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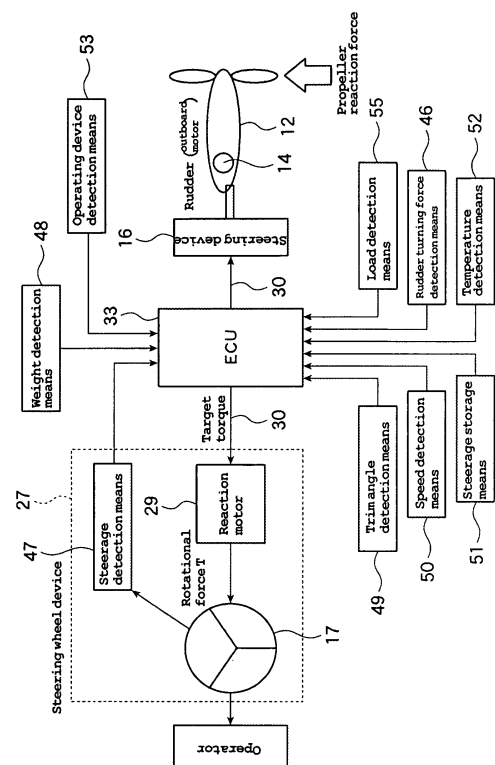
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(54) **Steering system for a watercraft**

(57) The present invention relates to a steering system for a watercraft, comprising: a watercraft propulsion unit (12), a steering device (16) actuated by an actuator (20) for changing a direction in which the watercraft travels, and a steering amount input means such as a steering wheel (17), operable by an operator, and electrically connected to the actuator (20) to provide an actuation signal corresponding to an operation amount of the actuator (20), and a control unit (33) comprising at least one of steerage status detection means (38) for detecting a steerage status following an operation of the steering amount input means (17), running status detection means (39) for detecting a running status of the watercraft, watercraft propulsion unit status recognition means (40) for recognizing a status of the watercraft propulsion unit such as an installation number thereof, and actuator status detection means (41) for detecting a status of the actuator (20); and comprising rudder turning force characteristic computation means (37) for computing a rudder turning force characteristic based on a detection value from at least one of the detection and recognition means; and control means (42,43,44,56) for controlling at least one of a reaction force to the steering amount input means (17), a limit rudder turning angle, and a propulsive force based on a computed rudder turning force characteristic and/or selecting the actuator to operate.

[FIG. 3]



Description

[0001] The present invention relates to a steering system for a watercraft, and in particular to a watercraft steering device having an electric actuator which is actuated as an operator operates a steering wheel for turning a rudder, and a watercraft provided with the steering device.

[0002] One conventional watercraft of this type is disclosed in Patent Document 1.

[0003] More specifically, Patent Document 1 discloses that "the electric actuator of the steering device is actuated as an operator operates the steering wheel. The watercraft is steered in response to the operation amount of the steering wheel. Further, an external force to the watercraft is detected. Based on the detected external force, a reaction torque is applied to the steering wheel. Accordingly, the operator can feel the external force to the watercraft due to a water current for example, directly through the steering wheel, and thus can recognize the movement of the watercraft corresponding to such an external force to thereby act without delay."

Patent Document 1: JP-A-2005-254848

[0004] In such conventional watercrafts, a reaction torque is applied to the steering wheel based on an external force to the watercraft. An operator can feel such an external force applied to the watercraft due to water current for example, directly through the steering wheel, and thus can recognize the movement of the watercraft corresponding to the external force to thereby act without delay. When the external force applied to the watercraft is small, an operation feeling of the steering wheel can be lighter. In the case where larger output is required for turning the rudder (rudder turning torque), when the steering wheel is operated faster, output from the steering motor (electric actuator) becomes less responsive.

[0005] Incidentally, rudder turning torque characteristic required for turning the rudder (required rudder turning force characteristic), as shown in FIG. 12, may change from the state shown by required rudder turning force characteristic line A1 to the state shown by required rudder turning force characteristic line A2, depending on a characteristic of the watercraft, a rudder turning angle, a steerage speed, and so forth. In such a case, a required rudder turning force may exceed the limit of the motor ability.

[0006] Further, as shown in FIG. 13, motor characteristic depends on the ambient condition such as temperature. When the temperature becomes high for example, the motor characteristic may change from the state shown by motor characteristic line B1 (solid line in the figure) to the state shown by motor characteristic line B2 (broken line in the figure). In such a case, a required rudder turning force exceeds the limit of the motor ability and responsiveness may be impaired.

[0007] In view of the foregoing problem, it is, therefore, an object of the present invention to provide a steering system for a watercraft and a watercraft with such steer-

ing system that enable rudder turning with constant effectiveness and excellent operation feeling corresponding to a running status of the watercraft.

[0008] This objective is solved in an inventive manner by a steering system for a watercraft, comprising: a watercraft propulsion unit, a steering device actuated by an actuator for changing a direction in which the watercraft travels, and a steering amount input means, operable by an operator, and electrically connected to the actuator to provided an actuation signal corresponding to an operation amount of the actuator, at least one of steerage status detection means for detecting a steerage status following an operation of the steering amount input means, running status detection means for detecting a running status of the watercraft, watercraft propulsion unit status recognition means for recognizing a status of the watercraft propulsion unit such as an installation number thereof, and actuator status detection means for detecting a status of the actuator; and comprising rudder turning force characteristic computation means for computing a rudder turning force characteristic based on a detection value from at least one of the detection and recognition means; and control means for controlling at least one of a reaction force to the steering amount input means, a limit rudder turning angle, and a propulsive force based on a computed rudder turning force characteristic and/or selecting the actuator to operate.

[0009] Preferably, the watercraft propulsion unit, in particular arranged at a stern of the watercraft, is used as the rudder.

[0010] Further, preferably the actuator configured to change a direction in which the watercraft travels is an electric actuator.

[0011] Still further, preferably the control means includes reaction actuator control means for controlling a reaction force to the steering amount input means, rudder turning angle control means for controlling a limit rudder turning force, and propulsive force control means for controlling a propulsive force.

[0012] Therein, it is beneficial if the control means controls a reaction force to the steering amount input means, a limit rudder turning angle, and a propulsive force based on a steerage status detected by the steerage status detection means, a running status detected by the running status detection means, a watercraft propulsion unit status recognized by the watercraft propulsion unit status recognition means, and a motor characteristic status detected by the motor detection means.

[0013] It is further beneficial if the steerage status detection means includes at least one of rudder turning force detection means for detecting a rudder turning force required for a rudder turning following the operation of the steering amount input means, load detection means for detecting a load acting on the rudder, steerage detection means for detecting a steering amount input means steerage angle, a steering amount input means steerage speed, a direction in which the steering amount input means is operated, a rudder turning angle, a rudder

turning speed, and a direction in which the rudder is turned, corresponding to an operation of the steering amount input means, and deviation detection means for detecting a deviation between a target rudder turning angle position corresponding to an operation of the steering amount input means and an actual rudder turning angle.

[0014] Preferably, the running status detection means includes at least one of weight detection means for detecting at least one of a draft position and a weight of the watercraft, trim angle detection means for detecting a trim angle of the watercraft, and speed detection means for detecting at least one of a speed, an acceleration, a propulsive force of the watercraft, and an output of the watercraft propulsion unit.

[0015] Further, preferably the watercraft propulsion unit status recognition means includes steerage storage means for storing therein any one of information among an installation number of the watercraft propulsion unit, an installation position of the watercraft propulsion unit relative to the watercraft, a rotational direction of a propeller provided in the watercraft propulsion unit, a propeller shape, a trim tab angle, and a trim tab shape.

[0016] Still further, preferably the actuator status detection means is an electric actuator status detection means, which includes at least one of temperature detection means for detecting a temperature of the electric actuator, and operating number detection means for detecting a number of the electric actuator in operation among a plurality of the electric actuator.

[0017] Yet further still, preferably the steering amount input means is a steering wheel or a control lever, operable by an operator, electrically connected to the electric actuator to provide an actuation signal corresponding to the amount of a steering operation input to the electric actuator.

[0018] There is further provided a watercraft steering device according to any one of the above embodiments.

[0019] In the following, the present invention is explained in greater detail with respect to several embodiments thereof in conjunction with the accompanying drawings, wherein:

FIG. 1 is a plan view of a watercraft according to an embodiment,

FIG. 2 is an enlarged plan view of a steering device of the watercraft according to the embodiment,

FIG. 3 is a block diagram of the watercraft according to the embodiment,

FIG. 4 is a block diagram showing an ECU according to the embodiment,

FIG. 5 is a flowchart of reaction control according to the embodiment,

FIGs. 6 are graphs showing a reaction control state depending on a rudder turning status according to the embodiment,

5 FIGs. 7 are graphs showing an effect of a reaction control according to the embodiment,

FIG. 8 is a schematic view showing a state that two outboard motors are mounted according to the embodiment,

10 FIG. 9 is a schematic view showing a state that three outboard motors are mounted according to the embodiment,

15 FIGs. 10 are graphs according to the embodiment. FIG. 10(a) shows the relationship between rudder turning speed and rudder turning force. FIG. 10(b) shows the relationship between rudder turning force and rudder turning angle,

20 FIGs. 11 are graphs according to the embodiment. FIGs. 11 (a), (b), and (c) show the relationship between rudder turning speed and rudder turning force based on a computation result of a rudder turning ability. FIG. 11 (d) shows the relationship between rudder turning speed and rudder turning force based on a selection of an electric motor,

25 FIG. 12 is a graph of a required rudder turning force characteristic showing the relationship between rudder turning torque and rudder turning speed, and

30 FIG. 13 is a graph of a motor characteristic showing the relationship between generated torque of the electric motor and rotational speed.

Description of Reference Numerals:

[0020]

- 45 10: hull
12: outboard motor (watercraft propulsion unit)
16: steering device
17: steering wheel
20: electric motor
50 28: steering wheel steerage angle sensor
29: reaction motor
33: ECU (control unit)
38: steerage status detection means
37: rudder turning force characteristic computation means
55 39: running status detection means
40: outboard motor status recognition means (watercraft propulsion unit status recognition means)

41: electric motor status detection means (electric actuator status detection means)
 42: reaction motor control means
 43: rudder turning angle control means
 44: propulsive force control means
 45: deviation detection means
 46: rudder turning force detection means
 47: steerage detection means
 48: weight detection means
 49: trim angle detection means
 50: speed detection means
 51: steerage storage means
 52: temperature detection means
 53: operating number detection means
 54: determination means
 55: load detection means
 56: selection control means

[0021] An embodiment will be described hereinafter.

[0022] FIGs. 1 through 11 shows an embodiment.

[0023] The constitution of this embodiment will be first described. As shown in FIG. 1, a watercraft in accordance with this embodiment has a hull 10 including a transom 11. To the transom 11, an outboard motor 12 as a "watercraft propulsion unit" is mounted via clamp brackets 13. The outboard motor 12 is pivotable about a swivel shaft (steering pivot shaft) 14 extending in a vertical direction. The outboard motor 12 serves as a rudder as it pivots, and thus a direction in which the watercraft is driven is changed.

[0024] A steering bracket 15 is fixed at the upper end of the swivel shaft 14. The steering bracket 15 is coupled at its front end 15a to a steering device 16. The steering device 16 is operated and driven by a steering wheel 17 disposed in an operator's seat.

[0025] As shown in FIG. 2, the steering device 16 includes a DD (direct drive) electric motor 20 for example, as an "electric actuator." The electric motor 20 is attached to a threaded rod 21 extending in a width direction of the watercraft, and is movable in the width direction of the watercraft along the threaded rod 21.

[0026] The threaded rod 21 is supported at its both ends by a pair of left and right support members 22. The support members 22 are supported by a tilt shaft 23.

[0027] The electric motor 20 has a coupling bracket 24 protruding rearward. The coupling bracket 24 and the steering bracket 15 are coupled with each other via a coupling pin 25.

[0028] As the electric motor 20 is actuated to move in the width direction of the watercraft relative to the threaded rod 21, the outboard motor 12 pivots about the swivel shaft 14 via the coupling bracket 24 and the steering bracket 15.

[0029] On the other hand, as shown in FIG. 1, the steering wheel 17 is fixed to a steering wheel shaft 26. At the proximal end of the steering shaft 26, there is provided a steering wheel control unit 27. The steering wheel control unit 27 is provided with a steering wheel steerage

angle sensor 28 for detecting a steerage angle of the steering wheel 17, and a reaction motor 29 for applying a desired reaction force to the steering wheel 17 during an operation of the steering wheel 17 by an operator.

[0030] The steering wheel control unit 27 is connected to an electronic control unit (ECU) 33 as "control means" via a signal cable 30. The control unit 33 is connected to the electric motor 20 of the steering device 16. The control unit 33 receives a signal from the steering wheel steerage angle sensor 28, controls the electric motor 20, and controls the reaction motor 29 and an engine of the outboard motor 12.

[0031] As shown in FIG. 4, the control unit 33 is provided with steerage status detection means 38 for detecting a steerage status corresponding to an operator's steering wheel operation, running status detection means 39 for detecting a running status of the watercraft, outboard motor status recognition means 40 as "watercraft propulsion unit status recognition means" for recognizing a status of the outboard motor 12 such as its installation number, and electric motor status detection means 41 as "electric actuator status detection means" for detecting a status of the electric motor 20. The control unit 33 also includes rudder turning force characteristic computation means 37 for computing a rudder turning force characteristic based on detection values from those means 38... and the like, reaction motor control means 42 as "reaction actuator control means" for controlling a reaction force to the steering wheel 17, rudder turning angle control means 43 for reducing a limit rudder turning angle, propulsive force control means 44 for controlling a propulsive force, and selection control means 56 for selecting the electric motor 20 to be operated.

[0032] As shown in FIG. 3, the steerage status detection means 38 is connected to rudder turning force detection means 46 for detecting a rudder turning force required for turning the rudder, load detection means 55 for detecting a load acting on the rudder, steerage detection means 47 for detecting a steering wheel steerage angle, a steering wheel steerage speed, a direction in which the steering wheel is operated, a rudder turning angle, a rudder turning speed, and a direction in which the rudder is turned, corresponding to the operation of the steering wheel, and deviation detection means 45 for detecting a deviation of a detected actual rudder turning angle from a target rudder turning angle corresponding to the steering wheel operation, as shown in FIG. 4. The steering wheel steerage angle sensor 28 provided in the steerage detection means 47 detects a steerage angle.

[0033] As shown in FIG. 3, the running status detection means 39 is connected to weight detection means 48 for detecting a draft position and a weight of the watercraft, trim angle detection means 49 for detecting a trim angle of the watercraft, speed detection means 50 for detecting a speed, an acceleration and a propulsive force of the watercraft, and an output of the outboard motor 12, and PTT actuation status detection means (not shown) for detecting a PTT actuation status.

[0034] Further, the outboard motor status recognition means 40 is connected to steerage storage means 51 for storing therein information about an installation number of the outboard motor 12, an installation position of the outboard motor 12 relative to the watercraft, a rotational direction, a size, and a shape of a propeller provided in the outboard motor 12, a trim tab angle, a trim tab shape, and the like. It is a matter of course that the steerage storage means 51 can be included in the ECU 33.

[0035] In addition, the electric motor status detection means 41 is connected to temperature detection means 52 for detecting a temperature of the electric motor 20, and operating number detection means 53 for detecting a number of the electric motor 20 in operation among a plurality of the electric motors 20 and which electric motor 20 is in operation in the case that a plurality of the outboard motors 12 are mounted and a plurality of the electric motors 20 are provided, and so forth.

[0036] Next, the effect of this embodiment will be described.

[0037] When an operator first turns the steering wheel 17 by a certain amount in a certain direction, a signal is sent from the steering wheel steerage angle sensor 28 of the steerage detection means 47 to the ECU 33. A target rudder turning angle is detected by the steerage status detection means 38, and a deviation between the target rudder turning angle and an actual angle of the rudder (target control deviation) is computed.

[0038] A steerage status is detected by the steerage status detection means 38 in step S10 in FIG. 5. A steerage status means statuses such as a required rudder turning force corresponding to an operation of the steering wheel, a load acting on the rudder (the outboard motor 12), a steering wheel steerage angle, a steering wheel steerage speed, a direction in which the steering wheel is operated, a rudder (the outboard motor 12) turning angle, a rudder turning speed, and a direction in which the rudder is turned, corresponding to the operation of the steering wheel, a deviation mentioned above, and so forth.

[0039] A rudder turning force required for a rudder turning corresponding to an operation of the steering wheel is detected by the rudder turning force detection means 46. Load acting on the rudder is detected by the load detection means 55. A steering wheel steerage angle, a steering wheel steerage speed, a direction in which the steering wheel is operated, a rudder turning angle, a rudder turning speed, a direction in which the rudder is turned, corresponding to the operation of the steering wheel, are detected by the steerage detection means 47. Those detection signals are sent to the steerage status detection means 38, and thereby a steerage status is detected.

[0040] A running status is detected by the running status detection means 39 in step S11. A running status means statuses such as a draft position, a weight and a trim angle of the watercraft, a speed, an acceleration, a

deceleration and a propulsive force of the watercraft, and an output of the outboard motor 12, and so forth.

[0041] Further, the draft position and the weight of the watercraft are detected by the weight detection means 48. A trim angle of the watercraft is detected by the trim angle detection means 49. The speed, the acceleration, the propulsive force of the watercraft and the output of the outboard motor 12 are detected by the speed detection means 50. Those detection signals are sent to the running status detection means 39, and thereby a running status is detected.

[0042] In addition, a status of the outboard motor 12 is recognized by the outboard motor status recognition means 40 in step S12. A status of the outboard motor means statuses such as an installation number of the outboard motor 12, an installation position of the outboard motor 12 relative to the watercraft, a rotational direction of the propeller provided in the outboard motor 12, a propeller size, a propeller shape, a trim tab angle and a trim tab shape, and so forth.

[0043] Information about an installation number of the outboard motor 12, an installation position of the outboard motor 12 relative to the watercraft, and the rotational direction of the propeller provided in the outboard motor 12 is stored in the steerage storage means 51. This information is read out and sent to the outboard motor status recognition means 40, and thereby a status of the outboard motor 12 is recognized.

[0044] Next, a status of the electric motor 20 is detected by the electric motor status detection means 41 in step S13. A status of the electric motor 20 is a status of a factor which has an affect on an output characteristic of the electric motor 20, and means statuses such as a temperature and a voltage of the electric motor 20, and a number of the electric motor in operation or which actuation motor 20 is in operation, and so forth.

[0045] A temperature of the electric motor 20 is detected by the temperature detection means 52. Information about a number of the electric motor 20 in operation and which electric motor 20 is in operation is detected by the operating number detection means 53. Those detection signals are sent to the electric motor status detection means 41, and thereby a status of the electric motor 20 is detected.

[0046] In step S14, an ability in the case that the electric motor 20 makes a rudder turning is computed with a signal from the electric motor status detection means 41 based on those detection values. Also, in step S15, a rudder turning force characteristic is computed by the rudder turning force characteristic computation means 37 with signals from the steerage status detection means 38 and the running status detection means 39, and so forth.

[0047] In step S16, a determination about if rudder turning control is necessary or not is made by a determination means 54. That is, in step S16, if the determination means 54 determines that a rudder turning ability of the electric motor 20 computed in step S14 satisfies a rudder

turning force characteristic required for a rudder turning computed in step S15, the determination is "NO" because a control is not necessary. Now, the process goes to step S17, a rudder turning actuation is made and the process returns to step S10.

[0048] On the other hand, in step S16, if a determination is conversely made that a rudder turning ability of the electric motor 20 computed in step S14 does not satisfy a rudder turning force characteristic required for a rudder turning computed in step S15, the determination is "YES" because a control is necessary. The process goes to step S18, and a motor actuation setting of the reaction motor 29, the electric motor 20, the engine and the like is made.

[0049] In step S19, the reaction motor 29 is actuated and a reaction force control is made. In step S20, an actuation length of the electric motor 20 is controlled and a rudder turning angle is controlled. In step S21, a propulsive force of the engine of the outboard motor 12 is controlled. Further, in step S22, a control for selecting the electric motor 20 to operate is made. Then, the process goes to step S17, a rudder turning actuation is made, and the process returns to step S10.

[0050] Thereby, a reaction force control, a rudder turning angle control, a propulsive force control, and a selection control of the electric motor 20 are made corresponding to a running status and so forth of the watercraft as an operator operates. Therefore, an actuation of the electric motor 20 is constantly effective, and an operator can steer with an excellent operation feeling.

[0051] More specifically,

(1) A control corresponding to a steerage status is made so that a reaction force is larger, a limit rudder turning force is smaller, a propulsive force is smaller, or a number of the electric motor 20 to operate is larger, or the electric motor 20 with a larger output is selected as a steerage speed is faster or a steerage angle is larger.

Usually, a required rudder turning load becomes larger as a steerage speed is faster in the watercraft steering device in which the steering wheel 17 is connected to the outboard motor 12 by a mechanical cable. Therefore, in this embodiment, corresponding to such a situation, a control is made so that a reaction force is large, a limit rudder turning angle is small, a propulsive force is small, or a number of the electric motor 20 to operate is large, or the electric motor 20 with a large output is selected.

More specifically, in FIG. 6, the relationship between rudder turning force and rudder angle is a proportional relationship such that a rudder turning force increases as a rudder angle increases as shown in (b). The relationship between rudder turning force and rudder turning speed is a proportional relationship such that a rudder turning force increases as a rudder turning speed increases as shown in (c). In the case of (b), or the case of (c) and the relationship

between rudder turning speed and rudder turning force is set in a manner that the broken line in (a) represents the rudder turning ability characteristic line, a reaction force of the steering wheel 17 does not have to be increased more than a present size if a rudder angle is value a_1 and inside the area of the rudder turning ability characteristic line, and rudder turning responsiveness can be assured.

On the other hand, if a rudder turning speed is value b_1 and outside the area of the rudder turning ability characteristic line, rudder turning responsiveness can be assured by increasing a reaction force of the steering wheel 17 and thereby making the value fall inside the area of the rudder turning ability characteristic line as shown by value b_2 in FIG. 6(a).

That is, if a reaction force value is increased from d_1 to d_2 as shown in FIG. 7(a), a steerage speed of the steering wheel 17 slows down from d_1 to d_2 , and thereby a steerage speed is slowed down from e_1 to e_2 as shown in FIG. 7(b).

As a result, as shown in FIG. 7(c), a steerage angle (rudder angle) sharply changes about time t as shown by the broken line in the figure in an operation of the steering wheel 17 in a conventional situation that a reaction force is not controlled. However, a reaction force is increased as mentioned above, and thereby a change of steerage angle (rudder angle) about time t is mild as shown by the solid line in the figure.

(2) A control corresponding to a running status is made so that a reaction force is large, a limit rudder turning angle is small, a propulsive force is small, or a number of the electric motor 20 to be operated is large, or the electric motor 20 with a large output is selected when the watercraft is sailing at a high speed, the watercraft is heavy, the watercraft is in a trim in state, the watercraft is accelerating or decelerating, or the like.

In the usual watercraft steering device in which the steering wheel 17 is connected to the outboard motor 12 by a mechanical cable, a required rudder turning load increases when the watercraft is sailing at a high speed, the watercraft is heavy, the watercraft is in a trim in state, the watercraft is accelerating or decelerating, or the like. Therefore, in this embodiment, corresponding to such a situation, a control is made so that a reaction force is large, a limit rudder turning angle is small, a propulsive force is small, or a number of the electric motor 20 to operate is large, or the electric motor 20 with a large output is selected.

(3) A control corresponding to a status of the outboard motor 12 is made so that a reaction force is large, a limit rudder turning angle is small, a propulsive force is small, or a number of the electric motor 20 to operate is large, or the electric motor 20 with a large output is selected. In the case that a propeller reaction force occurs in one direction due to a rota-

tional direction of the propeller provided in the outboard motor 12, a control is made so that a reaction force is larger, a limit rudder turning angle is smaller, a propulsive force is smaller, or a number of the electric motor 20 to be operated is larger, or the electric motor 20 with a larger output is selected comparing with a rudder turning in the opposite direction when a rudder turn is made in the direction resisting to the propeller reaction force.

In the watercraft in which the steering wheel 17 is connected to the outboard motor 12 by a cable, as shown in FIG. 3, a required rudder turning load becomes larger in a steerage in the direction opposite to a direction that the outboard motor 12 receives a propeller reaction force than in a rudder turning in the direction that the outboard motor 12 receives a propeller reaction force. Therefore, in this embodiment, corresponding to such a situation, a control is made so that a reaction force is large, a limit rudder turning angle is small, a propulsive force is small, or a number of the electric motor 20 to be operated is large, or the electric motor 20 with a large output is selected.

An installation position of the outboard motor 12 provides a different load characteristic depending on if a rudder turning is to the left or to the right in the case that a plurality of the outboard motors 12 are mounted and the watercraft is actually running using only a part of those outboard motors 12, or in the case that a trim status of each outboard motor 12 is different (the case that the depths that lower parts of the outboard motors 12 immersed in water are different). Therefore, a reaction force, a limit rudder turning angle and a propulsive force in a rudder turning are corrected corresponding to installation positions or differences in trim angles of the outboard motors 12. For example, in the case that a rudder turning is made to a side where the outboard motor 12 with a small trim angle is mounted, a reaction force in turning the steering wheel back after a rudder turning is increased.

FIG. 8 shows a case that two outboard motors 12 are mounted. FIG. 9 shows a case that three outboard motors 12 are mounted. FIG. 8(a) shows a case that both the outboard motors are operating as shown by the solid line in the figure. FIG. 8(b) shows a case that one of the two outboard motors 12 is operating as shown by the solid line in the figure. FIG. 8(c) shows a case that the steering device 16 of one of the two outboard motors 12 shown by the broken line is out of order. FIG. 9(a) shows a case that all the three outboard motors 12 are operating as shown by the solid line. FIG. 9(b) shows a case that two of the three outboard motors 12 on both the sides (motor S, motor P) shown by the solid line are operating. FIG. 9(c) shows a case that one of the three outboard motors 12 in the middle (motor C) shown by the solid line is operating.

(4) In a control corresponding to a motor status, the electric motor 20 exhibits a motor characteristic shown by the broken line in FIG. 13 mentioned above and a less torque is output as a motor temperature rises. Therefore, to prevent a case that the electric motor 20 overshoots its ability limit, a control is made so that a reaction force is large, a limit rudder turning angle is small, a propulsive force is small, or a number of the electric motor 20 to operate is large, or the electric motor 20 with a large output is selected.

[0052] In the case that a plurality of the electric motors 20 are used, a reaction force is made larger, a limit rudder turning angle is made smaller, and a propulsive force is made smaller as a number of the electric motor that can operate among those electric motors 20 is less so that the electric motor 20 does not overshoot its ability limit.

[0053] As foregoing, the steering wheel 17 can be operated lightly because a rudder turning of the outboard motor 12 is operated with the electric motor 20 in the watercraft. However, if the rudder is excessively turned for example, a larger load is required in turning the rudder back than in turning the rudder to a certain side. Therefore, an output from the electric motor 20 becomes less responsive, and an operation feeling of a rudder turning action may be deteriorated. However, in this embodiment, a reaction force is made large, a limit rudder turning angle is made small, and a propulsive force is made small corresponding to a motor characteristic of the electric motor 20, and thereby a limit of the motor characteristic is not exceeded in turning the rudder back.

[0054] Therefore, an operation feeling of a rudder turning action is not deteriorated in turning the rudder back because the outboard motor 12 is steered in an output range of the electric motor 20.

[0055] That is, as shown in FIG. 10(b), the relationship between rudder turning angle and rudder turning force changes from a characteristic shown by the solid line in the figure to a characteristic shown by the broken line in the figure as variables such as a watercraft speed, a trim angle, a weight, an acceleration, a deceleration and so forth in a running status, an electric motor status and so forth increase. In such a situation, a certain rudder turning angle corresponding to position a1 on a characteristic line represented by the solid line corresponds to position a2 on a characteristic line represented by the broken line, and a rudder turning force becomes larger to correspond to position a2. A certain rudder turning force corresponding to position a1 on the characteristic line represented by the solid line corresponds to position a3 of the characteristic represented by the broken line, and a rudder turning angle becomes smaller to correspond to position a3.

[0056] If a rudder turning force and so forth become larger in such a case and a limit rudder turning angle is large, a value may fall outside of the area of ability characteristic line C of the electric motor 20 as shown by

position b1 on characteristic line B1 in FIG. 10(a) that shows the relationship between rudder turning force and rudder turning speed. In such a case, a limit rudder turning angle is controlled by a small amount in the present invention, and thereby a motor characteristic is changed as characteristic line B2. As shown by position b2, a rudder turning force becomes smaller at a rudder turning speed corresponding to position b1, and falls inside the area of ability characteristic line C. Therefore, the outboard motor 12 can be steered in the output area of the electric motor 20, and thereby a response delay to a rudder turning action does not occur.

[0057] On the other hand, in a selection control of the electric motor 20, a computation is made corresponding to a status of each electric motor 20, and, at the same time, a computation is made to obtain a rudder turning force characteristic in the case that a plurality of the electric motors 20 are selected from the electric motors 20 that can operate among the electric motors 20. The electric motor 20 and its operating number such that a rudder turning ability exceeds a required rudder turning force characteristic are selected. For example, in the case that a rudder turning force of an electric motor A, a rudder turning force of electric motors A + B, and a rudder turning force of electric motors A + B + C are computed as shown by characteristic line a in FIG. 11 (a), characteristic line b in FIG. 11 (b), and characteristic line c in FIG. 11 (c), respectively, and a required rudder turning force characteristic is computed as shown by characteristic line d in FIG. 11(d), a rudder turning characteristic shown in FIG. 11 (a), (b) and (c) is compared with a required rudder turning force characteristic shown in FIG. 11 (d), and thereby a control is made so that, here, the rudder turning force characteristic exceeds the required rudder turning force characteristic, that is, the electric motors A + B + C operate as shown by characteristic line c in FIG. 11 (c).

[0058] It is a matter of course that while in the foregoing embodiment, the outboard motor 12 is used as the "watercraft propulsion unit," the present teaching is not limited to this, but it may include an inboard/outboard motor. Further, the foregoing embodiment includes the steerage status detection means 38, the running status detection means 39, the outboard motor status recognition means 40 and the electric motor status detection means 41. However, it is only required that at least one of those means is provided.

[0059] The description above discloses (amongst others), in order to achieve the foregoing object, an embodiment (first embodiment) of a watercraft steering device having a watercraft propulsion unit disposed at a stern of a watercraft, a steering device actuated by an electric actuator for changing a direction in which the watercraft travels, a steering wheel operable by an operator and electrically connected to the electric actuator to provided an actuation signal corresponding to an operation amount to the electric actuator, and further including at least one of steerage status detection means for detecting a steerage status following an operation of the steer-

ing wheel, running status detection means for detecting a running status of the watercraft, watercraft propulsion unit status recognition means for recognizing a status of the watercraft propulsion unit such as an installation number thereof, and electric actuator status detection means for detecting a status of the electric actuator; and further including rudder turning force characteristic computation means for computing a rudder turning force characteristic based on a detection value from at least one of the means; and control means for controlling at least one of a reaction force to the steering wheel, a limit rudder turning angle, and a propulsive force based on a computed rudder turning force characteristic and/or selecting the electric actuator in operation.

[0060] Further, according to a second embodiment, in addition to the constitution described in the first embodiment, the control means includes reaction actuator control means for controlling a reaction force to the steering wheel, rudder turning angle control means for controlling a limit rudder turning force and propulsive force control means for controlling a propulsive force.

[0061] Further, according to a third embodiment, in addition to the constitution described in the first or second embodiment, the control means controls a reaction force to the steering wheel, a limit rudder turning angle, and a propulsive force based on a steerage status detected by the steerage status detection means, a running status detected by the running status detection means, a watercraft propulsion unit status recognized by the watercraft propulsion unit status recognition means, and motor characteristic status detected by the motor detection means.

[0062] Further, according to a fourth embodiment, in addition to the constitution described in any one of the first to third embodiments, the steerage status detection means includes at least one of rudder turning force detection means for detecting a rudder turning force required for a rudder turning following the operation of the steering wheel, load detection means for detecting a load acting on the rudder, steerage detection means for detecting a steering wheel steerage angle, a steering wheel steerage speed, a direction in which the steering wheel is operated, a rudder turning angle, a rudder turning speed, and a direction in which the rudder is turned, corresponding to an operation of the steering wheel, and deviation detection means for detecting a deviation between a target rudder turning angle position corresponding to an operation of the steering wheel and an actual rudder turning angle.

[0063] Further, according to a fifth embodiment, in addition to the constitution described in any one of the first to fourth embodiments, the running status detection means includes at least one of weight detection means for detecting at least one of a draft position and a weight of the watercraft, trim angle detection means for detecting a trim angle of the watercraft, and speed detection means for detecting at least one of a speed, an acceleration, a propulsive force of the watercraft, and an output of the

watercraft propulsion unit.

[0064] Further, according to a sixth embodiment, in addition to the constitution described in any one of the first to fifth embodiments, the watercraft propulsion unit status recognition means includes steerage storage means for storing therein any one of information among an installation number of the watercraft propulsion unit, an installation position of the watercraft propulsion unit relative to the watercraft, a rotational direction of a propeller provided in the watercraft propulsion unit, a propeller shape, a trim tab angle, and a trim tab shape.

[0065] Further, according to a seventh embodiment, in addition to the constitution described in any one of the first to sixth embodiments, the electric actuator status detection means includes at least one of temperature detection means for detecting a temperature of the electric actuator, and operating number detection means for detecting a number of the electric actuator in operation among a plurality of the electric actuator.

[0066] Further, according to an eighth embodiment, there is provided a watercraft, in which the watercraft steering device described in any one of first to seventh embodiments is provided.

[0067] In accordance with the above embodiments, the watercraft steering device includes the control means, which has at least one of the steerage status detection means for detecting a steerage status following an operation of the steering wheel, the running status detection means for detecting a running status of the watercraft, the watercraft propulsion unit status recognition means for recognizing a status of the watercraft propulsion unit such as an installation number thereof, and the electric actuator status detection means for detecting a status of the electric actuator. The control means has also the rudder turning force computation means for computing a rudder turning force characteristic based on a detection value from at least one of the means, controls at least one of a reaction force to the steering wheel, a limit rudder turning angle, and a propulsive force based on a computed rudder turning force characteristic, and/or selects the electric actuator in operation. Therefore, the above aspects of the present teaching can provide a watercraft steering device and a watercraft that enables rudder turning with constant effectiveness and excellent operation feeling corresponding to a running status of the watercraft.

[0068] The description further discloses, according to a preferred first aspect, a watercraft steering device, having a watercraft propulsion unit disposed at a stern of a watercraft, a steering device actuated by an electric actuator for changing a direction in which the watercraft travels, and a steering wheel operable by an operator and electrically connected to the electric actuator to provide an actuation signal corresponding to an operation amount of the electric actuator, and further comprising: at least one of steerage status detection means for detecting a steerage status following an operation of the steering wheel, running status detection means for de-

tecting a running status of the watercraft, watercraft propulsion unit status recognition means for recognizing a status of the watercraft propulsion unit such as an installation number thereof, and electric actuator status detection means for detecting a status of the electric actuator; and further comprising: rudder turning force characteristic computation means for computing a rudder turning force characteristic based on a detection value from at least one of the means; and control means for controlling at least one of a reaction force to the steering wheel, a limit rudder turning angle, and a propulsive force based on a computed rudder turning force characteristic and/or selecting the electric actuator to operate.

[0069] Further, according to a preferred second aspect, the control means includes reaction actuator control means for controlling a reaction force to the steering wheel, rudder turning angle control means for controlling a limit rudder turning force, and propulsive force control means for controlling a propulsive force.

[0070] Further, according to a preferred third aspect, the control means controls a reaction force to the steering wheel, a limit rudder turning angle, and a propulsive force based on a steerage status detected by the steerage status detection means, a running status detected by the running status detection means, a watercraft propulsion unit status recognized by the watercraft propulsion unit status recognition means, and a motor characteristic status detected by the motor detection means.

[0071] Further, according to a preferred fourth aspect, the steerage status detection means includes at least one of rudder turning force detection means for detecting a rudder turning force required for a rudder turning following the operation of the steering wheel, load detection means for detecting a load acting on the rudder, steerage detection means for detecting a steering wheel steerage angle, a steering wheel steerage speed, a direction in which the steering wheel is operated, a rudder turning angle, a rudder turning speed, and a direction in which the rudder is turned, corresponding to an operation of the steering wheel, and deviation detection means for detecting a deviation between a target rudder turning angle position corresponding to an operation of the steering wheel and an actual rudder turning angle.

[0072] Further, according to a preferred fifth aspect, the running status detection means includes at least one of weight detection means for detecting at least one of a draft position and a weight of the watercraft, trim angle detection means for detecting a trim angle of the watercraft, and speed detection means for detecting at least one of a speed, an acceleration, a propulsive force of the watercraft, and an output of the watercraft propulsion unit.

[0073] Further, according to a preferred sixth aspect, the watercraft propulsion unit status recognition means includes steerage storage means for storing therein any one of information among an installation number of the watercraft propulsion unit, an installation position of the watercraft propulsion unit relative to the watercraft, a ro-

tational direction of a propeller provided in the watercraft propulsion unit, a propeller shape, a trim tab angle, and a trim tab shape.

[0074] Further, according to a preferred seventh aspect, the electric actuator status detection means includes at least one of temperature detection means for detecting a temperature of the electric actuator, and operating number detection means for detecting a number of the electric actuator in operation among a plurality of the electric actuator.

[0075] Further, according to a preferred eighth aspect, there is provided a watercraft wherein the watercraft steering device according to any one of the first to seventh aspects is provided.

[0076] The description further discloses, in order to provide a watercraft that enables rudder turning with constant effectiveness and excellent operation feeling corresponding to a running status of the watercraft, an embodiment of a watercraft steering device including at least one of steerage status detection means for detecting a steerage status following an operation of the steering wheel, running status detecting means for detecting a running status of the watercraft, watercraft propulsion unit status recognition means for recognizing a status of an outboard motor 12 such as an installation number thereof, and electric motor status detection means for detecting a status of an electric motor, and further including rudder turning force characteristic computation means for computing a rudder turning force characteristic based on a detection value from at least one of the means, and an ECU 33 for controlling at least one of a reaction force to the steering wheel, a limit rudder turning angle, and a propulsive force based on a computed rudder turning force characteristic and/or selecting the electric actuator to operate.

Claims

1. Steering system for a watercraft, comprising:

a watercraft propulsion unit,
a steering device actuated by an actuator for changing a direction in which the watercraft travels, and
a steering amount input means, operable by an operator, and electrically connected to the actuator to provided an actuation signal corresponding to an operation amount of the actuator,
at least one of steerage status detection means for detecting a steerage status following an operation of the steering amount input means, running status detection means for detecting a running status of the watercraft, watercraft propulsion unit status recognition means for recognizing a status of the watercraft propulsion unit such as an installation number thereof, and actuator status detection means for detecting a status of

the actuator; and

comprising rudder turning force characteristic computation means for computing a rudder turning force characteristic based on a detection value from at least one of the detection and recognition means; and

control means for controlling at least one of a reaction force to the steering amount input means, a limit rudder turning angle, and a propulsive force based on a computed rudder turning force characteristic and/or selecting the actuator to operate.

2. Steering system according to claim 1, wherein the watercraft propulsion unit, in particular arranged at a stern of the watercraft, is used as the rudder.

3. Steering system according to claim 1 or 2, wherein the actuator configured to change a direction in which the watercraft travels is an electric actuator.

4. Steering system according to one of the claims 1 to 3, wherein the control means includes reaction actuator control means for controlling a reaction force to the steering amount input means, rudder turning angle control means for controlling a limit rudder turning force, and propulsive force control means for controlling a propulsive force.

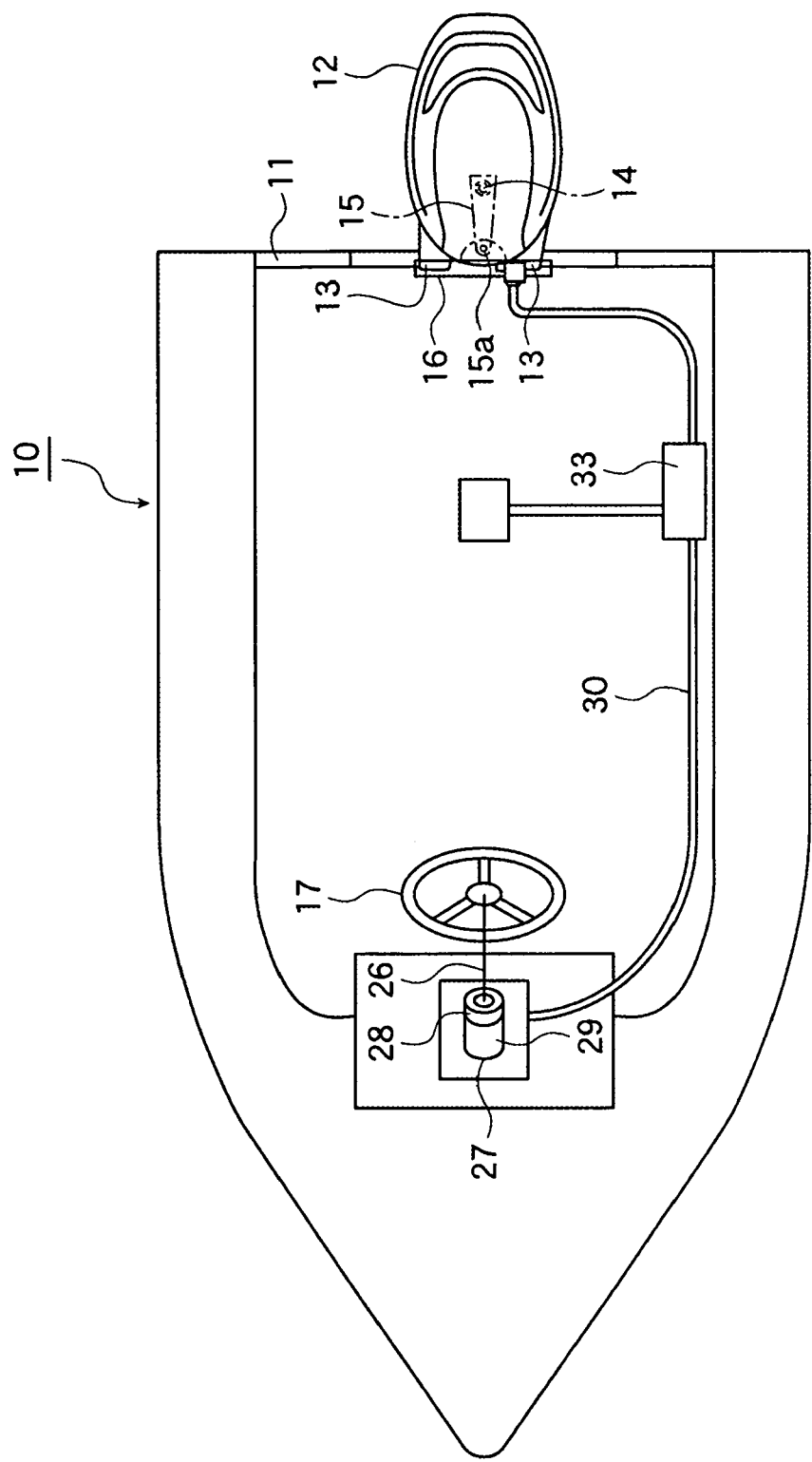
5. Steering system according to one of the claims 1 to 4, wherein the control means controls a reaction force to the steering amount input means, a limit rudder turning angle, and a propulsive force based on a steerage status detected by the steerage status detection means, a running status detected by the running status detection means, a watercraft propulsion unit status recognized by the watercraft propulsion unit status recognition means, and a motor characteristic status detected by the motor detection means.

6. Steering system according to one of the claims 1 to 5, wherein the steerage status detection means includes at least one of rudder turning force detection means for detecting a rudder turning force required for a rudder turning following the operation of the steering amount input means, load detection means for detecting a load acting on the rudder, steerage detection means for detecting a steering amount input means steerage angle, a steering amount input means steerage speed, a direction in which the steering amount input means is operated, a rudder turning angle, a rudder turning speed, and a direction in which the rudder is turned, corresponding to an operation of the steering amount input means, and deviation detection means for detecting a deviation between a target rudder turning angle position corresponding to an operation of the steering amount

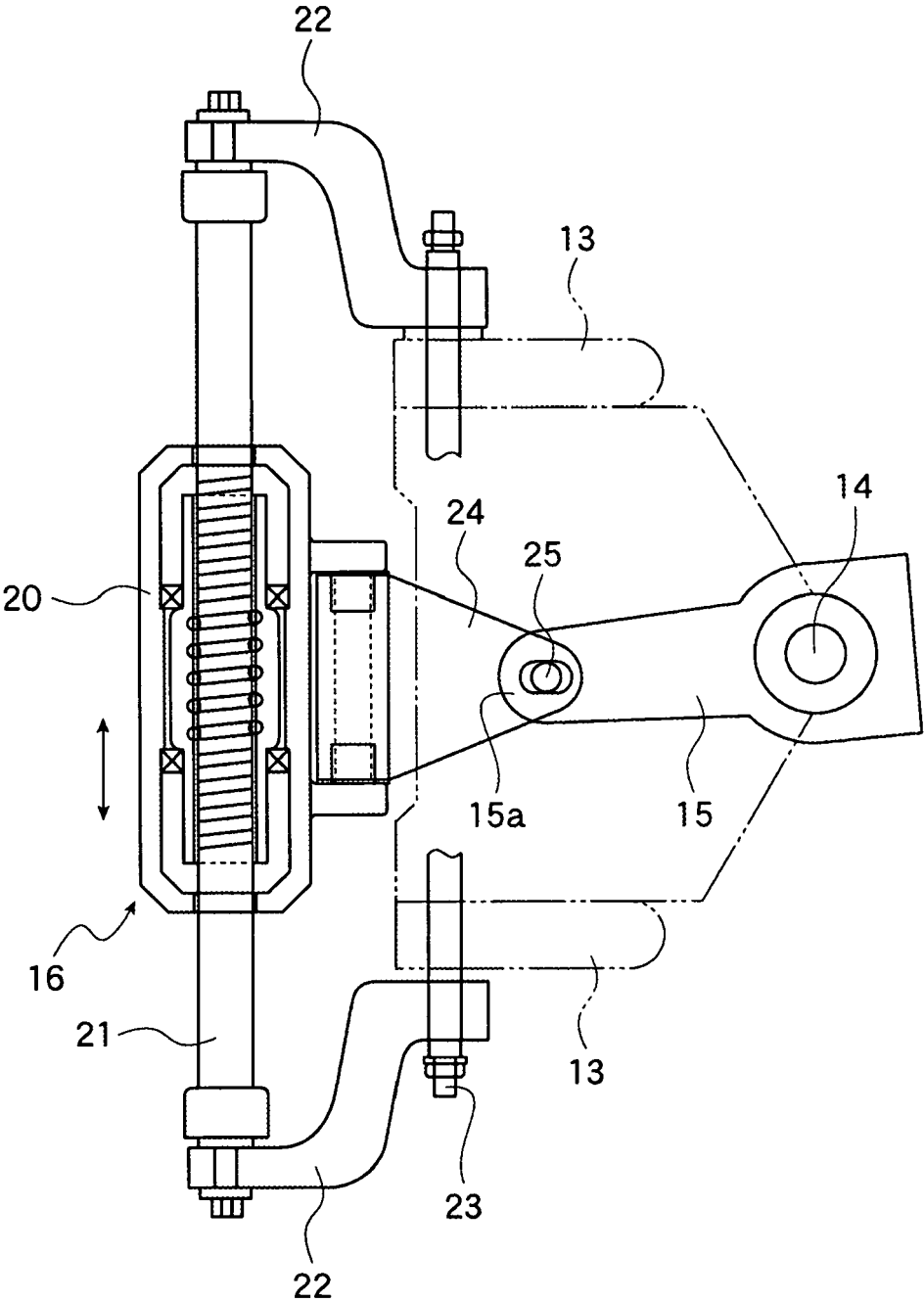
input means and an actual rudder turning angle.

7. Steering system according to one of the claims 1 to 6, wherein the running status detection means includes at least one of weight detection means for detecting at least one of a draft position and a weight of the watercraft, trim angle detection means for detecting a trim angle of the watercraft, and speed detection means for detecting at least one of a speed, an acceleration, a propulsive force of the watercraft, and an output of the watercraft propulsion unit. 5 10
8. Steering system according to one of the claims 1 to 7, wherein the watercraft propulsion unit status recognition means includes steerage storage means for storing therein any one of information among an installation number of the watercraft propulsion unit, an installation position of the watercraft propulsion unit relative to the watercraft, a rotational direction of a propeller provided in the watercraft propulsion unit, a propeller shape, a trim tab angle, and a trim tab shape. 15 20
9. Steering system according to one of the claims 3 to 8, wherein the actuator status detection means is an electric actuator status detection means, which includes at least one of temperature detection means for detecting a temperature of the electric actuator, and operating number detection means for detecting a number of the electric actuator in operation among a plurality of the electric actuator. 25 30
10. Steering system according to one of the claims 1 to 8, wherein the steering amount input means is a steering wheel or a control lever, operable by an operator, electrically connected to the electric actuator to provide an actuation signal corresponding to the amount of a steering operation input to the electric actuator. 35 40
11. Watercraft having the watercraft steering device according to any one of claims 1 through 10. 45 50 55

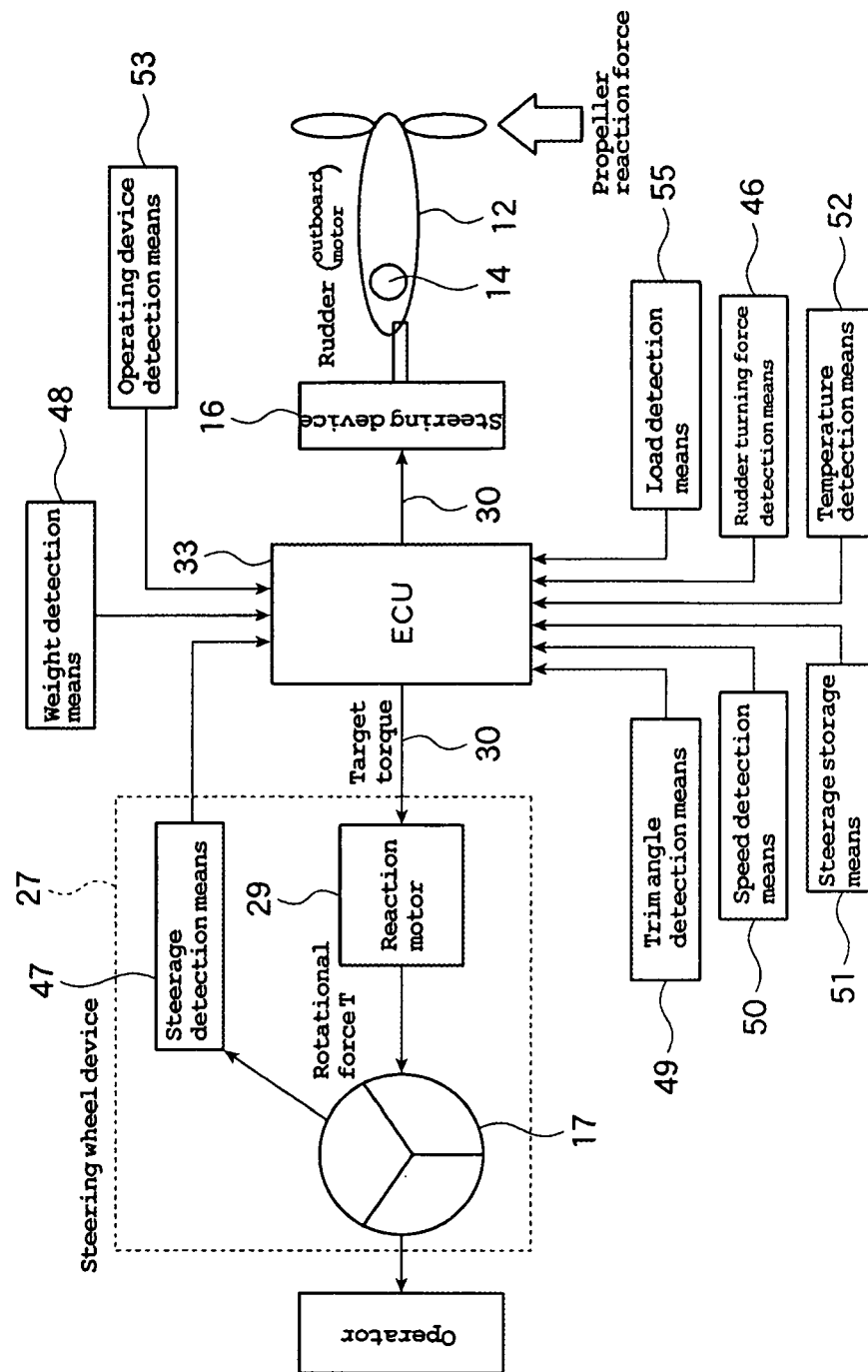
[FIG. 1]



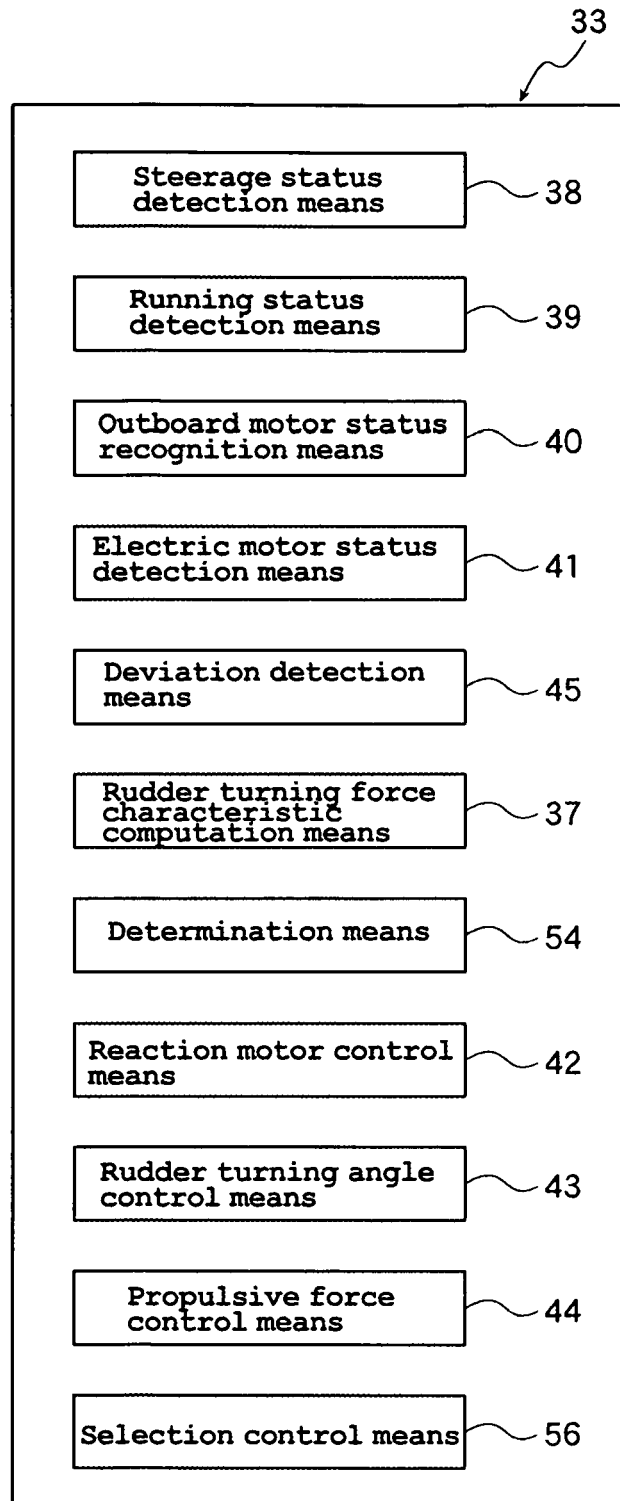
[FIG. 2]



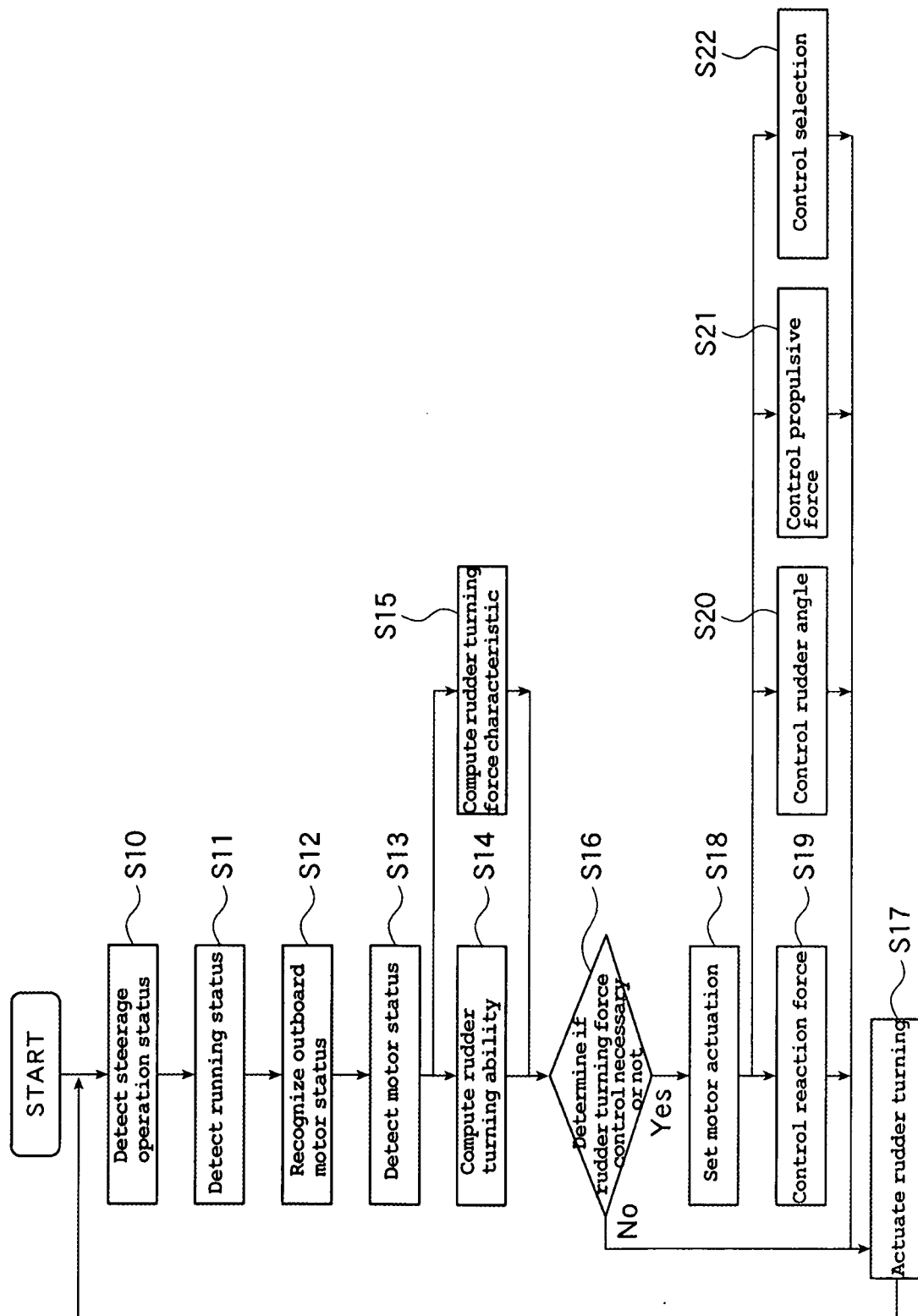
[FIG. 3]



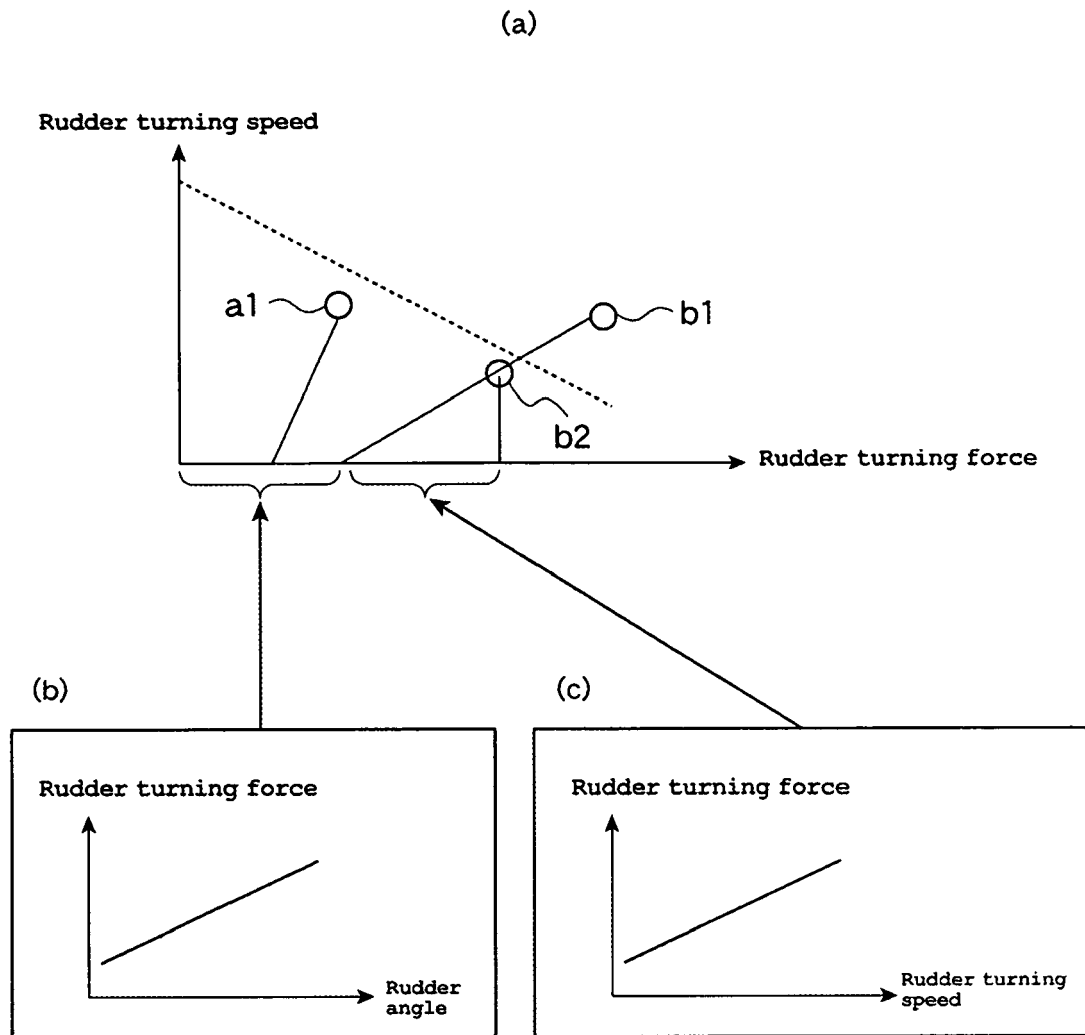
[FIG. 4]



[FIG. 5]

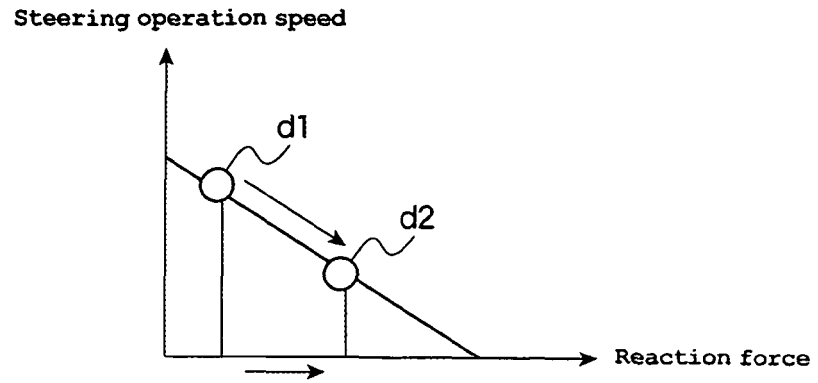


[FIG. 6]

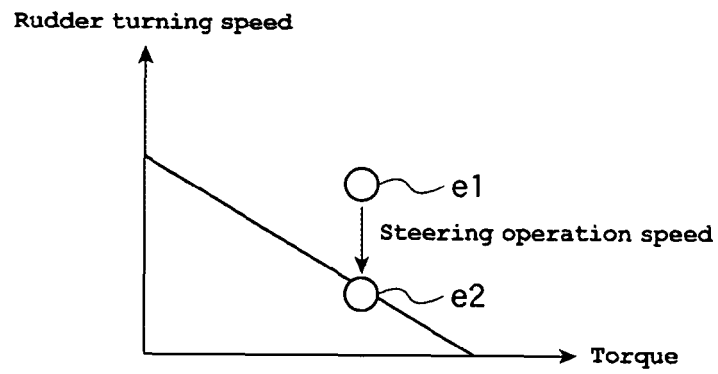


[FIG. 7]

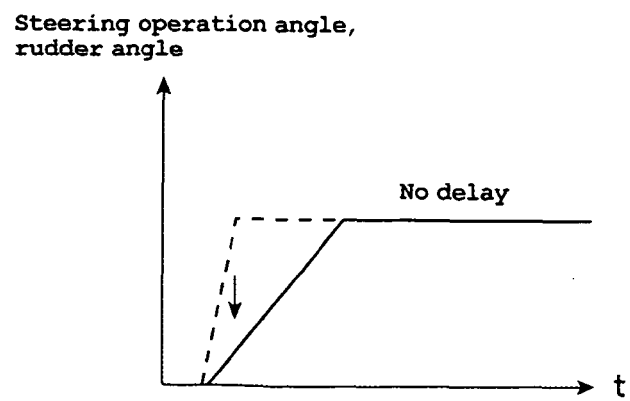
(a)



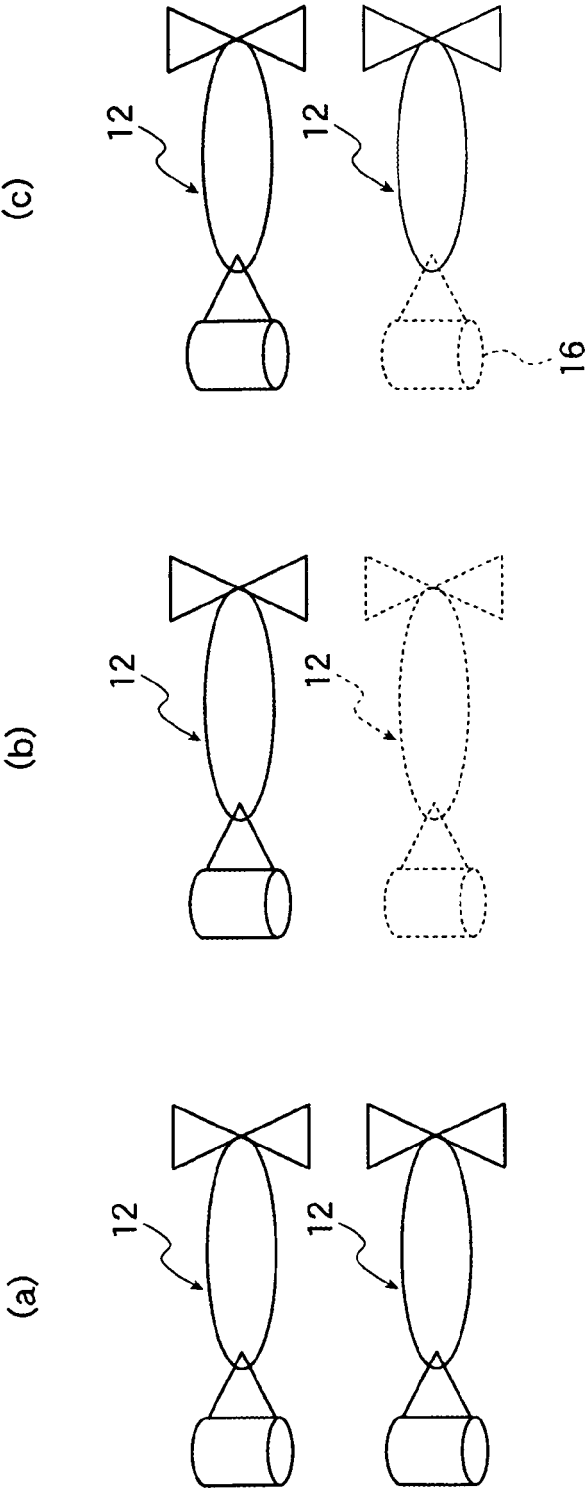
(b)



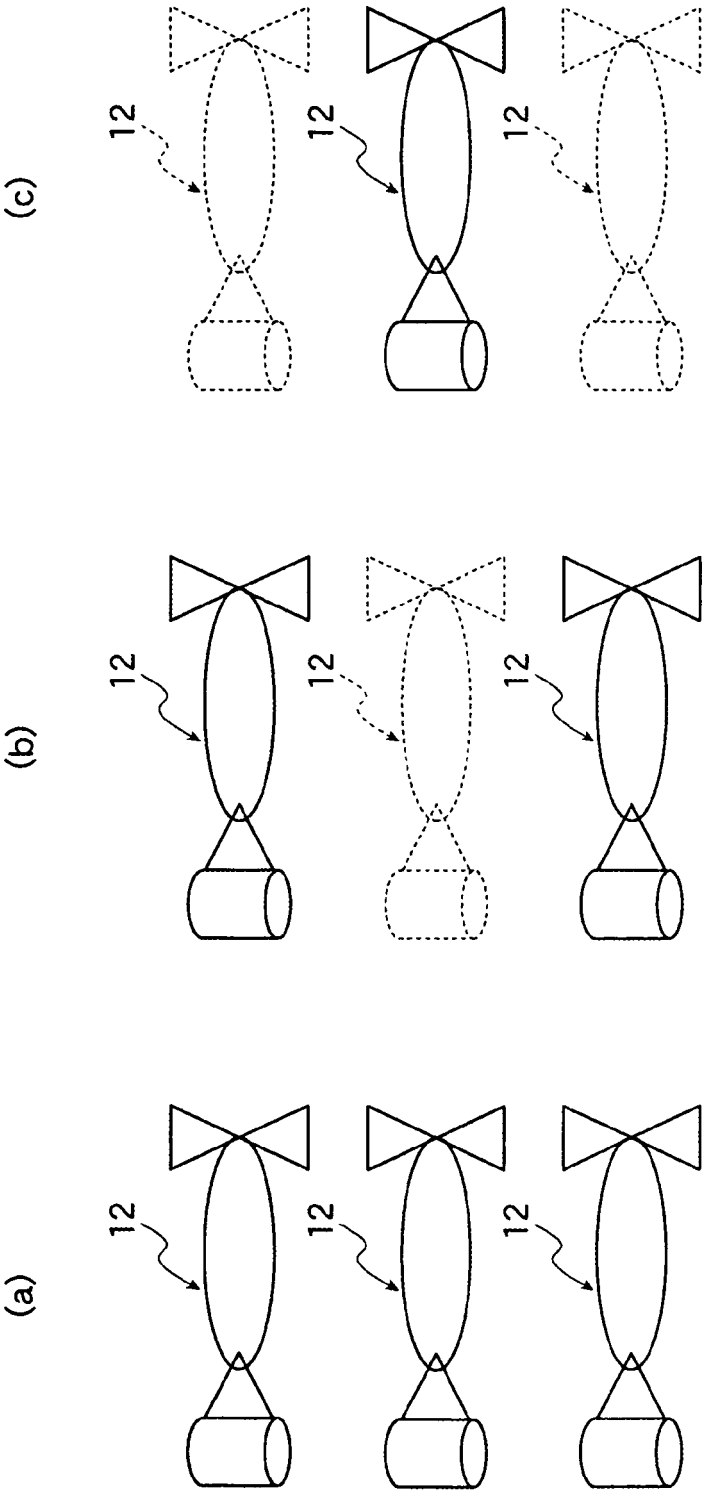
(c)



[FIG. 8]

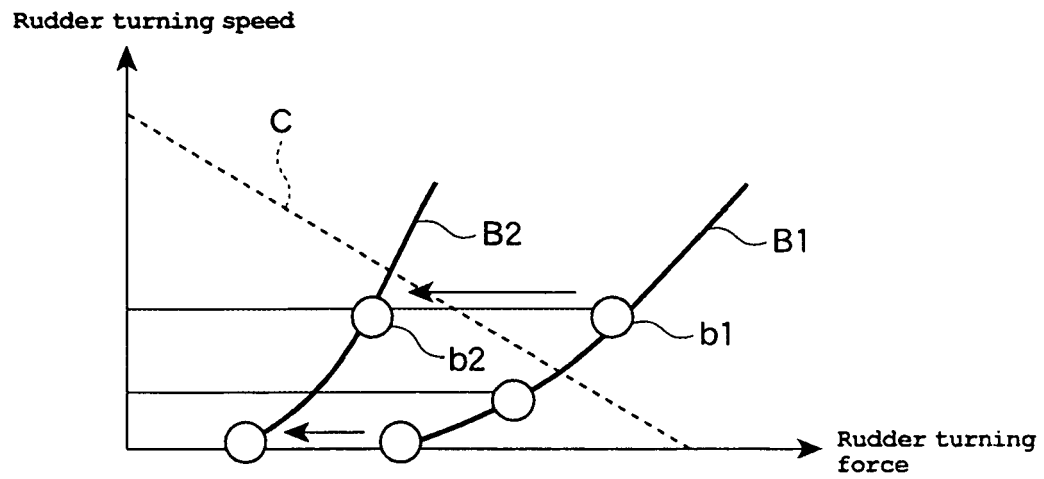


[FIG. 9]

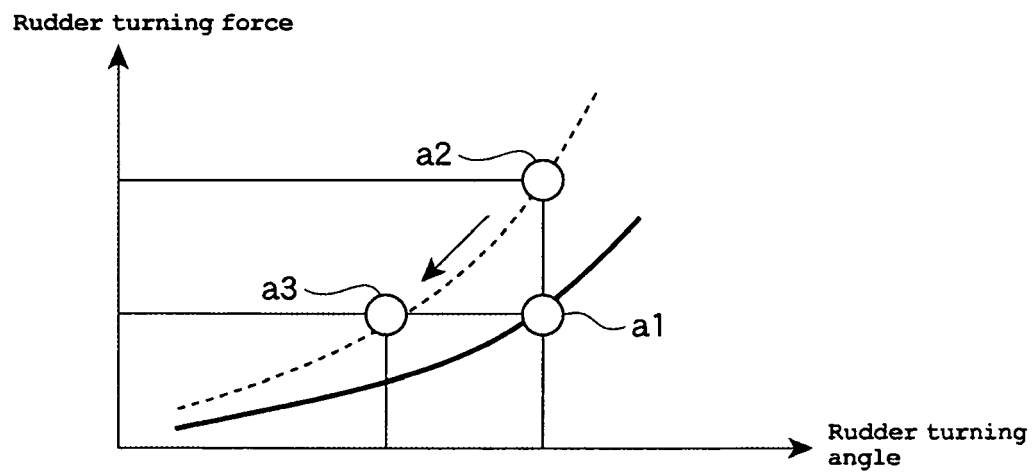


[FIG. 10]

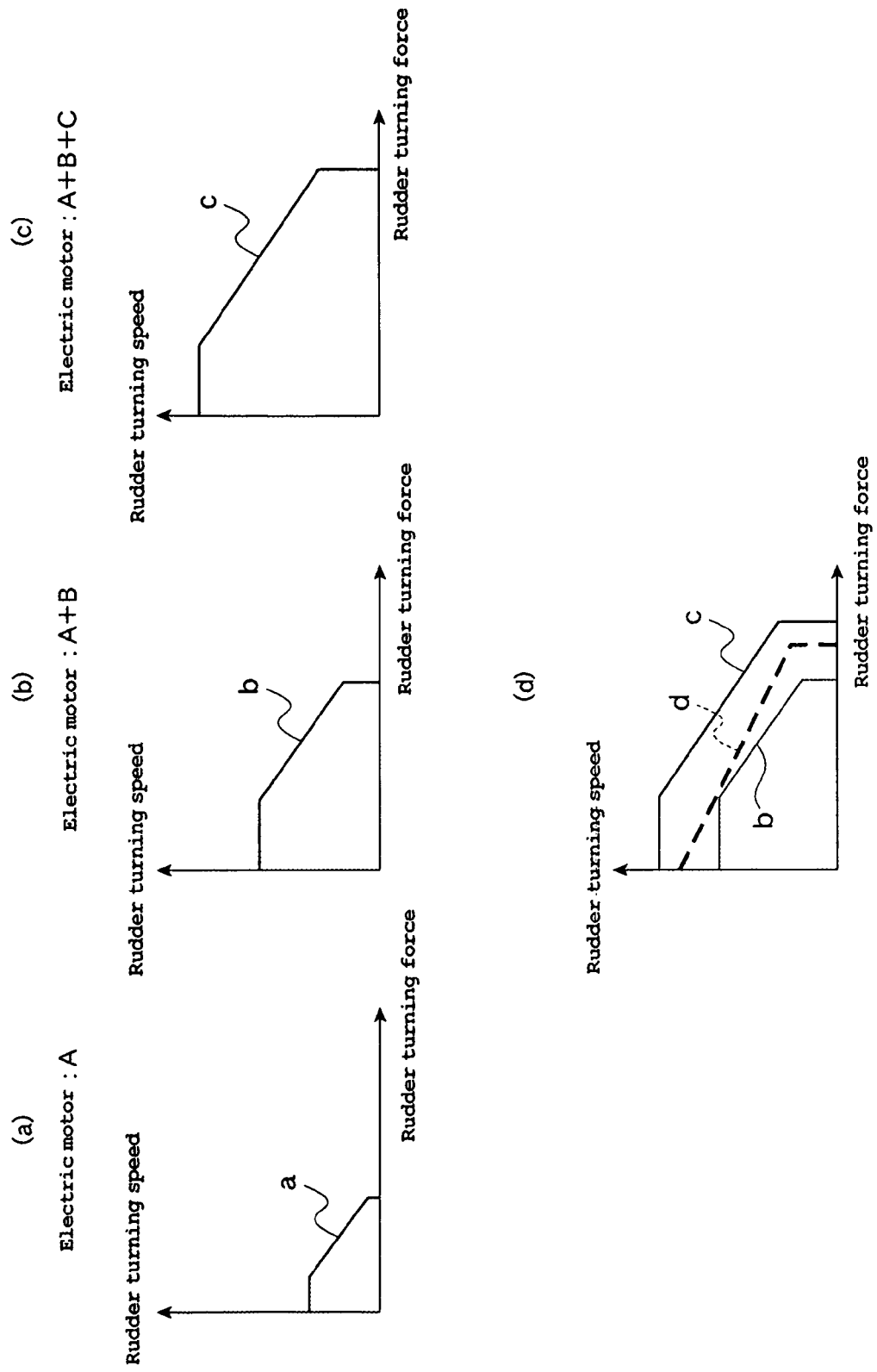
(a)



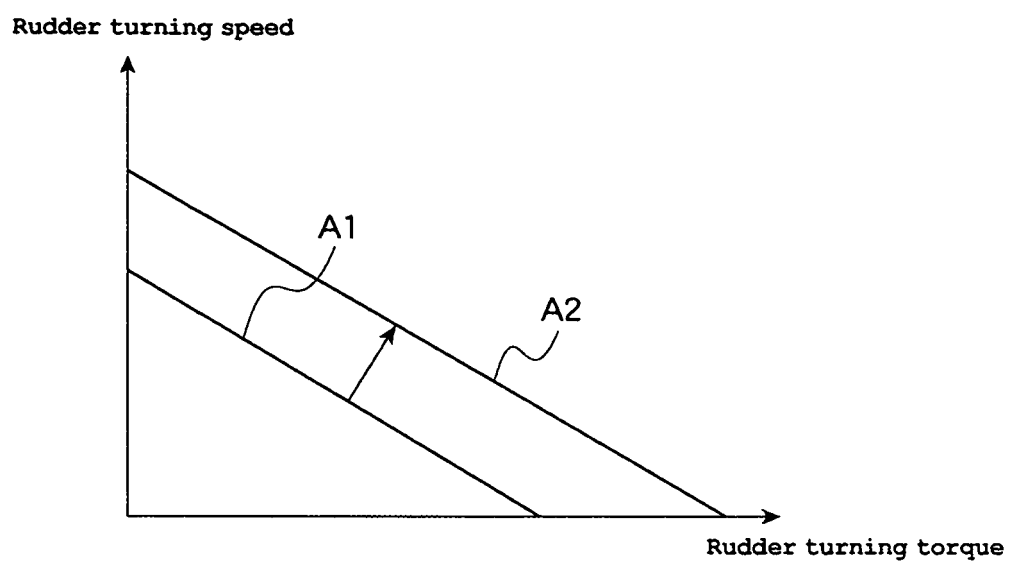
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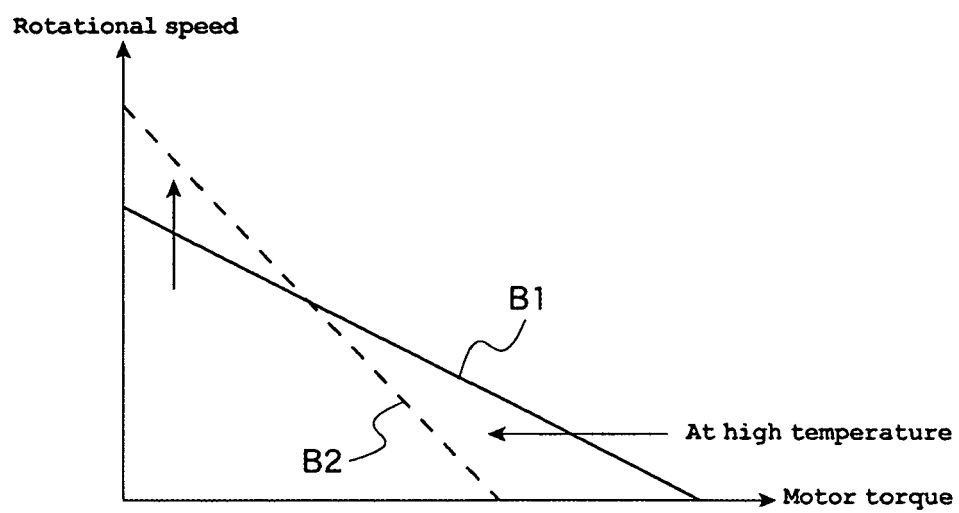
[FIG. 11]



[FIG. 12]



[FIG. 13]



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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