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(54) STEERING ASSIST SYSTEM FOR BOAT

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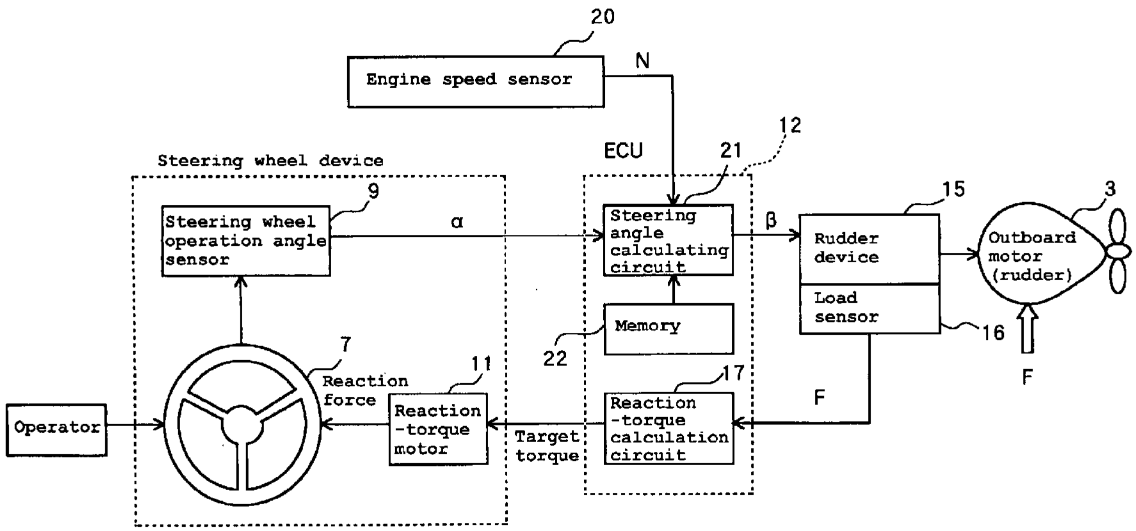
(57) **ABSTRACT**

A steering system can be provided for a boat. Such a boat can include a rudder device using an electric actuator to allow a rudder to rotate about a rotational shaft, and a steering wheel **7** for operation by an operator. The steering system can include a steering wheel displacement sensor for detecting the displacement of the steering wheel and a controller for calculating the rotational displacement of the rudder device corresponding to the detected steering wheel displacement and sending an actuation signal to the electric actuator based on the calculated rotational displacement, in which the controller receives a signal indicating an engine speed for producing a propulsive force in the boat, and changes, in accordance with the engine speed, the ratio of the rotational displacement of the rudder relative to the steering wheel displacement.



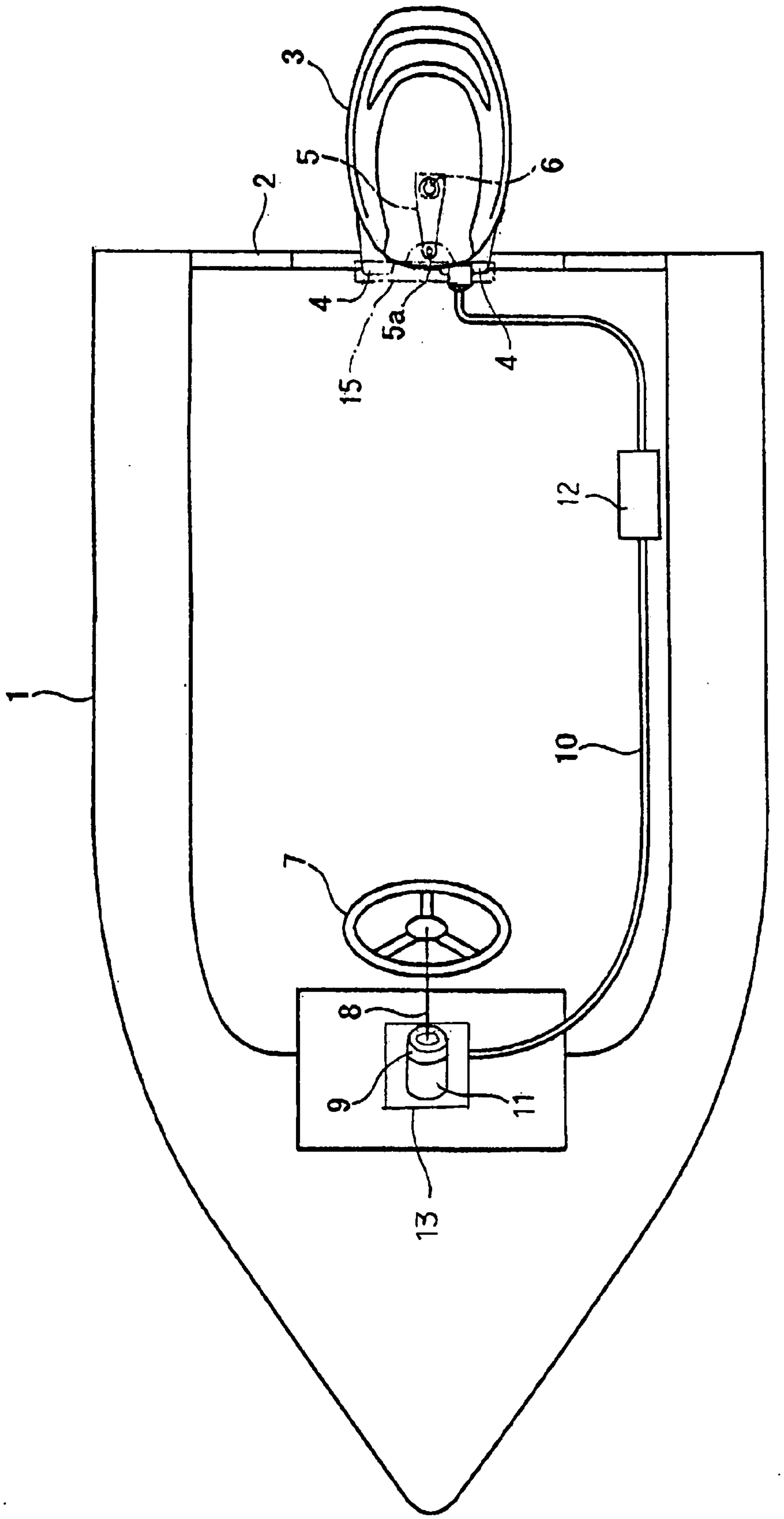


Figure 1

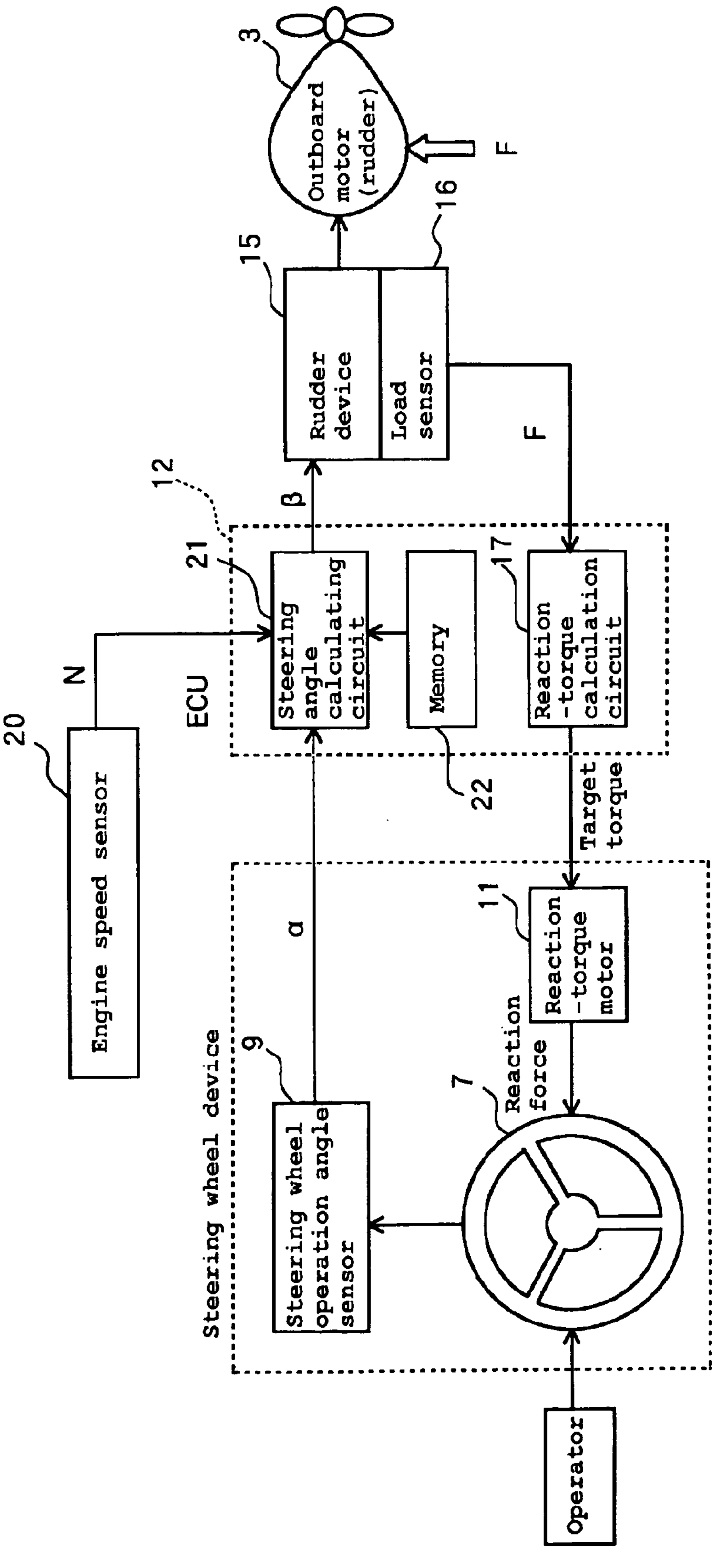

Outboard motor (rudder)
3
F
Rudder device
15
Load sensor
16
F
β
12
ECU
Steering angle calculating circuit
21
Memory
22
Reaction -torque calculation circuit
17
Target torque
Engine speed sensor
20
N
Steering wheel device
Steering wheel operation angle sensor
9
α
Reaction -torque motor
11
Reaction force
7
Operator

Figure 2

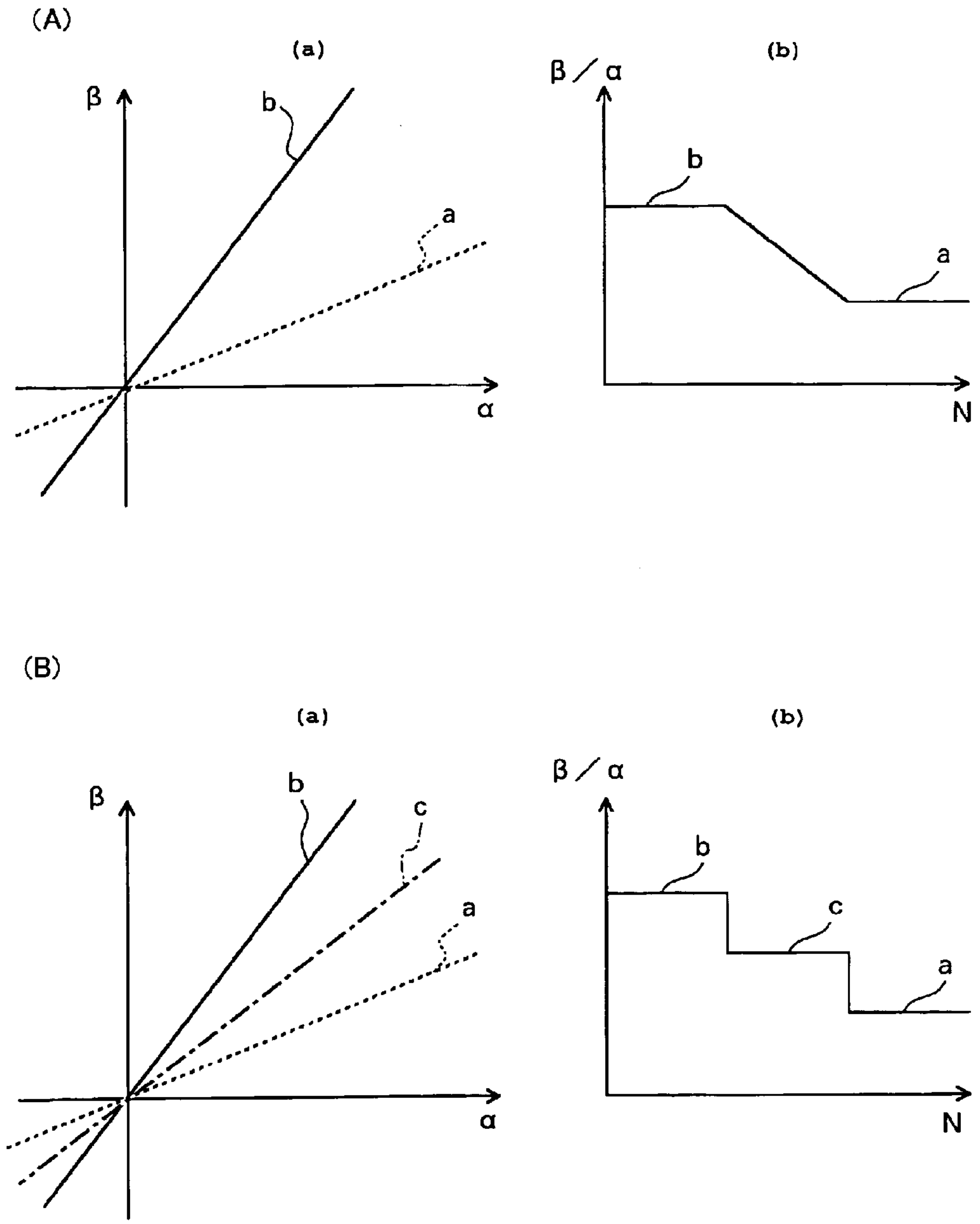


Figure 3

STEERING ASSIST SYSTEM FOR BOAT

PRIORITY INFORMATION

[0001] This application is based on and claims priority under 35 U.S.C. §119 to Japanese Patent Application No. 2004-065701, filed on Mar. 9, 2004, the entire contents of which is hereby expressly incorporated by reference herein.

BACKGROUND OF THE INVENTIONS

[0002] 1. Field of the Inventions

[0003] The present inventions relate to an electric steering system for a small boat, and in particular, to steering systems that provide variable steering response.

[0004] 2. Description of the Related Art

[0005] Japanese Patent Publication JP-B-Hei 6-33077 discloses a steering system for a small boat having a boat speed sensor, which is designed to change the ratio of the displacement of a rudder device relative to steering wheel angle depending on the boat speed. This system generates proportionally larger rudder displacements at low boat speeds by raising the steering angle to the steering wheel turning angle ratio. Similarly, the system generates proportionally smaller rudder displacements at higher boat speeds by decreasing the steering angle to steering wheel angle ratio, thereby providing speed dependant steering response.

[0006] However, unlike ground vehicles, a boat speed (velocity relative to the water in which the boat operates) is influenced by tide flows, waves and/or winds. Thus, it is difficult to realize a highly accurate control if boat operations are controlled based on the boat speed. In addition, boat speed sensors are expensive, can become clogged and thus inoperable, and installation thereof on a boat makes the wiring layout and control mechanism more complicated.

SUMMARY OF THE INVENTION

[0007] An aspect of at least one of the embodiments disclosed herein includes the realization that an electric steering system for a small boat can constantly provide good steering performance corresponding to the boat running speed without a boat speed sensor, thereby reducing the cost and improving the reliability of the system. For example, such a steering system can change, in accordance with the boat running speed, the ratio of the rudder steering angle or displacement relative to the steering wheel turning angle.

[0008] Thus, in accordance with an embodiment, a steering system is provided for a boat comprising an engine configured to provide propulsion for the hull and a rudder device including an electric actuator to rotate a rudder about a rotational shaft, a steering wheel configured to be operated by an operator of the boat. The steering system includes a steering wheel displacement sensor configured to detect the displacement of the steering wheel, and a controller configured to calculate the rotational displacement of the rudder device corresponding to the detected steering wheel displacement and to send an actuation signal to the electric actuator based on the calculated rotational displacement. The controller is also configured to receive a signal indicating a speed of the engine, and to change, in accordance with the engine speed, a ratio of the rotational displacement of the rudder relative to the steering wheel displacement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The above-mentioned and other features of the inventions disclosed herein are described below with reference to the drawings of the preferred embodiments. The illustrated embodiments are intended to illustrate, but not to limit the inventions. The drawings contain the following Figures:

[0010] **FIG. 1** is a schematic top plan view of a watercraft having a steering system in accordance with an embodiment.

[0011] **FIG. 2** is a block diagram of an electric steering system according to the embodiment of the present invention.

[0012] FIGS. **3**(A) and **3**(B) are explanatory graphs, showing examples of preset steering angle relative to steering wheel turning angle.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0013] **FIG. 1** is a schematic top plan view of a small boat including an outboard motor with which the present embodiments are applicable. The embodiments disclosed herein are described in the context of a marine propulsion system of a small boat because these embodiments have particular utility in this context. However, the embodiments and inventions herein can also be applied to other marine vessels, such as personal watercraft and small jet boats, as well as other vehicles.

[0014] An outboard motor **3** is mounted to a transom plate **2** of a hull **1** through clamp brackets **4**. The outboard motor **3** is rotatable about a swivel shaft **6**. A steering bracket **5** is fixed to an upper end of the swivel shaft **6**. A rudder device **15** is connected to an end **5***a* of the steering bracket **5**.

[0015] The rudder device **15** includes, for example, a DD (Direct Drive) type electric motor including a motor body (not shown). The motor body slides along a threaded shaft (not shown) that can be oriented generally parallel to the transom plate **2**. The steering bracket **5** is connected to the motor body to allow the outboard motor **3** to rotate about the swivel shaft **6** in conjunction with the sliding motion of the motor body.

[0016] A steering wheel **7** is provided in the vicinity of an operator's seat on the hull **1**. A steering wheel control section **13** can be provided at the root or base of a steering column shaft **8** of the steering wheel **7**, however other locations can also be utilized. A steering wheel displacement (e.g. operation angle) sensor **9** and a reaction torque motor **11** are provided inside the steering wheel control section **13**. The steering wheel control section **13** can be connected, via a signal cable **10**, to a controller **12**, which in turn is connected to the rudder device **15**.

[0017] The controller **12** can be configured to calculate a steering angle based on a detection signal from the steering wheel operation angle sensor **9**. The calculated steering angle is sent to the rudder device **15** as an electric command signal, to drive the rudder device **15** so as to allow the outboard motor **3** to rotate about the swivel shaft **6** for boat steering.

[0018] A load sensor **16** (See **FIG. 2**) that can be provided in the outboard motor **3** or the rudder device **15** itself, can be configured to detect an external force F (See **FIG. 2**) exerted on the outboard motor **3**. The controller **12** can be configured to calculate a target value of reaction torque to be exerted to the steering wheel **7** by the reaction torque motor **11** based on the external force. The controller **12** then drives the reaction torque motor **11** in accordance with the target torque, thereby applying a reaction force corresponding to the external force to the steering wheel **7**.

[**0019**] **FIG. 2** is a block diagram of a steering system according to an embodiment of the present invention.

[**0020**] When an operator rotates the steering wheel **7**, the rotated angle is detected by the steering wheel operation angle sensor **9**. Based on the detection signal, a steering angle calculation circuit **21** of the controller (ECU) **12** calculates a steering angle as will be described later, and converts it into an electrical current value to drive the electric motor (not shown) of the rudder device **15**. This allows the outboard motor **3** to swing about the swivel shaft **6** (See **FIG. 1**), to change the direction of the boat.

[**0021**] While the outboard motor **3** rotates, an external resistance (external force) F as a reaction force is applied to the outboard motor **3**. The load sensor **16** detects the external force F, and data of which is sent to a reaction torque calculating circuit **17**. Based on the data for the detected external force, a target torque is calculated and the reaction torque motor **11** is so driven as to apply such target torque. This causes a reaction force corresponding to the steering operation to be applied to the steering wheel **7** so that the operator can steer the steering wheel while feeling the reaction force in response to the steering wheel operation.

[**0022**] The outboard motor **3** functions as a rudder when it rotates about the swivel shaft. In this case, the steering angle calculating circuit **21** calculates the displacement of the rudder or the steering angle (e.g. rudder angle) β based on the steering wheel turning angle a detected by the steering wheel operation angle sensor **9**. At this time, the steering angle calculating circuit **21** calculates β such that the value β/a varies with the engine speed N detected by the engine speed sensor **20**. The value β/a corresponding to the engine speed N can be stored in a memory **22** as a preset map. On calculating β, the steering angle calculating circuit **21** reads out the map of the value β/a stored in the memory **22** to calculate the steering angle β based on the data of the turning angle a detected by the steering wheel operation angle sensor **9**.

[**0023**] FIGS. **3**(A) and **3**(B) are explanatory graphs, showing examples of preset steering angle relative to steering wheel turning angle. **FIG. 3**(A)(a) shows two preset gradient values of the steering angle β relative to the steering wheel turning angle a, that is, a smaller preset value (a) and a larger preset value (b), between which there are included additional preset gradient values proportional to the engine speed N. In other words, as shown in **FIG. 3**(A)(b), the value β/a is set to a larger value for use in a lower speed range, smaller value for use in a higher speed range, and set to vary more linearly with the engine speed N in a middle speed range (an engine speed range between the lower and higher engine speeds). Thus, in the middle speed rage, the value β/a itself can change proportionally to the engine speed N. As used herein, the tem "proportionally" is intended to include any type of relationship, whether it is linear or non-linear. For example, the term "proportional" encompasses relationships where incremental increases in a engine speed N trigger incremental increases (or decreases) in the value β/a.

[**0024**] **FIG. 3**(B)(a) shows three preset gradient values of the steering angle β relative to the steering wheel turning angle a; a smaller preset value (a), a larger preset vale (b) and a medium preset value (c). In other words, as shown in **FIG. 3**(B)(b), the preset value β/a sequentially decreases in a stepped manner in three stages, a low, medium and high speed range of the engine speed N.

[**0025**] The preset value β/a relative to the engine speed N as shown in FIGS. **3**(A)(b) or **3**(B)(b) is stored in the memory as a map, and read out when the steering wheel is operated to calculate the steering angle β based on the steering wheel turning angle a and engine speed N.

[**0026**] Boats troll at low speed in the port or on the sea for fishing while generally cruising at high speed on the sea. Both speeds approximately correspond to engine speed, when the boat has reached a steady-state of operation, i.e., when the boat is no longer accelerating or decelerating or decelerating speed with high load variation. This is because most boats used a single-speed reduction gear to drive a propeller or jet pump. Thus, the steering system can simply use engine speed N as the basis for changing the value β/a and still provide a response that is like the response provided by systems that use boat speed (and a more expensive and less reliable boat speed sensor).

[**0027**] Moreover, there is no need to connect the expensive boat speed sensor to an engine controller, resulting in cost reduction as well as simplified control mechanism, wiring layout and the like. In some embodiments, if a boat sensor is used at all, it can be directly connected to a gauge (not shown) near the steering wheel **7**, and thus does not affect the complexity of the controller **12** or wiring layout of the boat. In addition, a typical engine control unit is provided with the engine speed sensor since it is such is commonly used for fuel and ignition timing controls. Thus, no additional sensor is required because the existing engine speed sensor can be used with the present steering system.

[**0028**] In the embodiments where the engine speed is categorized into stages, e.g. three speed ranges including low, middle and high speed the steering control is more simple, and thus less expensive to manufacture. Additionally, when in the low-speed range, steering response is more nimble because the steering displacement relative to the steering wheel operation angle is increased.

[**0029**] The present inventions can be effectively applied to a small boat having an outboard motor or a stern drive, particularly to a rudder device using an electric motor. However, although these inventions have been disclosed in the context of certain preferred embodiments and examples, it will be understood by those skilled in the art that the present inventions extend beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the inventions and obvious modifications and equivalents thereof. In addition, while several variations of the inventions have been shown and described in detail, other modifications, which are within the scope of these inventions, will be readily apparent to those of skill in the art based upon this disclosure. It is also contemplated that various combination or sub-combinations of the specific features and aspects of the embodiments may be made and still fall within the scope of the inventions. It should be understood that various features and aspects of the disclosed embodiments can be combined with or substituted for one another in order to form varying modes of the disclosed inventions. Thus, it is intended that the scope of at least some of the present inventions herein disclosed should not be limited by the particular disclosed embodiments described above.

What is claimed is:

1. A steering system for a boat comprising an engine configured to provide propulsion for the hull and a rudder device including an electric actuator to rotate a rudder about a rotational shaft, a steering wheel configured to be operated by an operator of the boat, a steering wheel displacement sensor configured to detect the displacement of the steering wheel, and a controller configured to calculate the rotational displacement of the rudder device corresponding to the detected steering wheel displacement and to send an actuation signal to the electric actuator based on the calculated rotational displacement, the controller being further configured to receive a signal indicating a speed of the engine, and to change, in accordance with the engine speed, a ratio of the rotational displacement of the rudder relative to the steering wheel displacement.

2. The steering system according to claim 1, wherein the ratio is varied in stages in accordance with the preset ranges of the speed of the engine.

3. The steering system according to claim 1, wherein the engine is mounted in an outboard motor.

4. The steering system according to claim 1 additionally comprising a load sensor configured to detect loads applied to the rudder and a reaction torque motor configured to apply a torque to the steering wheel, the controller being configured to apply a torque to the steering wheel based on loads detected by the load sensor.

5. The steering system according to claim 1, wherein the ratio is changed proportional to changes in the speed of the engine.

6. The steering system according to claim 1, wherein a value of the ratio is changed incrementally with incremental changes in the speed of the engine.

7. A steering system for a boat comprising an engine configured to provide propulsion for the hull and a rudder device including an electric actuator to rotate a rudder about a rotational shaft, a steering wheel configured to be operated by an operator of the boat, a steering wheel displacement sensor configured to detect the displacement of the steering wheel, and means for changing a ratio of the rotational displacement of the rudder relative to the steering wheel displacement in accordance with the engine speed.

8. The steering system according to claim 7 additionally comprising means for detecting loads applied to the rudder and means for applying torque to the steering wheel based on the loads detected by the means for detecting loads.

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