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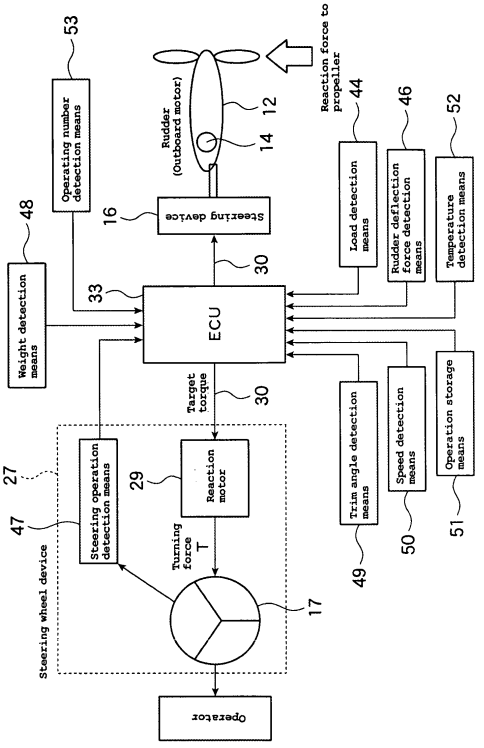
(54) Steering system for a watercraft

(57) The present invention relates to a steering system for a watercraft, comprising: a rudder, in particular an outboard motor (12); a steering device (16) including an actuator, in particular an electric motor (20) configured to change a direction in which the watercraft travels; a steering amount input means, such as a steering wheel (17), operable by an operator, electrically connected to the actuator (20) to provide an actuation signal corresponding to the amount of a steering operation to the actuator (20); and control means (33) for controlling a limit of a rudder deflection angle, the control means (33) including at least one of operation status detection means (38) for detecting an operation status corresponding to the steering operation, 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 a watercraft propulsion unit, such as an outboard motor (12), such as the installation number thereof, and actuator status detection means (41) for detecting a status of the actuator (20); and rudder deflection angle control means (42) for controlling a limit rudder deflection angle based on the detection value from the at least one of the detection and recognition means.

[FIG. 3]



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Description

[0001] The present invention relates to a steering system, and in particular to a watercraft steering device having an electric actuator which is actuated as an operator operates a steering wheel for rudder deflection, and particularly to a watercraft steering device which can control a limit rudder deflection angle, and to a watercraft 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 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 external force due to a 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. However, a load of water pressure during the rudder deflection may be larger when the rudder is returned than when the rudder is deflected, depending on a watercraft size. Thus, deflecting the rudder overly could provide output from a steering motor (electric actuator) lower than a required rudder deflection force when the rudder is returned, resulting in impaired responsiveness and a poorer operation feel.

[0005] It should be noted that ruder deflection torque characteristics required for rudder deflection (required rudder deflection force characteristics) may change from the state shown by required rudder deflection force characteristic line A1 to the state shown by required rudder deflection force characteristic line A2, as shown in FIG. 7, depending on the characteristics of the watercraft, a rudder deflection angle, an operation speed, or the like. In such case, if a limit rudder deflection angle is invariable, a rudder deflection force required when the rudder is returned after being deflected to a maximum position may exceed the limit of the motor ability, resulting in impaired responsiveness and a poorer operation feel.

[0006] Further, as shown in FIG. 8, motor characteristics depend on the surroundings such as temperature. When the temperature becomes high for example, the motor characteristics 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 case, since the motor characteristics at high temperatures provide lower motor torque, a rudder deflection force required when the rudder is returned after being deflected to the maximum position may exceed the motor ability, resulting in impaired responsiveness and a poorer operation feel.

[0007] In view of the foregoing problem, it is, therefore, an object of the present invention to provide a steering device which provides an operator with invariably excellent efficiency and an excellent operation feel during rudder deflection, depending on a running status of the watercraft.

[0008] This objective is solved in an inventive manner by a steering system for a watercraft, comprising: a rudder; a steering device including an actuator configured to change a direction in which the watercraft travels; a steering amount input means, operable by an operator, electrically connected to the actuator to provide an actuation signal corresponding to the amount of a steering operation to the actuator; and control means for controlling a limit of a rudder deflection angle, the control means including at least one of operation status detection means for detecting an operation status corresponding to the steering operation, running status detection means for detecting a running status of the watercraft, watercraft propulsion unit status recognition means for recognizing a status of a watercraft propulsion unit of the watercraft, such as the installation number thereof, and actuator status detection means for detecting a status of the actuator; and rudder deflection angle control means for controlling a limit rudder deflection angle based on the detection value from the at least one of the detection and recognition means.

[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 operation status detection means includes at least one of rudder deflection force detection means for detecting a rudder deflection force required for rudder deflection, load detection means for detecting a load to the rudder, steering operation detection means for detecting a direction in which the rudder is deflected, corresponding to a direction in which the steering wheel is operated and/or the steering wheel operation, and deviation detection means for detecting a deviation of a detected actual rudder deflection angle from a target rudder deflection angle corresponding to the steering wheel operation.

[0012] Therein, it is beneficial if the running status detection means includes at least one of weight detection means for detecting at least one of a position of a waterline 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 deceleration and a propulsive force of the watercraft, and an output of the watercraft

propulsion unit.

[0013] It is further beneficial if the watercraft propulsion unit status recognition means includes operation storage means for storing therein any one of pieces of information on the 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 of the watercraft propulsion unit, a propeller shape, a tab trim angle and a tab trim shape.

[0014] Preferably, the actuator status detection means is an electric actuator status detection means, which includes temperature detection means for detecting a temperature of the electric actuator.

[0015] Further, preferably the actuator status detection means is an electric actuator status detection means includes operating number detection means for detecting the number of the electric actuator in operation.

[0016] According to a preferred embodiment, the steering system further comprises: a reaction motor for applying a reaction force to the steering wheel; and reaction motor control means for increasing a reaction force to the reaction motor as the rudder nearly achieves the limit rudder deflection angle.

[0017] 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 input operation to the electric actuator.

[0018] According to another preferred embodiment, the steering system further includes an electronic control unit (ECU) for controlling a limit of a steering means deflection angle, the ECU including at least one of operation status detection means for detecting an operation status corresponding to a steering amount input means operation, running status detection means for detecting a running status of the watercraft, outboard motor status recognition means for recognizing a status of an outboard motor, such as the installation number thereof, and electric motor status detection means for detecting a status of an electric motor, and the ECU also including steering means deflection angle control means for controlling a limit steering means deflection angle based on the detection value from the at least one of the means.

[0019] There is further provided a watercraft provided with a steering system for a watercraft according to one of the above embodiments.

[0020] 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 in accordance with an embodiment of the present teaching,

FIG. 2 is an enlarged plan view of a steering device of the watercraft in accordance with the embodiment of the present teaching,

FIG. 3 is a block diagram of the watercraft in accordance with the embodiment of the present teaching,

FIG. 4 is a block diagram of an ECU in accordance with the embodiment of the present teaching,

FIG. 5 is a flowchart of a reaction control process in accordance with the embodiment of the present teaching,

FIGs. 6 are graphs illustrating the operation in accordance with the embodiment of the present teaching, in which FIG. 6(a) illustrates the relationship between rudder deflection speeds and rudder deflection forces; and FIG. 6(b) illustrates the relationship between rudder deflection angles and rudder deflection forces,

FIG. 7 is a graph of required rudder deflection force characteristics, illustrating the relationship between rudder deflection forces and rudder deflection speeds, and

FIG. 8 is a graph of motor characteristics, illustrating the relationship between torques generated by an electric motor and rotational speeds.

Description of Reference Numerals:

[0021]

10: hull
12: outboard motor (watercraft propulsion unit)
16: steering device
17: steering wheel
20: electric motor
28: steering wheel operation angle sensor
29: reaction motor
33: ECU (control unit)
38: operation status detection means
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: rudder deflection angle control means
41: reaction motor control means
44: load detection means
45: deviation detection means
46: rudder deflection force detection means
47: steering operation detection means
48: weight detection means
49: trim angle detection means
50: speed detection means
51: operation storage means
52: temperature detection means
53: operating number detection means

[0022] An embodiment of the present teaching will now be described.

[0023] FIGs. 1 to 6 illustrate the embodiment of the present teaching.

[0024] 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 the direction in which the watercraft is driven is changed.

[0025] 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 driven by operating a steering wheel 17 disposed in an operator's section.

[0026] 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.

[0027] The threaded rod 21 is supported at its both ends by a pair of left and right supports 22. The supports 22 are supported by a tilt shaft 23.

[0028] The electric motor 20 has a coupling bracket 24 extending rearward. The coupling bracket 24 and the steering bracket 15 are coupled with each other via a coupling pin 25.

[0029] As a result, 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 will pivot about the swivel shaft 14 via the coupling bracket 24 and the steering bracket 15.

[0030] 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 includes a steering wheel operation angle sensor 28 for detecting an operation 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 the operator.

[0031] The steering wheel control device 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 operation angle sensor 28, controls the electric motor 20, and controls the reaction motor 29.

[0032] As shown in FIG. 4, the control unit 33 includes operation status detection means 38 for detecting an operation 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 deflection angle control means 42 for controlling to make a limit rudder deflection angle smaller when it determines that a load to the electric motor 20 during rudder deflection will increase, based on the detection values from those means 38... , and reaction motor control means 43 for increasing a reaction force for the reaction motor 29 as the rudder nearly achieves the limit rudder deflection angle.

[0033] The operation status detection means 38 includes rudder deflection force detection means 46 for detecting a rudder deflection force required for rudder deflection, load detection means 53 for detecting a load to the rudder, such as water pressure, and steering operation detection means 47 for detecting a direction in which the rudder is deflected, corresponding to a direction in which the steering wheel 17 is operated and/or a steering wheel operation, as shown in FIG. 3, and deviation detection means 45 for detecting a deviation of a detected actual rudder deflection angle from a target rudder deflection angle corresponding to the steering wheel operation, as shown in FIG. 4. The steering wheel operation angle sensor 28 provided in the steering operation detection means 47 detects a steering wheel operation angle.

[0034] To the running status detection means 39, there are connected weight detection means 48 for detecting the position of a waterline and the 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 operation status detection means (not shown) for detecting a PTT operation status, as shown in FIG. 3.

[0035] Further, to the outboard motor status recognition means 40, there is connected operation storage means 51 for storing therein information on the installation number of the outboard motor 12, the installation position of the outboard motor 12 relative to the watercraft, a rotational direction of a propeller of the outboard motor 12, a propeller size, a propeller shape, a tab trim angle, a tab trim shape, and the like. It is a matter of course that the operation storage means 51 can be included in the ECU 33.

[0036] Furthermore, the electric motor status detection means 41 includes temperature detection means 52 for detecting a temperature of the electric motor 20, and operating number detection means 53 for detecting the number of electric motors 20 in operation.

[0037] The operation of this embodiment will now be described.

[0038] As the operator first turns the steering wheel 17

in any direction by any angle, a signal will be transmitted from the steering wheel operation angle sensor 28 in the steering operation detection means 47 to the ECU 33. Then, in step S10 of FIG. 5, a target rudder deflection angle is detected, and in step S11, a target deviation is computed.

[0039] Further, in step S12, the operation status detection means 38 detects an operation status. As used herein, the term "operation status" refers to a rudder deflection force required for deflecting the outboard motor 12, a load to the rudder (outboard motor 12), a direction in which the steering wheel 17 is operated, a direction in which the rudder (outboard motor 12) is deflected, a deviation of a detected actual rudder deflection angle from a target rudder deflection angle corresponding to a steering wheel operation, and the like.

[0040] The rudder deflection force is detected by the rudder deflection force detection means 46. The load to the rudder is detected by the load detection means 44. The direction in which the steering wheel 17 is operated and the direction in which the rudder is deflected are detected by the steering operation detection means 47. The deviation of a detected actual rudder deflection angle from a target rudder deflection angle corresponding to the steering wheel operation is detected by the deviation detection means 45. Detection signals from those means are transmitted to the operation status detection means 38 to thereby detect the operation status.

[0041] Further, in step S13, the running status detection means 39 detects a running status. As used herein, the term "running status" refers to the position of a waterline, the weight, a trim angle, a speed, an acceleration, a deceleration and a propulsive force of the watercraft, an output of the outboard motor 12, and the like.

[0042] The position of a waterline and the weight of the watercraft are detected by the weight detection means 48. The trim angle of the watercraft is detected by the trim angle detection means 49. The speed, the acceleration, the deceleration and the propulsive force of the watercraft, and the output of the outboard motor 12 are detected by the speed detection means 50. Detection signals from those means are transmitted to the running status detection means 39 to thereby detect the running status.

[0043] Further, in step S14, the outboard motor status recognition means 40 recognizes a status of the outboard motor 12. As used herein, the term "the status of the outboard motor 12" refers to the installation number of the outboard motor 12, the installation position of the outboard motor 12 relative to the watercraft, a rotational direction of the propeller of the outboard motor 12, a propeller shape, a tab trim angle, a tab trim shape, and the like.

[0044] Information on the installation number of the outboard motor 12, the installation position of the outboard motor 12 relative to the watercraft, the rotational direction of the propeller of the outboard motor 12, and the like are stored in the operation storage means 51. Such information is read and then transmitted to the outboard motor status recognition means 40 to thereby recognize the status of the outboard motor 12.

[0045] Thereafter, in step S15, the electric motor status detection means 41 detects a status of the electric motor 20. As used herein, the term "the status of the electric motor 20" refers to factors which influence the output characteristics of the electric motor 20, specifically a temperature and a voltage of the electric motor 20, the number of the electric motor 20 in operation, and the like.

[0046] The temperature of the electric motor 20 is detected by the temperature detection means 52. The number of the electric motor 20 in operation is detected by the operating number detection means 53. Detection signals from those means are transmitted to the electric motor status detection means 41 to thereby detect the status of the electric motor 20.

[0047] Based on such detection values, in step S16, the rudder deflection angle control means 42 in the ECU 33 computes a limit rudder deflection angle for rudder angle restriction, and in step S17, rudder deflection control is performed. The rudder deflection control is made such that the outboard motor 12 achieves the limit deflection angle as the ECU 33 controls the electric motor 20, and the process then returns to step S10.

[0048] As a result, during the operation of the watercraft by the operator, since rudder deflection angle restriction is performed depending on a running status of the watercraft, and the like, the electric motor 20 is actuated with excellent responsiveness invariably, and the operator can obtain an excellent feel of operation when deflecting the rudder.

More specifically,

(1) Control depending on steering operation status

[0049] When a rudder deflection force required for rudder deflection is large and thereby a load to the rudder is large, or when the rudder is deflected in a direction which receives a reaction force to the propeller in response to a direction in which the steering wheel 17 has been operated, or a direction in which the rudder is expected to deflect, a limit rudder deflection angle is made smaller to limit an increase in the rudder deflection force.

[0050] As a result, making the rudder deflection angle smaller limits an increase in the rudder deflection force, allowing a much faster steering wheel operation. This also prevents exceeding the limit of rudder deflection ability during rudder deflection.

(2) Control depending on running status

a. Operation of position of waterline, weight and trim angle

[0051] When the position of a waterline is high, the weight of the watercraft is heavy, or a trim angle is small

so that the watercraft 12 is positioned generally vertically in a certain fore-and-aft range, a rudder deflection force corresponding to a rudder angle will increase.

[0052] Thus, making a rudder deflection angle smaller limits an increase in rudder deflection force, allowing a much faster operation of the steering wheel 17. This also prevents exceeding the limit of rudder deflection ability during rudder deflection.

b. Operation of speed, propulsive force, acceleration, deceleration and output

[0053] When selectively accelerating or decelerating, the watercraft generates a propulsive force larger than that during cruising at a certain speed, which causes a reaction force to the propeller to increase.

[0054] As a result, making the rudder deflection angle smaller limits an increase in the rudder deflection force, allowing a much faster steering wheel operation. This also prevents exceeding the limit of rudder deflection ability during rudder deflection.

3) Control depending on status of outboard motor 12

[0055] A rudder deflection load increases as the installation number of the outboard motor 12 increases. A rudder deflection load increases as the propeller increases in size. A rudder deflection load increases in one direction depending on a rotational direction of the propeller. A rudder deflection load increases depending on the tab trim size. A rudder deflection load increases when a tab trim angle is deviating from a reference position corresponding to a watercraft speed, a trim angle, and a waterline.

[0056] As a result, making the rudder deflection angle smaller limits an increase in the rudder deflection force, allowing a much faster steering wheel operation. This also prevents exceeding the limit of rudder deflection ability during rudder deflection.

[0057] As to the installation position of the outboard motor 12, in a watercraft with a plurality of the outboard motors 12, when it is driven with only part of the outboard motors 12 actually in operation, or when the individual watercrafts are in different trim status (when the lower part of the individual outboard motor 12 has a different underwater depth), rudder deflection load characteristics will not be the same between rudder deflection to the left and rudder deflection to the right. Accordingly, a propulsive force is adjusted, depending on whether the outboard motor 12 generating the propulsive force is on the left or the right in the width direction of the watercraft, or the outboard motor 12 having a smaller trim angle and thereby a deeper underwater depth is on the left or the right in the width direction of the watercraft (the propulsive force is decreased when the rudder is returned from a deflected position to the side on which the outboard motor 12 of a deeper underwater depth is installed).

4) Control depending on motor status

[0058] As the motor temperature rises, the motor characteristics described above tends to be exhibited as shown by broken line in FIG. 8, and thus less torque will be outputted from the motor. Accordingly, a limit rudder deflection angle is made smaller to thereby prevent exceeding the limit of the ability of the electric motor 20.

[0059] Also, the number of the electric motor 20 in operation is detected, and for the fewer motor in operation, a limit rudder deflection angle is made smaller. More specifically, as the number of the motor operable is fewer, a limit rudder deflection angle is made smaller to thereby prevent exceeding the limit of the ability of the electric motor 20, e.g., in the case of a plurality of the electric motors 20 in use, if any of them is not operable due to a failure or the like; or in the case where a watercraft is equipped with a plurality of the outboard motors 12 operatively coupled to each other for the same rudder deflecting movement, each outboard motor 12 having the electric motor 20, when part of the outboard motors 12 is inactivated and the associated electric motor 20 is also inactivated, so that the ruder deflection is performed using the rest of the electric motors 20.

[0060] As such, in the above watercraft, the outboard motor 12 is deflected by the electric motor 20. Thus, it is advantageous that an operation feel of the steering wheel 17 can be lighter; however, in the case where the rudder is deflected overly for example, a larger load is required when the rudder is returned than when the rudder is deflected. Accordingly, output from the electric motor 20 may become less responsive, resulting in a delayed response to a rudder deflecting operation. In this embodiment, however, in accordance with the motor characteristics of the electric motor 20, a limit rudder deflection angle is made smaller to thereby prevent exceeding the limit of the motor characteristics of the electric motor even when the rudder is returned.

[0061] As a result, the rudder deflection range is limited, and thus the outboard motor 12 is deflected within the range of the output of the electric motor 20 even when the rudder is returned. This prevents a delayed response to a rudder deflecting operation.

[0062] More specifically, as shown in FIG. 6(b), as a running status or an electric motor status, e.g., a watercraft speed, a trim angle, the weight, an acceleration, a deceleration, or a propulsive force, increases, the relationship between rudder deflection angles and rudder deflection forces will change from the characteristics shown by solid line in FIG. 6(b) to the characteristics as shown in broken line in the figure. Accordingly, when a rudder deflection angle is the same as that in position a1 of the characteristics shown in solid line, a rudder deflection force increases as that in position a2 of the characteristics shown in broken line. When a rudder deflection force is the same as that in position a1 of the characteristics shown in solid line, a rudder deflection angle decreases as that in position a3 of the characteristics shown in bro-

ken line.

[0063] As a rudder deflection force or the like increases in this way, when a limit rudder deflection angle is large, the motor characteristics may fall outside of ability characteristic line C of the electric motor 20 as position b1 shown in characteristic line B1 in FIG. 6(a), which illustrates the relationship between rudder deflection forces and rudder deflection speeds. In such case, when a limit rudder deflection angle is made smaller according to the present invention, thereby changing the motor characteristics as shown by characteristic line B2, a rudder deflection force decreases as shown in position b2 while the same rudder deflection speed as in position b1 is kept. As a result, the motor characteristics falls within the range of ability characteristic line C. Accordingly, the outboard motor 12 can be deflected within the range of output of the electric motor 20, and thus no delayed response occurs during a rudder deflecting operation.

[0064] Optionally, the ECU 33 can include reaction motor control means 43 for controlling output of the reaction motor 29, so that when the rudder nearly achieves a limit rudder defection angle, output of the reaction motor 29 is increased based on a signal from the reaction motor control means 43 to increase a reaction force to the steering wheel 17.

[0065] This provides to the operator a response corresponding to a rudder deflection load directly through the steering wheel 17, thereby preventing operating overly beyond a limit rudder deflection angle.

[0066] 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 be replaced by an inboard-outdrive engine. Further, the foregoing embodiment includes the operation 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.

[0067] The description above discloses (amongst others) in order to achieve the foregoing problem, a preferred first aspect which provides a steering device for a watercraft, including: a watercraft propulsion unit at a stern of the watercraft; a steering device including an electric actuator for actuating the steering device, the steering device changing a direction in which the watercraft travels; a steering wheel, operable by an operator, electrically connected to the electric actuator to provide an actuation signal corresponding to the amount of a steering wheel operation to the electric actuator; and control means for controlling a limit of the rudder deflection angle, the control means including: at least one of operation status detection means for detecting an operation status corresponding to the steering wheel operation, 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 the installation number thereof, and electric actuator status detection means for detecting a status of the electric actuator; and rudder deflection angle control means for controlling a limit rudder deflection angle based on the detection value from the at least one of the means.

[0068] Further, a preferred second aspect provides the steering device for a watercraft in accordance with the first aspect, in which the operation status detection means includes at least one of rudder deflection force detection means for detecting a rudder deflection force required for rudder deflection, load detection means for detecting a load to the rudder, steering operation detection means for detecting a direction in which the rudder is deflected, corresponding to a direction in which the steering wheel is operated and/or the steering wheel operation, and deviation detection means for detecting a deviation of a detected actual rudder deflection angle from a target rudder deflection angle corresponding to the steering wheel operation.

[0069] Further, a preferred third aspect provides the steering device for a watercraft in accordance with the first or second aspect, in which the running status detection means includes at least one of weight detection means for detecting at least one of a position of a waterline 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 and a propulsive force of the watercraft, and an output of the watercraft propulsion unit.

[0070] Further, a preferred fourth aspect provides the steering device for a watercraft in accordance with any one of the first to third aspects, in which the watercraft propulsion unit status recognition means includes operation storage means for storing therein any one of pieces of information on the 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 of the watercraft propulsion unit, a propeller shape, a tab trim angle and a tab trim shape.

[0071] Further, a preferred fifth aspect provides the steering device for a watercraft in accordance with any one of the first to fourth aspects, in which the electric actuator status detection means includes temperature detection means for detecting a temperature of the electric actuator.

[0072] Further, a preferred sixth aspect provides the steering device for a watercraft in accordance with any one of the first to fifth aspects, in which the electric actuator status detection means includes operating number detection means for detecting the number of the electric actuator in operation.

[0073] Further, a preferred seventh aspect provides the steering device for a watercraft in accordance with any one of the first to sixth aspects, further including: a reaction motor for applying a reaction force to the steering wheel; and reaction motor control means for increasing a reaction force to the reaction motor as the rudder nearly achieves the limit rudder deflection angle.

[0074] Further, a preferred eighth aspect provides a watercraft provided with the steering device for a watercraft in accordance with any one of the first to seventh aspects.

[0075] In accordance with the above aspects of the present teaching, control means includes at least one of operation status detection means for detecting an operation status corresponding to the steering wheel operation, 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 the installation number thereof, and electric actuator status detection means for detecting a status of the electric actuator. The control means also includes rudder deflection angle control means for controlling a limit rudder deflection angle based on the detection value from the at least one of the means. Therefore, the present invention can provide a watercraft steering device and a watercraft which provide an operator with invariably excellent efficiency and an excellent operation feel during rudder deflection, depending on a running status of the watercraft.

[0076] The description above, thus, discloses according to a preferred first aspect, a steering device for a watercraft, comprising: a watercraft propulsion unit at a stern of the watercraft; a steering device including an electric actuator for actuating the steering device, the steering device changing a direction in which the watercraft travels; a steering wheel, operable by an operator, electrically connected to the electric actuator to provide an actuation signal corresponding to the amount of a steering wheel operation to the electric actuator; and control means for controlling a limit of the rudder deflection angle, the control means including: at least one of operation status detection means for detecting an operation status corresponding to the steering wheel operation, 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 the installation number thereof, and electric actuator status detection means for detecting a status of the electric actuator; and rudder deflection angle control means for controlling a limit rudder deflection angle based on the detection value from the at least one of the means.

[0077] Further, according to a preferred second aspect, the operation status detection means includes at least one of rudder deflection force detection means for detecting a rudder deflection force required for rudder deflection, load detection means for detecting a load to the rudder, steering operation detection means for detecting a direction in which the rudder is deflected, corresponding to a direction in which the steering wheel is operated and/or the steering wheel operation, and deviation detection means for detecting a deviation of a detected actual rudder deflection angle from a target rudder deflection angle corresponding to the steering wheel operation.

[0078] Further, according to a preferred third aspect, the running status detection means includes at least one of weight detection means for detecting at least one of a position of a waterline 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 deceleration and a propulsive force of the watercraft, and an output of the watercraft propulsion unit.

[0079] Further, according to a preferred fourth aspect, the watercraft propulsion unit status recognition means includes operation storage means for storing therein any one of pieces of information on the 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 of the watercraft propulsion unit, a propeller shape, a tab trim angle and a tab trim shape.

[0080] Further, according to a preferred fifth aspect, the electric actuator status detection means includes temperature detection means for detecting a temperature of the electric actuator.

[0081] Further, according to a preferred sixth aspect, the electric actuator status detection means includes operating number detection means for detecting the number of the electric actuator in operation.

[0082] Further, according to a preferred seventh aspect, the steering device for a watercraft further comprises: a reaction motor for applying a reaction force to the steering wheel; and reaction motor control means for increasing a reaction force to the reaction motor as the rudder nearly achieves the limit rudder deflection angle.

[0083] There is further disclosed a watercraft provided with the steering device for a watercraft according to any one of the first to seventh aspects.

[0084] The description still further discloses, in order to provide a watercraft which provides an operator with invariably excellent efficiency and an excellent operation feel during rudder deflection, depending on a running status of the watercraft, an embodiment of a watercraft steering device which includes an ECU 33 for controlling a limit of a rudder deflection angle. Therein, the ECU 33 includes at least one of operation status detection means for detecting an operation status corresponding to a steering wheel operation, running status detection means for detecting a running status of the watercraft, outboard motor status recognition means for recognizing a status of an outboard motor 11, such as the installation number thereof, and electric motor status detection means for detecting a status of an electric motor. Further, the ECU also includes rudder deflection angle control means for controlling a limit rudder deflection angle based on the detection value from the at least one of the means.

Claims

1. Steering system for a watercraft, comprising:

   a rudder;
   a steering device including an actuator configured to change a direction in which the watercraft travels;
   a steering amount input means, operable by an operator, electrically connected to the actuator to provide an actuation signal corresponding to the amount of a steering operation to the actuator; and
   control means for controlling a limit of a rudder deflection angle,
   the control means including at least one of operation status detection means for detecting an operation status corresponding to the steering operation, running status detection means for detecting a running status of the watercraft, watercraft propulsion unit status recognition means for recognizing a status of a watercraft propulsion unit of the watercraft, such as the installation number thereof, and actuator status detection means for detecting a status of the actuator; and rudder deflection angle control means for controlling a limit rudder deflection angle based on the detection value from the at least one of the detection and recognition means.

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 operation status detection means includes at least one of rudder deflection force detection means for detecting a rudder deflection force required for rudder deflection, load detection means for detecting a load to the rudder, steering operation detection means for detecting a direction in which the rudder is deflected, corresponding to a direction in which the steering wheel is operated and/or the steering wheel operation, and deviation detection means for detecting a deviation of a detected actual rudder deflection angle from a target rudder deflection angle corresponding to the steering wheel operation.

5. Steering system according to one of the claims 1 to 4, wherein the running status detection means includes at least one of weight detection means for detecting at least one of a position of a waterline 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 deceleration and a propulsive force of the watercraft, and an output of the watercraft propulsion unit.

6. Steering system according to one of the claims 1 to 5, wherein the watercraft propulsion unit status recognition means includes operation storage means for storing therein any one of pieces of information on the 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 of the watercraft propulsion unit, a propeller shape, a tab trim angle and a tab trim shape.

7. Steering system according to one of the claims 1 to 6, wherein the actuator status detection means is an electric actuator status detection means, which includes temperature detection means for detecting a temperature of the electric actuator.

8. Steering system according to one of the claims 1 to 7, wherein the actuator status detection means is an electric actuator status detection means includes operating number detection means for detecting the number of the electric actuator in operation.

9. Steering system according to one of the claims 1 to 8, further comprising: a reaction motor for applying a reaction force to the steering wheel; and reaction motor control means for increasing a reaction force to the reaction motor as the rudder nearly achieves the limit rudder deflection angle.

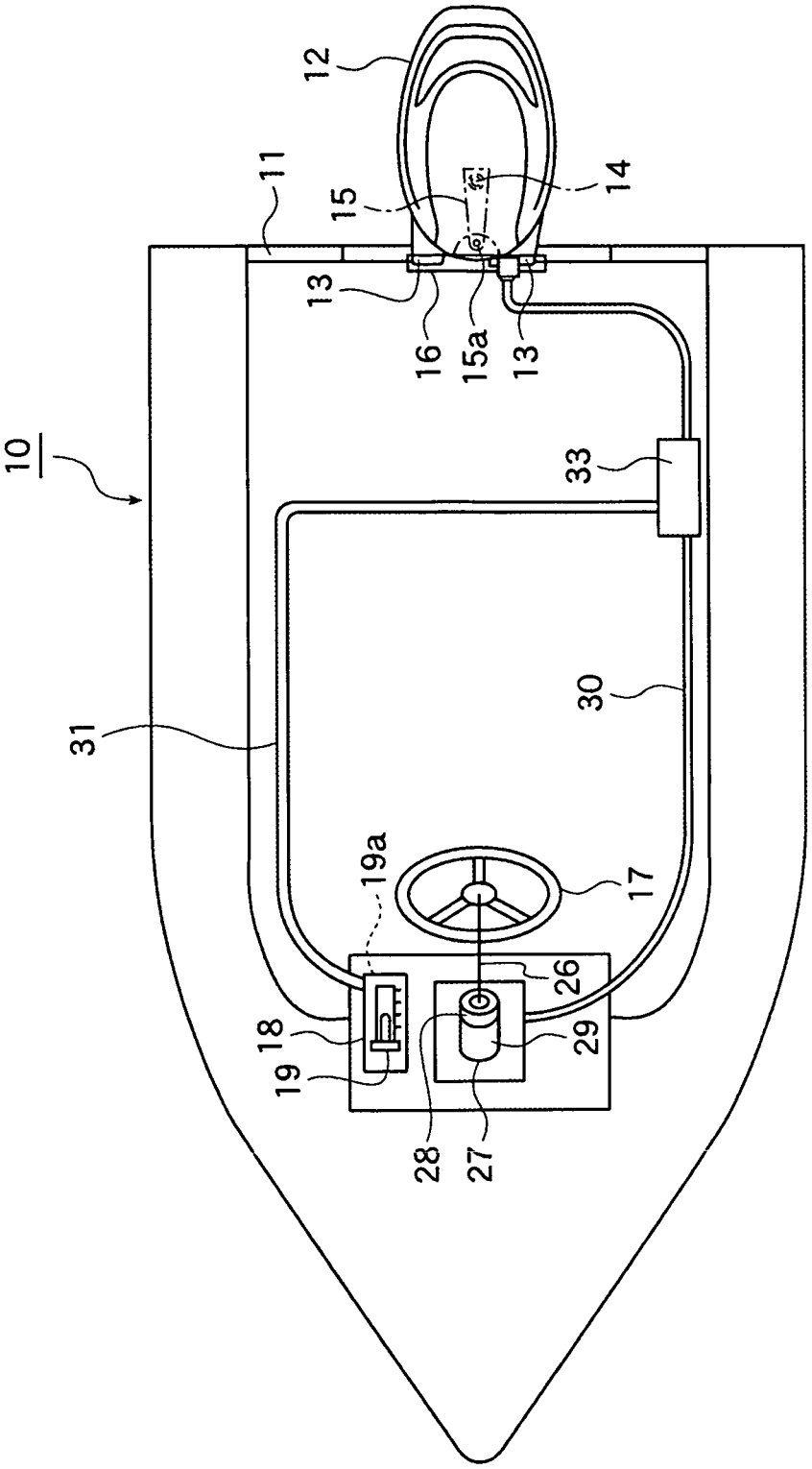
10. Steering system according to one of the claims 1 to 9, wherein the steering amount input means is a steering wheel or a control lever, operable by an operator, electrically connected to the electric actuator to provide an actuation signal corresponding to the amount of a steering input operation to the electric actuator.

11. Steering system according to one of the claims 1 to 10, further including an electronic control unit (ECU) for controlling a limit of a steering means deflection angle, the ECU (33) including at least one of operation status detection means for detecting an operation status corresponding to a steering amount input means operation, running status detection means for detecting a running status of the watercraft, outboard motor status recognition means for recognizing a status of an outboard motor (11), such as the installation number thereof, and electric motor status detection means for detecting a status of an electric motor, and the ECU also including steering means deflection angle control means for controlling a limit

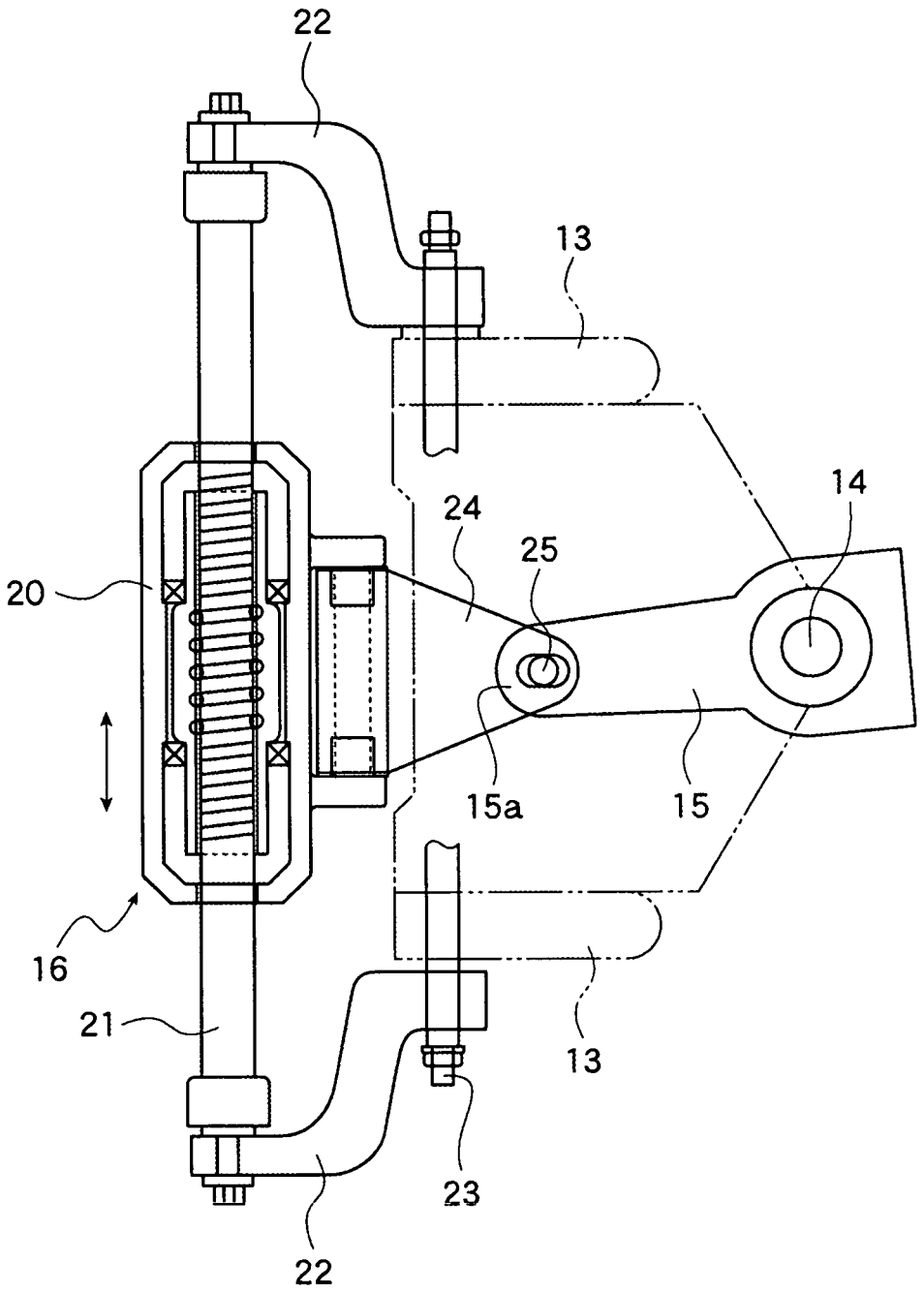
steering means deflection angle based on the detection value from the at least one of the means.

12. Watercraft provided with a steering system for a watercraft according to one of the claims 1 to 10.

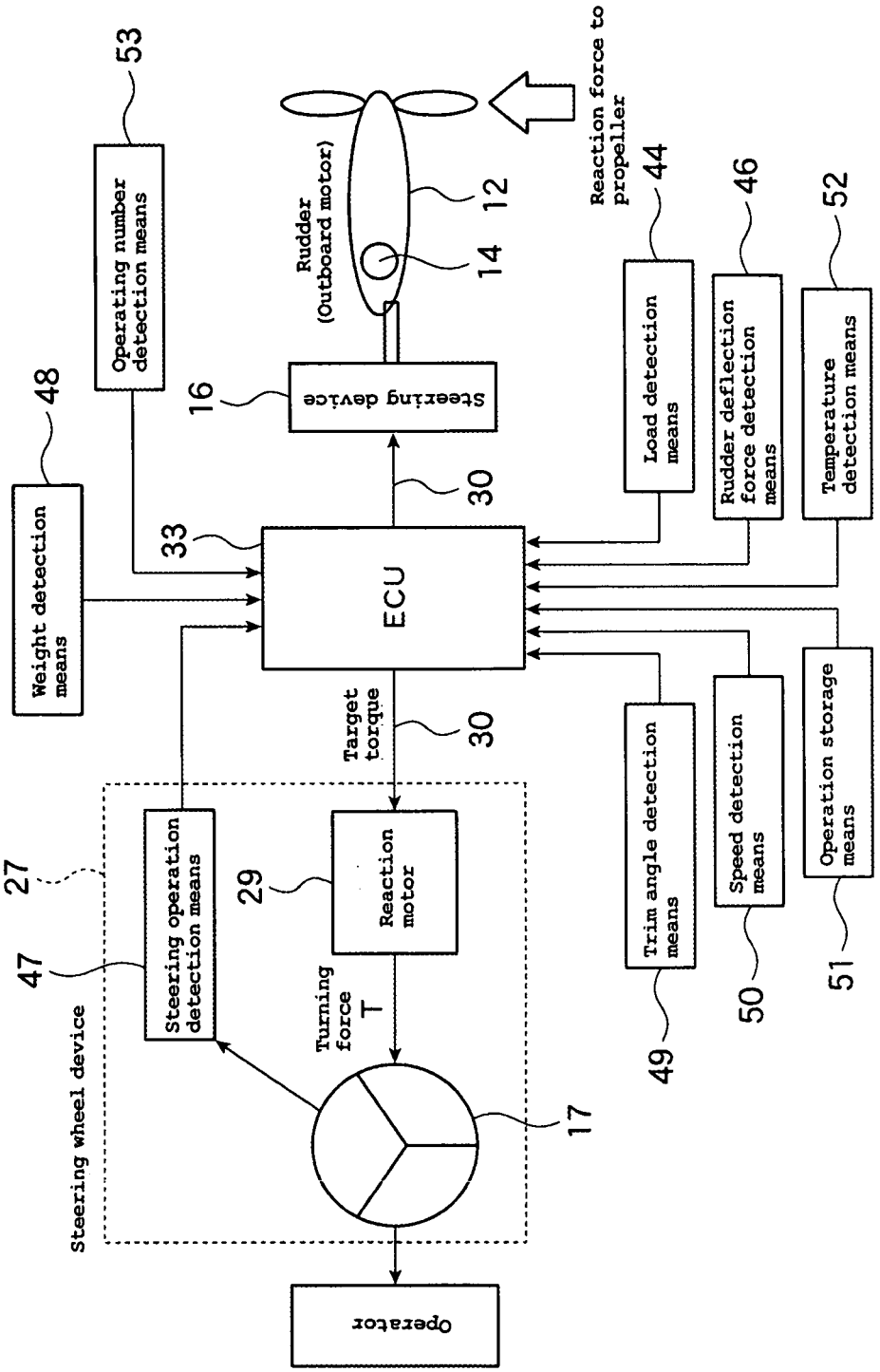
[FIG. 1]



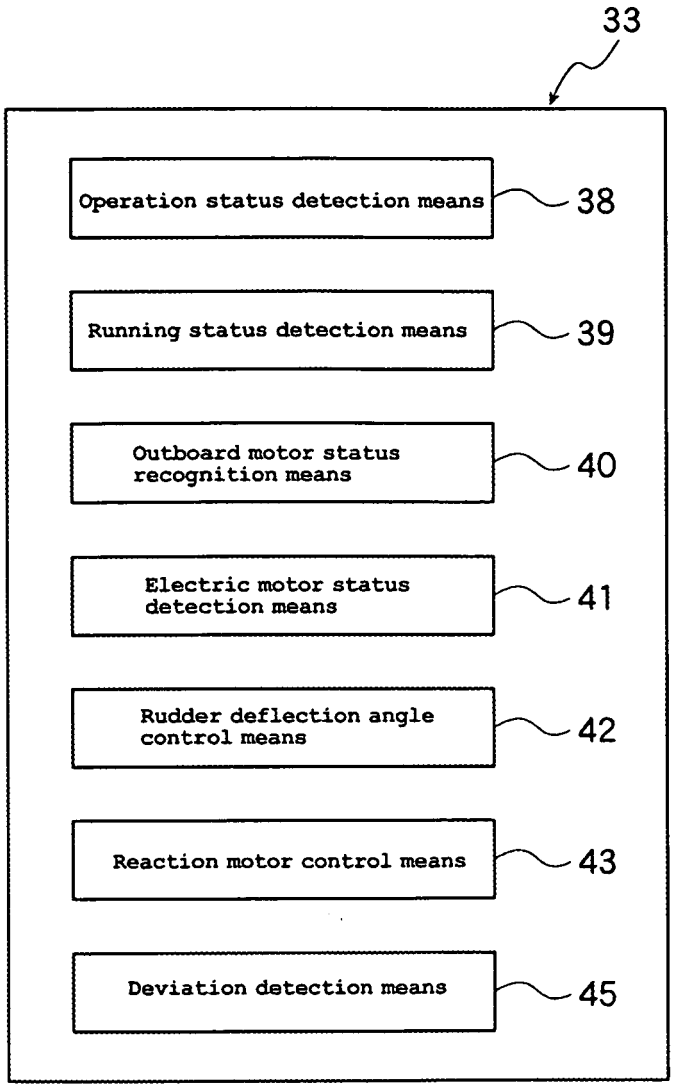
[FIG. 2]



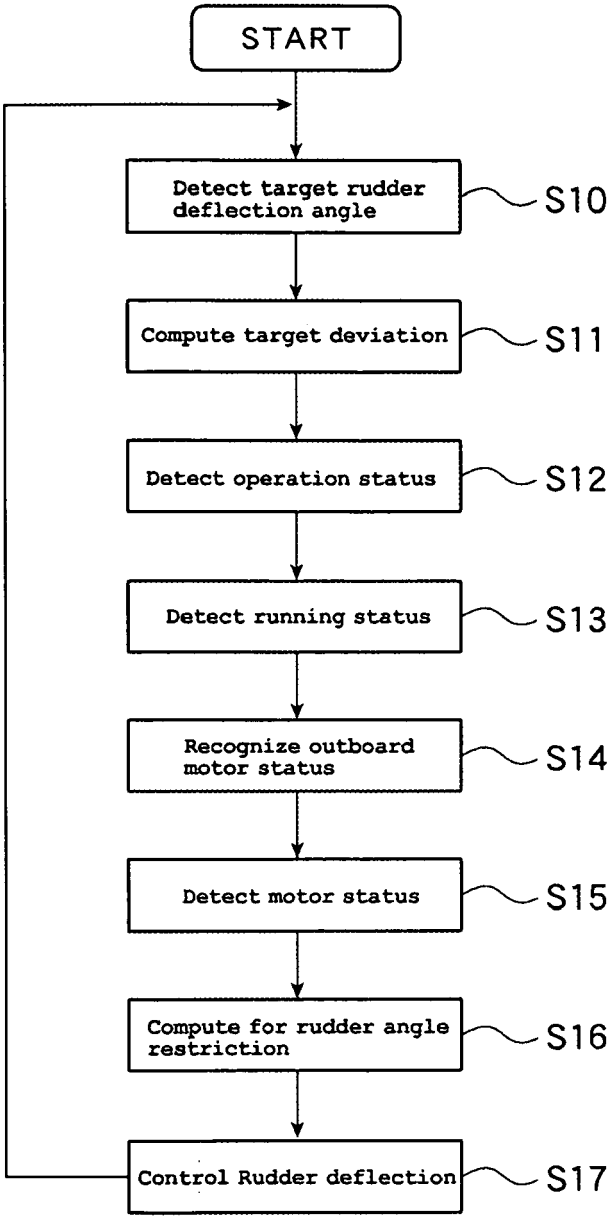
[FIG. 3]


53
Operating number detection means
Rudder (Outboard motor)
12
14
Reaction force to propeller
44
Load detection means
46
Rudder deflection force detection means
52
Temperature detection means
48
16
Steering device
30
Weight detection means
33
ECU
Target torque
30
27
29
Reaction motor
47
Steering operation detection means
Turning force T
Steering wheel device
17
Trim angle detection means
49
Speed detection means
50
Operation storage means
51
Operator

[FIG. 4]

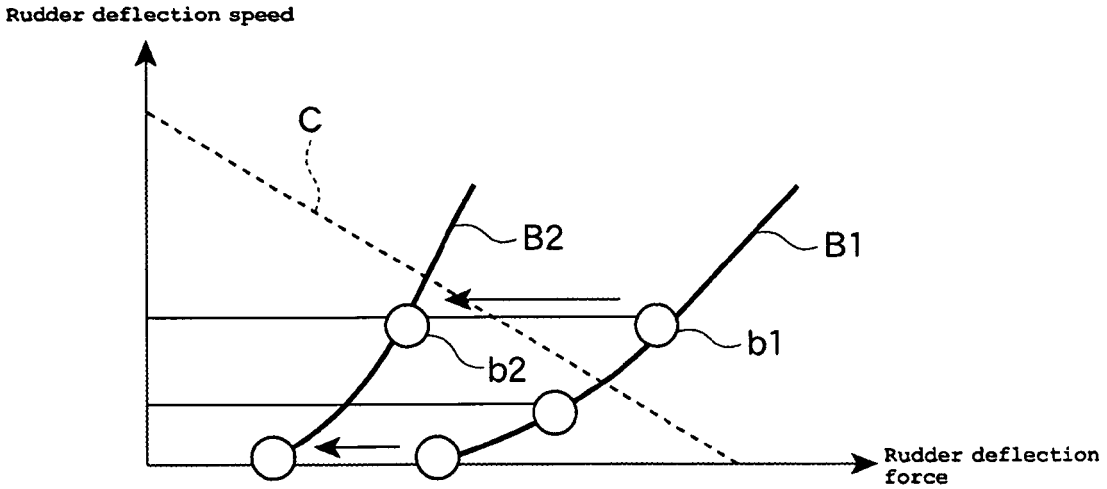

33
Operation status detection means
38
Running status detection means
39
Outboard motor status recognition means
40
Electric motor status detection means
41
Rudder deflection angle control means
42
Reaction motor control means
43
Deviation detection means
45

[FIG. 5]

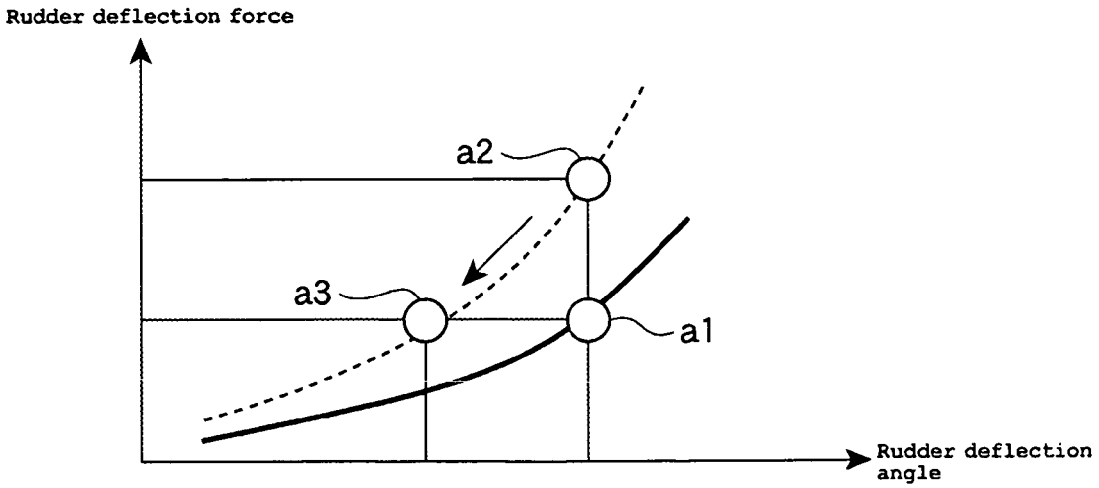

START
Detect target rudder deflection angle
S10
Compute target deviation
S11
Detect operation status
S12
Detect running status
S13
Recognize outboard motor status
S14
Detect motor status
S15
Compute for rudder angle restriction
S16
Control Rudder deflection
S17

[FIG. 6]

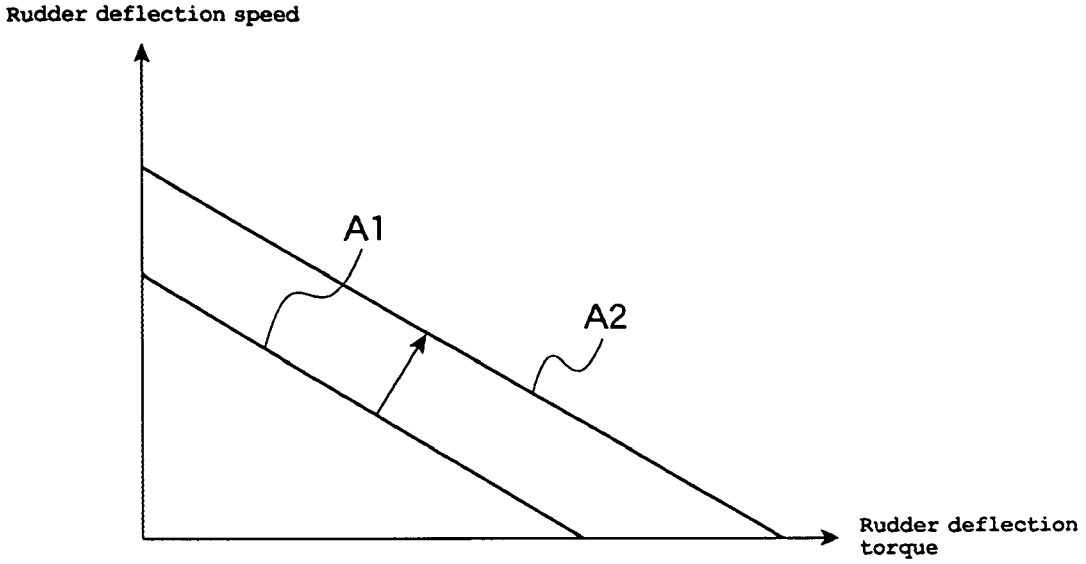
(a)


Rudder deflection speed
C
B2
B1
b1
b2
Rudder deflection force

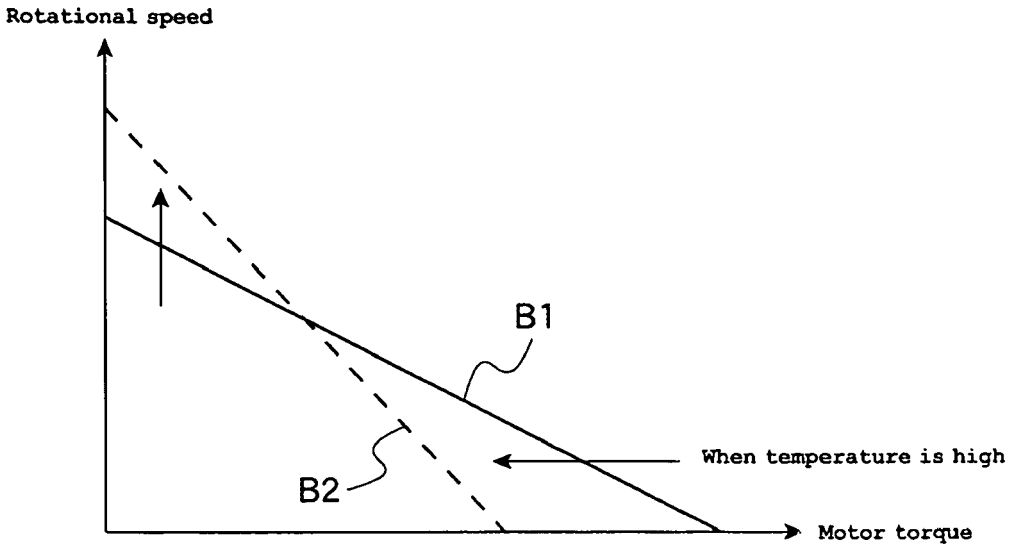
(b)


Rudder deflection force
a2
a3
a1
Rudder deflection angle

[FIG. 7]



[FIG. 8]


Rotational speed
B1
B2
When temperature is high
Motor torque

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2005254848 A **[0003]**