



US 20070017426A1

(19) **United States**(12) **Patent Application Publication****Kaji et al.**(10) **Pub. No.: US 2007/0017426 A1**(43) **Pub. Date:****Jan. 25, 2007**

(54) **MARINE VESSEL MANEUVERING
SUPPORTING APPARATUS, MARINE
VESSEL INCLUDING THE MARINE VESSEL
MANEUVERING SUPPORTING APPARATUS,
AND MARINE VESSEL MANEUVERING
SUPPORTING METHOD**

(76) Inventors: **Hiroataka Kaji**, Shizuoka (JP); **Masaru
Suemori**, Shizuoka (JP)

Correspondence Address:

**YAMAHA HATSUDOKI KABUSHIKI KAISHA
C/O KEATING & BENNETT, LLP
8180 GREENSBORO DRIVE
SUITE 850
MCLEAN, VA 22102 (US)**

(21) Appl. No.: **11/013,567**(22) Filed: **Dec. 16, 2004**(30) **Foreign Application Priority Data**

Dec. 16, 2003 (JP) 2003-418421

Publication Classification(51) **Int. Cl.****B63H 25/00**

(2006.01)

(52) **U.S. Cl. 114/144 RE**(57) **ABSTRACT**

A marine vessel maneuvering supporting apparatus performs a stationary marine vessel maneuvering support operation, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of a hull, and a pair of steering mechanisms which respectively change steering angles. The apparatus includes a position detecting section which detects a position of the marine vessel, a marine vessel maneuvering support starting command section, a marine vessel maneuvering support starting position storing section, a steering controlling section which controls the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero in response to the marine vessel maneuvering support starting command, a target propulsive force calculating section which calculates target propulsive forces to be generated from the respective propulsion systems, such that at least one of x- and y-coordinates of the current marine vessel position is maintained substantially equal to a corresponding one of x- and y-coordinates of the marine vessel maneuvering support starting position, and a propulsive force controlling section which controls the propulsion systems to attain the target propulsive forces.

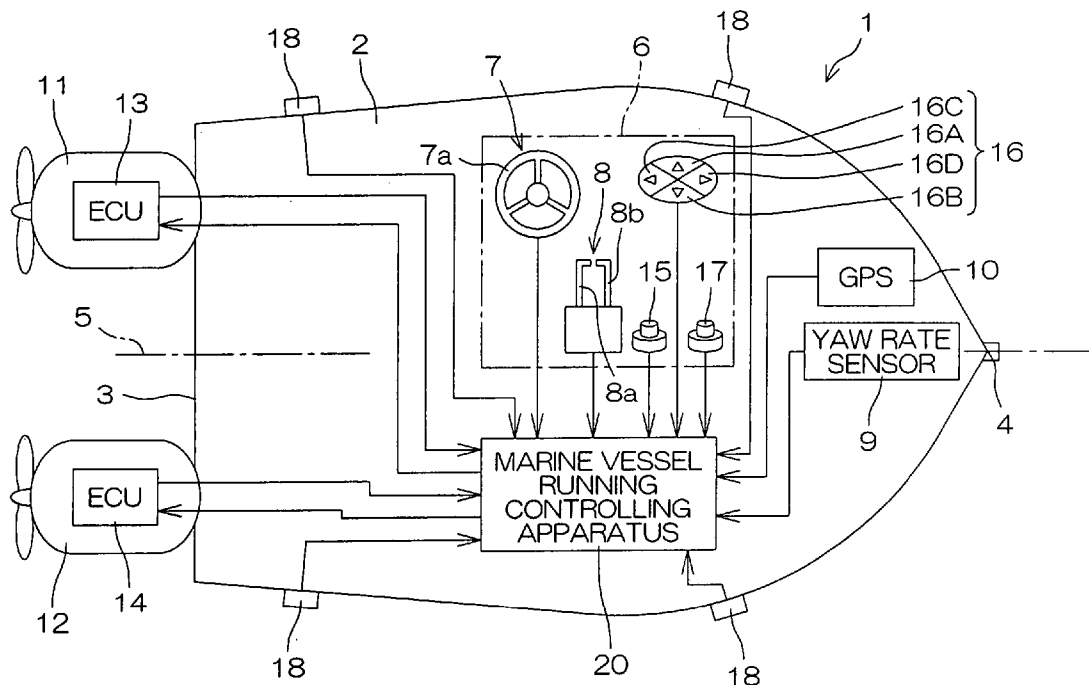


FIG. 1

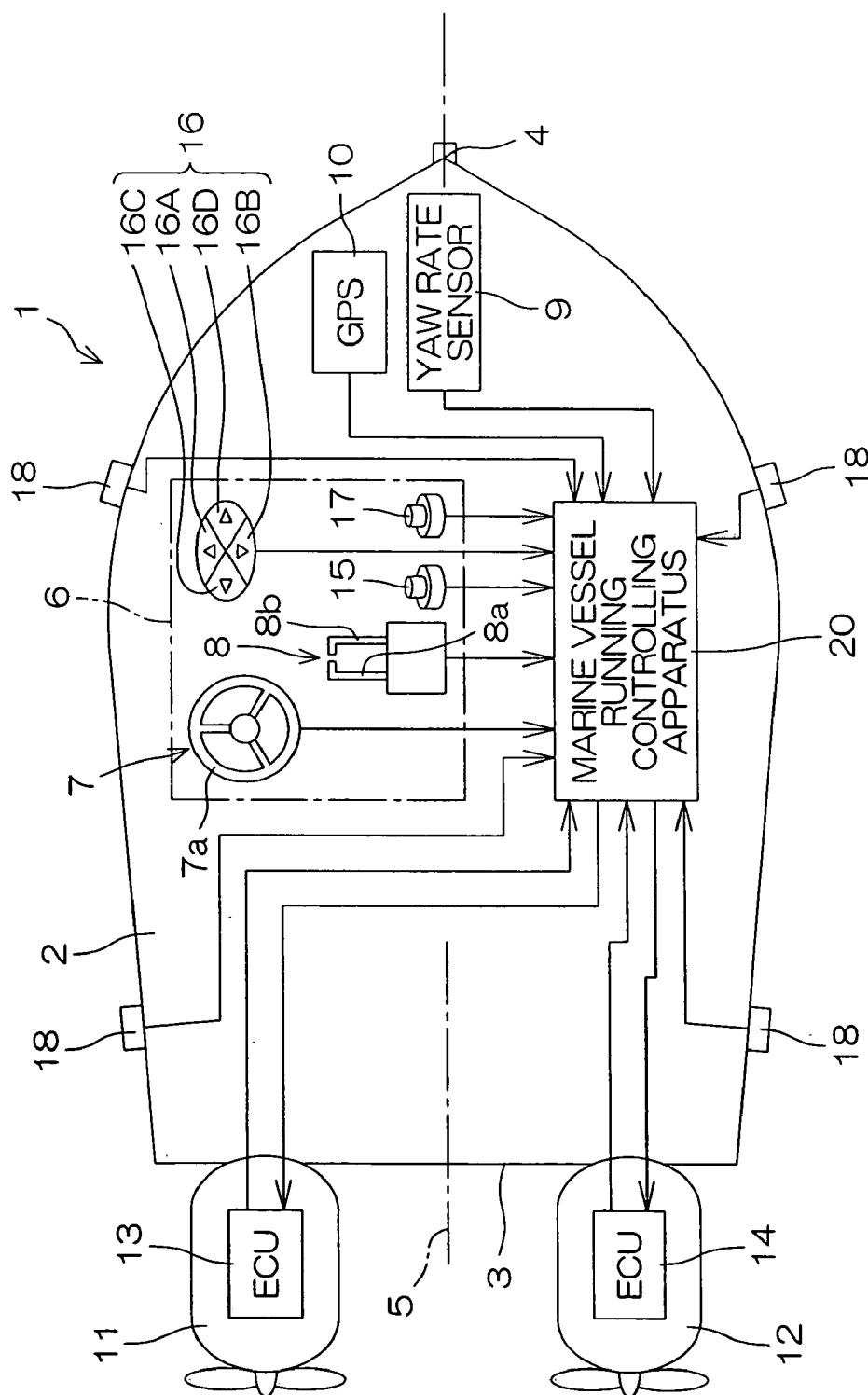


FIG. 2

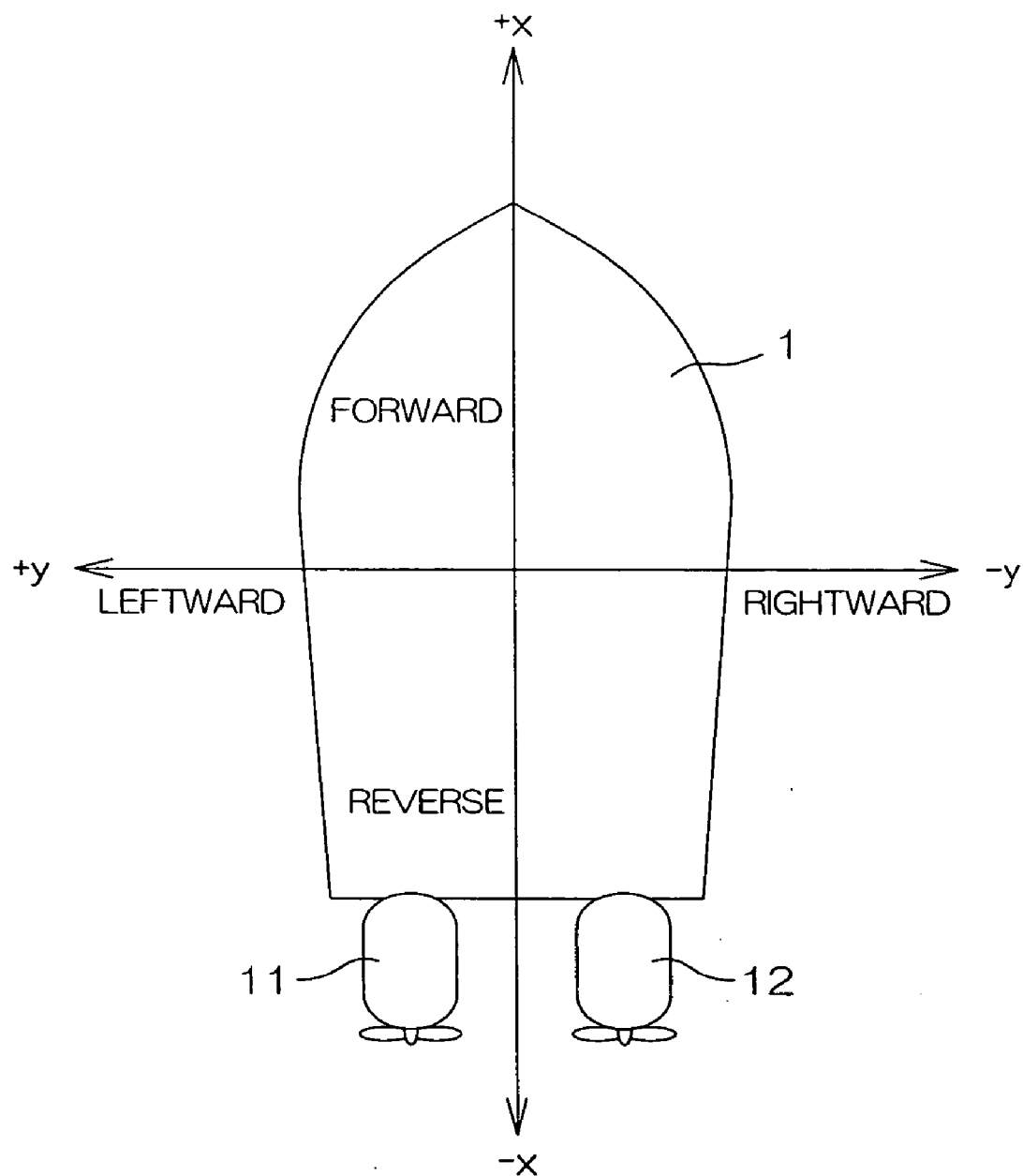


FIG. 3A

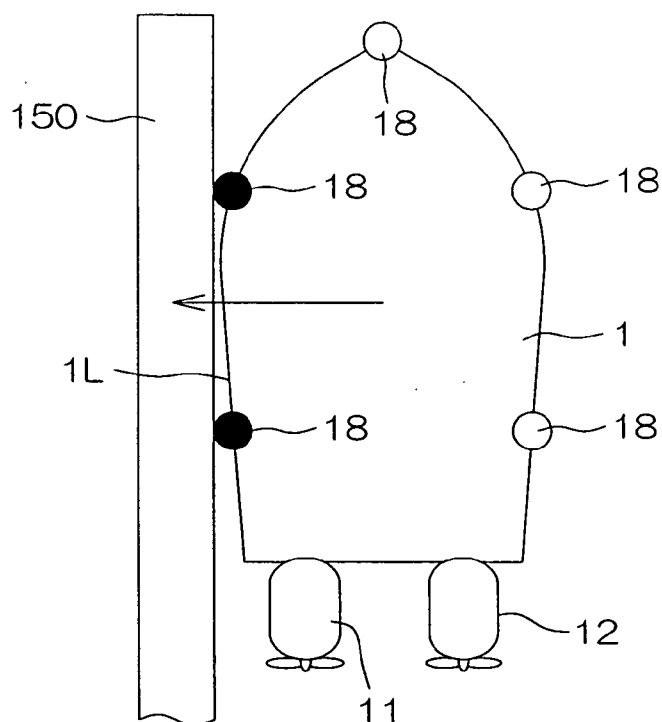


FIG. 3B

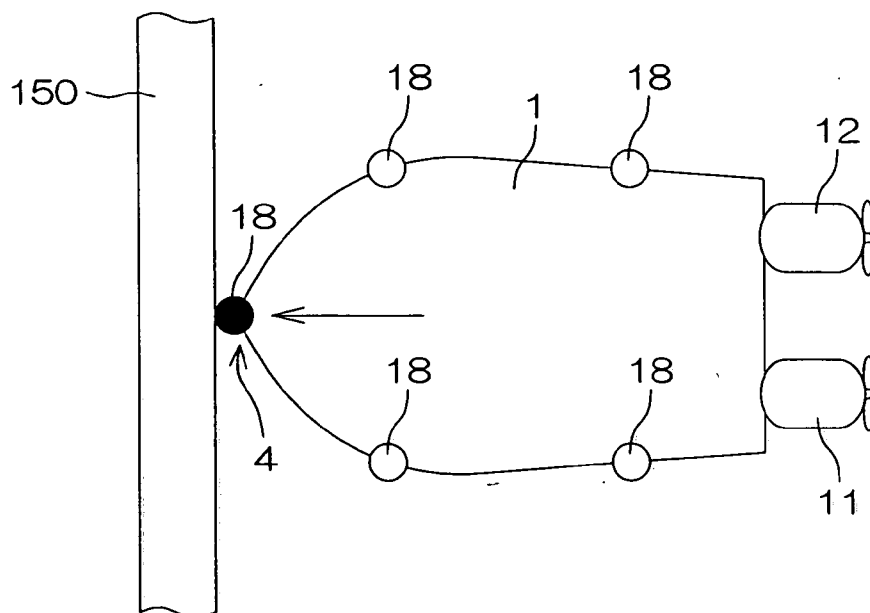


FIG. 3C

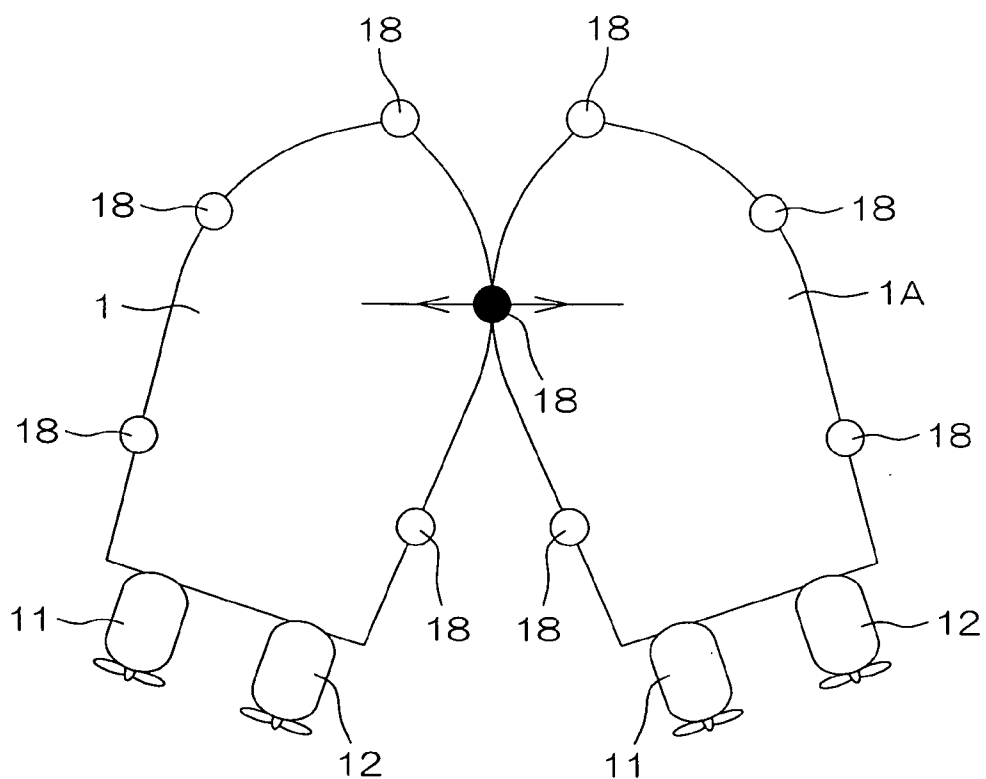


FIG. 3D

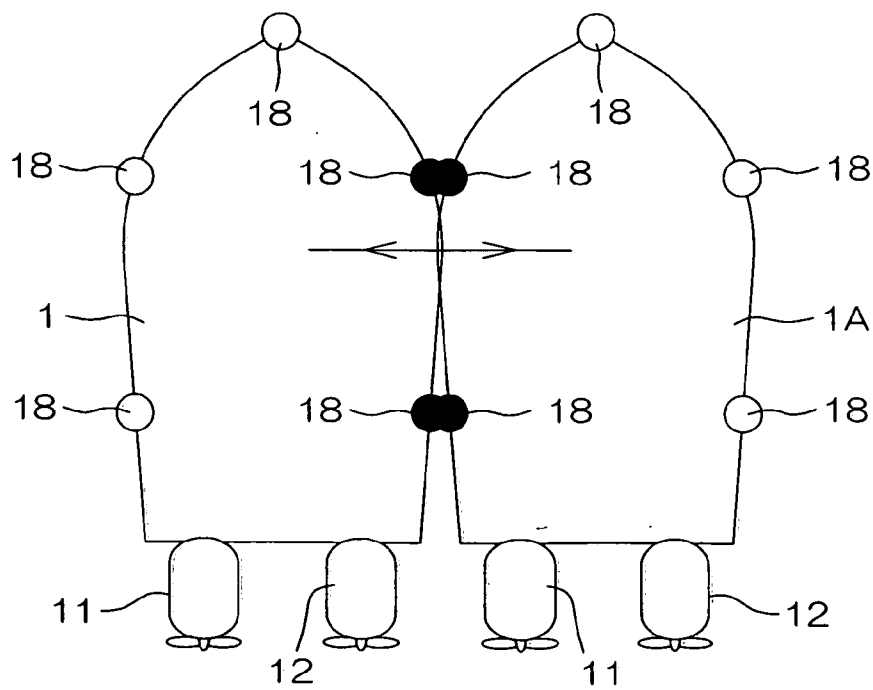
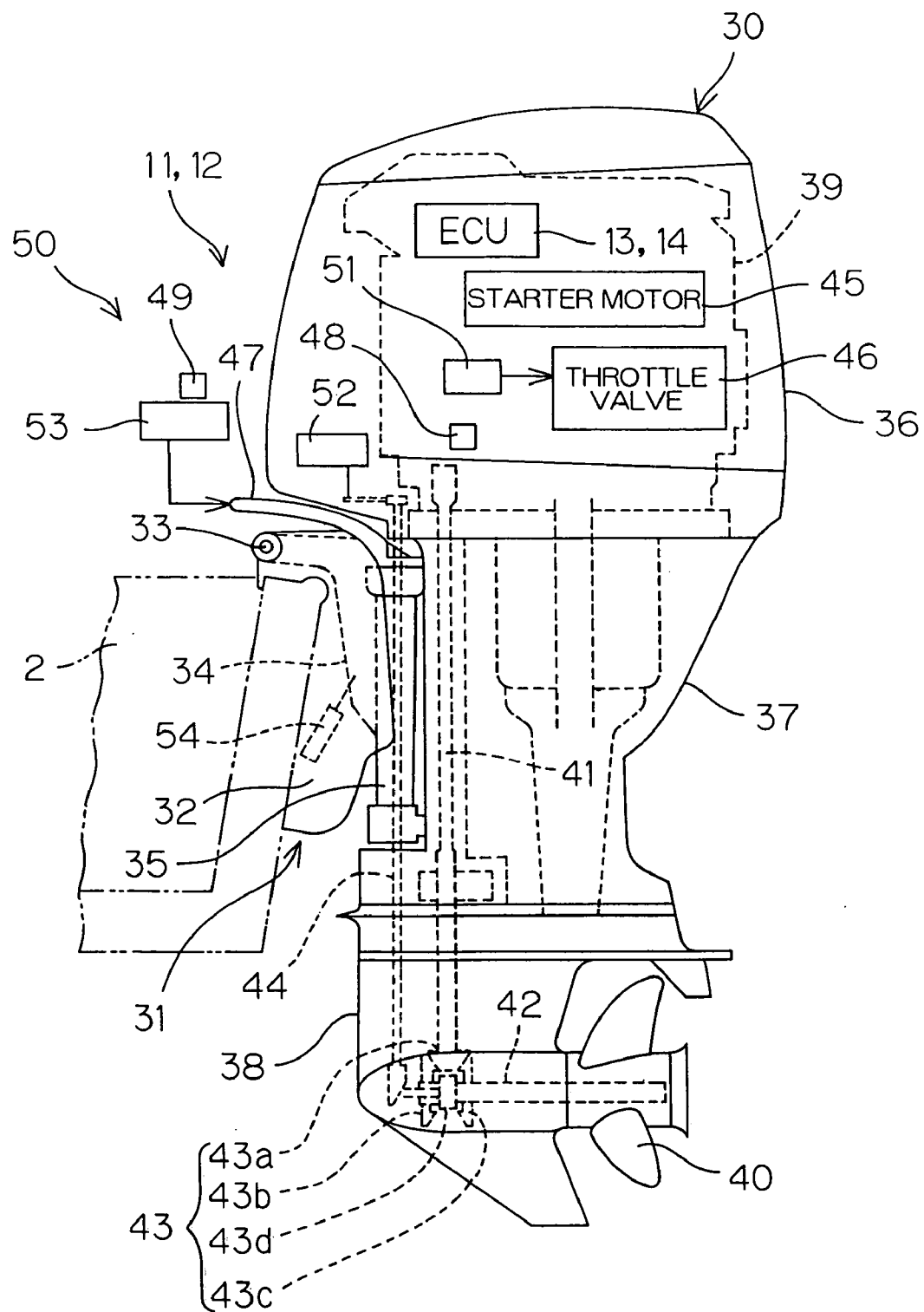


FIG. 4



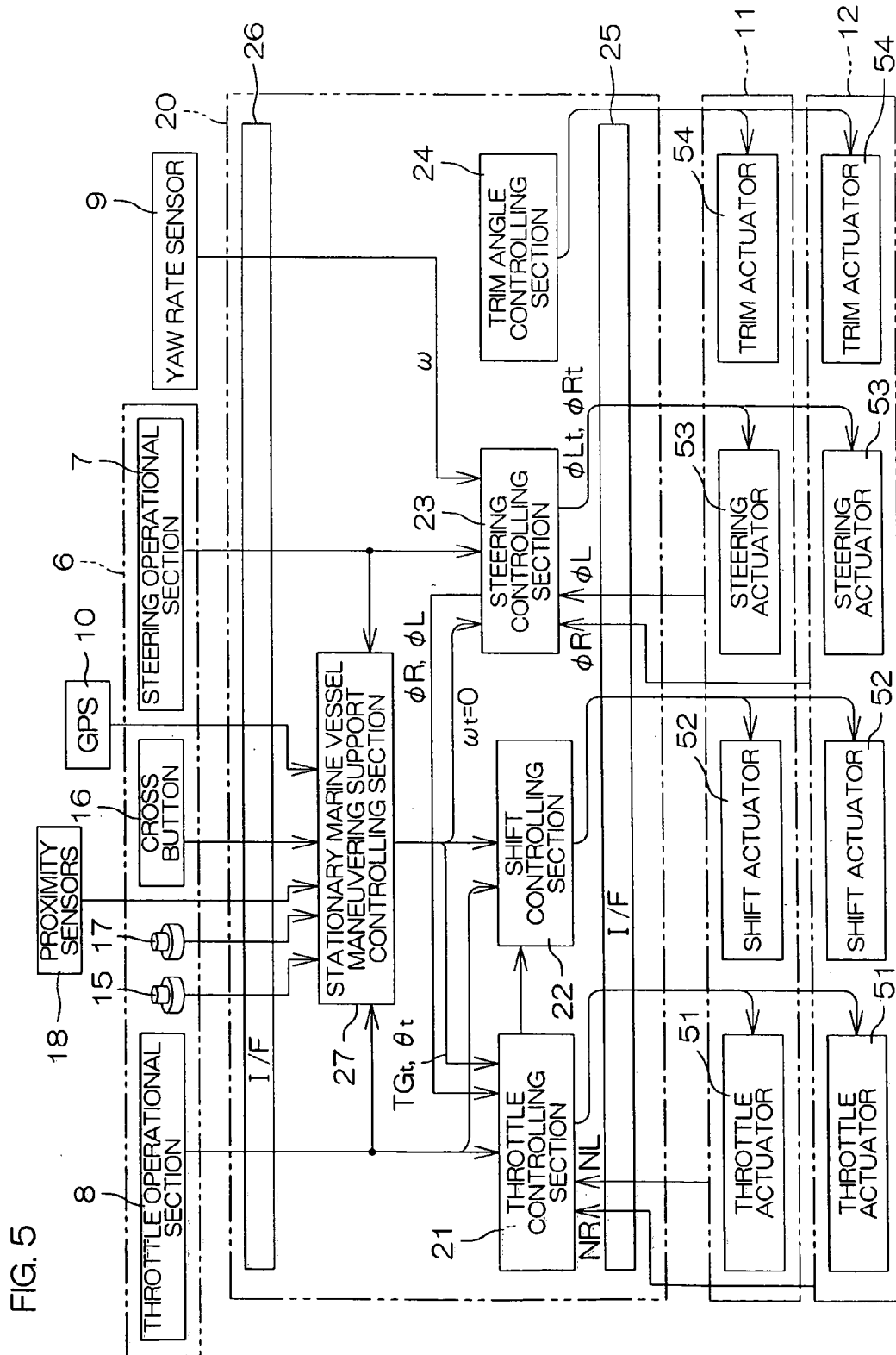


FIG. 8

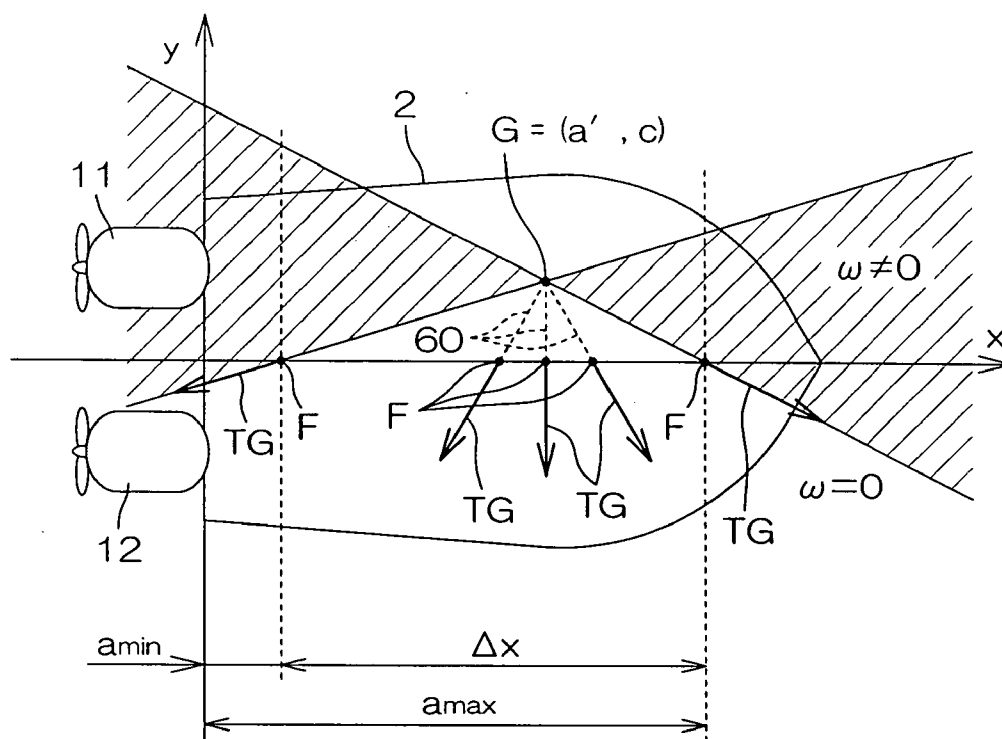
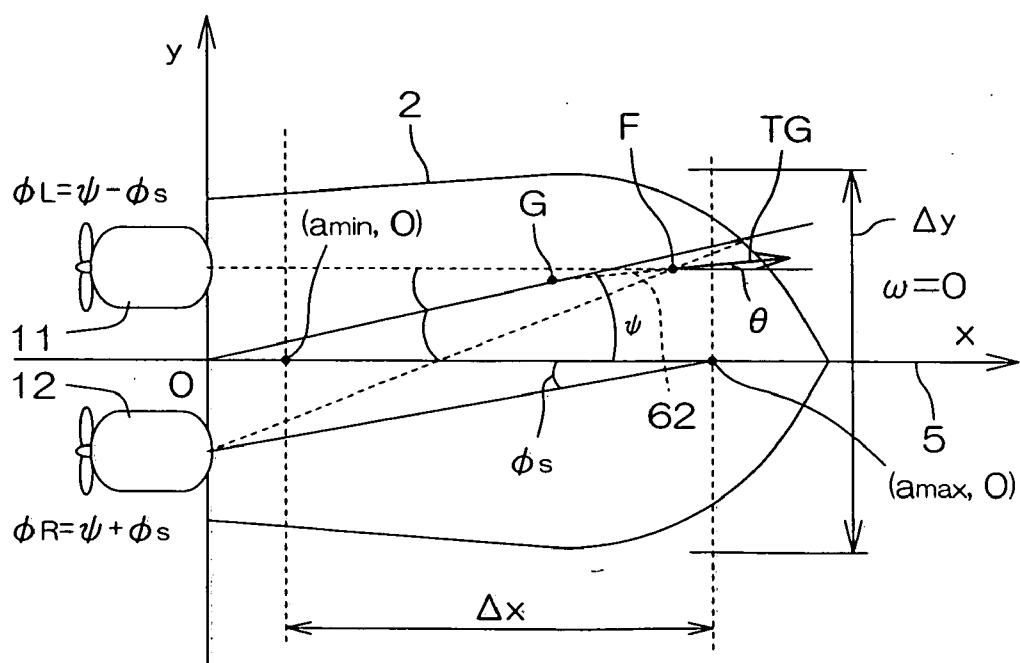


FIG. 9



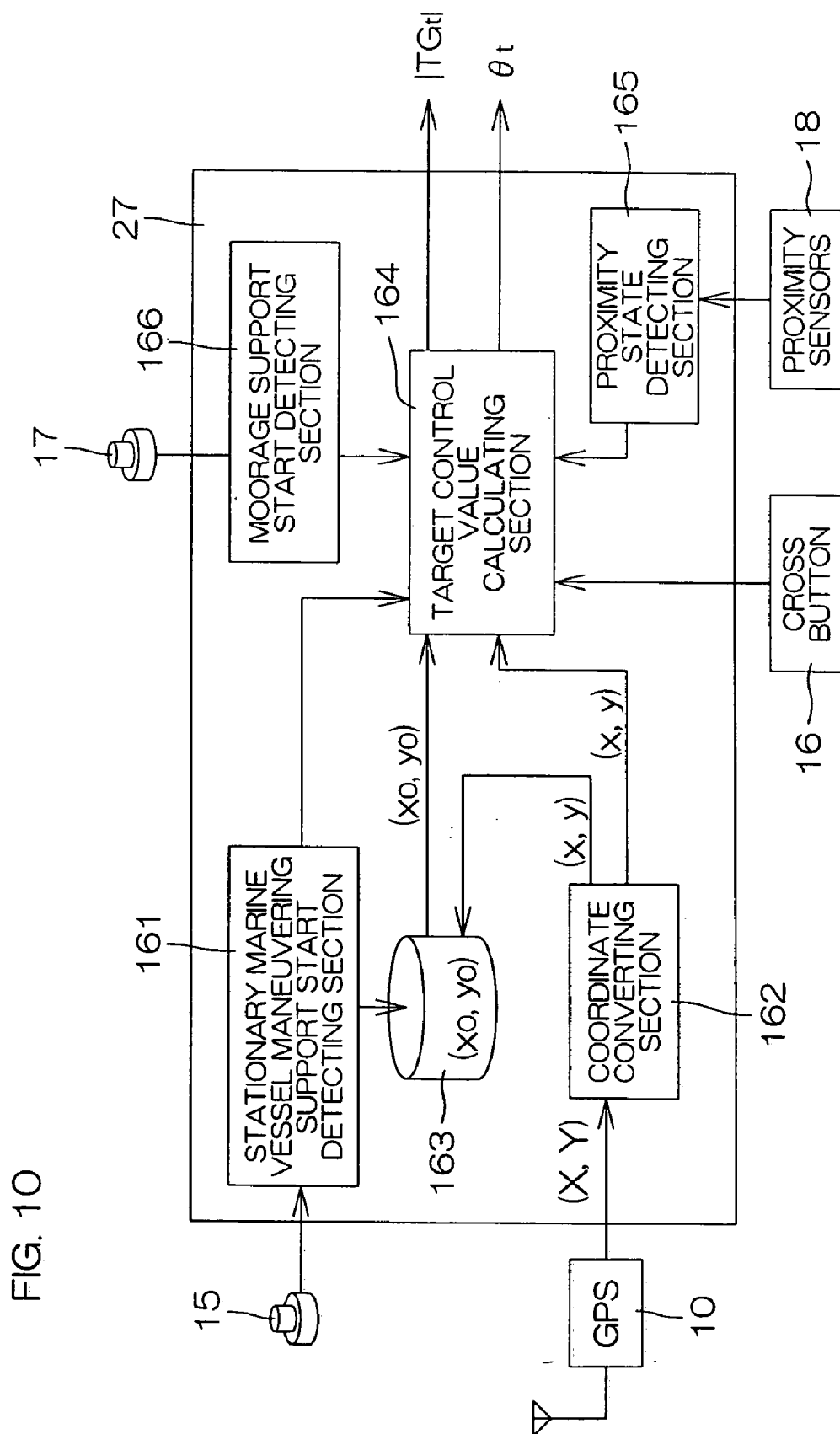


FIG. 11

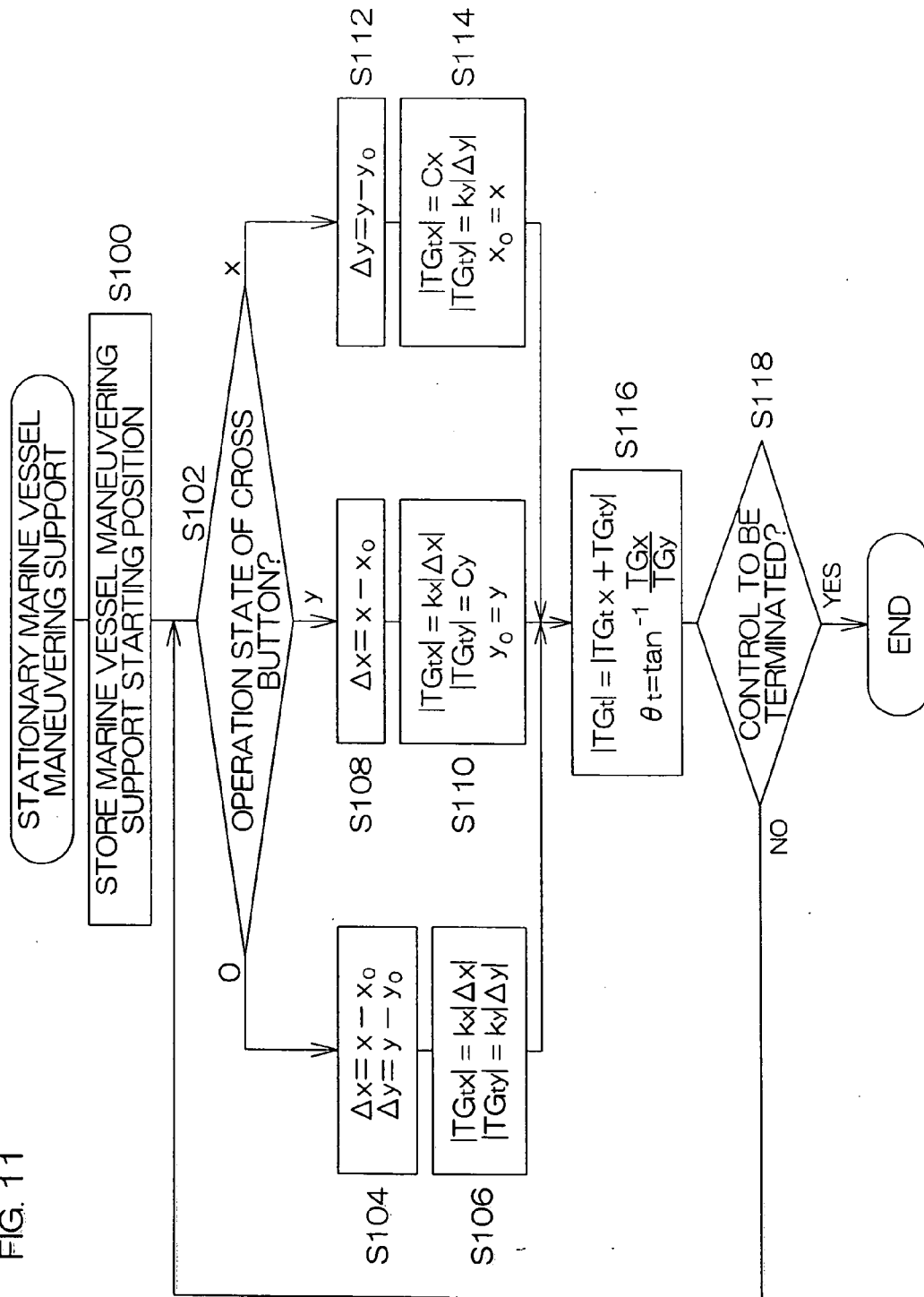


FIG. 12

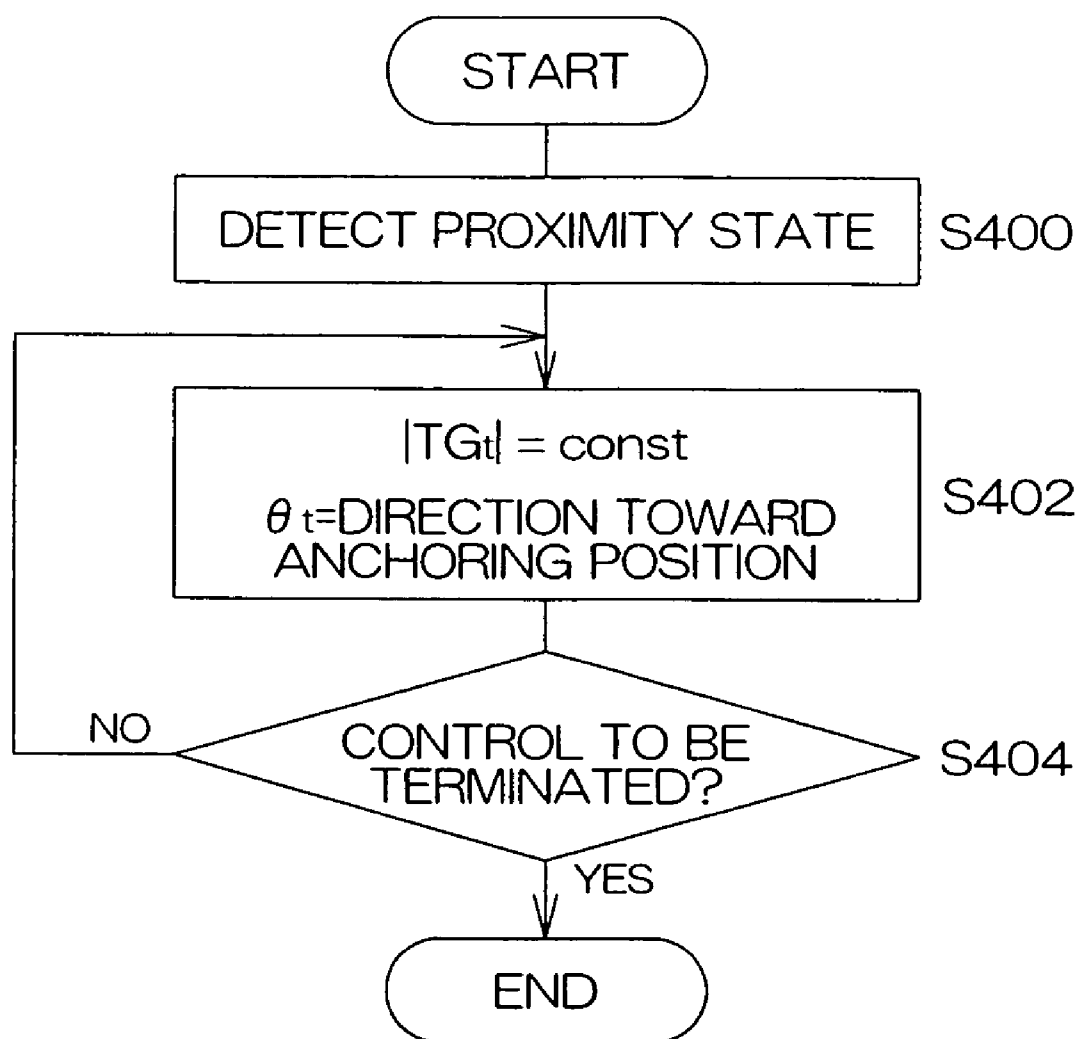


FIG. 13

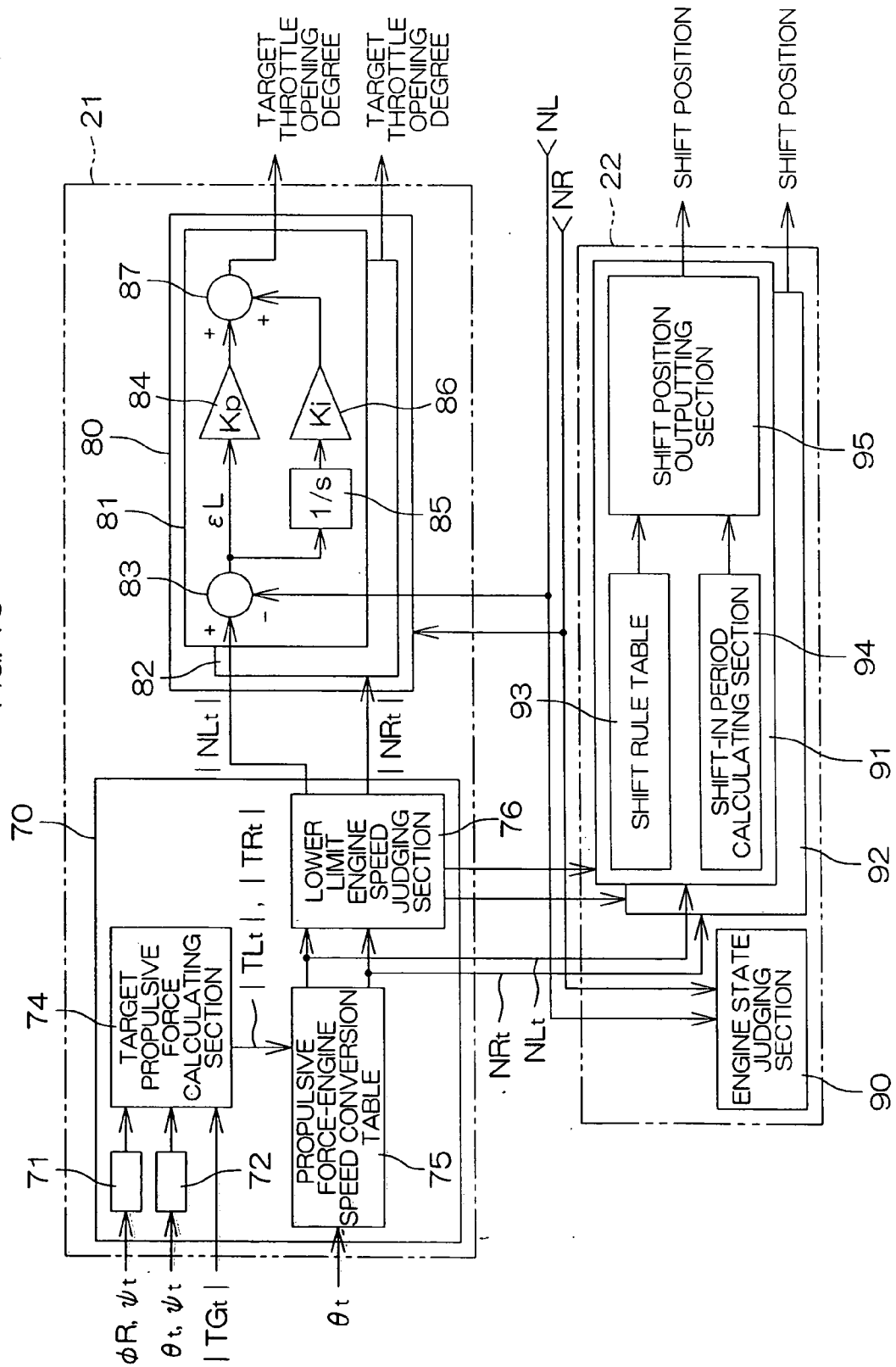


FIG. 14

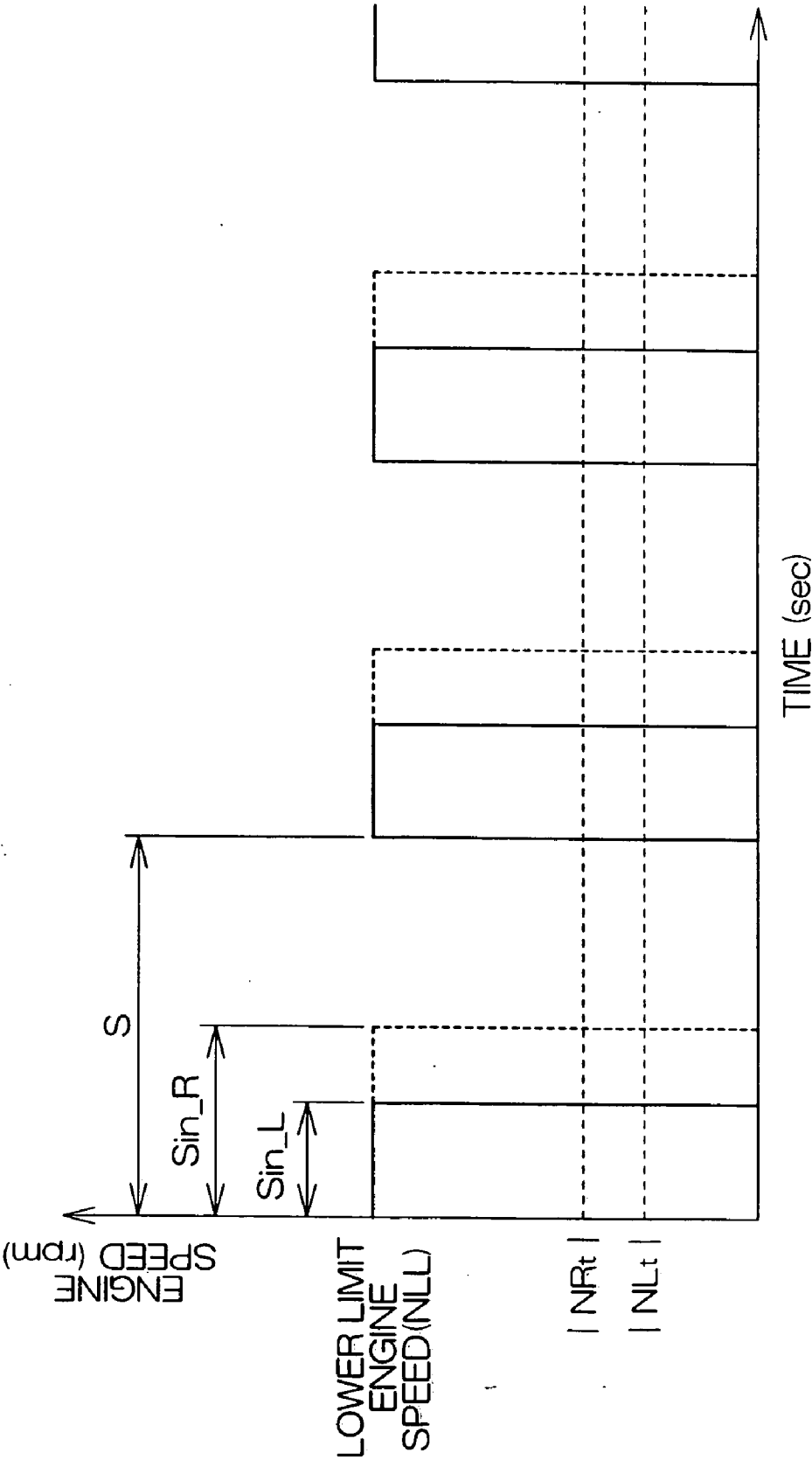


FIG. 15

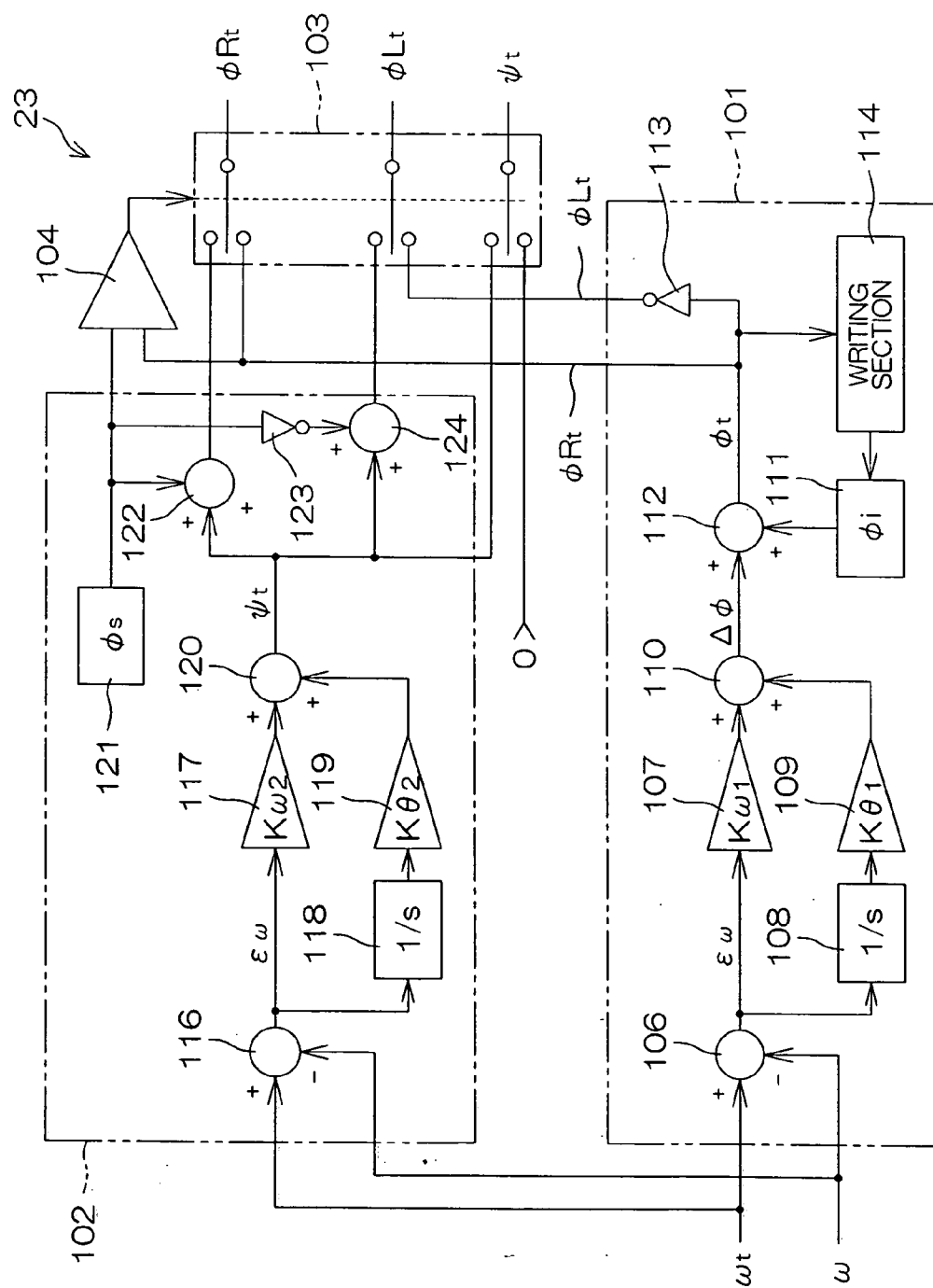


FIG 16

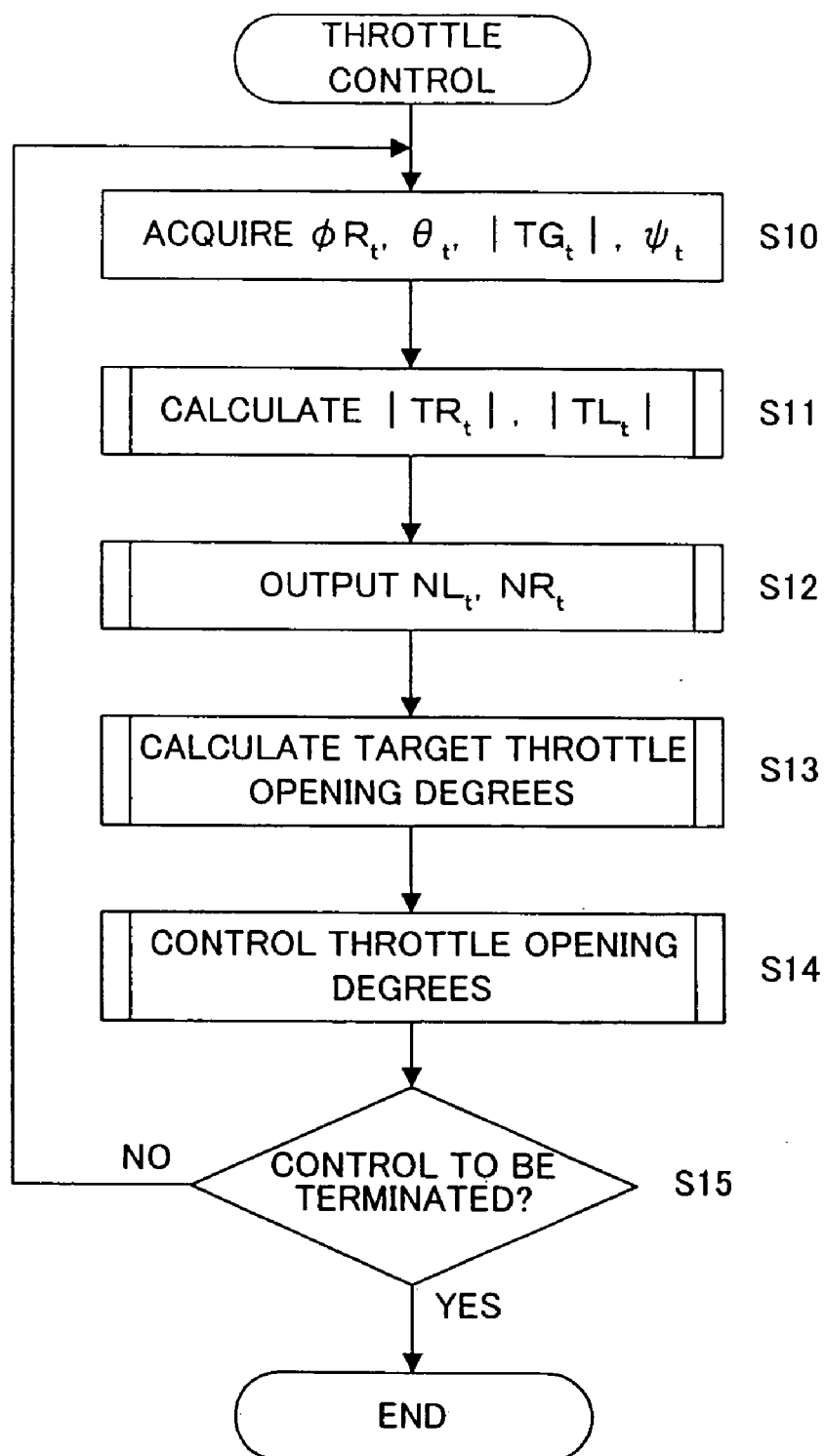


FIG. 17

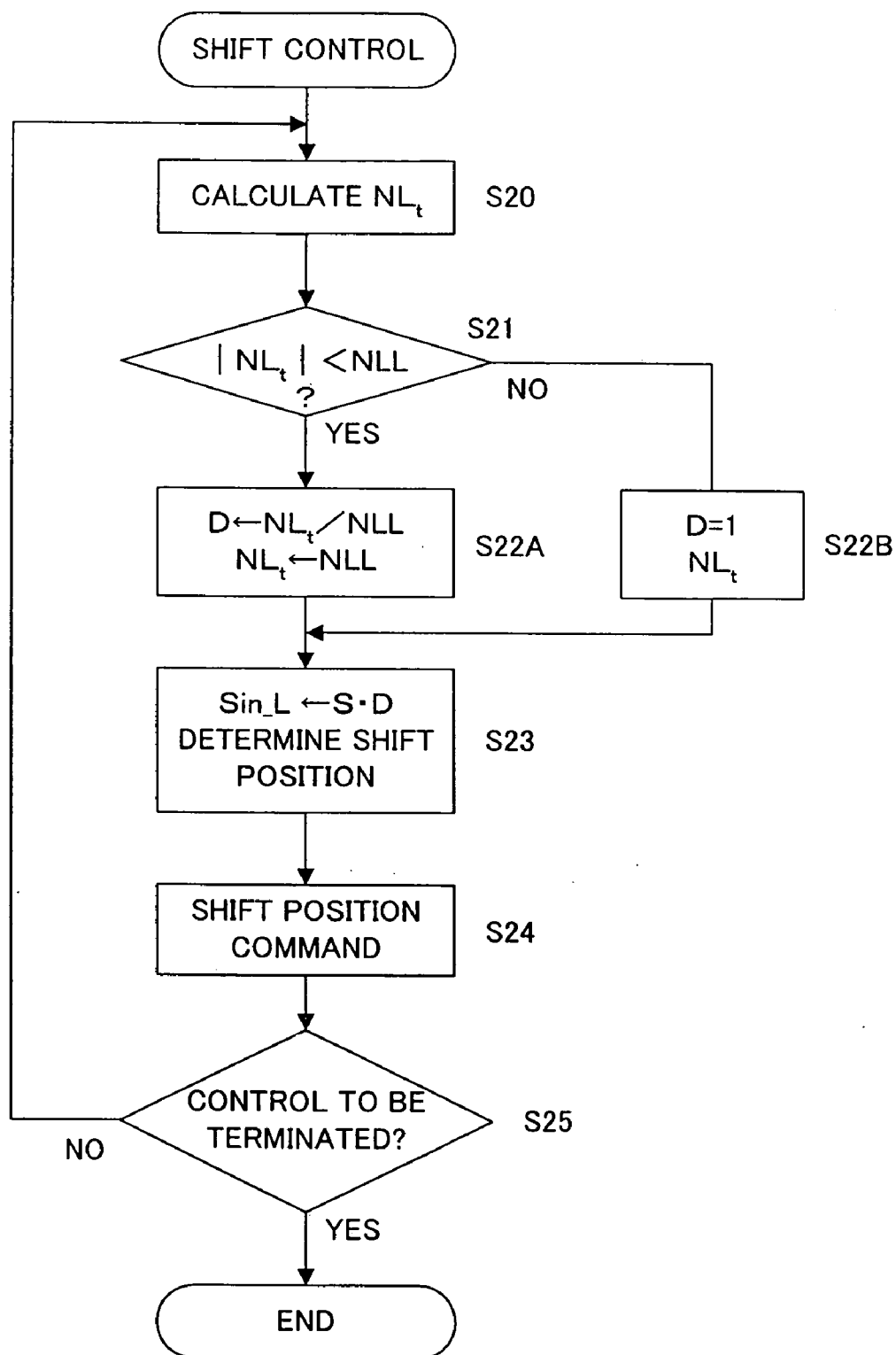


FIG. 18

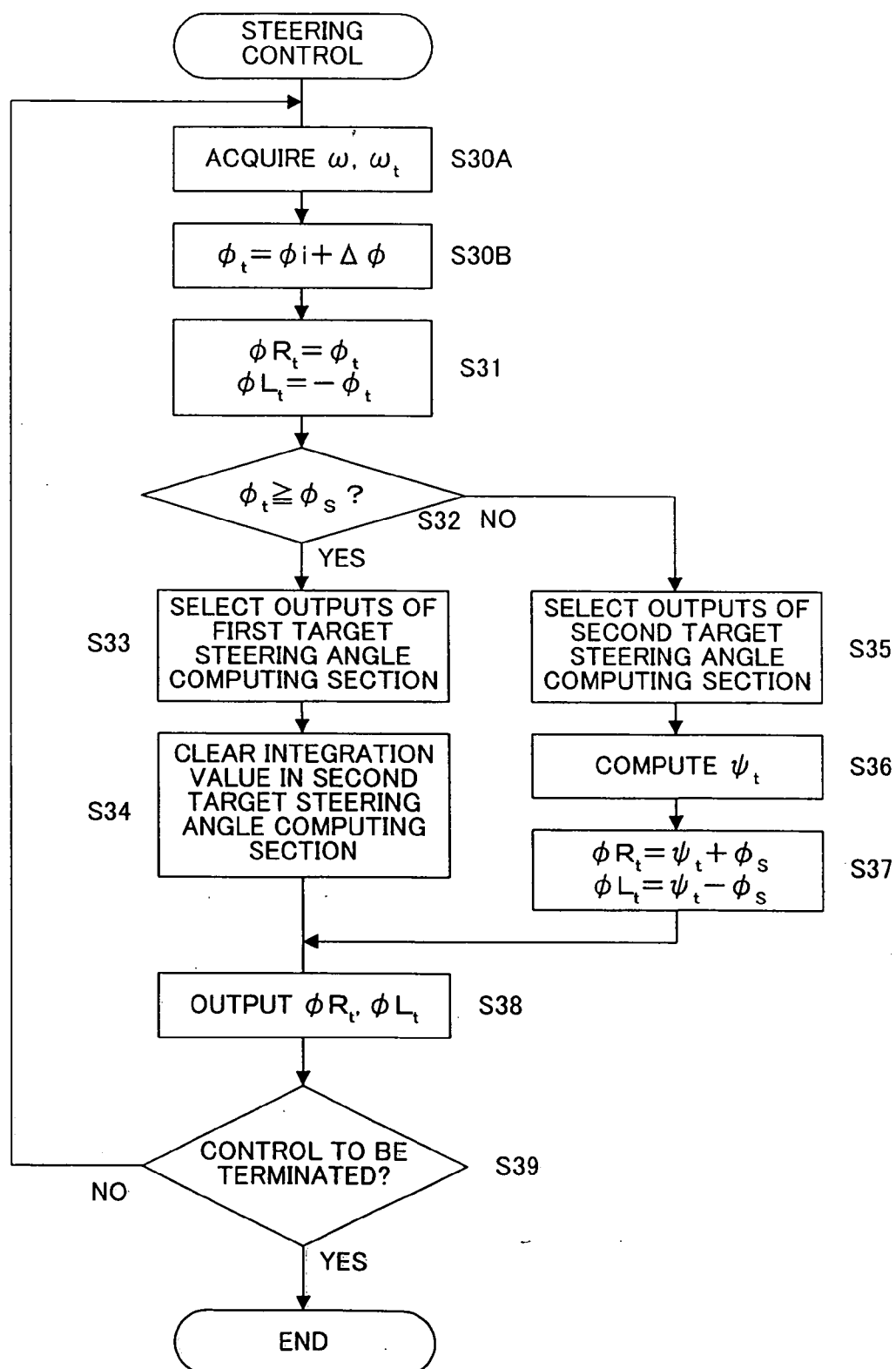


FIG. 19

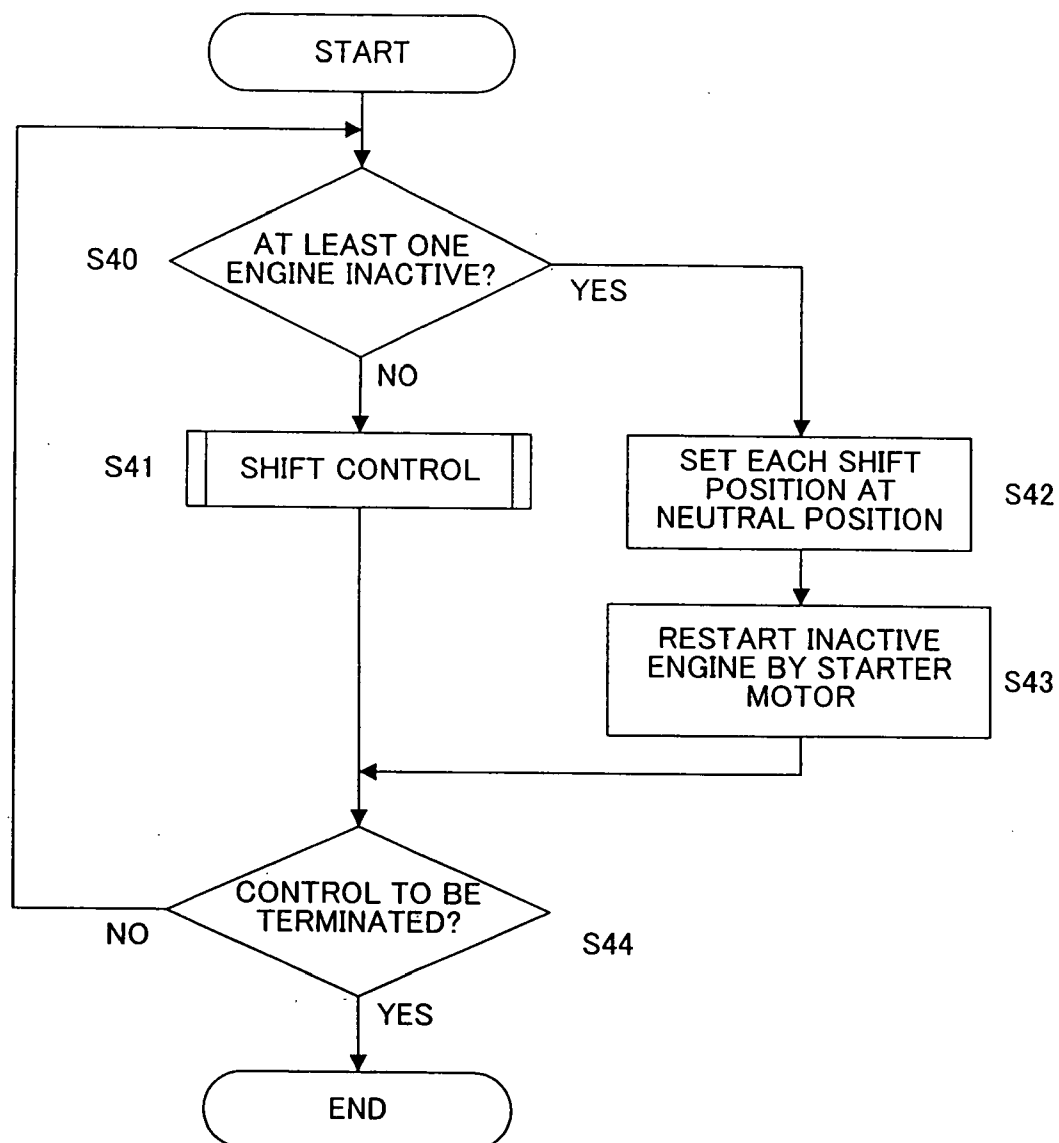
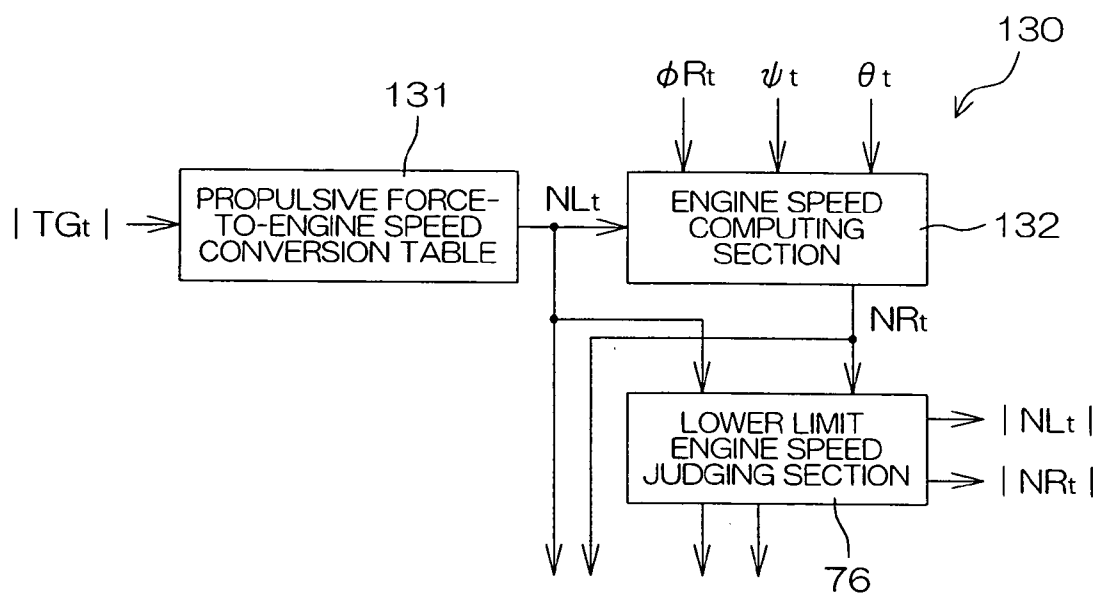


FIG. 20



MARINE VESSEL MANEUVERING SUPPORTING APPARATUS, MARINE VESSEL INCLUDING THE MARINE VESSEL MANEUVERING SUPPORTING APPARATUS, AND MARINE VESSEL MANEUVERING SUPPORTING METHOD

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a marine vessel maneuvering supporting apparatus which is applicable to a marine vessel having at least one pair of propulsion systems provided at a stern thereof, a marine vessel including the marine vessel maneuvering supporting apparatus, and a marine vessel maneuvering supporting method.

[0003] 2. Description of the Related Art

[0004] When a marine vessel travels toward or away from a wharf, a lateral maneuvering operation is performed to laterally move the hull of the marine vessel with the angular speed (stem turning speed) of the hull being maintained constant (for example, at zero). In general, large-scale marine vessels include a plurality of small propulsion systems called "side thrusters" provided at a stem and other locations of a hull to laterally move the hull. The side thrusters each generate a propulsive force in a lateral direction of the hull. Thus, the hull can be laterally moved toward and away from the wharf by operating the side thrusters.

[0005] However, small-scale marine vessels, such as cruisers, rarely include side thrusters because side thrusters cause various problems, such as an increase in costs, a need to modify the design of the hull to allow for installation of the side thrusters, and an increase in fuel consumption due to an increase in drag of the hull.

[0006] Cruisers and other leisure marine vessels are often operated by unskilled beginners. However, the lateral maneuvering of the small-scale marine vessels having no side thruster is very difficult, thereby requiring skilled operation of the marine vessel.

[0007] To this end, a marine vessel maneuvering apparatus which includes port-side and starboard-side propulsion systems provided at a stern of a marine vessel for facilitating the lateral maneuvering operation is disclosed, for example, in Japanese Patent No. 2810087. Japanese Patent No. 2810087 further discloses a mechanism for adjusting the orientation of the port-side and the starboard-side propulsion systems in accordance with each other, and a mechanism for operating engine throttles of the port-side and the starboard-side propulsion systems in accordance with each other. More specifically, the marine vessel maneuvering apparatus orients the port-side and starboard-side propulsion systems toward the center of the hull and generates a forward propulsive force from one of the propulsion systems and a reverse propulsive force from the other propulsion system.

[0008] However, the marine vessel maneuvering apparatus is not designed to calculate the directions and magnitudes of the propulsive forces required to be generated by the port-side and starboard-side propulsion systems for laterally moving the marine vessel in a desired direction. Therefore, the operator must manually operate the marine vessel for the lateral maneuvering operation to laterally move the marine vessel in a parallel manner, and thus must have a certain level of skill.

[0009] Further, the small-scale marine vessels are more likely to be influenced by disturbances than the large-scale marine vessels. More specifically, the instantaneous center (instantaneous rotation center) of the hull observed when the marine vessel is turned is easily changed by static disturbances such as the number and positions of passengers and the weight and positions of cargoes. Further, the instantaneous center is changed by dynamic disturbances such as winds and waves.

[0010] However, the prior art disclosed in Japanese Patent No. 2810087 is based on the assumption that the instantaneous center is fixed. Therefore, no consideration is given to the aforementioned disturbances. In reality, the lateral maneuvering operation for laterally moving the marine vessel toward and away from the wharf requires a substantial level of skill even using the device disclosed in this prior art.

[0011] Similarly, a marine vessel maneuvering operation for maintaining the marine vessel at a fixed position requires a higher level of marine vessel maneuvering skill. Therefore, it is difficult for the beginners to maintain the marine vessel at a fixed position when experiencing disturbances.

[0012] Thus, a so-called stationary marine vessel maneuvering operation including the maneuvering operation for maintaining the marine vessel at a fixed position and the maneuvering operation for moving the marine vessel toward or away from a wharf requires a higher level of marine vessel maneuvering skill.

SUMMARY OF THE INVENTION

[0013] To overcome the problems described above, preferred embodiments of the present invention provide marine vessel maneuvering supporting apparatuses and marine vessels which facilitate the stationary marine vessel maneuvering operation.

[0014] Other preferred embodiments of the present invention provide a marine vessel maneuvering supporting method which facilitates the stationary marine vessel maneuvering operation.

[0015] A marine vessel maneuvering supporting apparatus according to one preferred embodiment of the present invention performs a stationary marine vessel maneuvering support operation to support maneuvering of a marine vessel in a stationary state, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of a hull of the marine vessel, and a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull. The apparatus includes a position detecting section which detects a position of the marine vessel, a marine vessel maneuvering support starting command section which outputs a stationary marine vessel maneuvering support starting command for starting the stationary marine vessel maneuvering support operation, a marine vessel maneuvering support starting position storing section which stores a marine vessel maneuvering support starting position that is defined by a marine vessel position detected by the position detecting section in response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering sup-

port starting command section, a steering controlling section which controls the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero in response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering support starting command section, a target propulsive force calculating section which calculates target propulsive forces to be generated from the respective propulsion systems, based on a current marine vessel position detected by the position detecting section, such that at least one of x- and y-coordinates of the current marine vessel position defined with respect to an x-axis defined along a center line of the hull extending through a stem and a stern of the hull and a y-axis extending substantially perpendicularly relative to the center line is maintained substantially equal to a corresponding one of x- and y-coordinates of the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section in response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering support starting command section, and a propulsive force controlling section which controls the propulsion systems to attain the target propulsive forces calculated by the target propulsive force calculating section.

[0016] With this arrangement, the turning angular speed is maintained at zero to prevent the stem of the marine vessel from turning. At the same time, the propulsive forces to be generated from the respective propulsion systems are controlled such that at least one of the x- and y-coordinates of the current marine vessel position is maintained substantially equal to the corresponding one of the x- and y-coordinates of the marine vessel maneuvering support starting position. If the y-coordinate of the current marine vessel position is maintained, the marine vessel is moved in forward and reverse directions against disturbances without the turning of the stem thereof. If the x-coordinate of the current marine vessel position is maintained, the marine vessel is moved leftward and rightward against disturbances without the turning of the stem thereof. If the x- and y-coordinates of the current marine vessel position are maintained, the marine vessel is maintained at a fixed position on water. Thus, the marine vessel is moved forward and reverse or leftward and rightward, or maintained at the fixed position without the turning of the stem thereof. This facilitates the stationary marine vessel maneuvering support operation to bring the marine vessel into or out of contact with an object (e.g., a pier, a wharf or another marine vessel) or to maintain the marine vessel at a fixed position without skill.

[0017] For example, even an unskilled operator can easily perform a marine vessel maneuvering operation to bring the marine vessel into or out of contact with the object. Further, when the operator wants to move the marine vessel by a very small distance for changing a fishing point (for so-called trolling) or to maintain the marine vessel at a fixed position against a tidal current or a wind during fishing, the orientation of the hull can be easily and reliably maintained. Thus, the maneuvering of the marine vessel is greatly facilitated.

[0018] If an instantaneous center (instantaneous rotation center) of the hull is considered to be fixed, the steering angles of the respective steering mechanisms may be set at constant values according to a target angular speed. More specifically, the steering angles of the respective steering

mechanisms may be determined such that action lines along which the propulsive forces are generated by the respective propulsion systems intersect each other at the instantaneous center. In this case, the steering angles are determined based on geometrical information related to the hull and the propulsion systems. The geometrical information includes, for example, positions of the respective propulsion systems relative to the instantaneous center. In this case, the relative positions may be defined by the positions of the respective propulsion systems with respect to the center line of the hull extending through the stem and the stern of the hull (distances between the center line and propulsive force generating positions at which the propulsive forces are generated) and a distance from the instantaneous center to a midpoint between the propulsive force generating positions of the respective propulsion systems.

[0019] The instantaneous center is located, for example, on the center line of the hull. For example, the respective propulsion systems generate the propulsive forces at positions that are symmetrical with respect to the center line. In this case, the steering angles of the respective steering mechanisms may be determined so as to be symmetrical with respect to the center line.

[0020] The marine vessel may be a relatively small-scale marine vessel such as a cruiser, a fishing boat, a water jet or a watercraft.

[0021] The propulsion systems may be in the form of an outboard motor, an inboard/outboard motor (a stern drive), an inboard motor, or a water jet drive. The outboard motor includes a propulsion unit provided outboard and having a motor and a propulsive force generating member (propeller) and a steering mechanism which horizontally turns the entire propulsion unit with respect to the hull. The inboard/outboard motor includes a motor provided inboard, and a drive unit provided outboard and having a propulsive force generating member and a steering mechanism. The inboard motor includes a motor and a drive unit provided inboard, and a propeller shaft extending outward from the drive unit. In this case, a steering mechanism is separately provided. The water jet drive is such that water sucked from the bottom of the marine vessel is accelerated by a pump and ejected from an ejection nozzle provided at the stern of the marine vessel to provide a propulsive force. In this case, the steering mechanism includes the ejection nozzle and a mechanism for turning the ejection nozzle in a horizontal plane.

[0022] If both of the propulsion systems includes a motor (particularly an engine), the propulsive force controlling section preferably controls throttle opening degrees of the engines of the respective propulsion systems according to the target propulsive forces. More specifically, the propulsive force controlling section preferably includes a target engine speed calculating section which calculates target engine speeds according to the target propulsive forces, and a throttle opening degree controlling section which controls the throttle opening degrees so as to attain the calculated target engine speeds.

[0023] The motor may be an engine (internal combustion engine), an electric motor or other suitable types of motors.

[0024] The target propulsive force calculating section preferably includes a target control value calculating section

which calculates a target movement angle of the marine vessel with respect to a stem direction of the hull and a target combined propulsive force to be applied to the hull by the propulsion systems, based on a deviation of the current marine vessel position detected by the position detecting section from the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section, and an individual target propulsive force calculating section which calculates the target propulsive forces to be generated from the respective propulsion systems, based on the target movement angle and the target combined propulsive force calculated by the target control value calculating section.

[0025] With this arrangement, the target movement angle and the target combined propulsive force are calculated according to the deviation of the current marine vessel position and the marine vessel maneuvering support starting position, and attained by controlling the propulsive forces of the respective propulsion systems. Thus, the stationary marine vessel maneuvering support operation is performed.

[0026] The marine vessel maneuvering supporting apparatus preferably further includes a target movement direction inputting section which inputs one of a +x direction and a -x direction defined along the x-axis and a +y direction and a -y direction defined along the y-axis as the target movement direction of the marine vessel. In this case, the target propulsive force calculating section preferably calculates the target propulsive forces to be generated from the respective propulsion systems such that the y-coordinate of the current marine vessel position is maintained substantially equal to the y-coordinate of the marine vessel maneuvering support starting position if the target movement direction input by the target movement direction inputting section is the +x direction or the -x direction, and the x-coordinate of the current marine vessel position is maintained substantially equal to the x-coordinate of the marine vessel maneuvering support starting position if the target movement direction input by the target movement direction inputting section is the +y direction or the -y direction.

[0027] Thus, the marine vessel is moved forward and reverse along the x-axis or leftward and rightward along the y-axis depending upon the input by the target movement direction inputting section. Since the movement direction is limited to the aforementioned four directions, the marine vessel maneuvering operation is facilitated.

[0028] The target propulsive force calculating section preferably calculates the target propulsive forces to be generated from the respective propulsion systems such that the x- and y-coordinates of the current marine vessel position are maintained substantially equal to the x- and y-coordinates of the marine vessel maneuvering support starting position if nothing is input by the target movement direction inputting section. Thus, the marine vessel is maintained at a fixed position on water despite the occurrence and application of disturbances to the marine vessel.

[0029] The marine vessel maneuvering supporting apparatus preferably further includes a proximity state detecting section which detects a proximity state of the marine vessel. In this case, the target propulsive force calculating section preferably includes a proximity state maintaining target propulsive force calculating section which calculates the target propulsive forces to be generated from the respective

propulsion systems such that the marine vessel is maintained in the proximity state when the proximity state detecting section detects the proximity state.

[0030] The proximity state herein means that the marine vessel is located in contact with an object (e.g., a pier, a wharf, another marine vessel or the like) or in close proximity to the object.

[0031] With this arrangement, the target propulsive forces are determined so as to maintain the marine vessel in the proximity state. Therefore, a moorage marine vessel maneuvering operation is facilitated. That is, when the marine vessel is moored to the object such as pier, wharf and the like, the marine vessel is maintained in the proximity state. Therefore, crew members can safely move between the marine vessel and the object, and safely transfer cargoes between the marine vessel and the object. Since the marine vessel is maintained in the proximity state, the marine vessel is prevented from moving away from the object. Therefore, a crew member can safely move onto the object from the marine vessel and easily moor the marine vessel with a rope.

[0032] Similarly, when the marine vessel is to be moved away from the object, a crew member can safely step onto the marine vessel after unmooring the marine vessel from the object with the marine vessel maintained in the proximity state.

[0033] A marine vessel maneuvering supporting apparatus according to another preferred embodiment of the present invention performs a moorage marine vessel maneuvering support operation to support maneuvering of a marine vessel for moorage of the marine vessel, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of a hull of the marine vessel, and a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull. The apparatus includes a proximity state detecting section which detects a proximity state of the marine vessel, and a proximity state maintaining controlling section which controls the steering mechanisms and the propulsion systems so as to maintain the marine vessel in the proximity state when the proximity state detecting section detects the proximity state.

[0034] With this arrangement, the marine vessel can easily be moored to an object (e.g., a pier, a wharf or another marine vessel) because the marine vessel is maintained in the proximity state. In this state, crewmembers can safely move between the marine vessel and the object, and safely transfer cargoes between the marine vessel and the object. With the marine vessel maintained in the proximity state, a mooring operation can safely be performed to moor the marine vessel to the object with a rope. Similarly, a crew member can safely step onto the marine vessel after unmooring the marine vessel with the marine vessel maintained in the proximity state.

[0035] The proximity state maintaining controlling section preferably includes a steering controlling section which controls the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero, a target propulsive force calculating section which calculates target propulsive forces to be generated

from the respective propulsion systems such that the marine vessel is maintained in the proximity state detected by the proximity state detecting section, and a propulsive force controlling section which controls the propulsion systems so as to attain the target propulsive forces calculated by the target propulsive force calculating section. With this arrangement, the marine vessel can be maintained in the proximity state without turning a stem thereof. Therefore, the crew members can more safely move between the marine vessel and the object.

[0036] The marine vessel maneuvering supporting apparatus preferably further includes an angular speed detecting section which detects the turning angular speed of the marine vessel. In this case, the steering controlling section preferably includes a target steering angle calculating section which calculates target steering angles of the respective steering mechanisms such that the turning angular speed detected by the angular speed detecting section is set at zero.

[0037] With this arrangement, the marine vessel can be moved in a desired direction with the target angular speed being kept unchanged, even if an instantaneous center of the hull is changed. Therefore, the marine vessel can easily be moved forward and reverse or leftward and rightward in spite of disturbances attributable to variations in loads on the hull and winds and waves.

[0038] The target propulsive force calculating section preferably calculates the target propulsive forces by using the target steering angles calculated by the target steering angle calculating section as the steering angles of the respective steering mechanisms. Further, a steering angle detecting section which detects at least one of the steering angles of the steering mechanisms is preferably provided. That is, the target propulsive force calculating section calculates the target propulsive forces based on the steering angle detected by the steering angle detecting section.

[0039] The target steering angle calculating section preferably calculates the target steering angles of the respective steering mechanisms such that action lines along which the propulsive forces are generated by the respective propulsion systems intersect each other on a center line of the hull extending through a stem and a stern of the hull. With this arrangement, the steering angles of the port-side and starboard-side steering mechanisms are symmetrically set with respect to the center line. Therefore, the steering angles are easily controlled.

[0040] Preferably, the target steering angle calculating section calculates one of the target steering angles of the steering mechanisms by adding a constant ϕ_c to a steering angle correction value ψ ($\psi > 0$) and calculates the other target steering angle by subtracting the constant ϕ_c from the steering angle correction value ψ when an action point defined by an intersection of the action lines is located outside the center line.

[0041] With this arrangement, the target steering angles of the respective steering mechanisms are determined by determining the steering angle correction value ψ , whereby the computation for the control is simplified. When the steering angle correction value ψ is $\psi = 0$, the action point is located on the center line of the hull.

[0042] If the action point is spaced away from the propulsion systems on a stem side, increased propulsive forces

should be generated from the respective propulsion systems to laterally move the hull. However, each of the propulsion systems is limited in their capability to generate the propulsive force. If it is difficult to generate the propulsive forces in desired directions even with the action point being located in a predetermined range on the center line, the generation of the desired propulsive forces is facilitated by locating the action point outside the center line by setting the steering angle correction value to a value other than zero.

[0043] A marine vessel according to a preferred embodiment of the present invention includes a hull, a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of the hull, a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull, and a marine vessel maneuvering supporting apparatus having the aforementioned features.

[0044] With this marine vessel, the stationary marine vessel maneuvering operation and the moorage marine vessel maneuvering operation can easily be performed without requiring operator skill.

[0045] A marine vessel maneuvering supporting method according to a preferred embodiment of the present invention is a method for performing a stationary marine vessel maneuvering support operation to support maneuvering of a marine vessel in a stationary state, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of a hull of the marine vessel, and a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull. The method includes the steps of storing a marine vessel maneuvering support starting position at which the stationary marine vessel maneuvering support operation is started in a marine vessel maneuvering support starting position storing section, controlling the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero, calculating target propulsive forces to be generated from the respective propulsion systems such that at least one of x- and y-coordinates of a current position of the marine vessel defined with respect to an x-axis defined along a center line extending through a stem and a stern of the hull and a y-axis extending substantially perpendicularly relative to the center line is maintained substantially equal to corresponding one of x- and y-coordinates of the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section, and controlling the propulsion systems so as to attain the calculated target propulsive forces.

[0046] In this method, the marine vessel can be moved forward and reverse or leftward and rightward or maintained at a fixed position while experiencing disturbances, and without turning the stem thereof. Thus, the stationary marine vessel maneuvering operation can be facilitated.

[0047] The target propulsive force calculating step includes the steps of calculating a target movement angle of the marine vessel with respect to a stem direction of the hull and a target combined propulsive force to be applied to the hull by the propulsion systems, based on a deviation of the

current marine vessel position from the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section, and calculating the target propulsive forces to be generated from the respective propulsion systems, based on the calculated target movement angle and the calculated target combined propulsive force.

[0048] Where the marine vessel includes a target movement direction inputting section which inputs one of a +x direction and a -x direction defined along the x-axis and a +y direction and a -y direction defined along the y-axis as the target movement direction of the marine vessel, the target propulsive force calculating step preferably includes the step of calculating the target propulsive forces to be generated from the respective propulsion systems such that the y-coordinate of the current marine vessel position is maintained substantially equal to the y-coordinate of the marine vessel maneuvering support starting position if the target movement direction input by the target movement direction inputting section is the +x direction or the -x direction, and the x-coordinate of the current marine vessel position is maintained substantially equal to the x-coordinate of the marine vessel maneuvering support starting position if the target movement direction input by the target movement direction inputting section is the +y direction or the -y direction. Thus, the marine vessel can easily be moved forward and reverse or leftward and rightward.

[0049] The target propulsive force calculating step preferably includes the step of calculating the target propulsive forces to be generated from the respective propulsion systems such that the x- and y-coordinates of the current marine vessel position are maintained substantially equal to the x- and y-coordinates of the marine vessel maneuvering support starting position if nothing is input by the target movement direction inputting section. Thus, the marine vessel is maintained at a fixed position on water.

[0050] The method preferably further includes the step of detecting a proximity state of the marine vessel. In this case, the target propulsive force calculating step preferably includes the step of calculating the target propulsive forces to be generated from the respective propulsion systems such that the marine vessel is maintained in the proximity state when the proximity state is detected. Thus, the marine vessel is maintained in the proximity state for moorage thereof by controlling the propulsion systems.

[0051] A marine vessel maneuvering supporting method according to another preferred embodiment of the present invention is a method for performing a moorage marine vessel maneuvering support operation to support maneuvering of a marine vessel for moorage of the marine vessel, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard-side of a hull of the marine vessel, and a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull. The method includes the steps of detecting a proximity state of the marine vessel, and controlling the steering mechanisms and the propulsion systems so as to maintain the marine vessel in the proximity state when the proximity state is detected. In this method, the marine vessel is maintained in the proximity state for moorage thereof by controlling the propulsion systems.

[0052] The proximity state maintaining step includes the steps of controlling the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero, calculating target propulsive forces to be generated from the respective propulsion systems such that the marine vessel is maintained in the detected proximity state, and controlling the propulsion systems so as to attain the calculated target propulsive forces. Thus, the marine vessel can be maintained in the proximity state for moorage thereof without turning a stem thereof.

[0053] The foregoing and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0054] FIG. 1 is a schematic diagram illustrating a marine vessel according to one preferred embodiment of the present invention;

[0055] FIG. 2 is a schematic diagram showing marine vessel movement directions in which the marine vessel is moved in a stationary marine vessel maneuvering support mode;

[0056] FIG. 3A is a schematic diagram illustrating an exemplary operation to be performed in a moorage support mode;

[0057] FIG. 3B is a schematic diagram illustrating another exemplary operation to be performed in the moorage support mode;

[0058] FIG. 3C is a schematic diagram illustrating further another exemplary operation to be performed in the moorage support mode;

[0059] FIG. 3D is a schematic diagram illustrating still another exemplary operation to be performed in the moorage support mode;

[0060] FIG. 4 is a schematic sectional view illustrating an outboard motor;

[0061] FIG. 5 is a block diagram illustrating a marine vessel maneuvering supporting apparatus for controlling running of the marine vessel;

[0062] FIG. 6 is a diagram illustrating an operation for moving the marine vessel such that the orientation of a stem of the marine vessel kept remains unchanged;

[0063] FIG. 7 is a diagram illustrating an operation for horizontally moving the marine vessel substantially perpendicularly relative to a center line of the marine vessel;

[0064] FIG. 8 is a schematic diagram for explaining a steering controlling operation;

[0065] FIG. 9 is a schematic diagram for explaining the principle of operation for locating an action point outside the center line;

[0066] FIG. 10 is a block diagram illustrating the functions of a stationary marine vessel maneuvering support controlling section;

[0067] FIG. 11 is a flowchart of an operation to be performed by the stationary marine vessel maneuvering support controlling section in the stationary marine vessel maneuvering support mode;

[0068] FIG. 12 is a flowchart of an operation to be performed by the stationary marine vessel maneuvering support controlling section in the moorage support mode;

[0069] FIG. 13 is a block diagram illustrating the functions of a throttle controlling section and a shift controlling section, particularly, for explaining control operations to be performed by the throttle controlling section and the shift controlling section in the stationary marine vessel maneuvering support mode and the moorage support mode;

[0070] FIG. 14 is a timing chart of PWM operations to be performed by a port-side shift control module and a starboard-side shift control module;

[0071] FIG. 15 is a block diagram illustrating the functions of a steering controlling section, particularly, for explaining a control operation to be performed by the steering controlling section in the stationary marine vessel maneuvering support mode and the moorage support mode;

[0072] FIG. 16 is a flow chart for explaining a throttle controlling operation;

[0073] FIG. 17 is a flow chart for explaining an operation for controlling a shift mechanism of a port-side outboard motor;

[0074] FIG. 18 is a flow chart for explaining the control operation to be performed by the steering controlling section in the stationary marine vessel maneuvering support mode and the moorage support mode;

[0075] FIG. 19 is a flow chart for explaining an outboard motor stop detecting operation; and

[0076] FIG. 20 is a block diagram illustrating a second preferred embodiment of the present invention, particularly illustrating an engine speed calculating module that is preferably used in place of a target engine speed calculating module shown in FIG. 13.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0077] FIG. 1 is a schematic diagram illustrating a marine vessel 1 according to one preferred embodiment of the present invention. The marine vessel 1 is preferably a relatively small-scale marine vessel, such as a cruiser or a boat, and includes a pair of outboard motors 11, 12 attached to a stern (transom) 3 of a hull 2. The outboard motors 11, 12 are positioned laterally symmetrically with respect to a center line 5 of the hull 2 extending through the stern 3 and a stem 4 of the hull 2. That is, the outboard motor 11 is attached to a rear port-side portion of the hull 2, while the outboard motor 12 is attached to a rear starboard-side portion of the hull 2. The outboard motor 11 and the outboard motor 12 will hereinafter be referred to as "port-side outboard motor 11" and "starboard-side outboard motor 12", respectively, to differentiate therebetween. Electronic control units 13 and 14 (hereinafter referred to as "outboard motor ECU 13" and "outboard motor ECU 14", respectively) are incorporated in the port-side outboard motor 11 and the starboard-side outboard motor 12, respectively.

[0078] The marine vessel 1 includes a control console 6 provided on a deck thereof for controlling the marine vessel 1. The control console 6 includes, for example, a steering operational section 7 for performing a steering operation, and a throttle operational section 8 for controlling the outputs of the outboard motors 11, 12. The control console 6 further includes a stationary marine vessel maneuvering support starting button 15 for starting a stationary marine vessel maneuvering support controlling operation to support maneuvering of the marine vessel 1 in a stationary state (stationary marine vessel maneuvering operation), a cross button 16 (movement direction inputting section) for moving the marine vessel 1 at a very low speed in any of four directions (forward, reverse, rightward and leftward directions), and a moorage support starting button 17 for starting a moorage support controlling operation to support moorage of the marine vessel 1 in a proximity state.

[0079] The stationary marine vessel maneuvering operation herein includes a marine vessel approach maneuvering operation for moving the marine vessel 1 toward an object (e.g., a pier, a wharf or another marine vessel), a marine vessel departure maneuvering operation for moving the marine vessel 1 away from the object, and a fixed position marine vessel maintaining operation for maintaining the marine vessel 1 at a fixed position on water.

[0080] The steering operational section 7 includes a steering wheel 7a (operational member). The throttle operational section 8 includes throttle levers 8a, 8b for the port-side outboard motor 11 and the starboard-side outboard motor 12. The cross button 16 includes a forward movement button 16A for forward movement of the marine vessel 1, a reverse movement button 16B for reverse movement of the marine vessel 1, a leftward movement button 16C for leftward movement of the marine vessel 1, and a rightward movement button 16D for rightward movement of the marine vessel 1.

[0081] The operational signals of the operational sections 7, 8 provided on the control console 6 are input as electric signals to a marine vessel running controlling apparatus 20, for example, via a LAN (local area network, hereinafter referred to as an "inboard LAN") provided in the hull 2. Similarly, the output signals of the stationary marine vessel maneuvering support starting button 15, the cross button 16 and the moorage support starting button 17 are input to the marine vessel running controlling apparatus 20 via the inboard LAN. The marine vessel running controlling apparatus 20 includes an electronic control unit (ECU) including a microcomputer, and functions as a propulsive force controlling apparatus for propulsive force control and as a steering controlling apparatus for steering control. A yaw rate sensor 9 (angular speed detecting section) for detecting the angular speed (yaw rate or stem turning speed) of the hull 2 outputs an angular speed signal, which is also input to the marine vessel running controlling apparatus 20 via the inboard LAN. Further, a GPS (Global Positioning System) 10 (position detecting section) for detecting the position of the marine vessel 1 outputs a position signal, which is also input to the marine vessel running controlling apparatus 20 via the inboard LAN.

[0082] A plurality of proximity sensors 18 which detect the proximity state are provided on peripheral portions of the hull 2 to be brought into contact with the object (the pier, the

wharf or another marine vessel). Each of the proximity sensors **18** may be a contact sensor such as a limit switch or a pressure sensor which detects contact with the object, or a distance sensor such as an ultrasonic sensor which detects a distance from the object. The output signals of the respective proximity sensors **18** are also input to the marine vessel running controlling apparatus **20** via the inboard LAN.

[0083] The marine vessel running controlling apparatus **20** communicates with the outboard motor ECUs **13**, **14** via the inboard LAN. More specifically, the marine vessel running controlling apparatus **20** acquires engine speeds (rotational speeds of motors) NL, NR of the outboard motors **11**, **12** and steering angles ϕ_L , ϕ_R of the outboard motors **11**, **12** indicating the orientations of the outboard motors **11**, **12** from the outboard motor ECUs **13**, **14**. The marine vessel running controlling apparatus **20** applies data including target steering angles ϕ_{L_t} , ϕ_{R_t} (wherein a suffix “t” hereinafter means “target”), target throttle opening degrees, target shift positions (forward drive, neutral and reverse drive positions) and target trim angles to the outboard motor ECUs **13**, **14**.

[0084] In this preferred embodiment, the marine vessel running controlling apparatus **20** has a control mode to be switched between various modes including an ordinary running mode in which the outboard motors **11**, **12** are controlled according to the operations of the steering operational section **7** and the throttle operational section **8**, a stationary marine vessel maneuvering support mode in which the outboard motors **11**, **12** are controlled according to the operation of the cross button **16**, and a moorage support mode in which the marine vessel is moored. The marine vessel running controlling apparatus **20** is preferably usually in the ordinary running mode.

[0085] In the ordinary running mode, the marine vessel running controlling apparatus **20** controls the outboard motors **11**, **12** according to the operation of the steering wheel **7a** such that the steering angles ϕ_L , ϕ_R are substantially equal to each other. That is, the outboard motors **11**, **12** generate propulsive forces that are parallel with each other. In the ordinary running mode, the marine vessel running controlling apparatus **20** determines the target throttle opening degrees and the target shift positions of the outboard motors **11**, **12** according to the operation positions and directions of the throttle levers **8a**, **8b**. The throttle levers **8a**, **8b** are each inclinable in forward and reverse directions. When an operator inclines the throttle lever **8a** forward from a neutral position by a certain amount, the marine vessel running controlling apparatus **20** sets the target shift position of the port-side outboard motor **11** at the forward drive position. When the operator inclines the throttle lever **8a** further forward, the marine vessel running controlling apparatus **20** sets the target throttle opening degree of the port-side outboard motor **11** according to the position of the throttle lever **8a**. On the other hand, when the operator inclines the throttle lever **8a** in the reverse direction by a certain amount, the marine vessel running controlling apparatus **20** sets the target shift position of the port-side outboard motor **11** at the reverse drive position. When the operator inclines the throttle lever **8a** further in the reverse direction, the marine vessel running controlling apparatus **20** sets the target throttle opening degree of the port-side outboard motor **11** according to the position of the throttle lever **8a**. Similarly, the marine vessel running controlling

apparatus **20** sets the target shift position and the target throttle opening degree of the starboard-side outboard motor **12** according to the operation of the throttle lever **8b**.

[0086] Upper portions of the throttle levers **8a**, **8b** are bent toward each other to constitute generally horizontal holders. With this arrangement, the operator can simultaneously operate the throttle levers **8a**, **8b** to control the outputs of the outboard motors **11**, **12** with the throttle opening degrees of the port-side and starboard-side outboard motors **11**, **12** being maintained substantially the same.

[0087] When the operator operates the stationary marine vessel maneuvering support starting button **15**, the control mode of the marine vessel running controlling apparatus **20** is switched to the stationary marine vessel maneuvering support mode. In the stationary marine vessel maneuvering support mode, the marine vessel running controlling apparatus **20** sets the target steering angles ϕ_{L_t} , ϕ_{R_t} , the target shift positions and the target throttle opening degrees of the port-side and starboard-side outboard motors **11**, **12** according to the operation of the cross button **16**.

[0088] In the stationary marine vessel maneuvering support mode, as shown in FIG. 2, the movement directions of the marine vessel **1** are limited to four directions including a forward direction (+x direction), a reverse direction (−x direction), a leftward direction (+y direction) and a rightward direction (−y direction). That is, the marine vessel **1** is controlled with the orientation of the stem thereof being kept unchanged. In this state, the marine vessel **1** is moved forward when the forward movement button **16A** is operated, and moved in the reverse direction when the reverse movement button **16B** is operated. Further, the marine vessel **1** is moved leftward when the leftward movement button **16C** is operated, and moved rightward when the rightward movement button **16D** is operated. In any of these cases, the movement direction of the marine vessel **1** on water is kept unchanged despite disturbances such as winds and waves. When none of the buttons **16A** to **16D** is operated, a fixed position maintaining control operation is preferably performed to maintain the marine vessel **1** at a fixed position despite the disturbances.

[0089] On the other hand, when the operator operates the moorage support starting button **17**, the control mode of the marine vessel running controlling apparatus **20** is switched to the moorage support mode. In the moorage support mode, the marine vessel running controlling apparatus **20** sets the target steering angles ϕ_{L_t} , ϕ_{R_t} , the target shift positions and the target throttle opening degrees of the port-side and starboard-side outboard motors **11**, **12** so as to maintain the proximity state detected by the proximity sensors **18**.

[0090] FIGS. 3A to 3D are diagrams illustrating exemplary operations to be performed in the moorage support mode.

[0091] FIG. 3A illustrates a case where the marine vessel **1** is moored to a pier **150** (object) with its port side **1L** opposed to the pier **150**. In this case, two proximity sensors **18** (indicated by black circles) provided on the port side **1L** of the marine vessel **1L** detect the proximity state. The outboard motors **11**, **12** generate propulsive forces for moving the marine vessel **1** leftward toward the pier **150** such that the proximity sensors **18** continuously detect the proximity state. Thus, the marine vessel **1** is pressed toward the

pier 150 with the port side 1L thereof in contact with the pier 150. Since the marine vessel 1 is prevented from moving away from the pier 150, the operator and other crew members of the marine vessel 1 can safely step off the marine vessel 1 onto the pier 150. Further, the marine vessel 1 can easily be moored to the pier 150 with a rope.

[0092] FIG. 3B illustrates a case where the marine vessel 1 is moored to the pier 150 with the stem 4 thereof opposed to the pier 150. In this case, a proximity sensor 18 (indicated by a black circle) provided at the stem 4 detects the proximity state. The outboard motors 11, 12 generate propulsive forces for moving the marine vessel 1 forward toward the pier 150 such that the proximity sensor 18 continuously detects the proximity state. Thus, the stem 4 of the marine vessel 1 is moved toward and into contact with the pier 150. Therefore, the operator and other crew members of the marine vessel 1 can safely step off the marine vessel 1 onto the pier 150, and the marine vessel 1 can easily be moored to the pier 150 with a rope.

[0093] Where the object to be approached by the marine vessel 1 is a larger-scale marine vessel such as a tugboat, for example, the marine vessel 1 can be moved toward and into contact with the larger-scale marine vessel in the aforementioned manner. Thus, crew members can safely move between the marine vessel 1 and the larger-scale marine vessel, and easily transfer cargoes between the marine vessel 1 and the larger-scale marine vessel.

[0094] In any case, the marine vessel 1 is continuously pressed toward the object when the control is continued in the moorage support mode. Therefore, the rope is not necessarily required for the moorage.

[0095] FIGS. 3C and 3D illustrate cases where the marine vessel 1 is moored to another marine vessel 1A having substantially the same size as the marine vessel 1. Where the marine vessels 1, 1A have substantially the same construction, the marine vessels 1, 1A are preferably both controlled in the moorage support mode. Thus, the marine vessels 1, 1A are moved toward and into contact with each other. In FIG. 3C, the outboard motors 11, 12 generate propulsive forces for moving the marine vessels 1, 1A toward each other such that the starboard side of the marine vessel 1 and the port side of the marine vessel 1A move into contact with each other in the vicinity of their stems. In FIG. 3D, the outboard motors 11, 12 generate propulsive forces for moving the marine vessels 1, 1A toward each other in substantially parallel relation with the starboard side of the marine vessel 1 and the port side of the marine vessel 1A so as to move into contact with each other.

[0096] With the marine vessels 1, 1A moored to each other, crew members can move between the marine vessels 1 and 1A, and transfer cargoes between the marine vessels 1 and 1A. The marine vessels 1, 1A can be moored to each other in either of the moorage states shown in FIGS. 3C and 3D depending upon the constructions of the marine vessels 1, 1A and the positions of the cargoes.

[0097] In either case of FIGS. 3C and 3D, the marine vessels 1, 1A can be moored to each other by continuing the control in the moorage support mode. Further, the marine vessels 1, 1A can be moored with a rope while the marine vessels 1, 1A are pressed toward each other with the control thereof in the moorage support mode. After the moorage

with the rope, the control of the outboard motors 11, 12 in the moorage support mode may be terminated.

[0098] It is preferred to control the outboard motors 11, 12 in the moorage support mode when the marine vessel 1 is unmoored. Thus, the marine vessel 1 can be unmoored while being assuredly maintained in the proximity state by the propulsive forces generated from the outboard motors 11, 12. Therefore, a crew member can safely step onto the marine vessel 1 after unmooring the marine vessel 1.

[0099] FIG. 4 is a schematic sectional view illustrating the common construction of the outboard motors 11, 12. The outboard motors 11, 12 each include a propulsion unit 30, and an attachment mechanism 31 for attaching the propulsion unit 30 to the hull 2. The attachment mechanism 31 includes a clamp bracket 32 detachably fixed to the transom of the hull 2, and a swivel bracket 34 connected to the clamp bracket 32 pivotally about a tilt shaft 33 (horizontal pivot axis). The propulsion unit 30 is attached to the swivel bracket 34 pivotally about a steering shaft 35. Thus, the steering angle (which is equivalent to an angle defined by the direction of the propulsive force with respect to the center line of the hull 2) is changed by pivoting the propulsion unit 30 about the steering shaft 35. Further, the trim angle of the propulsion unit 30 (which is equivalent to an angle defined by the direction of the propulsive force with respect to a horizontal plane) is changed by pivoting the swivel bracket 34 about the tilt shaft 33.

[0100] The propulsion unit 30 has a housing which includes a top cowling 36, an upper case 37 and a lower case 38. An engine 39 (drive source) is provided in the top cowling 36 with an axis of a crank shaft thereof extending vertically. A drive shaft 41 for transmitting power is coupled to a lower end of the crank shaft of the engine 39, and vertically extends through the upper case 37 into the lower case 38.

[0101] A propeller 40 defining a propulsive force generating member is rotatably attached to a lower rear portion of the lower case 38. A propeller shaft 42 (rotation shaft) of the propeller 40 extends horizontally in the lower case 38. The rotation of the drive shaft 41 is transmitted to the propeller shaft 42 via a shift mechanism 43 (clutch mechanism).

[0102] The shift mechanism 43 includes a beveled drive gear 43a fixed to a lower end of the drive shaft 41, a beveled forward drive gear 43b rotatably provided on the propeller shaft 42, a beveled reverse drive gear 43c rotatably provided on the propeller shaft 42, and a dog clutch 43d provided between the forward drive gear 43b and the reverse drive gear 43c.

[0103] The forward drive gear 43b is meshed with the drive gear 43a from a forward side, and the reverse drive gear 43c is meshed with the drive gear 43a from a reverse side. Therefore, the forward drive gear 43b and the reverse drive gear 43c rotate in opposite directions when engaged with the drive gear 43a.

[0104] On the other hand, the dog clutch 43d is in spline engagement with the propeller shaft 42. That is, the dog clutch 43d is axially slidable with respect to the propeller shaft 42, but is not rotatable relative to the propeller shaft 42. Therefore, the dog clutch 43d is rotatable together with the propeller shaft 42.

[0105] The dog clutch 43 is disslidable on the propeller shaft 42 by pivotal movement thereof about a shift rod 44 that extends vertically parallel to the drive shaft 41. Thus, the dog clutch 43d is shifted to a forward drive position at which it is engaged with the forward drive gear 43b, a reverse drive position at which it is engaged with the reverse drive gear 43c, or a neutral position at which it is not engaged with either the forward drive gear 43b or the reverse drive gear 43c.

[0106] When the dog clutch 43d is in the forward drive position, the rotation of the forward drive gear 43b is transmitted to the propeller shaft 42 via the dog clutch 43d with virtually no slippage between the dog clutch 43d and the propeller shaft 42. Thus, the propeller 40 is rotated in one direction (in a forward drive direction) to generate a propulsive force in a direction for moving the hull 2 forward. On the other hand, when the dog clutch 43d is in the reverse drive position, the rotation of the reverse drive gear 43c is transmitted to the propeller shaft 42 via the dog clutch 43d with virtually no slippage between the dog clutch 43d and the propeller shaft 42. The reverse drive gear 43c is rotated in a direction opposite to that of the forward drive gear 43b, as mentioned above. The propeller 40 is therefore rotated in an opposite direction (in a reverse drive direction). Thus, the propeller 40 generates a propulsive force in a direction for moving the hull 2 reverse. When the dog clutch 43d is at the neutral position, the rotation of the drive shaft 41 is not transmitted to the propeller shaft 42. That is, transmission of a driving force between the engine 39 and the propeller 40 is prevented, such that no propulsive force is generated in either of the forward and reverse directions.

[0107] A starter motor 45 for starting the engine 39 is connected to the engine 39. The starter motor 45 is controlled by the outboard motor ECU 13, 14. The propulsive unit 30 further includes a throttle actuator 51 for actuating a throttle valve 46 of the engine 39 in order to change the throttle opening degree to change the intake air amount of the engine 39. The throttle actuator 51 may be an electric motor. The operation of the throttle actuator 51 is controlled by the outboard motor ECU 13, 14. The engine 39 includes an engine speed detecting section 48 for detecting the rotation of the crank shaft to detect the engine speed NL, NR of the engine 39.

[0108] A shift actuator 52 (clutch actuator) for changing the shift position of the dog clutch 43d is provided in cooperation with the shift rod 44. The shift actuator 52 is, for example, an electric motor, and its operation is controlled by the outboard motor ECU 13, 14.

[0109] Further, a steering actuator 53 which includes, for example, a hydraulic cylinder and is controlled by the outboard motor ECU 13, 14 is connected to a steering rod 47 fixed to the propulsion unit 30. By driving the steering actuator 53, the propulsion unit 30 is pivoted about the steering shaft 35 for a steering operation. The steering actuator 53, the steering rod 47 and the steering shaft 35 define a steering mechanism 50. The steering mechanism 50 includes a steering angle sensor 49 for detecting the steering angle ϕ_L , ϕ_R .

[0110] A trim actuator (tilt trim actuator) 54 which includes, for example, a hydraulic cylinder and is controlled by the outboard motor ECU 13, 14 is provided between the clamp bracket 32 and the swivel bracket 34. The trim

actuator 54 pivots the propulsion unit 30 about the tilt shaft 33 by pivoting the swivel bracket 34 about the tilt shaft 33. Thus, the trim angle of the propulsion unit 30 can be adjusted.

[0111] FIG. 5 is a block diagram illustrating a marine vessel maneuvering supporting apparatus for controlling the running of the marine vessel 1. The marine vessel running controlling apparatus 20 includes a throttle controlling section 21 which issues command signals regarding the target throttle opening degrees for controlling the throttle actuators 51 of the port-side and starboard-side outboard motors 11, 12, a shift controlling section 22 (clutch controlling section) which issues command signals of the target shift positions for controlling the shift actuators 52 of the outboard motors 11, 12, a steering controlling section 23 which issues command signals of the target steering angles ϕ_L , ϕ_R for controlling the steering actuators 53 of the outboard motors 11, 12, and a trim angle controlling section 24 which issues command signals of the target trim angles for controlling the trim actuators 54 of the outboard motors 11, 12. The functions of each of these controlling sections 21 to 24 may be provided by a predetermined software-based process performed by the microcomputer provided in the marine vessel running controlling apparatus 20.

[0112] The command signals generated by the respective controlling sections 21 to 24 are applied to the outboard motor ECUs 13, 14 via an interface (I/F) 25. The outboard motor ECUs 13, 14 control the actuators 51 to 54 based on the applied command signals.

[0113] The outboard motor ECUs 13, 14 respectively apply the engine speeds NL, NR detected by the engine speed detecting sections 48 and the steering angles ϕ_L , ϕ_R detected by the steering angle sensors 49 to the marine vessel running controlling apparatus 20 via the interface 25. More specifically, the engine speeds NL, NR are applied to the throttle controlling section 21, and the steering angles ϕ_L , ϕ_R are applied to the steering controlling section 23. The steering angles ϕ_L , ϕ_R may also be applied to the throttle controlling section 21 from the steering controlling section 23. The target steering angles ϕ_{Lt} , ϕ_{Rt} may be applied instead of the steering angles ϕ_L , ϕ_R to the throttle controlling section 21 from the steering controlling section 23.

[0114] On the other hand, signals from the steering operational section 7, the throttle operational section 8, the yaw rate sensor 9, the GPS 10, the stationary marine vessel maneuvering support starting button 15, the cross button 16, the moorage support starting button 17 and the proximity sensors 18 are input to the marine vessel running controlling apparatus 20 via an interface (I/F) 26. More specifically, signals from the steering operational section 7 are input to the steering controlling section 23 for calculating the target steering angles ϕ_L , ϕ_R . Signals indicating the magnitudes of the target propulsive forces are input from the throttle operational section 8 to the throttle controlling section 21, and signals indicating the directions of the propulsive forces are input from the throttle operational section 8 to the shift controlling section 22. The angular speed ω detected by the yaw rate sensor 9 is input to the steering controlling section 23.

[0115] Output signals of the GPS 10, the stationary marine vessel maneuvering support starting button 15, the cross button 16, the moorage support starting button 17 and the

proximity sensors 18 are input to a stationary marine vessel maneuvering support controlling section 27.

[0116] When the operation of the stationary marine vessel maneuvering support starting button 15 is detected, the stationary marine vessel maneuvering support controlling section 27 switches the control mode of the marine vessel running controlling apparatus 20 to the stationary marine vessel maneuvering support mode. In the stationary marine vessel maneuvering support mode, a target combined propulsive force TG_t to be generated by the port-side and starboard-side outboard motors 11, 12 and a target movement angle θ_t of the marine vessel 1 are calculated according to the input from the GPS 10 and the cross button 16 by the stationary marine vessel maneuvering support controlling section 27, and applied to the throttle controlling section 21. At the same time, a target angular speed (target stem turning speed) ω_t of the marine vessel 1 is set at zero by the stationary marine vessel maneuvering support controlling section 27, and input to the steering controlling section 23 in the stationary marine vessel maneuvering support mode.

[0117] When the operation of the moorage support starting button 17 is detected, the stationary marine vessel maneuvering support controlling section 27 switches the control mode of the marine vessel running controlling apparatus 20 to the moorage support mode. In the moorage support mode, the target combined propulsive force TG_t to be generated by the port-side and starboard-side outboard motors 11, 12 and the target movement angle θ_t of the marine vessel 1 are calculated based on the output signals of the proximity sensors 18 to maintain the marine vessel 1 in the proximity state by the stationary marine vessel maneuvering support controlling section 27, and applied to the throttle controlling section 21. At the same time, the target angular speed (target stem turning speed) ω_t of the marine vessel 1 is set at zero by the stationary marine vessel maneuvering support controlling section 27, and input to the steering controlling section 23 in the moorage support mode.

[0118] When the operation of the steering wheel 7a or the operation of the throttle lever 8a or 8b is detected in the stationary marine vessel maneuvering support mode, the stationary marine vessel maneuvering support controlling section 27 switches the control mode of the marine vessel running controlling apparatus 20 to the ordinary running mode from the stationary marine vessel maneuvering support mode. When the operation of the moorage support starting button 17 is detected in the stationary marine vessel maneuvering support mode, the stationary marine vessel maneuvering support controlling section 27 switches the control mode of the marine vessel running controlling apparatus 20 to the moorage support mode from the stationary marine vessel maneuvering support mode.

[0119] When the operation of the steering wheel 7a or the operation of the throttle lever 8a or 8b is detected in the moorage support mode, the stationary marine vessel maneuvering support controlling section 27 switches the control mode of the marine vessel running controlling apparatus 20 to the ordinary running mode from the moorage support mode. When the operation of the stationary marine vessel maneuvering support starting button 15 is detected in the moorage support mode, the stationary marine vessel maneuvering support controlling section 27 switches the control mode of the marine vessel running controlling apparatus 20

to the stationary marine vessel maneuvering support mode from the moorage support mode.

[0120] An intermittent shift command signal is also applied to the shift controlling section 22 from the throttle controlling section 21. Based on the intermittent shift command signal, the shift controlling section 22 performs an intermittent shift operation to shift the dog clutches 43/ alternately between the neutral position and the forward drive position or between the neutral position and the reverse drive position when the engine speeds for the target propulsive forces are lower than an idle speed of the engines 39 (a lower limit engine speed, for example, about 700 rpm). The intermittent shift operation makes it possible to generate propulsive forces for engine speeds lower than the idle speed. The intermittent shift operation will be described in detail below.

[0121] FIG. 6 is a diagram for explaining an operation for moving the marine vessel 1 with the orientation of the stem 4 of the marine vessel 1 being kept unchanged (i.e., with an angular speed ω of 0). A point at which the center line 5 of the hull 2 intersects the stern 3 is defined as an origin O. An axis extending along the center line 5 toward the stem 4 is defined as an x-axis, and an axis extending along the stern 3 (transom) toward the port side is defined as a y-axis. The origin O is a midpoint between propulsive force generating points at which the propulsive forces are generated by the respective propulsion units 30 provided in the outboard motors 11, 12.

[0122] In the stationary marine vessel maneuvering support mode and the moorage support mode, the steering controlling section 23 sets the target steering angles ϕL_t , ϕR_t of the port-side and starboard-side outboard motors 11, 12 such that action lines (indicated by broken lines) extending along vectors TL, TR of the propulsive forces generated by the respective outboard motors 11, 12 intersect each other in a predetermined range on the x-axis and the target angular speed ω_t ($=0$) is attained. At this time, the trim angle controlling section 24 controls the port-side and starboard-side outboard motors 11, 12 such that the trim angles of the respective outboard motors 11, 12 are substantially equal to each other so that horizontal components of the propulsive forces generated by the propulsion units 30 of the respective outboard motors 11, 12 are substantially equal to each other.

[0123] It is assumed that the intersection of the action lines of the propulsive force vectors TL, TR is defined as an action point $F=(a,0)$ (wherein $a>0$), and the port-side and starboard-side outboard motors 11, 12 respectively generate the propulsive forces at positions $(0,b)$, $(0,-b)$ (wherein b is a constant value $b>0$) that are symmetrical with respect to the center line 5. If the steering angle ϕR of the starboard-side outboard motor 12 is $\phi R=\phi$, the steering angle ϕL of the port-side outboard motor 11 is expressed by $\phi L=-\phi$. Here, the angle ϕ is expressed by $\phi=\tan^{-1}(b/a)$.

[0124] A combined vector obtained by combining the propulsive force vectors TL, TR at the action point F is herein expressed by TG. The direction of the combined vector TG (which forms a movement angle θ with the x-axis) indicates the direction of the combined propulsive force (the movement direction of the hull 2), and the magnitude of the combined vector TG indicates the magnitude of the combined propulsive force. Therefore, it is necessary to direct the combined vector TG at the target

movement angle θ_t applied from the stationary marine vessel maneuvering support controlling section 27 and to equalize the magnitude $|TG|$ of the combined vector TG with the magnitude of the target combined propulsive force applied from the stationary marine vessel maneuvering support controlling section 27. In other words, target propulsive force vectors TL_t , TR_t for the port-side and starboard-side outboard motors 11, 12 are determined so as to provide the aforementioned combined vector TG.

[0125] Where the action point F coincides with an instantaneous center G of the hull 2, the angular speed ω of the hull 2 (angular speed about the instantaneous center G) is zero, so that the hull 2 laterally moves parallel with the orientation of the stem 4 being maintained unchanged.

[0126] More specifically, as shown in FIG. 7, the steering angles ϕ_R , ϕ_L are set at $\phi_R = \phi$, $L = -\phi$ (wherein $\phi \geq 0$) such that the action point F coincides with the instantaneous center G. At the same time, the port-side outboard motor 11 and the starboard-side outboard motor 12 generate the propulsive forces in the reverse drive direction and in the forward drive direction, respectively, so as to satisfy an expression $|TL| = |TR|$. At this time, the hull 2 is moved parallel leftward perpendicularly to a stem direction (defined along the center line 5) with the orientation of the stem 4 being kept unchanged.

[0127] In this preferred embodiment, the steering angles ϕ_L , ϕ_R are controlled such that the angular speed ω detected by the yaw rate sensor 9 is substantially equal to the target angular speed ω_t ($=0$). In this case, if the angular speed ω is $\omega=0$, the action point F coincides with the instantaneous center G with the instantaneous center G being located on the center line 5. If the angular speed ω is $\omega \neq 0$, the action point F does not coincide with the instantaneous center G even with the instantaneous center G being located on the center line 5.

[0128] FIG. 8 is a schematic diagram for explaining a specific operation for controlling the steering angles ϕ_L , ϕ_R . The instantaneous center G is not always located on the center line 5. In the case of the small-scale marine vessel 1, for example, the instantaneous center G changes when a crew member moves on the hull 2 or when fish are loaded into an under-deck water tank. Therefore, the position of the instantaneous center G is not limited to positions on the center line 5.

[0129] However, it is possible to perform a lateral maneuvering operation to laterally move the marine vessel 1 as desired with the action point F being located on the center line 5, even if the instantaneous center G is not located on the center line 5. More specifically, a line 60 extending through the instantaneous center G at the target movement angle θ_t is drawn, and the action point F is located at an intersection of the line 60 and the center line 5. Then, the magnitudes of the propulsive force vectors TL , TR for the port-side and starboard-side outboard motors 11, 12 are determined so as to provide a combined propulsive force vector TG extending from the action point F along the line 60. Thus, the hull 2 can be moved parallel with the angular speed ω being kept at $\omega=0$.

[0130] The propulsion units 30 of the port-side and starboard-side outboard motors 11, 12 are preferably pivotal only in a mechanically limited angular range about the

steering shaft 35. Therefore, it is impossible, in reality, to locate the action point F within a range between the origin O and a predetermined lower limit point ($a_{\min}$, 0) on the center line 5. Furthermore, if the action point F is located at a position that is more distant from the origin O than a predetermined upper limit point ($a_{\max}$, 0) on the center line 5 to provide a desired combined vector TG extending laterally of the hull 2, greatly increased propulsive forces must be generated from the port-side and starboard-side outboard motors 11, 12. Therefore, the position of the action point F on the center line 5 is restricted within a range Δx between the points ($a_{\min}$, 0) and ($a_{\max}$, 0) due to limitations in the steering angles of the propulsion units 30 and limitations in the output capabilities of the engines 39.

[0131] Where the instantaneous center G is located at a position (a' , c) in FIG. 8, for example, the aforementioned limitations make it impossible to move the hull 2 parallel from the instantaneous center G into the cross-hatched ranges shown in FIG. 8 with the action point F being located on the center line 5. That is, it is impossible to set the angular speed ω at $\omega=0$, thereby imparting the hull 2 with a rotation moment.

[0132] That is, as shown in FIG. 9, there is a possibility that the angular speed ω cannot be set at $\omega=\omega_t$ ($=0$) even if the steering angle ϕ_R is reduced to a predetermined switching reference steering angle ϕ_s . When the steering angle ϕ_R is reduced to the switching reference steering angle ϕ_s , the action point F reaches the point ($a_{\max}$, 0) on the center line 5. In this case, the action point F is offset from the center line 5 in this preferred embodiment. Conversely, if the steering angles ϕ_L , ϕ_R are controlled to set the angular speed ω at $\omega=0$, the action point F is located on a line 62 extending through the instantaneous center G at the target movement angle θ . Then, the outputs (propulsive forces) of the port-side and starboard-side outboard motors 11, 12 are controlled to provide a combined vector TG having a desired magnitude and a desired direction.

[0133] In general, the instantaneous center G is located within the hull 2. Therefore, it is necessary to locate the action point F within a predetermined range Δy having a width that is roughly equivalent to the width of the hull 2. When it is impossible to obtain the target angular speed ω_t even with the action point F being located within the predetermined range Δy , an alarm may be provided to notify the operator of this situation.

[0134] Similarly, when it is impossible to attain the target angular speed ω_t even with the action point F being located at the point ($a_{\min}$, 0) on the center line 5 by increasing the steering angle ϕ_R , an alarm is preferably provided to notify the operator of this situation.

[0135] In the case shown in FIG. 9, the steering angles ϕ_L , ϕ_R of the port-side and starboard-side outboard motors 11, 12 are calculated from the following expressions so as to simplify the control operation.

$$\phi_L = \psi - \phi_s$$

$$\phi_R = \psi + \phi_s$$

wherein ψ is a steering angle correction value.

[0136] Therefore, the steering angles ϕ_L , ϕ_R are determined by properly determining the steering angle correction value ψ to attain the target angular speed ω_t . Thus, the

computation for the control operation is simplified. Here, the switching reference steering angle ϕ_s is a steering angle which is observed when the action point F is located at the point $(a_{\max}, 0)$ on the center line 5, and expressed by $\phi_s = \tan^{-1}(b/a_{\max})$.

[0137] Referring to FIG. 6, a method for calculating the magnitudes $|TL|$, $|TR|$ of the propulsive forces to be generated from the port-side and starboard-side outboard motors 11, 12 will be described in more detail.

[0138] It is herein assumed that the magnitude $|TR_t|$ of the target propulsive force vector TR_t for the starboard-side outboard motor 12 for providing the target combined propulsive force magnitude $|TG_t|$ is calculated from the following expression (1) by multiplying the magnitude $|TL_t|$ of the target propulsive force vector TL_t for the port-side outboard motor 11 by a scalar k.

$$|TL_t| = k/|TR_t| \quad (1)$$

[0139] It is further assumed that the target steering angles ϕ_{R_t} , ϕ_{L_t} of the port-side and starboard-side outboard motors 11, 12 are determined so as to satisfy an expression $\phi_t = \phi_{R_t} = -\phi_{L_t}$ (wherein ϕ_t is a target steering angle basic value) in the stationary marine vessel maneuvering support mode and the moorage support mode.

[0140] Where the target combined propulsive force vector TG_t is provided by combining the target propulsive force vectors TL_t , TR_t for the port-side and starboard-side outboard motors 11, 12, x-axis and y-axis components $TG_{t,x}$, $TG_{t,y}$ of the target combined propulsive force vector TG_t satisfy the following expressions (2) and (3):

$$TG_{t,x} = |TG_t| \cos \theta_t / |TR_t| \cos \phi_t + |TL_t| \cos \phi_t \quad (2)$$

$$TG_{t,y} = |TG_t| \sin \theta_t / |TR_t| \sin \phi_t - |TL_t| \sin \phi_t \quad (3)$$

[0141] Then, the magnitude $|TR_t|$ of the target propulsive force vector TR_t for the starboard-side outboard motor 12 is expressed by the following expression (4):

$$|TR_t| = \frac{|TG_t|(\cos \theta_t + \sin \theta_t)}{\{(1+k)\cos \phi_t + (1-k)\sin \phi_t\}} \quad (4)$$

[0142] On the other hand, the following expression (5) is obtained from the expressions (2) and (3).

$$\tan \theta_t = \frac{|TR_t| - |TL_t|}{|TR_t| + |TL_t|} \cdot \frac{\sin \phi_t}{\cos \phi_t} = \frac{|TR_t| - |TL_t|}{|TR_t| + |TL_t|} \cdot \tan \phi_t \quad (5)$$

[0143] The expression (1) is substituted in the expression (5) to provide the following expression (6).

$$\tan \theta_t = \frac{1-k}{1+k} \cdot \tan \phi_t \quad (6)$$

[0144] By solving this equation, the factor k is expressed by the following expression (7):

$$k = \frac{\tan \phi_t - \tan \theta_t}{\tan \phi_t + \tan \theta_t} \quad (7)$$

[0145] Therefore, the factor k is calculated from the expression (7) based on the target steering angle basic value $\phi_t (= \phi_{R_t})$ and the target movement angle θ_t . The target propulsive force $|TR_t|$ for the starboard-side outboard motor 12 is calculated from the expression (4) based on the factor k, the target steering angle basic value ϕ_t , the target movement angle θ_t and the target combined propulsive force $|TG_t|$. Further, the target propulsive force $|TL_t|$ for the port-side outboard motor 11 is calculated from the expression (1).

[0146] Therefore, the target propulsive forces $|TL_t|$, $|TR_t|$ for the port-side and starboard-side outboard motors 11, 12 are determined based on the input of the target steering angle basic value ϕ_t (which may be a value detected by the steering angle sensor 49 of the starboard-side outboard motor 12), the target movement angle θ_t and the target combined propulsive force $|TG_t|$ through a computation process performed by the microcomputer.

[0147] However, when the target movement angle θ_t is $\theta_t = -\pi/4$ or $3\pi/4$ (rad), it is impossible to calculate the target propulsive force $|TR_t|$ from the expression (4) with the right side of the expression (4) being 0/0. Therefore, the target propulsive forces $|TL_t|$, $|TR_t|$ for different target movement angles θ_t from 0 to 2π in increments of $\pi/36$ are preliminarily calculated based on different target steering angle basic values ϕ_t and different target combined propulsive forces $|TG_t|$, and the results of the calculation are stored in the form of a map, which is used for the control of the propulsive forces.

[0148] If the action point F is offset from the center line 5 as shown in FIG. 9, the relationship $\phi_L = -\phi_R = -\phi$ is not satisfied. Even in this case, the aforementioned map is useful. This is because the target steering angles ϕ_{L_t} , ϕ_{R_t} are determined from the expression $\phi_{L_t} = \psi_t - \phi_s$ and $\phi_{R_t} = \psi_t + \phi_s$. More specifically, the target steering angle basic value ϕ_t and the target movement angle θ_t are replaced with a target steering angle input value $\phi_{R_t} - \psi_t$ (or $\phi_t \leq \phi_R - \psi_t$) and a target movement angle input value $\theta_t - \psi_t$, respectively, when the map is used.

[0149] FIG. 10 is a block diagram illustrating the functions of the stationary marine vessel maneuvering support controlling section 27. The stationary marine vessel maneuvering support controlling section 27 includes a stationary marine vessel maneuvering support start detecting section 161 which detects the operation of the stationary marine vessel maneuvering support starting button 15, a coordinate converting section 162 which converts absolute coordinates (X, Y) of a position of the marine vessel 1 output from the GPS 10 into relative coordinates (x, y) defined based on the x-axis and the y-axis on the marine vessel 1, and a marine vessel maneuvering support starting position storing section 163 which stores coordinates (x_0, y_0) of a stationary marine vessel maneuvering support starting position generated by the coordinate converting section 162 when the operation of the stationary marine vessel maneuvering support starting button 15 is detected by the stationary marine vessel maneuvering support start detecting section 161.

[0150] The relative coordinates (x, y) are based on the origin O defined by the intersection of the x-axis and the y-axis at a predetermined time point, for example, when the operation of the stationary marine vessel maneuvering support starting button 15 is detected, and the origin O is fixed during the control in the stationary marine vessel maneuvering support mode.

[0151] The stationary marine vessel maneuvering support controlling section 27 further includes a target control value calculating section 164 which determines the magnitude $|TG_t|$ of the target combined propulsive force and the target movement angle θ_t to generate target control values. The target control value calculating section 164 receives the coordinates (x_0, y_0) of the stationary marine vessel maneuvering support starting position applied from the marine vessel maneuvering support starting position storing section 163 and coordinates (x, y) of a current position of the marine vessel 1 applied from the coordinate converting section 162.

[0152] The stationary marine vessel maneuvering support controlling section 27 further includes a proximity state detecting section 165 which detects the proximity state of the marine vessel 1 based on the output signals of the respective proximity sensors 18. The proximity state detecting section 165 generates proximity information indicating the proximity state, and applies the proximity information to the target control value calculating section 164.

[0153] The stationary marine vessel maneuvering support controlling section 27 further includes a moorage support start detecting section 166 which detects the operation of the moorage support starting button 17. A detection signal from the moorage support start detecting section 166 is applied to the target control value calculating section 164. A detection signal from the stationary marine vessel maneuvering support start detecting section 161 is also applied to the target control value calculating section 164. The output of the cross button 16 is also applied to the target control value calculating section 164.

[0154] When the stationary marine vessel maneuvering support starting button 15 is pressed to switch the control mode to the stationary marine vessel maneuvering support mode, the target control value calculating section 164 determines the target combined propulsive force $|TG_t|$ and the target movement angle θ_t based on the coordinates (x_0, y_0) of the stationary marine vessel maneuvering support starting position, the coordinates (x, y) of the current marine vessel position and the output of the cross button 16. On the other hand, when the moorage support starting button 17 is pressed to switch the control mode to the moorage support mode, the target control value calculating section 164 calculates the target combined propulsive force $|TG_t|$ and the target movement angle θ_t such that the marine vessel 1 is maintained in the proximity state according to the proximity information applied from the proximity state detecting section 165.

[0155] FIG. 11 is a flowchart of an operation to be performed by the stationary marine vessel maneuvering support controlling section 27 in the stationary marine vessel maneuvering support mode. When the stationary marine vessel maneuvering support starting button 15 is operated, the stationary marine vessel maneuvering support controlling operation is started in the stationary marine vessel maneuvering support mode. In the stationary marine vessel maneuvering support mode, the coordinate converting section 162 converts absolute coordinates of a current marine vessel position output from the GPS 10 into relative coordinates, which are in turn stored as the coordinates (x_0, y_0) of the stationary marine vessel maneuvering support starting position in the marine vessel maneuvering support starting position storing section 163 (Step S100).

[0156] On the other hand, the target control value calculating section 164 detects the operation state of the cross button 16 (Step S102).

[0157] If the operation of the cross button 16 is not detected, the routine goes to Step S104 at a branch in Step S102. That is, a deviation $\Delta x (=x-x_0)$ of a current position x-coordinate x (relative position coordinate) from a reference x-coordinate x_0 with respect to the x-axis (hereinafter referred to as "x-axis deviation Δx ") and a deviation $\Delta y (=y-y_0)$ of a current position y-coordinate y (relative position coordinate) from a reference y-coordinate y_0 with respect to the y-axis (hereinafter referred to as "y-axis deviation Δy ") are determined.

[0158] Then, the magnitudes $|TG_x|$, $|TG_y|$ of the x-axis and y-axis components of the target combined propulsive force TG_t are calculated from the following expressions (8), (9), respectively (Step S106).

$$|TG_x| = k_x / \Delta x \quad (8)$$

$$|TG_y| = k_y / \Delta y \quad (9)$$

wherein k_x and k_y are proportionality constants greater than zero ($k_x > 0$, $k_y > 0$).

[0159] That is, the magnitude $|TG_x|$ of the x-axis component is directly proportional to the magnitude $|\Delta x|$ of the x-axis deviation, and the magnitude $|TG_y|$ of the y-axis component is directly proportional to the magnitude $|\Delta y|$ of the y-axis deviation.

[0160] Based on the magnitudes $|TG_x|$, $|TG_y|$ of the x-axis and y-axis components, the target combined propulsive force $|TG_t|$ is calculated as the magnitude of a vector obtained by combining the x-axis and y-axis component vectors TG_x , TG_y from the following expression (10) (Step S116). The directions of the x-axis and y-axis component vectors TG_x , TG_y are determined by signs of the x-axis and y-axis deviations Δx , Δy , respectively.

$$|TG_t| = \sqrt{|TG_x|^2 + |TG_y|^2} \quad (10)$$

[0161] Further, the target movement direction θ_t is calculated based on a ratio between the x-axis component of the x-axis component vector TG_x and the y-axis component of the y-axis component vector TG_y from the following expression (11) (Step S116).

$$\theta_t = \tan^{-1}(TG_x / TG_y) \quad (11)$$

[0162] The target movement direction θ_t is such that the x-axis deviation Δx and the y-axis deviation Δy are eliminated to move the marine vessel 1 back to the stationary marine vessel maneuvering support starting position (x_0, y_0) .

[0163] Thereafter, it is determined whether the stationary marine vessel maneuvering support controlling operation is to be terminated (Step S118). This judgment is positive if the operation of any of the steering wheel 7a, the throttle levers 8a, 8b and the moorage support starting button 17 is detected, and is negative if the operation of any of the steering wheel 7a, the throttle levers 8a, 8b and the moorage support starting button 17 is not detected.

[0164] When the leftward movement button 16C or the rightward movement button 16D is operated to move the marine vessel 1 along the y-axis, the routine goes to Step S108 at the branch in Step S102. That is, the x-axis deviation Δx is determined (Step S108).

[0165] Then, the magnitudes $|TG_x|$, $|TG_y|$ of the x-axis component and the y-axis component of the target combined propulsive force TG_t are calculated from the following expressions (12), (13) (Step S110).

$$|TG_x| = k_x |\Delta x| \quad (12)$$

$$|TG_y| = C_y \quad (13)$$

[0166] That is, the magnitude $|TG_x|$ of the x-axis component is directly proportional to the magnitude $|\Delta x|$ of the x-axis deviation with a proportionality constant k_x , and the magnitude $|TG_y|$ of the y-axis component has a very small constant value C_y (>0).

[0167] The reference y-coordinate y_0 is updated to the y-coordinate y of the current position (Step S110). This prevents the marine vessel 1 from being moved back to the stationary marine vessel maneuvering support starting position when the routine goes to Step S104 from Step S102 with the operation of the leftward movement button 16C or the rightward movement button 16D cancelled.

[0168] Thereafter, a process sequence beginning from Step S116 is performed. In this case, the sign of the x-axis component vector TG_x is determined by the sign of the x-axis deviation Δx . Further, the y-axis component vector TG_y has a plus sign if the leftward movement button 16D is operated, and has a minus sign if the rightward movement button 16C is operated.

[0169] Thus, the target movement direction θ_t indicating the direction of the target combined propulsive force vector TG_t is determined to eliminate the x-axis deviation Δx and move the marine vessel 1 along the y-axis.

[0170] When the forward movement button 16A or the reverse movement button 16B is operated to move the marine vessel 1 along the x-axis, the routine goes to Step S112 at the branch in Step S112. That is, the y-axis deviation Δy is determined. Then, the magnitudes $|TG_x|$, $|TG_y|$ of the x-axis component and the y-axis component of the target combined propulsive force TG_t are calculated from the following expressions (14), (15) (Step S114).

$$|TG_x| = C_x \quad (14)$$

$$|TG_y| = k_y |\Delta y| \quad (15)$$

[0171] That is, the magnitude $|TG_x|$ of the x-axis component has a very small constant value C_x (>0), and the magnitude $|TG_y|$ of the y-axis component is directly proportional to the magnitude $|\Delta y|$ of the y-axis deviation with a proportionality constant k_y .

[0172] The reference x-coordinate x_0 is updated to the x-coordinate x of the current position (Step S114). This prevents the marine vessel 1 from being moved back to the stationary marine vessel maneuvering support starting position when the routine goes to Step S104 from Step S102 with the operation of the forward movement button 16A or the reverse movement button 16B cancelled.

[0173] Thereafter, a process sequence beginning from Step S116 is performed. In this case, the sign of the y-axis component vector TG_y is determined by the sign of the y-axis deviation Δy . Further, the x-axis component vector TG_x has a plus sign if the forward movement button 16A is operated, and has a minus sign if the reverse movement button 16B is operated.

[0174] Thus, the target movement direction θ_t indicating the direction of the target combined propulsive force vector TG_t is determined to eliminate the y-axis deviation Δy and move the marine vessel 1 along the x-axis.

[0175] In this manner, the fixed position marine vessel maintaining operation is performed to maintain the marine vessel 1 at the stationary marine vessel maneuvering support starting position despite disturbances being applied to the marine vessel, if none of the buttons 16A to 16D of the cross button 16 is operated in the stationary marine vessel maneuvering support mode. When the forward movement button 16A or the reverse movement button 16B is operated, the marine vessel 1 is moved along the x-axis with movement of the marine vessel 1 along the y-axis due to disturbances being prevented. When the leftward movement button 16C or the rightward movement button 16D is operated, the marine vessel 1 is moved along the y-axis with movement of the marine vessel 1 along the x-axis due to disturbances being prevented. Since the angular speed ω of the marine vessel 1 is maintained at zero in this mode, the orientation of the stem 4 of the marine vessel 1 is kept unchanged without turning of the stem 4.

[0176] Therefore, the operator first operates the steering wheel 7a and the throttle levers 8a, 8b to move the marine vessel 1 into the vicinity of a desired stop position with the stem 4 of the marine vessel 1 oriented in a desired direction (e.g., with the center line 5 of the marine vessel 1 maintained parallel to the pier), and then operates the stationary marine vessel maneuvering support starting button 15. Thereafter, the operator operates the cross button 16 to move the marine vessel 1 forward, reverse, leftward or rightward with the orientation of the stem 4 of the marine vessel 1 kept unchanged, and then stops the marine vessel 1 at the desired stop position.

[0177] The stationary marine vessel maneuvering support mode is also useful for moving the marine vessel 1 away from the pier or other objects. In this case, the operator operates the cross button 16 to move the marine vessel 1 away from the pier or other objects with the orientation of the stem 4 of the marine vessel being kept unchanged.

[0178] FIG. 12 is a flow chart of an operation (proximity state maintaining controlling operation) to be performed by the stationary marine vessel maneuvering support controlling section 27 (serving as a proximity state maintaining controlling section in this case) in the moorage support mode. When the operation of the moorage support starting button 17 is detected, the target control value calculating section 164 acquires the proximity information from the proximity state detecting section 165 (Step S400). Then, the target control value calculating section 164 determines the target combined propulsive force vector TG_t so as to maintain the marine vessel 1 in the proximity state as indicated by the proximity information. That is, the magnitude $|TG_t|$ of the target combined propulsive force vector TG_t is set at a very small constant value C (proximity maintaining target propulsive force), and the target movement direction θ_t defining the direction of the target combined propulsive force vector TG_t is determined such that the marine vessel 1 is moved toward an anchoring position (along a line extending from the center of the marine vessel 1 to the anchoring position) (Step S402).

[0179] Thus, the port-side and starboard-side outboard motors 11, 12 generate propulsive forces to maintain the

marine vessel 1 in the proximity state, whereby the moorage support controlling operation is performed to move and press the marine vessel 1 toward the pier and the other object with a minute force. At this time, the steering angles of the respective outboard motors 11, 12 are controlled by the steering controlling section 23 to maintain the angular speed of the marine vessel 1 at zero.

[0180] In Step S404, it is determined whether the moorage support controlling operation is to be terminated. This judgment is positive if the operation of any of the steering wheel 7a, the throttle levers 8a, 8b and the stationary marine vessel maneuvering support starting button 15 is detected, and is negative if the operation of any of the steering wheel 7a, the throttle levers 8a, 8b and the stationary marine vessel maneuvering support starting button 15 is not detected.

[0181] When the marine vessel 1 is to be brought into contact with the object (the pier or another marine vessel), the operator performs an ordinary marine vessel maneuvering operation with the use of the steering wheel 7a and the like to move the marine vessel 1 sufficiently close to the object with the stem 4 of the marine vessel 1 oriented in a desired direction, and then operates the stationary marine vessel maneuvering support starting button 15. In this state, the operator operates the cross button 16 to move the marine vessel 1 parallel in the forward, reverse, leftward or rightward direction toward the object. After the marine vessel 1 is brought into contact with the object, the operator operates the moorage support starting button 17. Thus, the marine vessel 1 is continuously pressed toward the object. Then, the marine vessel 1 is moored to the object with a rope as required.

[0182] On the other hand, when the marine vessel 1 is to be moved away from the object (the pier or another marine vessel), the operator first operates the moorage support starting button 17. Thus, the marine vessel 1 is pressed toward the object, so that the marine vessel 1 can safely be unmoored from the object. After operating the stationary marine vessel maneuvering support starting button 15, the operator operates the cross button 16 to move the marine vessel 1 away from the object with the orientation of the stem 4 of the marine vessel 1 kept unchanged. After the marine vessel 1 is moved sufficiently away from the object, the operator performs the ordinary marine vessel maneuvering operation with the use of the steering wheel 7a and the throttle levers 8a, 8b to move the marine vessel 1.

[0183] The control mode may automatically be switched from the stationary marine vessel maneuvering support mode to the moorage support mode. That is, the stationary marine vessel maneuvering support controlling section 27 may automatically switch the control mode to the moorage support mode in response to the proximity sensors 18 detecting the object in contact with the marine vessel 1 (or in close proximity to the marine vessel 1) without the operation of the moorage support starting button 17 in the stationary marine vessel maneuvering support mode.

[0184] FIG. 13 is a block diagram illustrating the functions of the throttle controlling section 21 and the shift controlling section 22, particularly, for explaining the control operations to be performed by the throttle controlling section 21 and the shift controlling section 22 in the stationary marine vessel maneuvering support mode and the moorage support mode. The throttle controlling section 21

includes a target engine speed calculating module 70 (individual target propulsive force calculating section) which calculates target engine speeds $|NL_t|$, $|NR_t|$ of the engines 39 of the port-side and starboard-side outboard motors 11, 12, and a throttle opening degree calculating module 80 (propulsive force controlling section) which calculates the target throttle opening degrees of the engines 39 of the outboard motors 11, 12 based on the calculated target engine speeds $|NL_t|$, $|NR_t|$.

[0185] The target engine speed calculating module 70 includes a steering angle input value calculating section 71 which receives the steering angle ϕR (or the target steering angle ϕR_t) of the starboard-side outboard motor 12 and the target steering angle correction value ψ_t from the steering controlling section 23 and calculates the steering angle input value $\phi R - \psi_t$ (or $\phi R_t - \psi_t$) to be used in a map search, and a target movement angle input value calculating section 72 which calculates the target movement angle input value $\theta_t - \psi_t$ to be used in the map search based on the target movement angle θ_t and the target steering angle correction value ψ_t from the stationary marine vessel maneuvering support controlling section 27. The target engine speed calculating module 70 further includes a target propulsive force calculating section 74 which calculates the target propulsive forces $|TL_t|$, $|TR_t|$ of the port-side and starboard-side outboard motor 11, 12, a propulsive force-to-engine speed conversion table 75 which determines the target engine speeds NL_t , NR_t (with signs indicating the directions of the propulsive forces to be generated) of the port-side and starboard-side outboard motors 11, 12 for the target propulsive forces $|TL_t|$, $|TR_t|$, and a lower limit engine speed judging section 76 which calculates the absolute values $|NL_t|$, $|NR_t|$ of the target engine speeds and compares the absolute values $|NL_t|$, $|NR_t|$ with the lower limit engine speed (which is, for example, equal to the idle speed of the engines 39).

[0186] The target propulsive force calculating section 74 is defined by the aforementioned map which outputs the target propulsive forces $|TL_t|$, $|TR_t|$ of the port-side and starboard-side outboard motors 11, 12 based on the steering angle input value $\phi R - \psi_t$ (or $\phi R_t - \psi_t$), the target movement angle input value $\theta_t - \psi_t$, and the target combined propulsive force $|TG_t|$ applied from the stationary marine vessel maneuvering support controlling section 27.

[0187] The target propulsive forces $|TL_t|$, $|TR_t|$ are not suitable for the control of the engines 39 and, therefore, are converted into the target engine speeds NL_t , NR_t according to the characteristics of the engines 39 with reference to the propulsive force-to-engine speed conversion table 75. The signs of the target engine speeds NL_t , NR_t are determined according to the target movement angle θ_t . More specifically, if the target movement angle θ_t is $0 \leq \theta_t \leq \pi$, a minus sign indicating the reverse drive direction is assigned to the target engine speed NL_t of the port-side outboard motor 11, and a plus sign indicating the forward drive direction is assigned to the target engine speed NR_t of the starboard-side outboard motor 12. On the other hand, if the target movement angle θ_t is $\pi < \theta_t < 2\pi$ (or $-\pi < \theta_t < 0$), a plus sign indicating the forward drive direction is assigned to the target engine speed NL_t of the port-side outboard motor 11, and a minus sign indicating the reverse drive direction is assigned to the target engine speed NR_t of the starboard-side outboard motor 12. The target engine speeds NL_t , NR_t thus deter-

mined are input not only to the lower limit engine speed judging section 76 (rotational speed comparing section), but also to the shift controlling section 22.

[0188] The lower limit engine speed judging section 76 determines whether the absolute values $|NL_t|$, $|NR_t|$ of the target engine speeds are less than the lower limit engine speed NLL (which is equal to the idle speed), and applies judgment results to the shift controlling section 22. Further, the absolute values $|NL_t|$, $|NR_t|$ of the target engine speeds are applied to the throttle opening degree calculating module 80. However, if the target engine speed $|NL_t|$ of the port-side outboard motor 11 is less than the lower limit engine speed NLL, the lower limit engine speed judging section 76 substitutes the lower limit engine speed NLL for the target engine speed $|NL_t|$. Similarly, if the target engine speed $|NR_t|$ of the starboard-side outboard motor 12 is less than the lower limit engine speed NLL, the lower limit engine speed judging section 76 substitutes the lower limit engine speed NLL for the target engine speed $|NR_t|$.

[0189] The throttle opening degree calculating module 80 includes a port-side PI (proportional integration) control module 81 and a starboard-side PI control module 82, which have substantially the same construction. The port-side PI control module 81 receives the target engine speed $|NL_t|$ of the port-side outboard motor 11 input from the lower limit engine speed judging section 76, and a current engine speed NL (≥ 0) input from the outboard motor ECU 13 of the port-side outboard motor 11. A deviation $eL = |NL_t| - NL$ of the current engine speed NL from the target engine speed $|NL_t|$ of the port-side outboard motor 11 is calculated by a deviation computing section 83. The deviation eL is output from the deviation computing section 83 to a proportional gain multiplying section 84, and to an integrating section 85 in which the deviation eL is subjected to a discrete integration process. The integration result provided by the integrating section 85 is applied to an integration gain multiplying section 86. The proportional gain multiplying section 84 outputs a value obtained by multiplying the deviation eL by a proportional gain k_p , and the integration gain multiplying section 86 outputs a value obtained by multiplying the integration value of the deviation eL by an integration gain k_i . These values are added by the adding section 87 to provide a target throttle opening degree of the engine 39 of the port-side outboard motor 11. The target throttle opening degree is applied to the outboard motor ECU 13 of the port-side outboard motor 11. The port-side PI control module 81 thus performs a so-called PI (proportional integration) control.

[0190] The starboard-side PI control module 82 preferably has substantially the same construction as the port-side PI control module 81. That is, the starboard-side PI control module 82 processes a deviation eR of a current engine speed NR (≥ 0) from the target engine speed $|NR_t|$ of the starboard-side outboard motor 12 through the PI (proportional integration) control, and outputs a target throttle opening degree of the engine 39 of the starboard-side outboard motor 12. The target throttle opening degree is applied to the outboard motor ECU 14 of the starboard-side outboard motor 12.

[0191] The shift controlling section 22 includes a port-side shift control module 91 and a starboard-side shift control module 92, which have substantially the same construction.

Each of the shift control modules 91, 92 generates a shift controlling signal for controlling the shift mechanism 43 (more specifically, the dog clutch 43d) of the outboard motor 11, 12 based on the target engine speed NL_t , NR_t applied from the propulsive force-to-engine speed conversion table 75 to switch the shift position of the shift mechanism 43 to the forward drive position, the reverse drive position or the neutral position. Each of the shift control modules 91, 92 performs an intermittent shift control operation (intermittent coupling control operation) for periodically switching the shift position of the shift mechanism 43 alternately between the neutral position and the forward drive position or between the neutral position and the reverse drive position to intermittently couple the engine 39 to the propeller 40 when the target engine speed NL_t , NR_t is less than the lower limit engine speed NLL.

[0192] The intermittent shift control operation will hereinafter be referred to as "PWM control" (pulse width modulation control). In a shift-in period S_{in} of a PWM control period S , the rotation of the engine 39 is transmitted to the propeller shaft 42 with the shift position being set at the forward drive position or the reverse drive position. In a neutral period $S - S_{in}$ of the PWM control period S , the shift position is set at the neutral position.

[0193] The port-side shift control module 91 includes a shift rule table 93 which outputs the shift position (the forward drive position, the reverse drive position or the neutral position) of the shift mechanism 43 based on the sign of the target engine speed NL_t of the port-side outboard motor 11 applied from the propulsive force-to-engine speed conversion table 75. The port-side shift control module 91 further includes a shift-in period calculating section 94 (coupling duration calculating section) which calculates the shift-in period S_{in} based on the absolute value $|NL_t|$ of the target engine speed NL_t applied from the propulsive force-to-engine speed conversion table 75. The port-side shift control module 91 further includes a shift position outputting section 95 (intermittent coupling controlling section) which generates a shift position signal indicating the shift position of the shift mechanism 43 of the port-side outboard motor 11 based on the outputs of the shift rule table 93 and the shift-in period calculating section 94.

[0194] The shift rule table 93 outputs a signal indicating the forward drive position when the target engine speed NL_t has a plus sign, and outputs a signal indicating the reverse drive position when the target engine speed NL_t has a minus sign. Where the absolute value of the target engine speed NL_t is determined to be substantially zero (for example, not higher than about 100 rpm), the shift rule table 93 outputs a signal indicating the neutral position.

[0195] The shift-in period calculating section 94 sets the shift-in period S_{in} at $S_{in} = S$ if the lower limit engine speed judging section 76 determines that the target engine speed NL_t is not less than the lower limit engine speed NLL. In this case, the PWM control is not performed, but the shift position of the shift mechanism 43 is maintained at the shift position output from the shift rule table 93. On the other hand, if the lower limit engine speed judging section 76 determines that the target engine speed NL_t is less than the lower limit engine speed NLL, the shift-in period calculating section 94 sets the shift-in period S_{in} at $S_{in} = S \cdot D$ wherein $D = NL_t / NLL$ is a duty ratio for the PWM control.

[0196] The shift position outputting section 95 outputs the shift position signal in a cycle of the PWM period S. More specifically, the shift position outputting section 95 continuously generates the shift position signal according to the output of the shift rule table 93 over the shift-in period S_{in} calculated by the shift-in period calculating section 94 in the PWM period S, and generates the shift position signal indicating the neutral position in the neutral period irrespective of the output of the shift rule table 93. If the shift-in period S_{in} is $S_{in}=S$, the shift position signal according to the output of the shift rule table 93 is continuously output.

[0197] The starboard-side shift control module 92 has substantially the same construction as the port-side shift control module 91, and controls the shift position of the shift mechanism 43 of the starboard-side outboard motor 12 by performing the aforementioned operation based on the target engine speed NR_t of the starboard-side outboard motor 12 and the judgment result on the absolute value of the target engine speed NR_t provided by the lower limit engine speed judging section 76.

[0198] The engines 39 of the outboard motors 11, 12 are each intrinsically inoperative at an engine speed less than the lower limit engine speed NLL, such that an output less than the lower limit engine speed NLL is not provided. In this preferred embodiment, therefore, if the target engine speeds NL_t , NR_t are each set to have an absolute value that is less than the lower limit engine speed NLL, the engines 39 are each operated at the lower limit engine speed NLL, and the rotation thereof is intermittently transmitted to the propeller 40 at the duty ratio D which depends upon the target engine speed NL_t , NR_t . Thus, the propulsive force can be provided for an engine speed that is less than the idle speed NLL.

[0199] The shift controlling section 22 further includes an engine state judging section 90 (motor state judging section) for judging whether the engines 39 of the port-side and starboard-side outboard motors 11, 12 are inactive in the stationary marine vessel maneuvering support mode and the moorage support mode. The engine state judging section 90 acquires the engine speeds NL , NR of the engines 39 of the port-side and starboard-side outboard motors 11, 12 from the outboard motor ECUs 13, 14. Then, the engine state judging section 90 judges whether the engines 39 are active based on whether or not the engine speeds NL , NR are substantially zero. If at least one of the engines 39 of the outboard motors 11, 12 is inactive in the stationary marine vessel maneuvering support mode or the moorage support mode, a signal indicating the inactive engine state is applied to the shift position outputting sections 95 of the shift control modules 91, 92. In response to this signal, each of the shift position outputting sections 95 controls the shift mechanism 43 of the outboard motor 11, 12 to switch the shift position of the shift mechanism 43 to the neutral position.

[0200] The engine state judging section 90 also functions as a restart controlling section for controlling the restart of the engines 39. That is, when the engine state judging section 90 determines that at least one of the engines 39 of the outboard motors 11, 12 is inactive in the stationary marine vessel maneuvering support mode or the moorage support mode, the engine state judging section 90 provides a command to the outboard motor ECU 13, 14 of the corresponding outboard motor 11, 12 to restart the inactive

engine 39. In response to the command, the outboard motor ECU 13, 14 actuates the starter motor 45 of the inactive engine 39.

[0201] The engine state judging section 90 monitors the engine speeds NL , NR to determine whether the inactive engine 39 is restarted. When the engines 39 of the respective outboard motors 11, 12 become active after the restart of the inactive engine 39, a signal indicating the engine active state is applied to the shift position outputting sections 95. In response to this signal, the shift position outputting sections 95 of the shift control modules 91, 92 are each returned to an ordinary state to control the shift mechanism 43 according to the outputs of the shift rule table 93 and the shift-in period calculating section 94.

[0202] FIG. 14 is a timing chart of the PWM operation to be performed by the port-side shift control module 91 and the starboard-side shift control module 92. In FIG. 9, solid lines indicate a change in the shift position of the shift mechanism 43 of the port-side outboard motor 11 to be controlled by the port-side shift control module 91, and broken lines indicate a change in the shift position of the shift mechanism 43 of the starboard-side outboard motor 12 to be controlled by the starboard-side shift control module 92.

[0203] Herein, it is assumed that the absolute values of the target engine speeds NL_t , NR_t of the port-side and starboard-side outboard motors 11, 12 are less than the lower limit engine speed (idle speed) NLL. At this time, the shift-in period calculating sections 94 provided in the port-side shift control module 91 and the starboard-side shift control module 92 respectively calculate shift-in periods S_{in_L} and S_{in_R} . Therefore, the dog clutch 43d of the port-side outboard motor 11 is located at the forward drive position or the reverse drive position over the shift-in period S_{in_L} in the PWM period S, and located at the neutral position in a neutral period $S-S_{in_L}$. Similarly, the dog clutch 43d of the starboard-side outboard motor 12 is located at the forward drive position or the reverse drive position over the shift-in period S_{in_R} in the PWM period S, and located at the neutral position in a neutral period $(S-S_{in_R})$. In the shift-in periods S_{in_L} , S_{in_R} , the rotation of each of the engines 39 rotating at the lower limit engine speed NLL is transmitted to the corresponding propeller 40.

[0204] In this preferred embodiment, the PWM shift control operations performed by the shift position outputting sections 95 of the port-side and starboard-side shift control modules 91, 92 are synchronized with each other. That is, as shown in FIG. 14, the shift-in timings in the PWM shift control operations are synchronized in each PWM period. Thus, the on-board comfort is improved in the PWM control. Of course, the required propulsive forces can be generated from the respective outboard motors 11, 12 without synchronization of the PWM shift control operations. However, the lag of the shift timings of the port-side and starboard-side outboard motors 11, 12 results in poorer on-board comfort.

[0205] FIG. 15 is a block diagram illustrating the function of the steering controlling section 23, particularly, for explaining a control operation to be performed by the steering controlling section 23 in the stationary marine vessel maneuvering support mode and the moorage support mode. The steering controlling section 23 includes a first

target steering angle computing section **101** (target steering angle calculating section) which computes the target steering angles ϕ_{R_t} , ϕ_{L_t} to be set when the action point F is located on the center line **5**, a second target steering angle computing section **102** (target steering angle calculating section) which computes the target steering angle ϕ_{R_t} , ϕ_{L_t} to be set when the action point F is located outside the center line **5**, a selector **103** which selects outputs of either of the first target steering angle computing section **101** and the second target steering angle computing section **102**, and a comparing section **104** which controls switching of the selector **103**.

[0206] The comparing section **104** compares the target steering angle ϕ_{R_t} of the starboard-side outboard motor **12** computed by the first target steering angle computing section **101** with the switching reference steering angle ϕ_s ($=\tan^{-1}(b/a_{\max})$). That is, if the target steering angle ϕ_{R_t} of the starboard-side outboard motor **12** computed by the first target steering angle computing section **101** is not less than the switching reference steering angle ϕ_s , the comparing section **104** controls the selector **103** to select the outputs of the first target steering angle computing section **101**. On the other hand, if the target steering angle ϕ_{R_t} of the starboard-side outboard motor **12** computed by the first target steering angle computing section **101** is less than the switching reference steering angle ϕ_s , the comparing section **104** controls the selector **103** to select the outputs of the second target steering angle computing section **102**.

[0207] The first target steering angle computing section **101** is defined by a PI (proportional integration) control module based on the input of the angular speed ω detected by the yaw rate sensor **9** and the target angular speed ω_t applied from the stationary marine vessel maneuvering support controlling section **27**. That is, the first target steering angle computing section **101** is operative such that the angular speed ω is substantially equal to the target angular speed ω_t ($=0$) through PI control. More specifically, the first target steering angle computing section **101** includes a deviation computing section **106** which computes a deviation ϵ_ω of the angular speed ω from the target angular speed ω_t , a proportional gain multiplying section **107** which multiplies the output ϵ_ω of the deviation computing section **106** by a proportional gain $k_{\omega 1}$, an integrating section **108** which integrates the deviation ϵ_ω output from the deviation computing section **106**, an integration gain multiplying section **109** which multiplies the output of the integrating section **108** by an integration gain $k_{\theta 1}$, and a first adding section **110** which generates a steering angle deviation $\Delta\phi$ by adding the output of the proportional gain multiplying section **107** and the output of the integration gain multiplying section **109**. These components define a steering angle deviation computing section.

[0208] Further, the first target steering angle computing section **101** includes a memory **111** (basic target steering angle storing section) which stores an initial target steering angle ϕ_i as a basic target steering angle, and a second adding section **112** (adding section) which determines the target steering angle basic value ϕ_t ($=\phi_i+\Delta\phi$) by adding the steering angle deviation $\Delta\phi$ generated by the first adding section **110** to the initial target steering angle ϕ_i stored in the memory **111**. The target steering angle basic value ϕ_t is used as the target steering angle ϕ_{R_t} of the starboard-side outboard motor **12**. Further, the sign of the target steering angle basic

value ϕ_t is reversed by a reversing section **113** to provide a value $-\phi_t$ which is used as the target steering angle ϕ_{L_t} of the port-side outboard motor **11**.

[0209] The memory **111** is preferably a nonvolatile rewritable memory, such as a flash memory or an EEPROM (electrically erasable programmable read only memory). The initial target steering angle ϕ_i is written in the memory **111**, for example, by a special inputting device prior to delivery of the marine vessel **1** from a dealer to a user. The initial target steering angle ϕ_i is set at $\phi_i=\tan^{-1}(b/a_i)$ based on a design instantaneous center $G_i(a_i,0)$ which is determined by the type of the hull **2** and the outboard motors **11**, **12**. The instantaneous center $G_i(a_i,0)$ may be experimentally determined by test cruising.

[0210] Parameters a_i and b for the initial target steering angle ϕ_i may be stored as initial target steering angle information in the memory **111**. In this case, the initial target steering angle ϕ_i is calculated from an expression $\phi_i=\tan^{-1}(b/a_i)$.

[0211] In this preferred embodiment, a learning function is provided for learning the fluctuation of the instantaneous center G due to a change in the load on the marine vessel **1** and other factors. That is, a writing section **114** is provided for updating the initial target steering angle ϕ_i in the memory **111**. The writing section **114** writes the target steering angle basic value ϕ_t generated by the second adding section **112** as a new initial target steering angle ϕ_i in the memory **111** when the running control is terminated by stopping the driving of the outboard motors **11**, **12** or when the control mode is switched from the stationary marine vessel maneuvering support mode or the moorage support mode to the ordinary running mode.

[0212] The second target steering angle computing section **102** is also defined by a PI (proportional integration) control module based on the input of the angular speed ω detected by the yaw rate sensor **9** and the target angular speed ω_t applied from the stationary marine vessel maneuvering support controlling section **27**. That is, the second target steering angle computing section **102** is operative such that the angular speed ω is substantially equal to the target angular speed ω_t through PI control. More specifically, the second target steering angle computing section **102** includes a deviation computing section **116** which computes a deviation ϵ_ω of the angular speed ω from the target angular speed ω_t , a proportional gain multiplying section **117** which multiplies the output ϵ_ω of the deviation computing section **116** by a proportional gain $k_{\omega 2}$, an integrating section **118** which integrates the deviation ϵ_ω output from the deviation computing section **116**, an integration gain multiplying section **119** which multiplies the output of the integrating section **118** by an integration gain $k_{\theta 2}$, and a first adding section **120** which generates a target steering angle correction value ψ_t by adding the output of the proportional gain multiplying section **117** and the output of the integration gain multiplying section **119**. The second target steering angle computing section **102** further includes a memory **121** which stores the switching reference steering angle ϕ_s , a second adding section **122** which determines the target steering angle ϕ_{R_t} ($=\phi_s+\psi_t$) of the starboard-side outboard motor **12** by adding the switching reference steering angle θ_s stored in the memory **121** to the target steering angle correction value ψ_t generated by the first adding section **120**, a reversing section

123 which reverses the sign of the switching reference steering angle ϕ_s to provide an reversed value $-\phi_s$, and a third adding section **124** which provides the target steering angle ϕ_{L_t} ($=-\phi_s+\psi_t$) of the port-side outboard motor **11** by adding the target steering angle correction value ψ_t to the value $-\phi_s$ provided by the reversing section **123**. The switching reference steering angle ϕ_s is also applied to the comparing section **104** from the memory **121**.

[0213] Further, the selector **103** selectively outputs the target steering angle correction value ψ_t provided by the first adding section **120** or zero.

[0214] With this arrangement, if it is possible to attain the target angular speed ω_t by moving the action point F in the predetermined range Δx ($x-a_{\min}$ to $a_{\max}$, see FIG. 9) on the center line **5**, the selector **103** selects the target steering angles ϕ_{L_t} , ϕ_{R_t} provided by the first target steering angle computing section **101**, and applies the target steering angles ϕ_{L_t} , ϕ_{R_t} to the outboard motor ECUs **13**, **14**. At this time, the target steering angles ϕ_{L_t} , ϕ_{R_t} of the port-side and starboard-side outboard motors **11**, **12** satisfy the relationship $\phi_{L_t}=-\phi_{R_t}$. Further, the selector **103** outputs $\psi_t=0$ as the target steering angle correction value ψ_t to be used for the computation in the throttle controlling section **21**.

[0215] On the other hand, if it is not possible to attain the target angular speed ω_t by moving the action point F in the predetermined range Δx on the center line **5**, the target steering angle ϕ_{R_t} becomes less than the switching reference steering angle ϕ_s ($\phi_{R_t}<\phi_s$) when the action point F reaches the endpoint ($a_{\max}$, 0) of the range Δx . Therefore, the selector **103** selects the output of the second target steering angle computing section **102**. Thus, the target steering angles ϕ_{L_t} , ϕ_{R_t} based on the switching reference steering angle ϕ_s are set for the port-side and starboard-side outboard motors **11**, **12**, such that the action point F is located outside the center line **5**. Further, the selector **103** outputs the value provided by the first adding section **120** as the target steering angle correction value ψ_t to be used for the computation in the throttle controlling section **21**.

[0216] FIG. 16 is a flow chart for explaining a throttle controlling operation to be performed by the throttle controlling section **21**. The target engine speed calculating module **70** acquires the starboard-side target steering angle ϕ_{R_t} (or the actually detected steering angle ϕ_R) and the target steering angle correction value ψ_t from the steering controlling section **23**, and acquires the target movement angle θ_t and the target combined propulsive force $|TG_t|$ from the stationary marine vessel maneuvering support controlling section **27** (Step S10).

[0217] The target propulsive forces $|TL_t|$, $|TR_t|$ of the port-side and starboard-side outboard motors **11**, **12** are calculated based on the starboard-side target steering angle ϕ_{R_t} , the target steering angle correction value ψ_t , the target movement angle θ_t and the target combined propulsive force $|TG_t|$ primarily by the operation of the target propulsive force calculating section **74** (Step S11). Further, the target engine speeds NL_t , NR_t are determined according to the target propulsive forces $|TL_t|$, $|TR_t|$ and the target movement angle θ_t by the propulsive force-to-engine speed conversion table **75** (if the absolute values of the target engine speeds NL_t , NR_t are less than the lower limit engine speed NLL, the target engine speeds NL_t , NR_t are each set at the lower limit engine speed NLL) (Step S12). Throttle opening degree

commands are generated based on the target engine speeds NL_t , NR_t primarily by the operation of the throttle opening degree calculating module **80**, and applied to the outboard motor ECUs **13**, **14** (Step S13). According to the applied throttle opening degree commands, the outboard motor ECUs **13**, **14** control the respective throttle actuators **52** (Step S14). In this manner, the throttle opening degrees of the engines **39** of the respective outboard motors **11**, **12** are controlled, whereby the engine speeds of the engines **39** are controlled. Thus, the port-side and starboard-side outboard motors **11**, **12** generate the target propulsive forces $|TL_t|$, $|TR_t|$, respectively.

[0218] The throttle controlling section **21** determines whether the control operation in the stationary marine vessel maneuvering support mode or the moorage support mode is to be continued (Step S15). If a significant input from the steering operational section **7** or the throttle operational section **8** is detected, the control operation from Step S10 to Step S14 is terminated to return the control mode back to the ordinary running mode from the stationary marine vessel maneuvering support mode or the moorage support mode. If the control operation in the stationary marine vessel maneuvering support mode or the moorage support mode is continued, the process beginning from Step S10 is repeated.

[0219] FIG. 17 is a flow chart for explaining a control operation for controlling the shift mechanism **43** of the port-side outboard motor **11**. When the target engine speed NL_t is provided by the propulsion force-to-engine speed conversion table **75** (Step S20), the lower limit engine speed judging section **76** compares the absolute value $|NL_t|$ of the target engine speed NL_t with the lower limit engine speed NLL (Step S21). If the target engine speed NL_t is less than the lower limit engine speed NLL, the shift-in period calculating section **94** of the shift controlling section **22** sets the duty ratio D at $D=NL_t/NLL$, and the lower limit engine speed judging section **76** inputs the target engine speed NL_t having an absolute value replaced with the value of the lower limit engine speed NLL to the throttle opening degree calculating module **80** (the port-side PI control module **81**) (Step S22A).

[0220] The shift-in period calculating section **94** calculates the shift-in period $S_{in}=S \cdot D$ (Step S23). Further, the shift position is determined according to the target engine speed NL_t by the shift rule table **93** (Step S23). Based on the shift-in period S_{in} and the shift position, a shift position command is output from the shift position outputting section **95** (Step S24). The outboard motor ECU **13** controls the shift actuator **52** based on the shift position command.

[0221] If the target engine speed NL_t is not less than the lower limit engine speed NLL (Step S21), the shift-in period calculating section **94** sets the duty ratio D at $D=1$, and the lower limit engine speed judging section **76** inputs the target engine speed NL_t as is to the throttle opening degree calculating module **80** (the port-side PI control module **81**) (Step S22B). Thereafter, an operation from Step S23 is performed.

[0222] Judgment in Step S25 is performed in the same manner as in Step S15 of FIG. 16 by the throttle controlling section **21**.

[0223] A control operation for the shift mechanism **43** of the starboard-side outboard motor **12** is performed in substantially the same manner.

[0224] FIG. 18 is a flow chart for explaining a control operation to be performed by the steering controlling section 23 in the stationary marine vessel maneuvering support mode and the moorage support mode. The steering controlling section 23 acquires the angular speed ω detected by the yaw rate sensor 9 and the target angular speed ω_t ($=0$) input from the stationary marine vessel maneuvering support controlling section 27 (Step S30A). The first target steering angle computing section 101 determines the target steering angle basic value $\phi_t = \phi_i + \Delta\phi$ through the PI control (Step S30B). Then, the target steering angles $\phi_{Lt} = -\phi_t$, $\phi_{Rt} = \phi_t$ of the port-side and starboard-side outboard motors 11, 12 are determined and input to the selector 103 (Step S31).

[0225] On the other hand, the comparing section 104 compares the target steering angle basic value ϕ_t with the switching reference steering angle ϕ_s ($=\tan^{-1}(b/a_{\max})$) (Step S32). If $\phi_t \geq \phi_s$, the selector 103 is controlled to select the output of the first target steering angle computing section 101 (Step S33). Then, the steering controlling section 23 resets the integration value of the integrating section 118 of the second target steering angle computing section 102 to zero (Step S34). If $\phi_t < \phi_s$, the selector 103 is controlled to select the output of the second target steering angle computing section 102 (Step S35). The second target steering angle computing section 102 calculates the target steering angle correction value ψ_t through the PI control (Step S36). Based on the target steering angle correction value ψ_t , the target steering angles $\phi_{Lt} = \psi_t - \phi_s$, $\phi_{Rt} = \psi_t + \phi_s$ of the port-side and starboard-side outboard motors 11, 12 are calculated (Step S37).

[0226] The target steering angles ϕ_{Lt} , ϕ_{Rt} of the port-side and starboard-side outboard motors 11, 12 selected by the selector 103 are output to the outboard motor ECUs 13, 14 (Step S38). Then, the outboard motor ECUs 13, 14 respectively control the steering actuators 53 of the port-side and starboard-side outboard motors 11, 12 based on the applied target steering angles ϕ_{Lt} , ϕ_{Rt} . Thereafter, the steering controlling section 23 determines whether the control operation in the stationary marine vessel maneuvering support mode or the moorage support mode is to be terminated (Step S39). The judgment is performed in the same manner as in Step S15 of FIG. 16 by the throttle controlling section 21. If the control operation in the stationary marine vessel maneuvering support mode or the moorage support mode is continued, the process beginning from Step S30A is repeated.

[0227] FIG. 19 is a flow chart for explaining an engine stop checking process to be performed in the stationary marine vessel maneuvering support mode and the moorage support mode by the engine state judging section 90 of the shift controlling section 22 for checking the engine stop of the outboard motors 11, 12. The engine state judging section 90 monitors the engine speeds NL, NR applied from the outboard motor ECUs 13, 14 to determine whether or not the engines 39 of the outboard motors 11, 12 are inactive (Step S40). If the engines 39 of the outboard motors 11, 12 are both active, the shift position outputting sections 95 continuously control the respective shift mechanisms 43 (Step S41).

[0228] On the other hand, if the inactive state of at least one of the engines 39 of the outboard motors 11, 12 is detected, a command for setting the shift position of each of

the shift mechanisms 43 of the outboard motors 11, 12 at the neutral position is applied to the shift position outputting sections 95 (Step S42). Thus, neither of the outboard motors 11, 12 generate the propulsive forces. Then, a restart command for restarting the inactive engine 39 is applied to the corresponding one of the outboard motor ECUs 13, 14 of the outboard motors 11, 12 from the engine state judging section 90 (Step S43). Thus, the inactive engine 39 is restarted by the starter motor 45 of the corresponding outboard motor 11, 12.

[0229] Thereafter, the engine state judging section 90 determines whether the control operation is to be terminated (Step S44). The judgment is preferably performed in the same manner as in Step S15 of FIG. 16 by the throttle controlling section 21. If the control operation in the stationary marine vessel maneuvering support mode or the moorage support mode is continued, the process beginning from Step S40 is repeated.

[0230] FIG. 20 is a block diagram illustrating a second preferred embodiment of the present invention, and particularly illustrating the construction of an engine speed calculating module 130 to be provided instead of the target engine speed calculating module 70 shown in FIG. 13. In FIG. 20, functional components corresponding to those shown in FIG. 13 are denoted by the same reference characters as in FIG. 13. Further, reference will be made again to FIGS. 1 to 19.

[0231] In this preferred embodiment, the target engine speed NL_t of the port-side outboard motor 11 is determined according to the target combined propulsive force $|TG_t|$ applied from the stationary marine vessel maneuvering support controlling section 27 by a propulsive force-to-engine speed conversion table 131 (first rotational speed setting section). The target engine speed NL_t is applied to an engine speed computing section 132 (second rotational speed setting section). Further, the target steering angle ϕ_{Rt} (or the detected steering angle ϕ_R) of the starboard-side outboard motor 12, the target steering angle correction value ψ_t , and the target movement angle θ_t are applied to an engine speed computing section 132. Based on the target engine speed NL_t , the target steering angle ϕ_{Rt} , the target steering angle correction value ψ_t , and the target movement angle θ_t , the engine speed computing section 132 determines the target engine speed NR_t for the engine 39 of the starboard-side outboard motor 12 so as to provide the combined propulsive force for moving the hull 2 at the target movement angle θ_t .

[0232] The target engine speed NL_t is not necessarily equal to an engine speed required to generate a propulsive force from the outboard motor 11 for providing the target combined propulsive force $|TG_t|$, but is preferably less than that engine speed. In a lateral maneuvering operation for anchorage and moorage, the directions of the propulsive forces generated by the outboard motors 11, 12 are significantly different from the movement direction of the hull 2 and, therefore, the engines 39 of the outboard motors 11, 12 are operated at high engine speeds in spite of the fact that the combined propulsive force $|TG|$ is relatively small. Therefore, a loud engine sound arouses unnatural or uncomfortable feeling in the operator and the crew during the lateral maneuvering operation.

[0233] In this preferred embodiment, the target combined propulsive force generated by the stationary marine vessel

maneuvering support controlling section 27 is associated with the engine speed of the port-side outboard motor 11. Therefore, the operator's unnatural feeling and the crew's uncomfortable feeling attributable to the loud engine sound are prevented.

[0234] While two preferred embodiments of the present invention have thus been described, the present invention may be embodied in many other ways. In the preferred embodiments described above, it is assumed that the instantaneous center G of the hull 2 varies. However, where the instantaneous center G is considered to be virtually fixed, the construction of the marine vessel maneuvering supporting apparatus and the control method are simplified. More specifically, the target steering angle basic value ϕ_t in the stationary marine vessel maneuvering support mode or the moorage support mode may be fixed at a value which is determined by a geometrical relationship between the instantaneous center G and the propulsive force generating positions of the outboard motors 11, 12 (to coincide the action point F with the instantaneous center G). In this case, the construction of the marine vessel maneuvering supporting apparatus and the control method are further simplified.

[0235] The propulsive forces are controlled by controlling the outputs of the engines 39 in the preferred embodiments described above. However, the propulsive forces may be controlled by using propulsion systems including a variable pitch propeller whose propeller angle (pitch) is controllable. In this case, target pitches of the variable pitch propellers are calculated according to target propulsive forces, and the pitches of the variable pitch propellers are set at the target pitches thus calculated.

[0236] Although the preferred embodiments described above are directed to the marine vessel 1 including two outboard motors 11, 12, the marine vessel 1 may further include a third outboard motor provided on the center line 5 of the hull 2.

[0237] While the present invention has been described in detail with reference to the preferred embodiments thereof, it should be understood that the foregoing disclosure is merely illustrative of the technical principles of the present invention but not limitative of the same. The spirit and scope of the present invention are to be limited only by the appended claims.

[0238] This application corresponds to Japanese Patent Application No. 2003-418421 filed with the Japanese Patent Office on Dec. 16, 2003, the disclosure of which is incorporated herein by reference.

What is claimed is:

1. A marine vessel maneuvering supporting apparatus for performing a stationary marine vessel maneuvering support operation to support maneuvering of a marine vessel in a stationary state, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of a hull of the marine vessel, and a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull, the marine vessel maneuvering supporting apparatus comprising:

a position detecting section which detects a position of the marine vessel;

a marine vessel maneuvering support starting command section which outputs a stationary marine vessel maneuvering support-starting command for starting the stationary marine vessel maneuvering support operation;

a marine vessel maneuvering support starting position storing section which stores a marine vessel maneuvering support starting position that is defined by a marine vessel position detected by the position detecting section in response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering support starting command section;

a steering controlling section which controls the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero in response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering support starting command section;

a target propulsive force calculating section which calculates, in response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering support starting command section, target propulsive forces to be generated from the respective propulsion systems, based on a current marine vessel position detected by the position detecting section, such that at least one of x- and y-coordinates of the current marine vessel position defined with respect to an x-axis defined along a center line of the hull extending through a stem and a stern of the hull and a y-axis extending substantially perpendicularly relative to the center line is maintained substantially equal to a corresponding one of x- and y-coordinates of the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section; and

a propulsive force controlling section which controls the propulsion systems to attain the target propulsive forces calculated by the target propulsive force calculating section.

2. A marine vessel maneuvering supporting apparatus as set forth in claim 1, wherein the target propulsive force calculating section includes:

a target control value calculating section which calculates a target movement angle of the marine vessel with respect to a stem direction of the hull and a target combined propulsive force to be applied to the hull by the propulsion systems, based on a deviation of the current marine vessel position detected by the position detecting section from the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section; and

an individual target propulsive force calculating section which calculates the target propulsive forces to be generated from the respective propulsion systems, based on the target movement angle and the target combined propulsive force calculated by the target control value calculating section.

3. A marine vessel maneuvering supporting apparatus as set forth in claim 1, further comprising a target movement direction inputting section which inputs one of a +x direc-

tion and a $-x$ direction defined along the x -axis and a $+y$ direction and a $-y$ direction defined along the y -axis as the target movement direction of the marine vessel, wherein

the target propulsive force calculating section calculates the target propulsive forces to be generated from the respective propulsion systems such that the y -coordinate of the current marine vessel position is maintained substantially equal to the y -coordinate of the marine vessel maneuvering support starting position if the target movement direction input by the target movement direction inputting section is the $+x$ direction or the $-x$ direction, and the x -coordinate of the current marine vessel position is maintained substantially equal to the x -coordinate of the marine vessel maneuvering support starting position if the target movement direction input by the target movement direction inputting section is the $+y$ direction or the $-y$ direction.

4. A marine vessel maneuvering supporting apparatus as set forth in claim 3, wherein the target propulsive force calculating section calculates the target propulsive forces to be generated from the respective propulsion systems such that the x - and y -coordinates of the current marine vessel position are maintained substantially equal to the x - and y -coordinates of the marine vessel maneuvering support starting position if nothing is input by the target movement direction inputting section.

5. A marine vessel maneuvering supporting apparatus as set forth in claim 1, further comprising a proximity state detecting section which detects a proximity state of the marine vessel, wherein

the target propulsive force calculating section includes a proximity state maintaining target propulsive force calculating section which calculates the target propulsive forces to be generated from the respective propulsion systems such that the marine vessel is maintained in the proximity state when the proximity state detecting section detects the proximity state.

6. A marine vessel maneuvering supporting apparatus as set forth in claim 1, further comprising an angular speed detecting section which detects the turning angular speed of the marine vessel, wherein

the steering controlling section includes a target steering angle calculating section which calculates target steering angles of the respective steering mechanisms such that the turning angular speed detected by the angular speed detecting section is set at zero.

7. A marine vessel maneuvering supporting apparatus for performing a moorage marine vessel maneuvering support operation to support maneuvering of a marine vessel for moorage of the marine vessel, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of a hull of the marine vessel, and a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull, the marine vessel maneuvering supporting apparatus comprising:

a proximity state detecting section which detects a proximity state of the marine vessel; and

a proximity state maintaining controlling section which controls the steering mechanisms and the propulsion

systems so as to maintain the marine vessel in the proximity state when the proximity state detecting section detects the proximity state.

8. A marine vessel maneuvering supporting apparatus as set forth in claim 7, wherein the proximity state maintaining controlling section includes:

a steering controlling section which controls the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero;

a target propulsive force calculating section which calculates target propulsive forces to be generated from the respective propulsion systems such that the marine vessel is maintained in the proximity state detected by the proximity state detecting section; and

a propulsive force controlling section which controls the propulsion systems so as to attain the target propulsive forces calculated by the target propulsive force calculating section.

9. A marine vessel maneuvering supporting apparatus as set forth in claim 8, further comprising an angular speed detecting section which detects the turning angular speed of the marine vessel, wherein

the steering controlling section includes a target steering angle calculating section which calculates target steering angles of the respective steering mechanisms such that the turning angular speed detected by the angular speed detecting section is set at zero.

10. A marine vessel comprising:

a hull;

a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of the hull;

a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull; and

a marine vessel maneuvering supporting apparatus for performing a stationary marine vessel maneuvering support operation to support maneuvering of the marine vessel in a stationary state, wherein the marine vessel maneuvering supporting apparatus includes:

a position detecting section which detects a position of the marine vessel;

a marine vessel maneuvering support starting command section which outputs a stationary marine vessel maneuvering support starting command for starting the stationary marine vessel maneuvering support operation;

a marine vessel maneuvering support starting position storing section which stores a marine vessel maneuvering support starting position that is defined by a marine vessel position detected by the position detecting section in response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering support starting command section;

a steering controlling section which controls the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero in

response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering support starting command section;

a target propulsive force calculating section which calculates, in response to the marine vessel maneuvering support starting command output from the marine vessel maneuvering support starting command section, target propulsive forces to be generated from the respective propulsion systems, based on a current marine vessel position detected by the position detecting section, such that at least one of x- and y-coordinates of the current marine vessel position defined with respect to an x-axis defined along a center line of the hull extending through a stem and a stern of the hull and a y-axis extending perpendicularly to the center line is maintained substantially equal to a corresponding one of x- and y-coordinates of the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section; and

a propulsive force controlling section which controls the propulsion systems to attain the target propulsive forces calculated by the target propulsive force calculating section.

11. A marine vessel comprising:

a hull;

a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of the hull;

a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull; and

a marine vessel maneuvering supporting apparatus for performing a moorage marine vessel maneuvering support operation to support maneuvering of the marine vessel for moorage of the marine vessel, wherein the marine vessel maneuvering supporting apparatus includes:

a proximity state detecting section which detects a proximity state of the marine vessel; and

a proximity state maintaining controlling section which controls the steering mechanisms and the propulsion systems so as to maintain the marine vessel in the proximity state when the proximity state detecting section detects the proximity state.

12. A marine vessel maneuvering supporting method for performing a stationary marine vessel maneuvering support operation to support maneuvering of a marine vessel in a stationary state, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of a hull of the marine vessel, and a pair of steering mechanisms which respectively change steering angles defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull, the method comprising the steps of:

storing a marine vessel maneuvering support starting position at which the stationary marine vessel maneu-

vering support operation is started in a marine vessel maneuvering support starting position storing section;

controlling the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero;

calculating target propulsive forces to be generated from the respective propulsion systems such that at least one of x- and y-coordinates of a current position of the marine vessel defined with respect to an x-axis defined along a center line extending through a stem and a stern of the hull and a y-axis extending substantially perpendicularly to the center line is maintained substantially equal to a corresponding one of x- and y-coordinates of the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section; and

controlling the propulsion systems so as to attain the calculated target propulsive forces.

13. A marine vessel maneuvering supporting method as set forth in claim 12, wherein the target propulsive force calculating step includes the steps of:

calculating a target movement angle of the marine vessel with respect to a stem direction of the hull and a target combined propulsive force to be applied to the hull by the propulsion systems, based on a deviation of the current marine vessel position from the marine vessel maneuvering support starting position stored in the marine vessel maneuvering support starting position storing section; and

calculating the target propulsive forces to be generated from the respective propulsion systems, based on the calculated target movement angle and the calculated target combined propulsive force.

14. A marine vessel maneuvering supporting method as set forth in claim 12, wherein

the marine vessel further includes a target movement direction inputting section which inputs one of a +x direction and a -x direction defined along the x-axis and a +y direction and a -y direction defined along the y-axis as the target movement direction of the marine vessel, and

the target propulsive force calculating step includes the step of calculating the target propulsive forces to be generated from the respective propulsion systems such that the y-coordinate of the current marine vessel position is maintained substantially equal to the y-coordinate of the marine vessel maneuvering support starting position if the target movement direction input by the target movement direction inputting section is the +x direction or the -x direction, and the x-coordinate of the current marine vessel position is maintained substantially equal to the x-coordinate of the marine vessel maneuvering support starting position if the target movement direction input by the target movement direction inputting section is the +y direction or the -y direction.

15. A marine vessel maneuvering supporting method as set forth in claim 14, wherein

the target propulsive force calculating step includes the step of calculating the target propulsive forces to be

generated from the respective propulsion systems such that the x- and y-coordinates of the current marine vessel position are maintained substantially equal to the x- and y-coordinates of the marine vessel maneuvering support starting position if nothing is input by the target movement direction inputting section.

16. A marine vessel maneuvering supporting method as set forth in claim 12, further comprising the step of detecting a proximity state of the marine vessel, wherein

the target propulsive force calculating step includes the step of calculating the target propulsive forces to be generated from the respective propulsion systems such that the marine vessel is maintained in the proximity state when the proximity state is detected.

17. A marine vessel maneuvering supporting method for performing a moorage marine vessel maneuvering support operation to support maneuvering of a marine vessel for moorage of the marine vessel, the marine vessel including a pair of propulsion systems which respectively generate propulsive forces on a rear port side and a rear starboard side of a hull of the marine vessel, and a pair of steering mechanisms which respectively change steering angles

defined by directions of the propulsive forces generated by the respective propulsion systems with respect to the hull, the method comprising the steps of:

detecting a proximity state of the marine vessel; and

controlling the steering mechanisms and the propulsion systems so as to maintain the marine vessel in the proximity state when the proximity state is detected.

18. A marine vessel maneuvering supporting method as set forth in claim 17, wherein the proximity state maintaining step includes the steps of:

controlling the steering angles of the respective steering mechanisms such that the marine vessel has a turning angular speed of zero;

calculating target propulsive forces to be generated from the respective propulsion systems such that the marine vessel is maintained in the detected proximity state; and

controlling the propulsion systems so as to attain the calculated target propulsive forces.

* * * * *