2 to the mooring start position P3 closer to the quay than the arrival start position P2; and the mooring maneuver in which the hull 5 is moved from the mooring start position P3 and is made to reach the quay. In the arrival maneuver, the thrust is distributed to the propulsion structures 2, 3, 10A, and 10B such that the thrust distributed to the mooring structures 10A and 10B becomes zero. Moreover, in the mooring maneuver, the thrust is distributed to the propulsion structures 2, 3, 10A, and 10B such that among the propulsion structures 2, 3, 10A, and 10B, the thrust

is distributed to the mooring structures 10A and 10B more preferentially than the propulsion structures 2 and 3.

[0088] As above, according to the arrival maneuver in which the mooring ropes R are not being moored to the mooring posts 35, the thrust can be applied to the hull 5 by the operations of the propulsors 2 and 3. According to the mooring maneuver in which the mooring ropes R are being moored to the mooring posts 35, the thrust can be applied to the hull 5 by the operations of the propulsion structures 2, 3, 10A, and 10B including the mooring structures 10A and 10B. In addition, in the mooring maneuver, the propulsion structures 2, 3, 10A, and 10B can be operated such that: the thrust is distributed preferentially to the mooring structures 10A and 10B; the hull 5 is moved mainly by the tension of each mooring rope R; and the shortage of the thrust is compensated by the thrust generated by the propulsors 2 and 3.

[0089] Moreover, in the ship maneuvering system 20 according to the above embodiment, the ship maneuvering circuitry 6 includes the hull kinetic model configured to estimate the thrust output from the mooring structure 10A, 10B based on the tension of the mooring rope R of the mooring structure 10A, 10B.

[0090] Similarly, in the ship maneuvering method according to the above embodiment, the thrust distributed to the mooring structure 10A, 10B is determined by using the hull kinetic model configured to estimate the thrust output from the mooring structure 10A, 10B based on the tension of the mooring rope R of the mooring structure 10A, 10B.

[0091] As above, the thrust acting on the hull 5 by the tension of the mooring rope R is estimated by using the hull kinetic model. Therefore, more accurate behavior of the hull 5 can be realized in a complex system, and this can be utilized for the distribution of the thrust.

[0092] The foregoing has described a preferred embodiment of the present disclosure. Modifications of specific structures and/or functional details of the above embodiment may be included in the present disclosure as long as they are within the scope of the present disclosure.

Reference Signs List

[0093]

2	front-rear propulsor (propulsion structure)
3	lateral propulsor (propulsion structure)
3A	stern lateral propulsor (propulsion structure)
3B	bow lateral propulsor (propulsion structure)
5	hull
6	ship maneuvering circuitry
7	instrument group
8	user interface
9	ship maneuvering equipment group
10	mooring structure (propulsion structure)
10A	stern mooring structure (propulsion structure)
10B	bow mooring structure (propulsion structure)

20 ship maneuvering system
 26 ship position measurer
 27 distance meter
 81 joystick
 P2 arrival start position
 P3 mooring start position
 R mooring rope
 S ship

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Claims

1. A ship maneuvering system comprising:

a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull;
 a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull;
 at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope; and
 ship maneuvering circuitry configured to control operations of the front-rear propulsor, the lateral propulsor, and the mooring structures, wherein: when making the hull reach a quay, with the mooring ropes locked to mooring posts located at the quay, the ship maneuvering circuitry makes the mooring structures wind the mooring ropes, and at the same time, makes at least one of the front-rear propulsor and the lateral propulsor output the thrust by which tension of each mooring rope is reduced.

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2. The ship maneuvering system according to claim 1, further comprising a tension meter that measures the tension of each mooring rope, wherein the ship maneuvering circuitry makes at least one of the front-rear propulsor and the lateral propulsor output the thrust by which the tension of each mooring rope is reduced, such that the tension of the mooring rope which is measured by the tension meter is maintained within a range of not more than a predetermined threshold that is larger than zero and smaller than maximum winding force of the mooring structure.

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3. A ship maneuvering system comprising:

a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull;
 a lateral propulsor that outputs lateral thrust toward both sides in a lateral direction of the hull;
 at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind

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and unwind a mooring rope; and
 ship maneuvering circuitry configured to control operations of propulsion structures including the front-rear propulsor, the lateral propulsor, and the mooring structures, the mooring structures being regarded as the propulsion structures each of which outputs thrust corresponding to the tension of the mooring rope, wherein the ship maneuvering circuitry

acquires a command vector defined such that a direction and magnitude of the command vector represent a command thrust acting on the hull,
 distributes thrust corresponding to the command vector to the propulsion structures, and
 controls the propulsion structures such that the propulsion structures output the distributed thrust.

4. The ship maneuvering system according to claim 3, wherein the ship maneuvering circuitry distributes the thrust to the propulsion structures such that a thrust vector corresponds to the command vector, the thrust vector being defined such that a direction and magnitude of the thrust vector represent resultant force of the thrust output from the propulsion structures.

5. The ship maneuvering system according to claim 3 or 4, further comprising a joystick that receives an operation and inputs the operation to the ship maneuvering circuitry, wherein:

a tilt angle of the joystick corresponds to magnitude of the command vector;
 a tilt direction of the joystick corresponds to a direction of the command vector; and
 the ship maneuvering circuitry acquires the command vector corresponding to the operation received by the joystick.

6. The ship maneuvering system according to claim 3, further comprising:

a distance meter that measures a hull-quay distance of the hull; and
 a ship position measurer that measures a ship position of the hull, wherein the ship maneuvering circuitry generates the command vector based on the hull-quay distance and the ship position.

7. The ship maneuvering system according to any one of claims 3 to 6, wherein the ship maneuvering circuitry

- acquires disturbance information including a wind direction, a wind speed, and a tidal current in an environment around the hull, estimates disturbance force acting on the hull based on the disturbance information, and corrects the command vector by the disturbance force.
8. The ship maneuvering system according to any one of claims 3 to 7, wherein:
- when the hull arrives at and is moored to a quay, the ship maneuvering circuitry performs
- arrival maneuver in which the hull is moved from a predetermined arrival start position to a mooring start position closer to the quay than the arrival start position, and mooring maneuver in which the hull is moved from the mooring start position and is made to reach the quay; and
- in the arrival maneuver, the ship maneuvering circuitry distributes the thrust to the propulsion structures such that the thrust distributed to the mooring structures becomes zero.
9. The ship maneuvering system according to claim 8, wherein in the mooring maneuver, the ship maneuvering circuitry distributes the thrust to the propulsion structures such that among the propulsion structures, the thrust is distributed to the mooring structures more preferentially than the other propulsion structures.
10. The ship maneuvering system according to any one of claims 3 to 9, wherein the ship maneuvering circuitry includes a hull kinetic model configured to estimate the thrust output from each mooring structure based on the tension of the mooring rope of the mooring structure.
11. A ship maneuvering method of a ship, the ship comprising:
- a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull; a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull; and at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope, the ship maneuvering method comprising when making the hull reach a quay, with the mooring ropes locked to mooring posts located at the quay, making the mooring structures wind
- the mooring ropes, and at the same time, making at least one of the front-rear propulsor and the lateral propulsor output the thrust by which tension of each mooring rope is reduced.
12. The ship maneuvering method according to claim 11, wherein at least one of the front-rear propulsor and the lateral propulsor is made to output the thrust by which the tension of each mooring rope is reduced, such that the tension of the mooring rope is maintained within a range of not more than a predetermined threshold that is larger than zero and smaller than maximum winding force of the mooring structure.
13. A ship maneuvering method of a ship, the ship comprising:
- a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull; a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull; and at least mooring structure located close to a stern of the hull and at least mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope,
- the ship maneuvering method comprising:
- acquiring a command vector defined such that a direction and magnitude of the command vector represent a command thrust acting on the hull; distributing thrust corresponding to the command vector to propulsion structures including the front-rear propulsor, the lateral propulsor, and the mooring structures, the mooring structures being regarded as the propulsion structures each of which outputs thrust corresponding to tension of the mooring rope; and controlling the propulsion structures such that the propulsion structures output the distributed thrust.
14. The ship maneuvering method according to claim 13, wherein the distributing step includes distributing the thrust to the propulsion structures such that a thrust vector corresponds to the command vector, the thrust vector being defined such that a direction and magnitude of the thrust vector represent resultant force of the thrust output from the propulsion structures.

15. The ship maneuvering method according to claim 13 or 14, wherein the step of acquiring the command vector includes acquiring the command vector corresponding to an operation received by a joystick, a tilt angle of the joystick corresponding to magnitude of the command vector, a tilt direction of the joystick corresponding to a direction of the command vector. 5
16. The ship maneuvering method according to claim 13 or 14, wherein the step of acquiring the command vector includes 10
- measuring a hull-quay distance of the hull, measuring a ship position of the hull, and generating the command vector based on the hull-quay distance and the ship position. 15
17. The ship maneuvering method according to any one of claims 13 to 16, wherein the step of acquiring the command vector includes 20
- acquiring disturbance information including a wind direction, a wind speed, and a tidal current in an environment around the hull, estimating disturbance force acting on the hull based on the disturbance information, and correcting the command vector by the disturbance force. 25
18. The ship maneuvering method according to any one of claims 13 to 17, further comprising, when the hull arrives at and is moored to a quay, performing 30
- arrival maneuver in which the hull is moved from a predetermined arrival start position to a mooring start position closer to the quay than the arrival start position, and 35
- mooring maneuver in which the hull is moved from the mooring start position and is made to reach the quay, wherein 40
- in the arrival maneuver, the thrust is distributed to the propulsion structures such that the thrust distributed to the mooring structures becomes zero. 45
19. The ship maneuvering method according to claim 18, wherein in the mooring maneuver, the thrust is distributed to the propulsion structures such that among the propulsion structures, the thrust is distributed to the mooring structures more preferentially than the other propulsion structures. 50
20. The ship maneuvering method according to any one of claims 13 to 19, wherein the thrust distributed to each mooring structure is determined by using a hull kinetic model configured to estimate the thrust output from the mooring structure based on the tension of the mooring rope of the mooring structure. 55

21. A ship maneuvering system comprising:

a front-rear propulsor that outputs thrust toward both sides in a front-rear direction of a hull;
 a lateral propulsor that outputs thrust toward both sides in a lateral direction of the hull;
 at least one mooring structure located close to a stern of the hull and at least one mooring structure located close to a bow of the hull, each of the mooring structures being configured to wind and unwind a mooring rope; and
 ship maneuvering circuitry configured to control operations of the front-rear propulsor, the lateral propulsor, and the mooring structures, wherein when making the hull reach a quay, with the mooring ropes locked to mooring posts located at the quay, the ship maneuvering circuitry makes the mooring structures wind the mooring ropes, and at the same time, makes at least one of the front-rear propulsor and the lateral propulsor output the thrust by which tension of each mooring rope becomes a predetermined threshold or less.

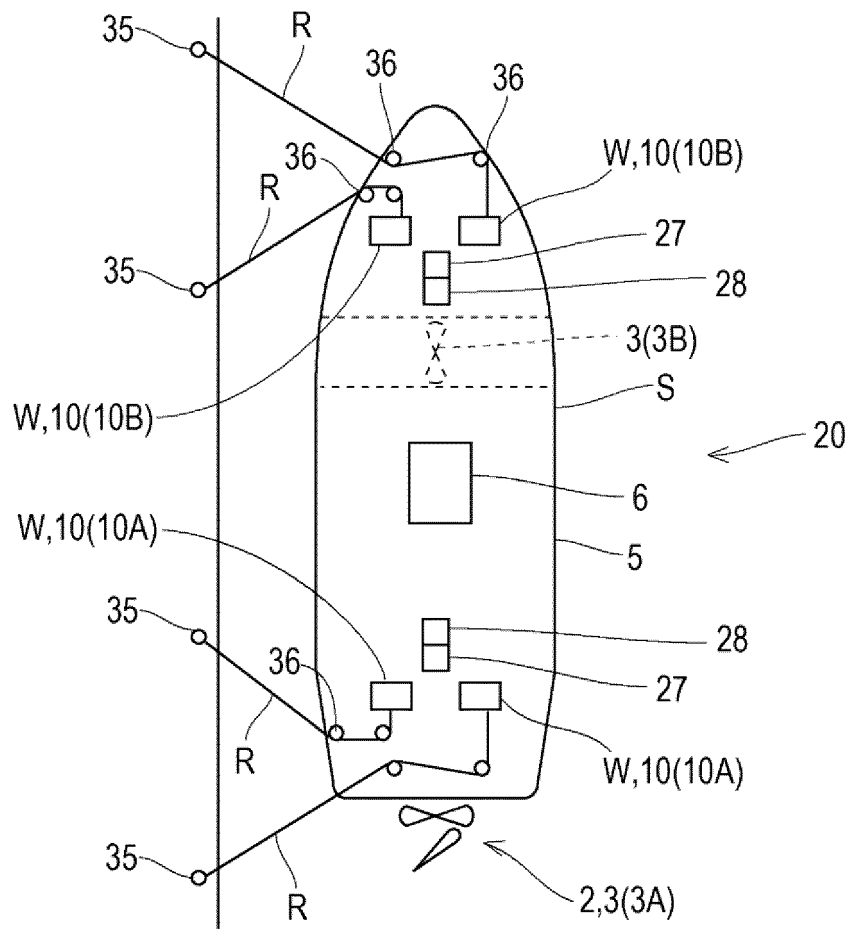


FIG.1

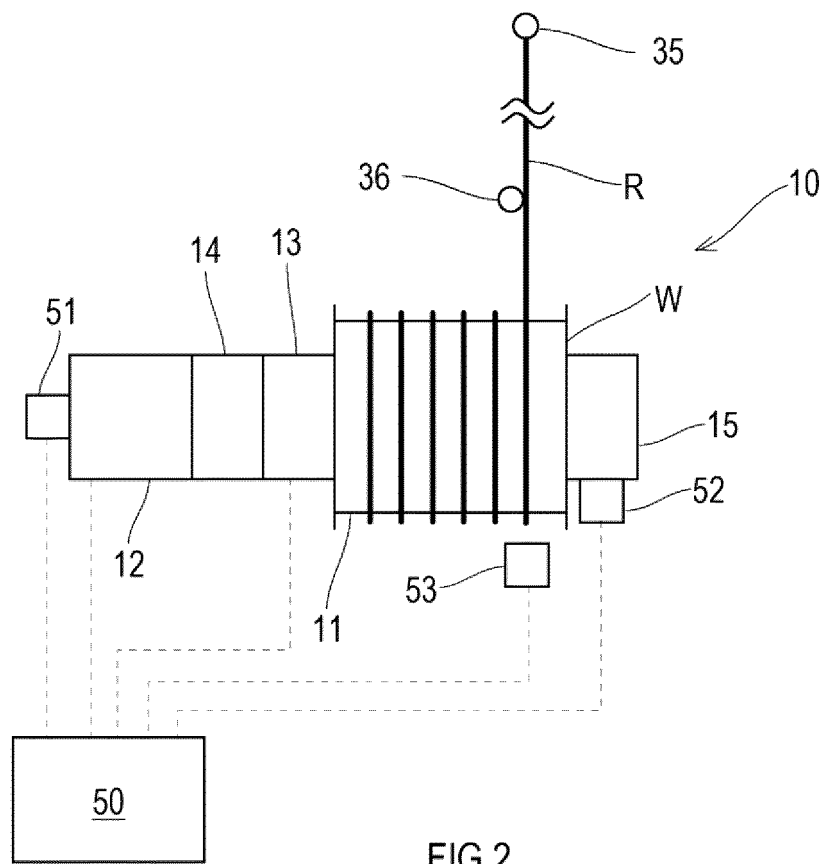
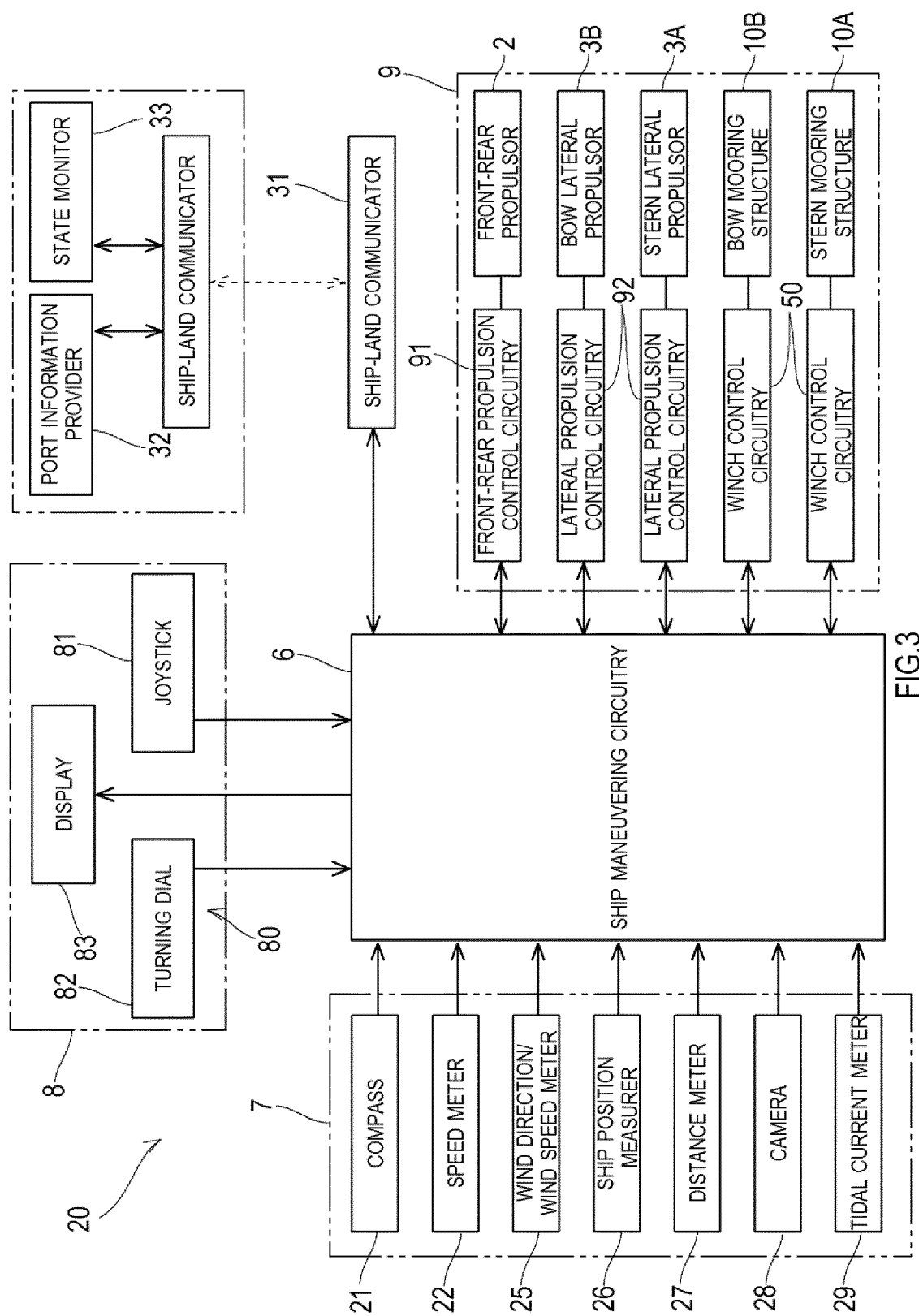


FIG.2



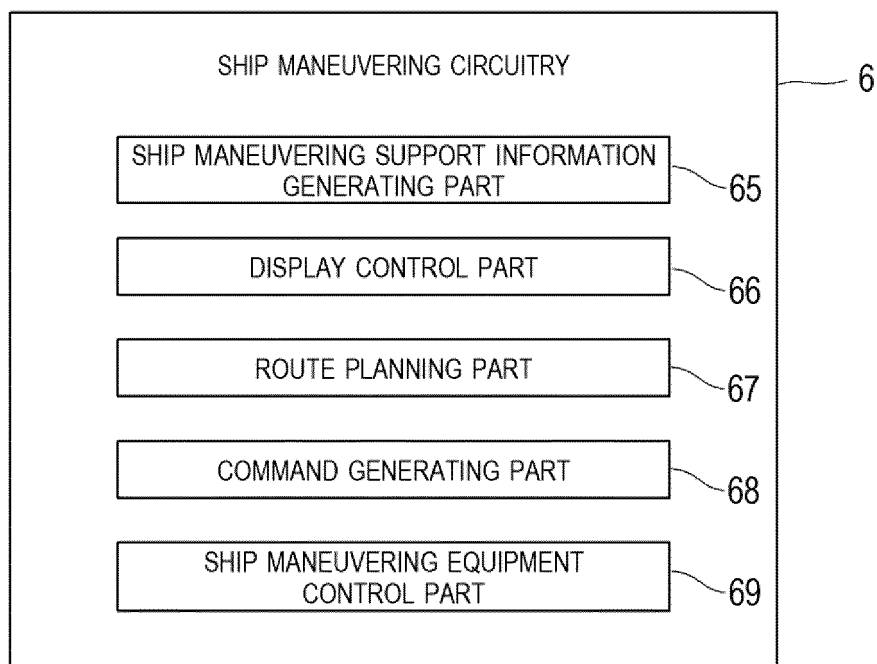


FIG.4

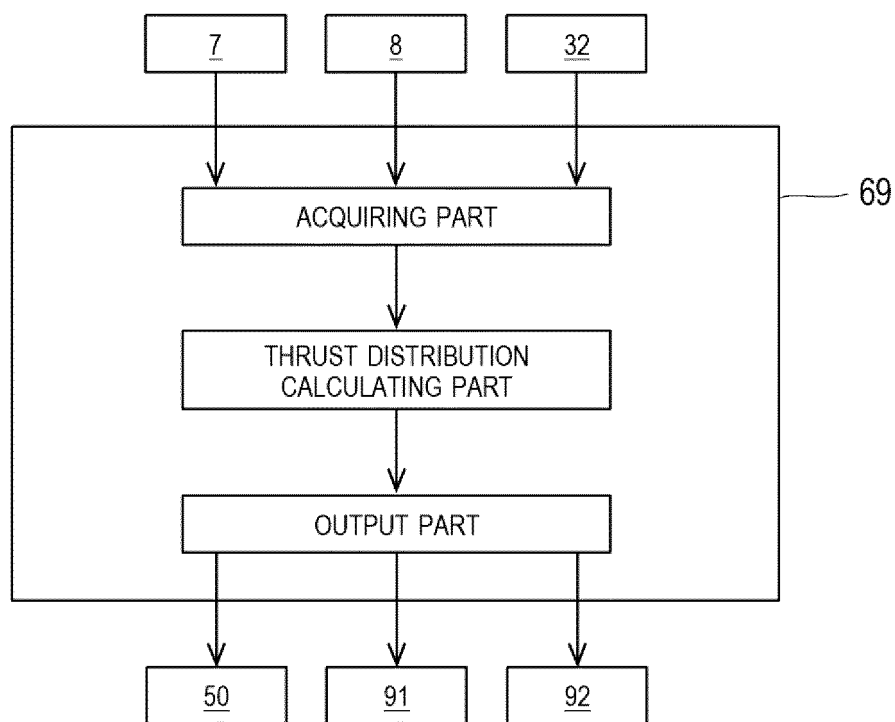
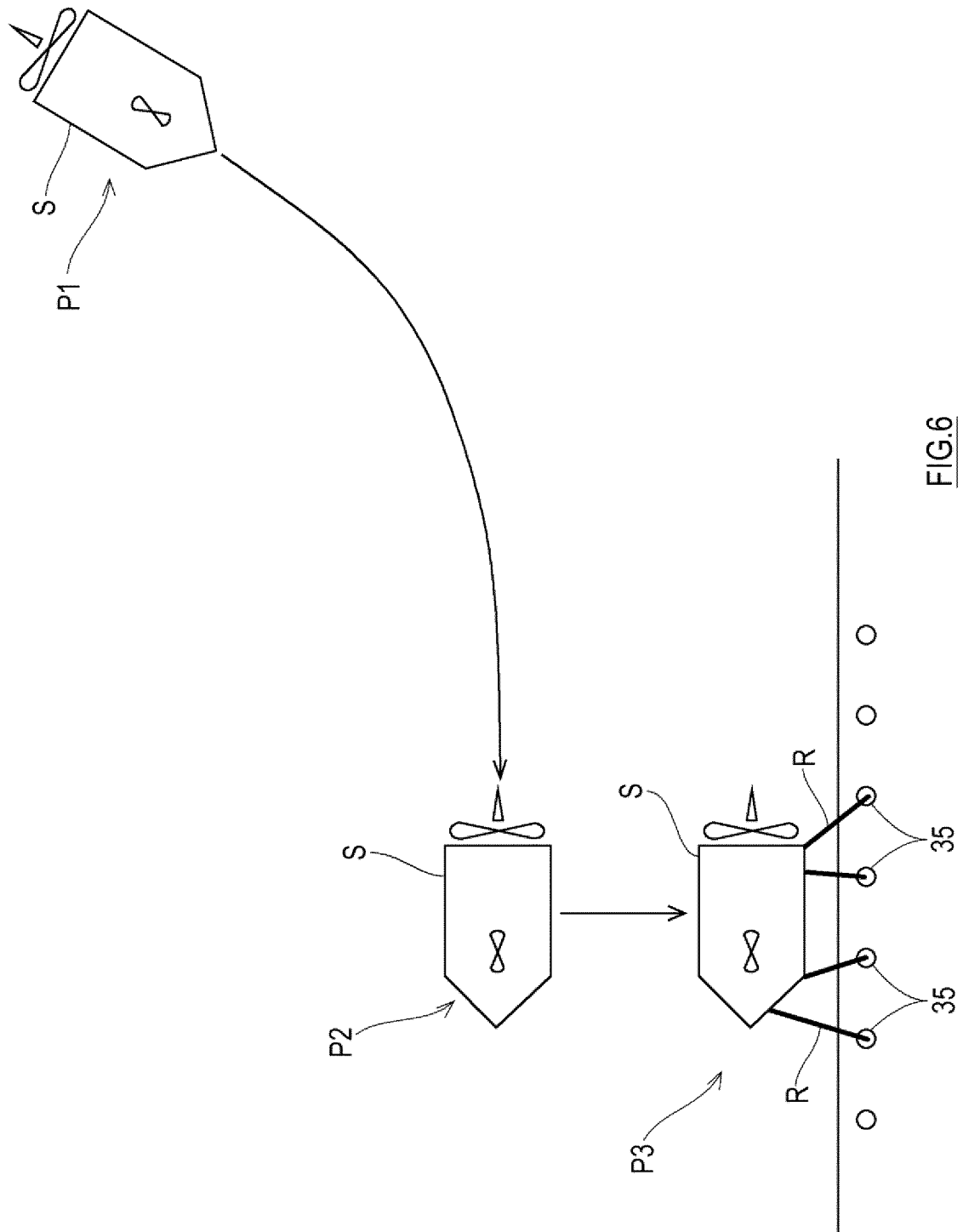


FIG.5



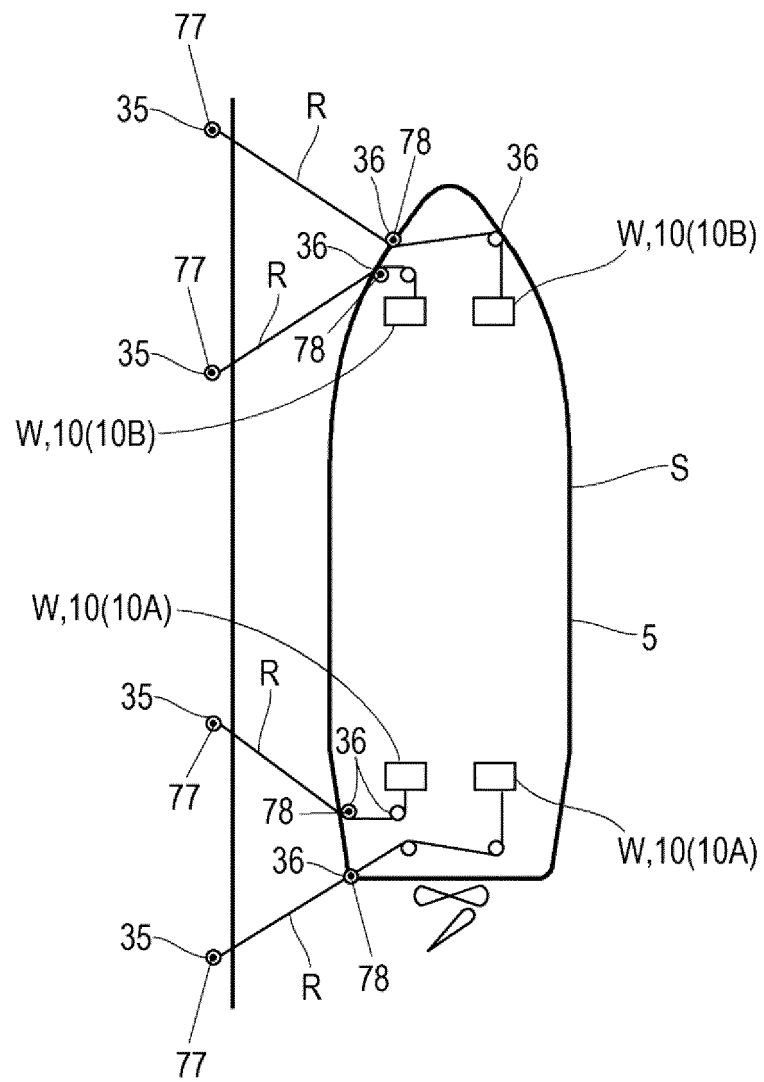


FIG.7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/043400

A. CLASSIFICATION OF SUBJECT MATTER

B63B 21/00(2006.01)i; **B63B 21/16**(2006.01)i; **B63H 25/02**(2006.01)i; **B63H 25/04**(2006.01)i; **B63H 25/42**(2006.01)i
FI: B63B21/00 A; B63B21/16; B63H25/42 G; B63H25/02 Z; B63H25/42 N; B63H25/42 J; B63H25/04 G; B63H25/04 Z

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B63B21/00; B63B21/16; B63H25/02; B63H25/04; B63H25/42

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2005-255058 A (SHIN KURUSHIMA DOCKYARD CO LTD) 22 September 2005 (2005-09-22) paragraphs [0009]-[0024], fig. 1-6	1-2, 11-12, 21
Y	JP 11-129978 A (MITSUI ZOSEN AKISHIMA KENKYUSHO:KK) 18 May 1999 (1999-05-18) paragraphs [0006]-[0030], fig. 1-4	1-2, 11-12, 21
Y	土井正好, 永本和寿, 出縄憲一, 森泰親, 荒天時棧橋停泊のための可変ピッチプロペラ操船法の自動化に関する一考察, 計測自動制御学会論文集, March 2013, vol. 49, no. 3, pp.336-344, DOI:10.9746/sicetr.49.336, ISSN 1883-8189 (online), 0453-4654 (print) p. 336, (DOI, Masayoshi. NAGAMOTO, Kazuhisa. IDENAWA, Kenichi. MORI, Yasuchika. Consideration Regarding Automation of Controllable Pitch Propeller for Mooring Pier in Stormy Weather. Transactions of the Society of Instrument and Control Engineers.)	1-2, 11-12, 21
A	JP 60-94889 A (MITSUBISHI HEAVY IND LTD) 28 May 1985 (1985-05-28) p. 2, lower left column, line 17 to lower right column, line 20, fig. 3-4	1-21

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

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Date of the actual completion of the international search

02 February 2022

Date of mailing of the international search report

15 February 2022

Name and mailing address of the ISA/JP

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Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/043400

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 2002-244543 A (MITSUBISHI HEAVY IND LTD) 30 August 2002 (2002-08-30) entire text, all drawings	1-21
A	JP 2019-512428 A (A.P. MØLLER - MÆRSK A/S) 16 May 2019 (2019-05-16) entire text, all drawings	1-21

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2021/043400

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2005-255058 A	22 September 2005	(Family: none)	
JP 11-129978 A	18 May 1999	(Family: none)	
JP 60-94889 A	28 May 1985	(Family: none)	
JP 5442071 B2	12 March 2014	(Family: none)	
JP 2002-244543 A	30 August 2002	(Family: none)	
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		WO 2017/167882 A1	
		EP 3436338 A1	
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Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2005255058 A [0004]