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Ikegaya

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(54) **SYSTEM FOR AND METHOD OF CONTROLLING WATERCRAFT INCLUDING MARINE PROPULSION DEVICE**

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(22) Filed: **Nov. 4, 2021**

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(30) **Foreign Application Priority Data**

Nov. 27, 2020 (JP) 2020-197453

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B63H 20/12 (2006.01)
B63H 25/38 (2006.01)

(52) **U.S. Cl.**
CPC ***B63H 20/12*** (2013.01); ***B63H 25/38*** (2013.01)

(58) **Field of Classification Search**
CPC B63H 20/12; B63H 25/38
See application file for complete search history.

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

JP 02-227396 A 9/1990

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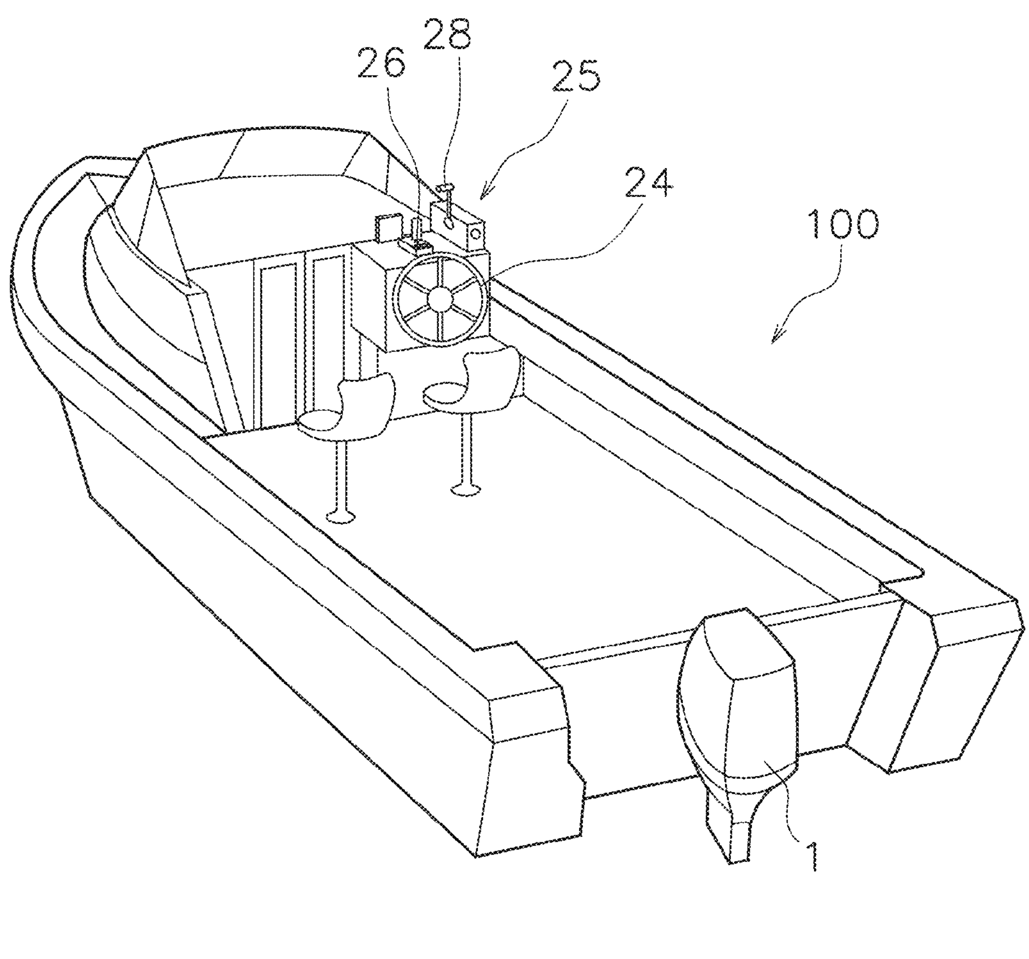
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A joystick outputs an operating signal indicating a tilt amount and a twist direction of the joystick. A controller receives the operating signal and controls a marine propulsion device to output a thrust having a magnitude depending on the tilt amount. The controller changes a rudder angle of the marine propulsion device such that a watercraft turns in a direction corresponding to the twist direction. The controller reduces a speed of changing the rudder angle with an increase in the magnitude of the thrust.

13 Claims, 10 Drawing Sheets



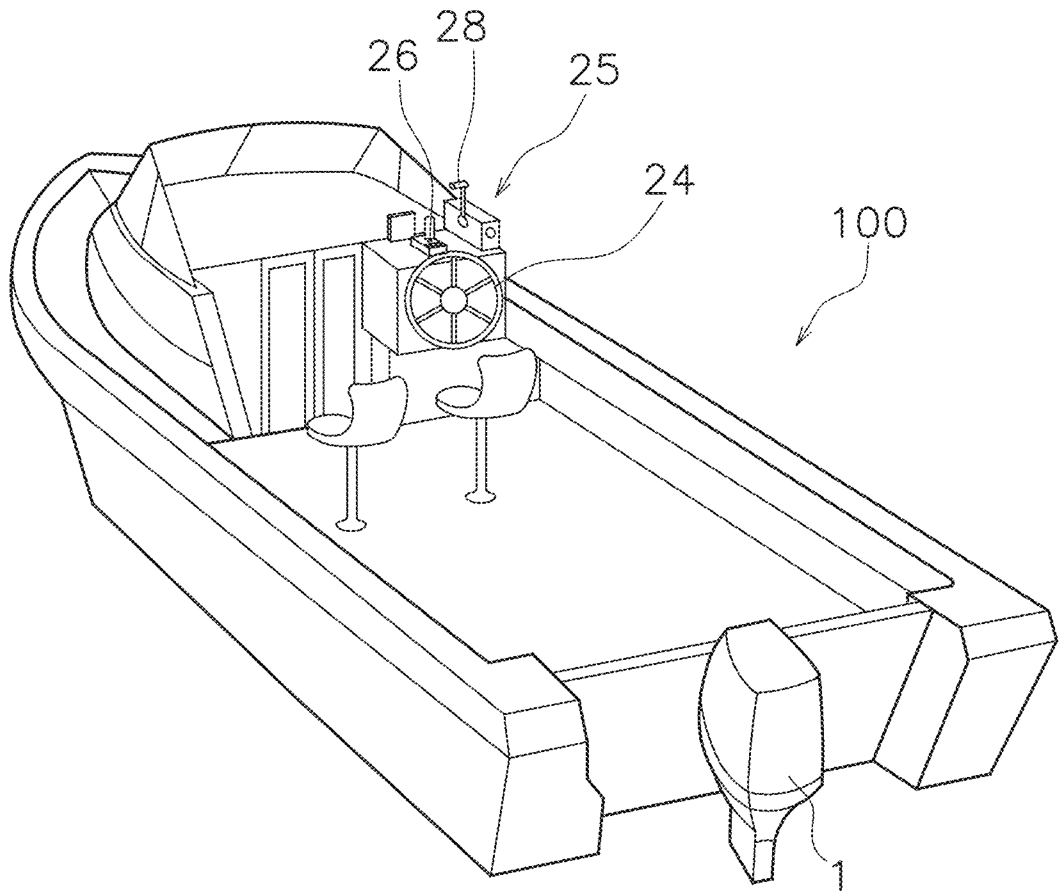


FIG. 1

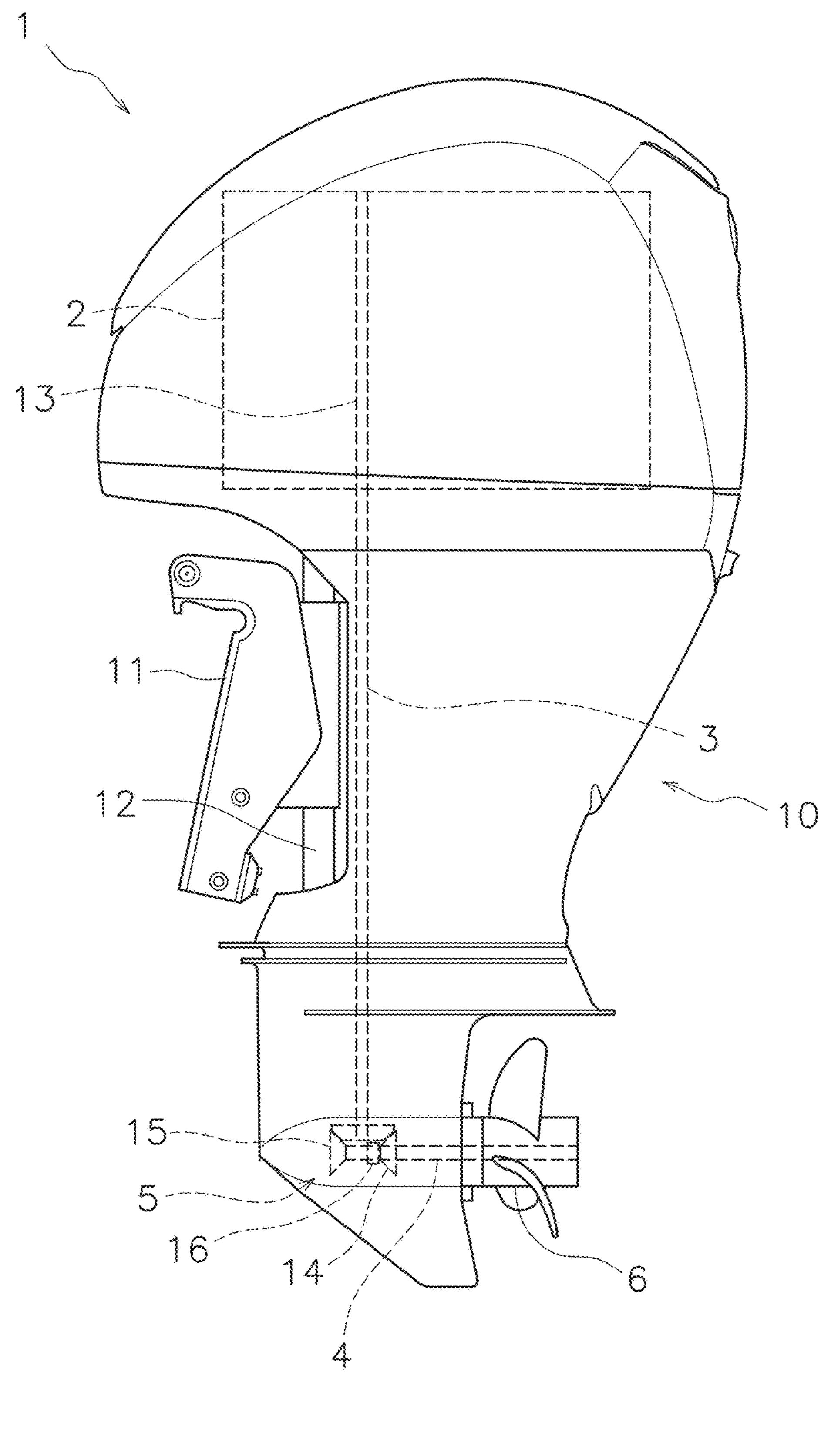


FIG. 2

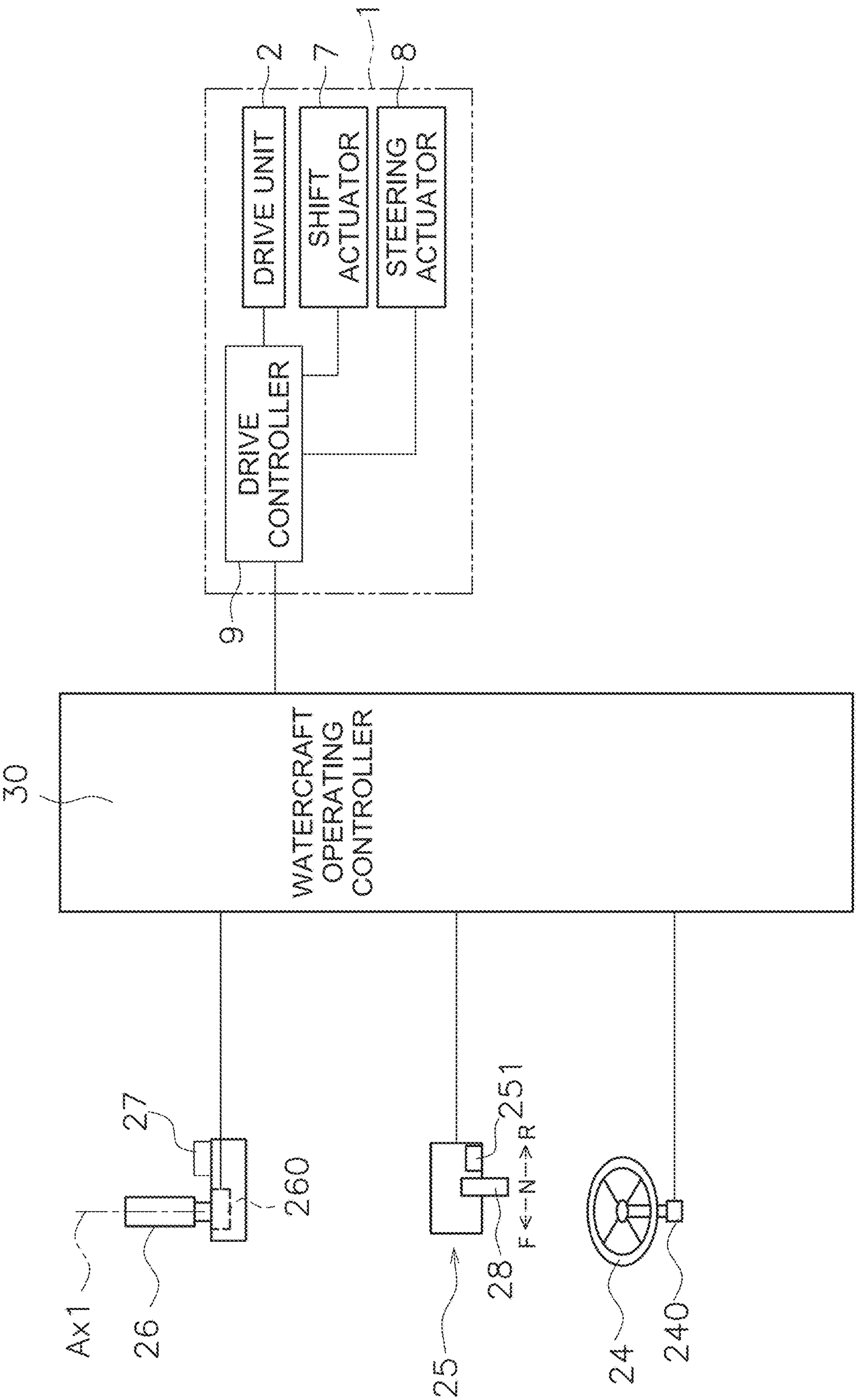

1
2
7
8
DRIVE UNIT
SHIFT ACTUATOR
STEERING ACTUATOR
DRIVE CONTROLLER
9
30
WATERCRAFT OPERATING CONTROLLER
27
251
260
Ax1
26
F ← N → R
28
25
24
240

FIG. 3

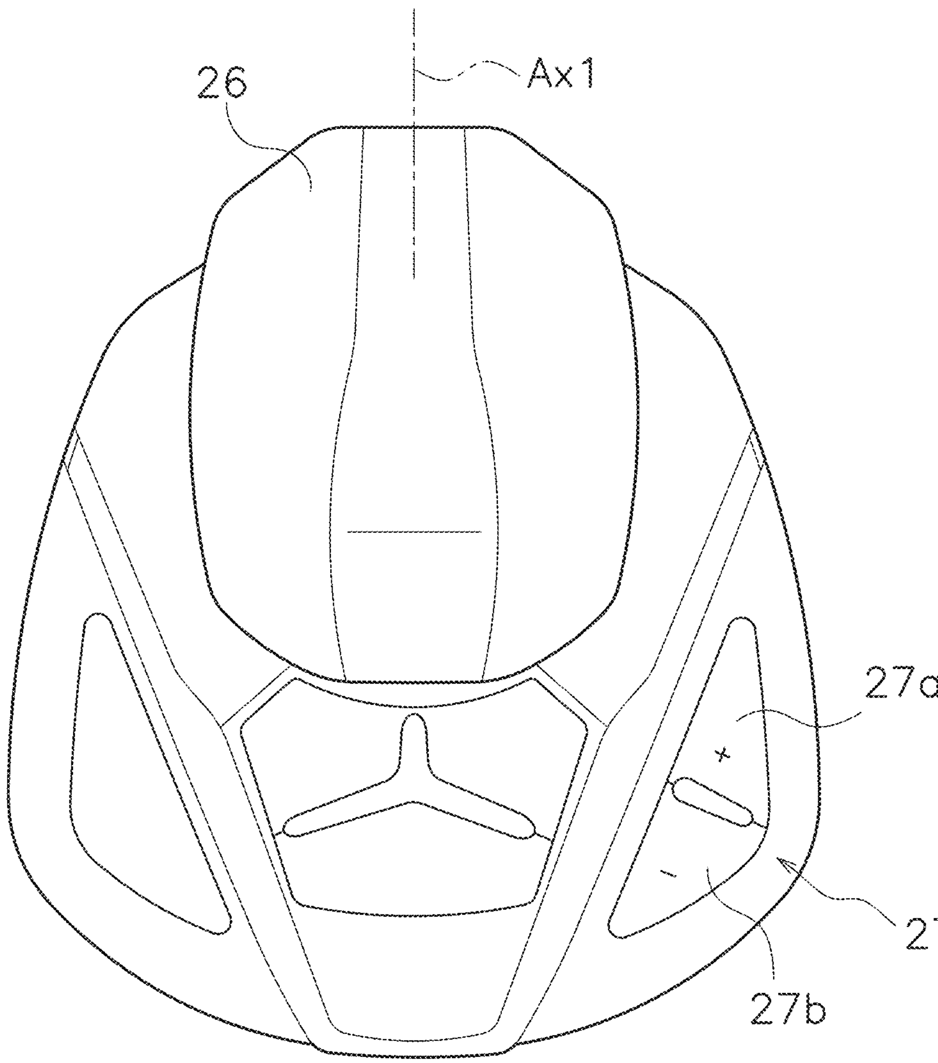


FIG. 4

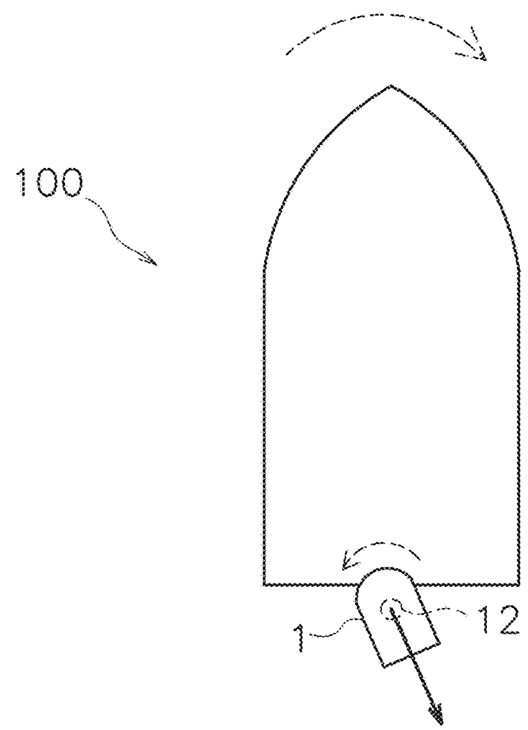


FIG. 5A

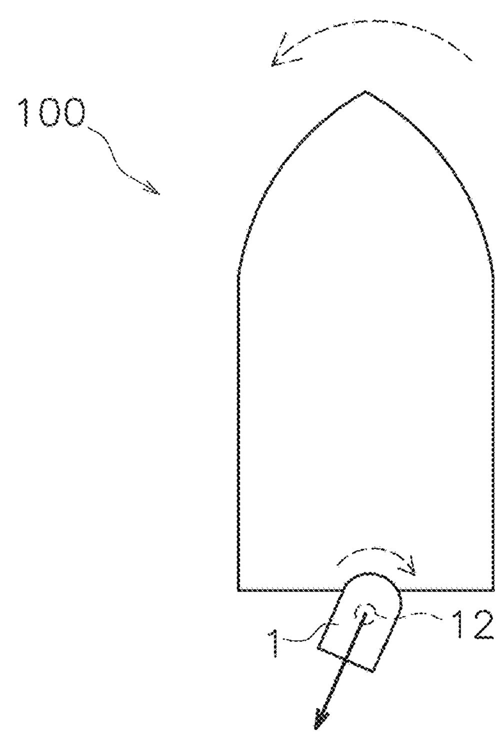


FIG. 5B

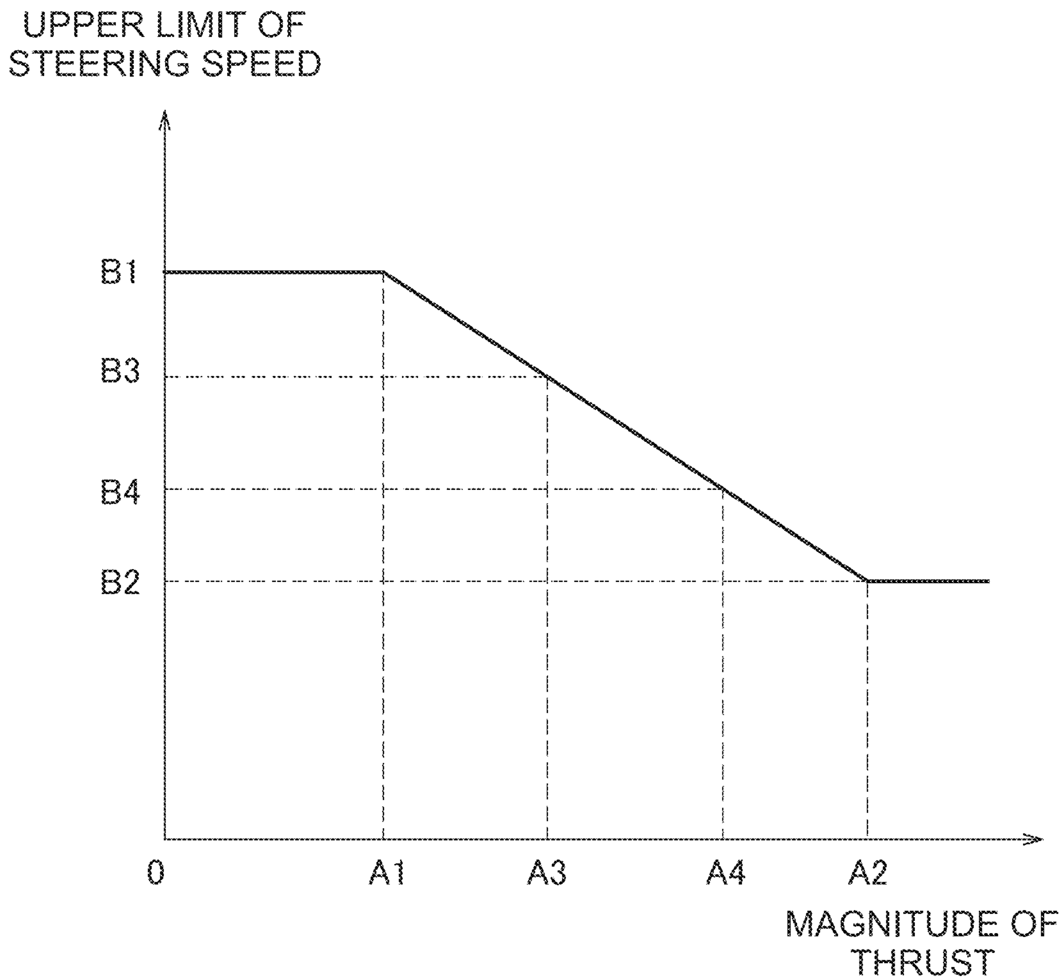

UPPER LIMIT OF
STEERING SPEED
B1
B3
B4
B2
0
A1
A3
A4
A2
MAGNITUDE OF
THRUST

FIG. 6

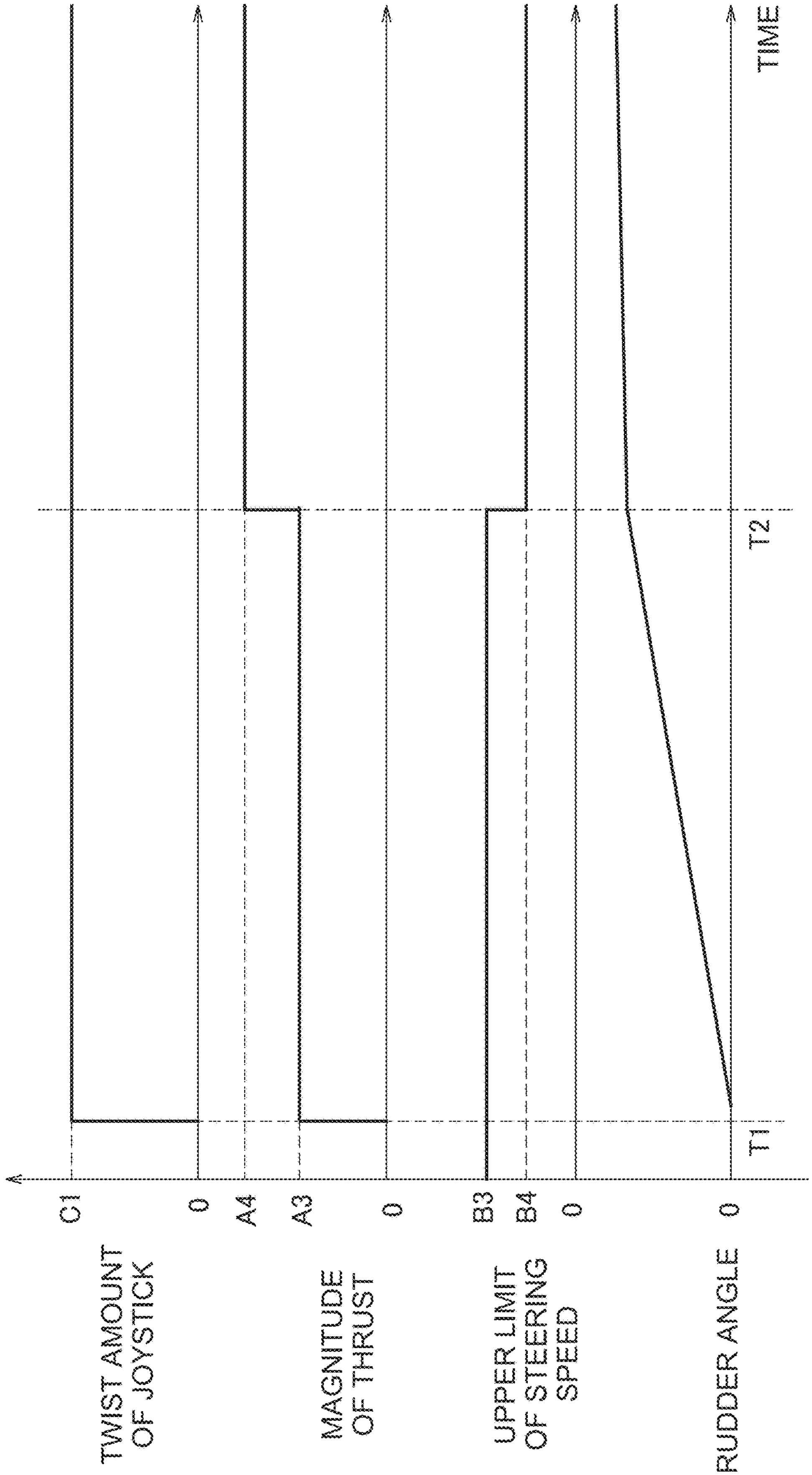

TWIST AMOUNT OF JOYSTICK
MAGNITUDE OF THRUST
UPPER LIMIT OF STEERING SPEED
RUDDER ANGLE
C1
0
A4
A3
0
B3
B4
0
0
T1
T2
TIME

FIG. 7

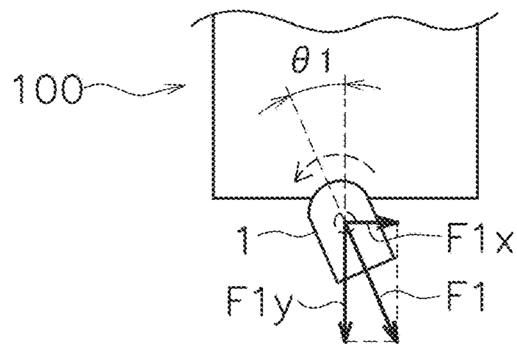


FIG. 8A

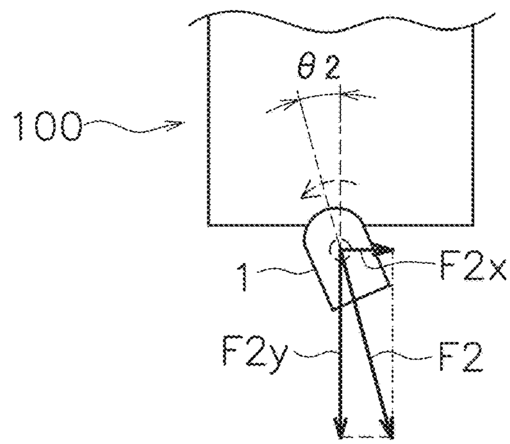


FIG. 8B

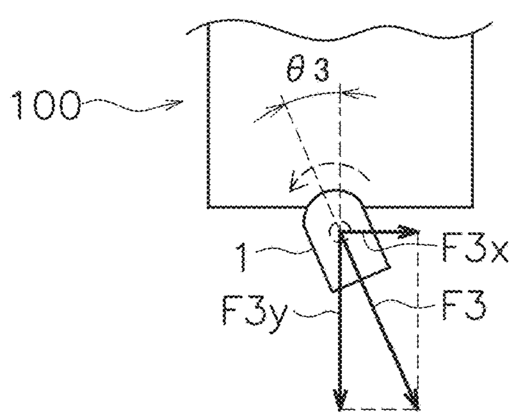


FIG. 8C

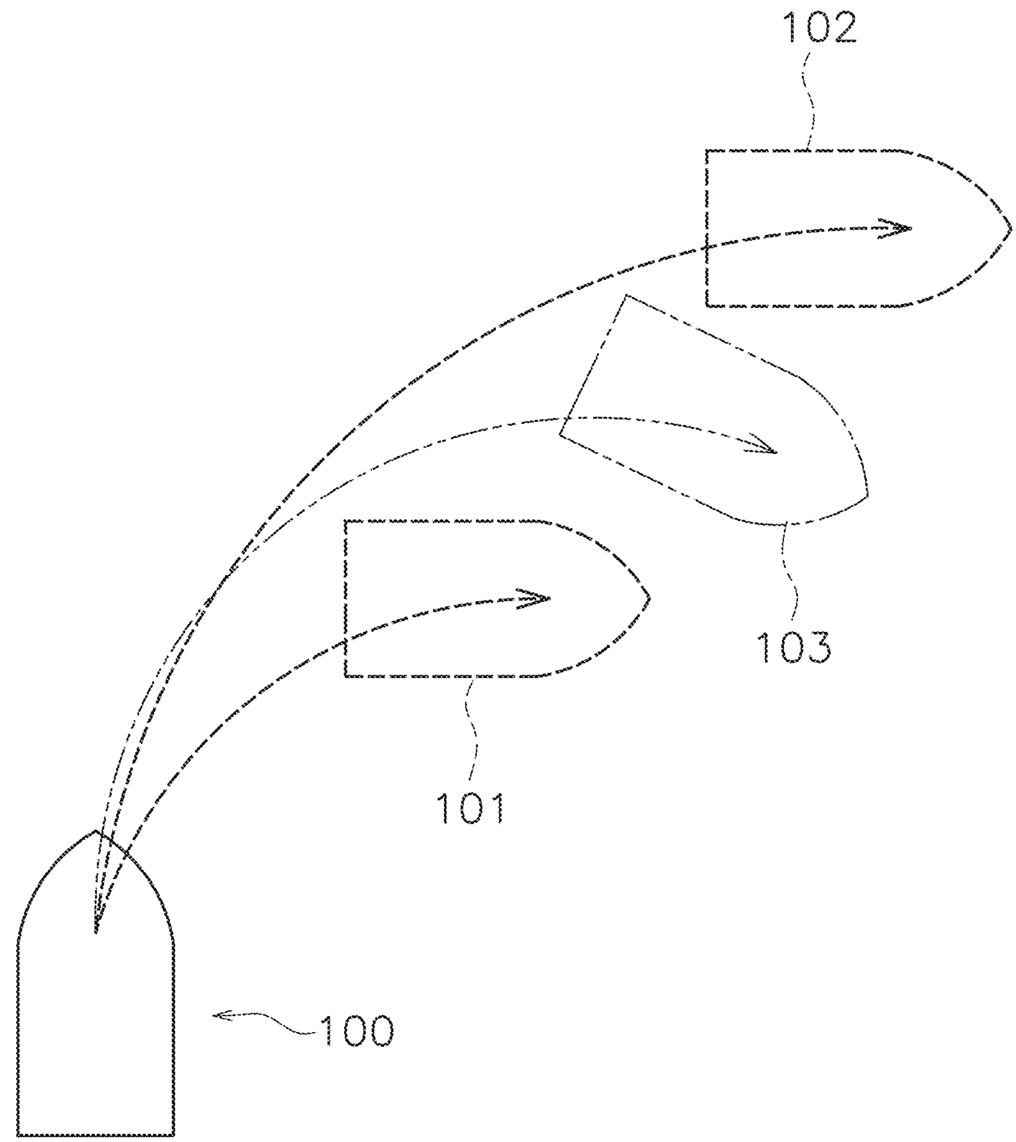


FIG. 9

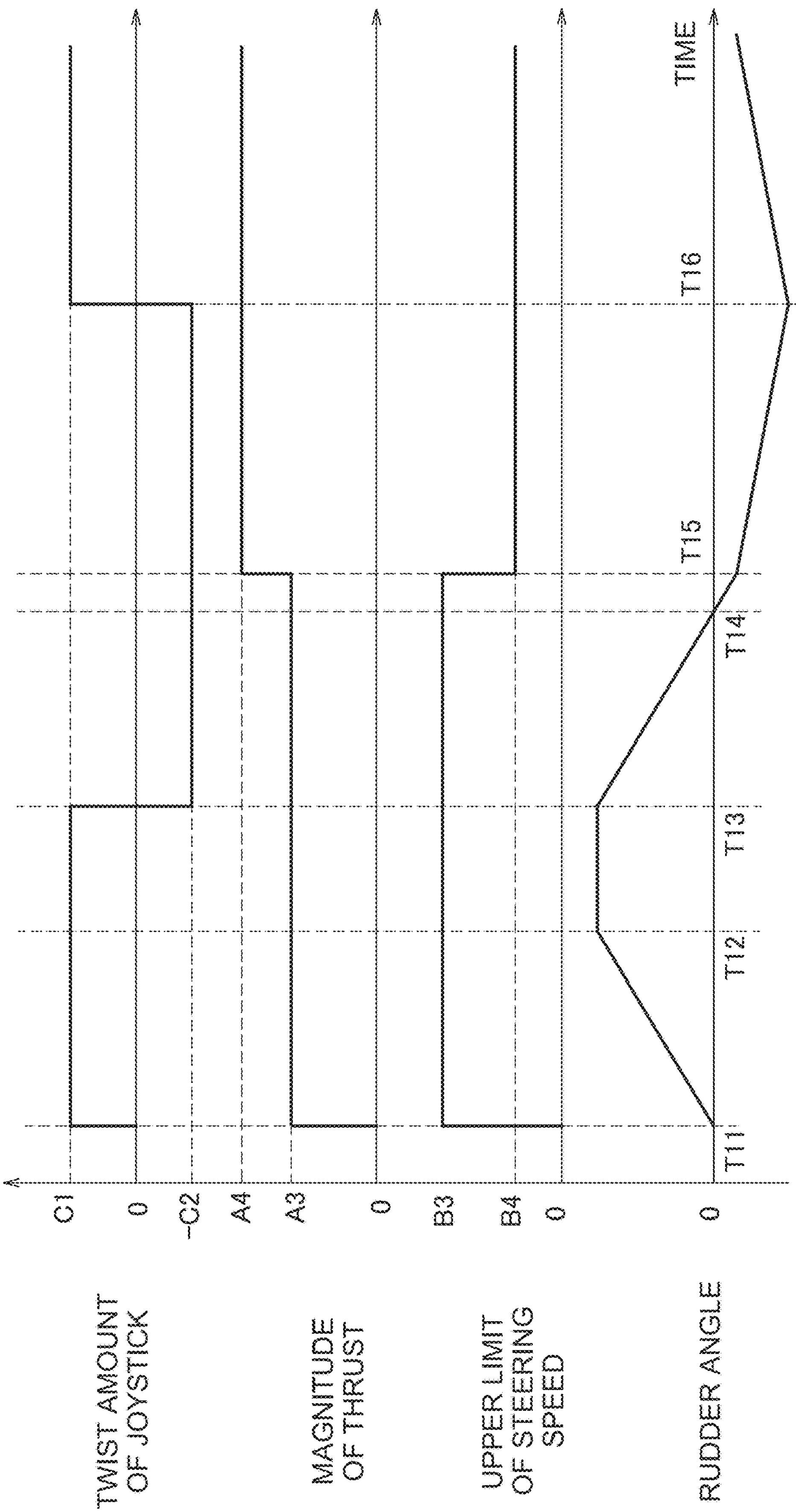

TWIST AMOUNT OF JOYSTICK
MAGNITUDE OF THRUST
UPPER LIMIT OF STEERING SPEED
RUDDER ANGLE
C1
0
−C2
A4
A3
0
B3
B4
0
0
T11
T12
T13
T14
T15
T16
TIME

FIG. 10

SYSTEM FOR AND METHOD OF CONTROLLING WATERCRAFT INCLUDING MARINE PROPULSION DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority to Japanese Patent Application No. 2020-197453 filed on Nov. 27, 2020. The entire contents of this application are hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a system for and a method of controlling a watercraft including a marine propulsion device.

2. Description of the Related Art

There has been conventionally known a type of system for operating a watercraft by a joystick. For example, a system described in Japan Laid-open Patent Application Publication No. H02-227396 includes a marine propulsion device and a joystick. The marine propulsion device is rotatable about a steering shaft. When rotated about the steering shaft, the marine propulsion device is changed in rudder angle. The joystick is operable by tilting and twisting. A controller in the system controls the marine propulsion device to generate a thrust in accordance with a tilt operation of the joystick. The controller changes the rudder angle of the marine propulsion device such that the watercraft turns in accordance with a twist direction of the joystick.

Even when the rudder angle of the marine propulsion device is changed at a constant velocity, the watercraft turns at a variable speed depending on the magnitude of the thrust of the watercraft. For example, the turning velocity of the watercraft increases with an increase in the magnitude of the thrust of the watercraft even when the speed of changing the rudder angle of the marine propulsion device is constant. Conversely, the turning velocity of the watercraft reduces with a reduction in the magnitude of the thrust of the watercraft even when the speed of changing the rudder angle of the marine propulsion device is constant. When the turning velocity of the watercraft is greatly variable depending on the magnitude of the thrust, the comfort could be deteriorated in operating the watercraft.

SUMMARY OF THE INVENTION

Preferred embodiments of the present invention enhance the comfort in operating a watercraft by a joystick. A system according to a preferred embodiment of the present invention controls a watercraft and includes a marine propulsion device, a joystick, and a controller. The marine propulsion device is rotatable about a steering shaft. The joystick is operable by tilting and twisting. The joystick outputs an operating signal indicating a tilt amount thereof and a twist direction thereof. The controller receives the operating signal. The controller is configured or programmed to control the marine propulsion device to output a thrust having a magnitude depending on the tilt amount. The controller changes a rudder angle of the marine propulsion device such that the watercraft turns in a direction corresponding to the

twist direction. The controller reduces a speed of changing the rudder angle with an increase in the magnitude of the thrust.

A method according to a preferred embodiment of the present invention controls a watercraft including a marine propulsion device rotatable about a steering shaft and includes receiving from a joystick operable by tilting and twisting an operating signal indicating a tilt amount of the joystick and a twist direction of the joystick; controlling the marine propulsion device to output a thrust having a magnitude depending on the tilt amount; changing a rudder angle of the marine propulsion device such that the watercraft turns in a direction corresponding to the twist direction; and reducing a speed of changing the rudder angle with an increase in the magnitude of the thrust.

A system according to a preferred embodiment of the present invention controls a watercraft and includes a marine propulsion device, a joystick, a selector, and a controller. The marine propulsion device is rotatable about a steering shaft. The joystick is operable by tilting and twisting. The joystick outputs an operating signal indicating a tilt amount thereof and a twist direction thereof. The selector is operable to select one of a plurality of levels as a thrust level. The selector outputs a setting signal indicating the thrust level. The controller receives the operating signal and the setting signal. The controller is configured or programmed to control the marine propulsion device to output a thrust having a magnitude depending on the tilt amount, while the magnitude of the thrust falls within a range up to a maximum thrust depending on the thrust level. The controller increases the maximum thrust with an increase in the magnitude of the thrust level. The controller changes a rudder angle of the marine propulsion device such that the watercraft turns in a direction corresponding to the twist direction. The controller reduces a speed of changing the rudder angle with the increase in the magnitude of the thrust level.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a watercraft to which a marine propulsion device according to a preferred embodiment of the present invention is mounted.

FIG. **2** is a side view of the marine propulsion device.

FIG. **3** is a schematic diagram showing a configuration of a watercraft operating system for the watercraft.

FIG. **4** is a front view of a joystick.

FIG. **5**A is a diagram showing a rudder angle of the marine propulsion device when the joystick is twisted clockwise.

FIG. **5**B is a diagram showing the rudder angle of the marine propulsion device when the joystick is twisted counterclockwise.

FIG. **6** is a chart showing an example of steering speed data.

FIG. **7** is a timing chart showing controls executed by the marine propulsion device when the joystick is tilted and twisted.

FIG. **8**A is a diagram showing the rudder angle of the marine propulsion device and thrust components when a thrust F**1** is generated in the watercraft operating system according to a preferred embodiment of the present invention.

FIG. **8**B is a diagram showing the rudder angle of the marine propulsion device and thrust components when a thrust F**2** is generated in the watercraft operating system according to a preferred embodiment of the present invention.

FIG. **8**C is a diagram showing the rudder angle of the marine propulsion device and thrust components when a thrust F**3** is generated in a watercraft operating system according to a comparative example.

FIG. **9** is a schematic diagram showing motions performed by the watercraft when the joystick is tilted and twisted.

FIG. **10** exemplifies another timing chart showing controls executed by the marine propulsion device when the joystick is tilted and twisted.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be hereinafter explained with reference to drawings. FIG. **1** is a perspective view of a watercraft **100** to which a marine propulsion device **1** according to a preferred embodiment of the present invention is mounted. The marine propulsion device **1** is mounted to the watercraft **100** as a single marine propulsion device, i.e., as the only marine propulsion device **1** mounted to the watercraft **100**. In the present preferred embodiment, the marine propulsion device **1** is an outboard motor. The marine propulsion device **1** is attached to the stern of the watercraft **100**. The marine propulsion device **1** generates a thrust to propel the watercraft **100**.

FIG. **2** is a side view of the marine propulsion device **1**. The marine propulsion device **1** is attached to the watercraft **100** through a bracket **11**. The bracket **11** supports the marine propulsion device **1** such that the marine propulsion device **1** is rotatable about a steering shaft **12**. The steering shaft **12** extends in an up-and-down direction of the marine propulsion device **1**.

The marine propulsion device **1** includes a drive unit **2**, a drive shaft **3**, a propeller shaft **4**, a shift mechanism **5**, and a housing **10**. The drive unit **2** generates the thrust to propel the watercraft **100**. The drive unit **2** is an internal combustion engine, for example. The drive unit **2** includes a crankshaft **13**. The crankshaft **13** extends in the up-and-down direction of the marine propulsion device **1**. The drive shaft **3** is connected to the crankshaft **13**. The drive shaft **3** extends in the up-and-down direction of the marine propulsion device **1**. The propeller shaft **4** extends in a back-and-forth direction of the marine propulsion device **1**. The propeller shaft **4** is connected to the drive shaft **3** through the shift mechanism **5**. A propeller **6** is attached to the propeller shaft **4**.

The shift mechanism **5** includes a forward moving gear **14**, a rearward moving gear **15**, and a dog clutch **16**. When gear engagement of each gear **14**, **15** is switched by the dog clutch **16**, the shift mechanism **5** is switched among a forward moving state, a rearward moving state, and a neutral state. When set in the forward moving state, the shift mechanism **5** transmits rotation, directed to move the watercraft **100** forward, from the drive shaft **3** to the propeller shaft **4**. When set in the rearward moving state, the shift mechanism **5** transmits rotation, directed to move the watercraft **100** rearward, from the drive shaft **3** to the propeller shaft **4**. When set in the neutral state, the shift mechanism **5** does not transmit rotation from the drive shaft **3** to the propeller shaft **4**. The housing **10** accommodates the drive unit **2**, the drive shaft **3**, the propeller shaft **4**, and the shift mechanism **5**.

FIG. **3** is a schematic diagram showing a configuration of a watercraft operating system for the watercraft **100**. As shown in FIG. **3**, the marine propulsion device **1** includes a shift actuator **7** and a steering actuator **8**.

The shift actuator **7** is connected to the dog clutch **16** of the shift mechanism **5**. The shift actuator **7** actuates the dog clutch **16** to switch gear engagement of each gear **14**, **15**. In response, the shift mechanism **5** is switched among the forward moving state, the rearward moving state, and the neutral state. The shift actuator **7** includes, for instance, an electric motor. However, the shift actuator **7** may be another type of actuator such as an electric cylinder, a hydraulic motor, or a hydraulic cylinder.

The steering actuator **8** is connected to the marine propulsion device **1**. The steering actuator **8** rotates the marine propulsion device **1** about the steering shaft **12**. Accordingly, a rudder angle of the marine propulsion device **1** is changed. The rudder angle refers to an angle of the propeller shaft **4** with respect to the back-and-forth direction of the marine propulsion device **1**. The steering actuator **8** includes, for instance, an electric motor. However, the steering actuator **8** may be another type of actuator such as an electric cylinder, a hydraulic motor, or a hydraulic cylinder.

The marine propulsion device **1** includes a drive controller **9**. The drive controller **9** includes a processor such as a CPU (Central Processing Unit) and memories such as a RAM (Random Access Memory) and a ROM (Read Only Memory). The drive controller **9** stores a program and data to control the marine propulsion device **1**. The drive controller **9** is configured or programmed to control the drive unit **2**.

The watercraft operating system includes a steering wheel **24**, a remote controller **25**, a joystick **26**, and a selector **27**. The steering wheel **24**, the remote controller **25**, the joystick **26**, and the selector **27** are located in a cockpit of the watercraft **100**. The steering wheel **24**, the remote controller **25**, the joystick **26**, and the selector **27** are manually operable.

The steering wheel **24** enables an operator to control a turning direction of the watercraft **100**. The steering wheel **24** includes a sensor **240**. The sensor **240** outputs a steering signal indicating an operating direction and an operating amount of the steering wheel **24**.

The remote controller **25** includes a throttle lever **28**. The throttle lever **28** enables the operator to regulate the magnitude of the thrust generated by the marine propulsion device **1**. The throttle lever **28** also enables the operator to switch the direction of the thrust generated by the marine propulsion device **1** between forward and rearward directions. The throttle lever **28** is operable from a neutral position to a forward moving position and a rearward moving position. The neutral position is located between the forward moving position and the rearward moving position. The throttle lever **28** includes a sensor **251**. The sensor **251** outputs a throttle signal indicating an operating direction and an operating amount of the throttle lever **28**.

The joystick **26** is tiltable at least back and forth from a neutral position in two directions. The joystick **26** may be tiltable in more than two directions, and preferably all directions. The joystick **26** is rotatable (twistable) about a rotational axis Ax**1**. In other words, the joystick **26** is operable to be twisted clockwise and counterclockwise about the rotational axis Ax**1** from the neutral position. The joystick **26** includes a sensor **260**. The sensor **260** outputs an operating signal that indicates the operation of the joystick **26**. The operating signal contains information regarding a tilt direction and a tilt amount of the joystick **26**. The operating signal also contains information regarding a twist direction and a twist amount of the joystick **26**.

The selector **27** is operable to select one of a plurality of levels as a thrust level in operating the watercraft **100** by the joystick **26**. An upper limit of the thrust outputted from the marine propulsion device **1** (hereinafter referred to as "maximum thrust") increases with an increase in the magnitude of the thrust level. The selector **27** is provided on the joystick **26**, for example. FIG. **4** is a diagram showing the joystick **26**. As shown in FIG. **4**, the selector **27** includes a plus switch **27***a* and a minus switch **27***b*. When the plus switch **27***a* is pressed once, the thrust level is increased by one. When the minus switch **27***b* is pressed once, the thrust level is decreased by one. The selector **27** outputs a setting signal indicating the thrust level.

The watercraft operating system includes a watercraft operating controller **30**. The watercraft operating controller **30** includes a processor such as a CPU and memories such as a RAM and a ROM. The watercraft operating controller **30** stores a program and data to control the marine propulsion device **1**. The watercraft operating controller **30** is connected to the drive controller **9** through wired or wireless communication. The watercraft operating controller **30** is connected to the steering wheel **24**, the remote controller **25**, the joystick **26**, and the selector **27** through wired or wireless communication.

The watercraft operating controller **30** receives the steering signal from the sensor **240**. The watercraft operating controller **30** receives the throttle signal from the sensor **251**. The watercraft operating controller **30** outputs command signals to the drive controller **9** based on the signals received from the sensors **240** and **251**. The command signals are transmitted to the drive unit **2**, the shift actuator **7**, and the steering actuator **8** through the drive controller **9**. For example, the watercraft operating controller **30** outputs a command signal for the shift actuator **7** in accordance with the operating direction of the throttle lever **28**. In response, shifting between forward movement and rearward movement by the marine propulsion device **1** is performed. The watercraft operating controller **30** outputs a throttle command for the drive unit **2** in accordance with the operating amount of the throttle lever **28**. The drive controller **9** controls an output rotational speed of the marine propulsion device **1** in accordance with the throttle command.

The watercraft operating controller **30** outputs a command signal for the steering actuator **8** in accordance with the operating direction and the operating amount of the steering wheel **24**. When the steering wheel **24** is operated leftward from the neutral position, the watercraft operating controller **30** controls the steering actuator **8** such that the marine propulsion device **1** is rotated clockwise. The watercraft **100** thus turns leftward. When the steering wheel **24** is operated rightward from the neutral position, the watercraft operating controller **30** controls the steering actuator **8** such that the marine propulsion device **1** is rotated counterclockwise. The watercraft **100** thus turns rightward. Additionally, the watercraft operating controller **30** controls the rudder angle of the marine propulsion device **1** depending on the operating amount of the steering wheel **24**.

The watercraft operating controller **30** receives the operating signal from the sensor **260**. The watercraft operating controller **30** receives the setting signal from the selector **27**. The watercraft operating controller **30** outputs a command signal to the drive controller **9** based on the operating signal and the setting signal. The command signal is transmitted to the drive unit **2**, the shift actuator **7**, and the steering actuator **8** through the drive controller **9**.

The watercraft operating controller **30** controls the marine propulsion device **1** to output a thrust, having a magnitude depending on the tilt amount of the joystick **26**, in a direction corresponding to the tilt direction of the joystick **26**. The watercraft operating controller **30** sets the thrust level in accordance with the setting signal received from the selector **27**. When the joystick **26** is tilted forward, the watercraft operating controller **30** causes the marine propulsion device **1** to generate a thrust oriented in the forward moving direction such that the thrust has a magnitude depending on the tilt amount of the joystick **26** and the magnitude of the thrust that falls within a range up to the maximum thrust depending on the thrust level. The watercraft **100** thus moves forward. When the joystick **26** is tilted rearward, the watercraft operating controller **30** causes the marine propulsion device **1** to generate a thrust oriented in the rearward moving direction such that the thrust has a magnitude depending on the tilt amount of the joystick **26** and the magnitude of the thrust falls within the range up to the maximum thrust depending on the thrust level. The watercraft **100** thus moves rearward.

The watercraft operating controller **30** changes the rudder angle of the marine propulsion device **1** such that the watercraft **100** turns in a direction corresponding to the twist direction of the joystick **26**. The watercraft operating controller **30** changes the rudder angle of the marine propulsion device **1** such that the rudder angle becomes a target angle depending on the twist amount of the joystick **26**. As shown in FIG. **5**A, when the joystick **26** is twisted clockwise, the watercraft operating controller **30** controls the steering actuator **8** such that the marine propulsion device **1** is rotated counterclockwise. The watercraft **100** thus turns rightward. As shown in FIG. **5**B, when the joystick **26** is twisted counterclockwise, the watercraft operating controller **30** controls the steering actuator **8** such that the marine propulsion device **1** is rotated clockwise. The watercraft **100** thus turns leftward.

When the joystick **26** is tilted and twisted, the watercraft operating controller **30** causes the marine propulsion device **1** to generate a thrust having a magnitude depending on the tilt amount of the joystick **26** and changes the rudder angle of the marine propulsion device **1** such that the watercraft **100** turns in a direction corresponding to the twist direction of the joystick **26**. At this time, the watercraft operating controller **30** reduces the steering speed with an increase in the magnitude of the thrust. The steering speed refers to a speed of changing the rudder angle. The watercraft operating controller **30** stores a default value to be set for the steering speed when the joystick **26** is twisted. The watercraft operating controller **30** sets an upper limit to the steering speed. The watercraft operating controller **30** reduces the upper limit with the increase in the magnitude of the thrust such that the steering speed is reduced.

The watercraft operating controller **30** stores steering speed data as shown in FIG. **6**. The steering speed data defines the upper limit of the steering speed with respect to the magnitude of the thrust. The watercraft operating controller **30** determines the magnitude of the thrust based on the thrust level and the tilt amount of the joystick **26**. With reference to the steering speed data, the watercraft operating controller **30** determines the upper limit of the steering speed with respect to the magnitude of the thrust. As shown in FIG. **6**, in the steering speed data, the upper limit is made constant at B**1** when the magnitude of the thrust falls within a range of 0 to A**1**. The upper limit reduces with the increase in the magnitude of the thrust when the magnitude of the thrust falls within a range of A**1** to A**2**. The upper limit is made constant at B2, which is less than B1, when the magnitude of the thrust falls within a range of A2 and greater.

FIG. 7 is a timing chart showing changes in the following items in tilting and twisting the joystick 26: the twist amount of the joystick 26, the magnitude of the thrust, the upper limit of the steering speed, and the rudder angle. The joystick 26 is tilted and twisted at time T1. At time T1, the joystick 26 is twisted by a twist amount C1, while the magnitude of the thrust is A3. With reference to the steering speed data shown in FIG. 6, the watercraft operating controller 30 determines B3 as the upper limit of the steering speed corresponding to the magnitude-of-thrust A3. The watercraft operating controller 30 changes the rudder angle of the marine propulsion device 1 such that the rudder angle is changed at a steering speed of the upper limit B3 or less so as to become a target angle. The rudder angle of the marine propulsion device 1 is thereby gradually increased from time T1 as shown in FIG. 7.

At time T2, the joystick 26 is further tilted by a large amount such that the magnitude of the thrust increases from A3 to A4. The twist amount of the joystick 26 is made constant at C1. With reference to the steering speed data, the watercraft operating controller 30 determines B4 as the upper limit of the steering speed corresponding to the magnitude-of-thrust A4. The watercraft operating controller 30 changes the rudder angle of the marine propulsion device 1 such that the rudder angle is changed at a steering speed of the upper limit B4 or less so as to become a target angle. The upper limit B4 is less than the upper limit B3 as shown in FIG. 6. Therefore, the rudder angle of the marine propulsion device 1 is more slowly increased at time T2 and thereafter than before time T2 as shown in FIG. 7.

FIG. 8A is a diagram showing the rudder angle of the marine propulsion device 1 and thrust components when a thrust F1 is generated in the watercraft operating system according to a preferred embodiment of the present invention. FIG. 8B is a diagram showing the rudder angle of the marine propulsion device 1 and thrust components when a thrust F2 is generated in the watercraft operating system according to a preferred embodiment of the present invention. The thrust F2 is greater in magnitude than the thrust F1. FIG. 8C is a diagram showing the rudder angle of the marine propulsion device 1 and thrust components when a thrust F3 is generated in a watercraft operating system according to a comparative example. The thrust F3 is equal in magnitude to the thrust F2. However, in the watercraft operating system according to the comparative example, the steering speed is constant regardless of the magnitude of the thrust. It is assumed that a predetermined length of time has commonly elapsed among FIGS. 8A, 8B, and 8C since starting a change in the rudder angle.

As shown in FIG. 8A, the rudder angle of the marine propulsion device 1 is θ1 when the thrust F1 is being generated. A thrust F1*y* is being generated in a longitudinal direction of the watercraft 100 as a longitudinal component of the thrust F1. A thrust F1*x* is being generated in a right-and-left direction of the watercraft 100 as a right-and-left component of the thrust F1.

As shown in FIG. 8B, the rudder angle of the marine propulsion device 1 is θ2 when the thrust F2 is being generated. In the watercraft operating system according to the present preferred embodiment, the steering speed is reduced with the increase in the magnitude of the thrust. Because of this, the angle θ2 is less than the angle θ1. A thrust F2*y* is being generated in the longitudinal direction of the watercraft 100 as a longitudinal component of the thrust F2. A thrust F2*x* is being generated in the right-and-left direction of the watercraft 100 as a right-and-left component of the thrust F2. The thrust F2 shown in FIG. 8B is greater in magnitude than the thrust F1 shown in FIG. 8A. However, the rudder angle θ2 shown in FIG. 8B is less than the rudder angle θ1 shown in FIG. 8A. Because of this, the thrust F2*x*, generated in the right-and-left direction of the watercraft 100 shown in FIG. 8B, is equivalent in magnitude to the thrust F1*x* generated in the right-and-left direction of the watercraft 100 shown in FIG. 8A.

FIG. 9 is a schematic diagram showing motions performed by the watercraft 100 when the joystick 26 is tilted and twisted. In FIG. 9, a position 101 shows a motion of the watercraft 100 turning in the condition shown in FIG. 8A. A position 102 shows a motion of the watercraft 100 turning in the condition shown in FIG. 8B. A position 103 shows a motion of the watercraft 100 turning in the condition shown in FIG. 8C. A moving distance of the watercraft 100 is greater in the condition indicated by the position 102, in which the magnitude of the thrust is large, than in the condition indicated by the position 101, in which the magnitude of the thrust is small. However, the thrusts F2*x* and F1*x*, both generated in the right-and-left direction of the watercraft 100, are equivalent in magnitude to each other, such that the turning velocity of the watercraft 100 is equal or approximately equal between when the magnitude of the thrust is large and when the magnitude of the thrust is small. Because of this, in the assumption that the predetermined length of time has commonly elapsed among turning motions as shown in FIG. 9, a turning angle of the watercraft 100 is equal or approximately equal between when the magnitude of the thrust is large and when the magnitude of the thrust is small.

As shown in FIG. 8C, in the watercraft operating system according to the comparative example, the rudder angle of the marine propulsion device 1 is θ3 when the thrust F3, equal in magnitude to the thrust F2, is being generated. However, in the watercraft operating system according to the comparative example, the steering speed is not reduced depending on the magnitude of the thrust. Therefore, even when the thrust F3 is being generated, the angle θ3 is equal to the angle θ1 shown in FIG. 8A. Because of this, in FIG. 8C, a thrust F3*x*, generated in the right-and-left direction of the watercraft 100, is greater in magnitude than the thrust Fix generated in the right-and-left direction of the watercraft 100 shown in FIG. 8A and the thrust F2*x* generated in the right-and-left direction of the watercraft 100 shown in FIG. 8B. In this case, the turning velocity is greater in FIG. 8C than in FIG. 8A. Because of this, as shown in FIG. 9, the turning angle of the watercraft 100 is greater in the condition indicated by the position 103 than in the condition indicated by the position 101, in which the magnitude of the thrust is small.

FIG. 10 exemplifies another timing chart showing changes in the following items in tilting and twisting the joystick 26: the twist amount of the joystick 26, the magnitude of the thrust, the upper limit of the steering speed, and the rudder angle. The joystick 26 is tilted and twisted clockwise at time T11. At time T11, the joystick 26 is twisted clockwise by a twist amount C1, while the magnitude of the thrust is A3. With reference to the steering speed data shown in FIG. 6, the watercraft operating controller 30 determines B3 as the upper limit of the steering speed corresponding to the magnitude-of-thrust A3. The watercraft operating controller 30 changes the rudder angle of the marine propulsion device 1 by turning the marine propulsion device 1 counterclockwise such that the rudder angle is changed at a steering speed of the upper limit B3 or less so as to become a target angle. The rudder angle of the marine propulsion device **1** is thereby gradually increased to the counterclockwise side from time T**11** as shown in FIG. **10**. The rudder angle of the marine propulsion device **1** reaches the target angle at time T**12** and is made constant at the target angle until time T**13**.

At time T**13**, the joystick **26** is twisted counterclockwise by a twist amount C**2**, while the tilt amount is maintained. In response to this, the watercraft operating controller **30** rotates the marine propulsion device **1** clockwise, while the magnitude of the thrust and the upper limit of the steering speed are kept as it is. The rudder angle of the marine propulsion device **1** is thereby gradually reduced from time T**13** and is then gradually increased to the clockwise side at time T**14** and thereafter as shown in FIG. **10**.

At time T**15**, the joystick **26** is further tilted by a large amount, such that the magnitude of the thrust increases from A**3** to A**4**. The twist amount of the joystick **26** is made constant at C**2**. With reference to the steering speed data, the watercraft operating controller **30** determines B**4** as the upper limit of the steering speed corresponding to the magnitude-of-thrust A**4**. The watercraft operating controller **30** changes the rudder angle of the marine propulsion device **1** such that the rudder angle is changed at a steering speed of the upper limit B**4** or less so as to become a target angle. The upper limit B**4** is less than the upper limit B**3**. Therefore, as shown in FIG. **10**, the rudder angle of the marine propulsion device **1** is increased to the clockwise side at time T**15** and thereafter more gently than before time T**15**.

At time T**16**, the joystick **26** is twisted clockwise by the twist amount C**1**, while the tilt amount is kept as it is. In response to this, the watercraft operating controller **30** rotates the marine propulsion device **1** counterclockwise, while the magnitude of the thrust and the upper limit of the steering speed are kept as it is. Accordingly, as shown in FIG. **10**, the rudder angle of the marine propulsion device **1** is gradually reduced from time T**16**.

In the watercraft operating systems according to preferred embodiments of the present invention explained above, the steering speed reduces with an increase in the magnitude of the thrust. Because of this, the difference in turning velocity of the watercraft **100** among different magnitudes of the thrust is made small, such that the difference in the turning angle of the watercraft **100** among different magnitudes of the thrust is made small as well. Consequently, the comfort is enhanced when operating the watercraft **100** by the joystick **26**.

Preferred embodiments of the present invention have been explained above. However, the present invention is not limited to the preferred embodiments described above, and a variety of changes can be made without departing from the gist of the present invention.

The marine propulsion device **1** is not limited to the outboard motor, and alternatively, may be another type of propulsion device such as an inboard engine outboard drive or a jet propulsion device. The structure of the marine propulsion device **1** is not limited to that in the preferred embodiments described above and may be changed. For example, the drive unit **2** is not limited to the internal combustion engine, and alternatively, may be an electric motor. Yet alternatively, the drive unit **2** may be a hybrid system of an internal combustion engine and an electric motor. The number of marine propulsion devices is not limited to one. The number of marine propulsion devices may be two or greater. The selector **27** may be separate from the joystick **26**. The selector **27** is not limited to the switch, and alternatively, may include another type of operating device such as a touchscreen.

In the preferred embodiments described above, the upper limit of the steering speed is reduced with an increase in the magnitude of the thrust, such that the steering speed is reduced. However, the watercraft operating controller **30** may directly reduce the steering speed with the increase in the magnitude of the thrust. In the preferred embodiments described above, the watercraft operating controller **30** reduces the steering speed with the increase in the magnitude of the thrust. However, the watercraft operating controller **30** may reduce the steering speed with the increase in the magnitude of the thrust level.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A system for controlling a watercraft, the system comprising:
- a marine propulsion device rotatable about a steering shaft;
- a joystick operable by tilting and twisting to output an operating signal indicating a tilt amount and a twist direction of the joystick; and
- a controller configured or programmed to:
  - receive the operating signal;
  - control the marine propulsion device to output a thrust having a magnitude depending on the tilt amount;
  - change a rudder angle of the marine propulsion device such that the watercraft turns in a direction corresponding to the twist direction; and
  - reduce a speed of changing the rudder angle with an increase in the magnitude of the thrust.

2. The system according to claim **1**, wherein the controller is configured or programmed to reduce the speed of changing the rudder angle such that a component of the thrust oriented in a right-and-left direction of the watercraft stays constant regardless of the increase in the magnitude of the thrust.

3. The system according to claim **1**, wherein the controller is configured or programmed to reduce the speed of changing the rudder angle by reducing an upper limit of the speed of changing the rudder angle with the increase in the magnitude of the thrust.

4. The system according to claim **3**, wherein the controller is configured or programmed to make the upper limit constant when the magnitude of the thrust is less than or equal to a predetermined threshold.

5. The system according to claim **1**, wherein the marine propulsion device is the only marine propulsion device mounted to the watercraft.

6. A method of controlling a watercraft including a marine propulsion device rotatable about a steering shaft, the method comprising:
- receiving an operating signal from a joystick operable by tilting and twisting, the operating signal indicating a tilt amount of the joystick and a twist direction of the joystick;
- controlling the marine propulsion device to output a thrust having a magnitude depending on the tilt amount;
- changing a rudder angle of the marine propulsion device such that the watercraft turns in a direction corresponding to the twist direction; and

reducing a speed of changing the rudder angle with an increase in the magnitude of the thrust.

7. The method according to claim **6**, wherein the speed of changing the rudder angle is reduced such that a component of the thrust oriented in a right-and-left direction of the watercraft stays constant regardless of the increase in the magnitude of the thrust.

8. The method according to claim **6**, wherein the speed of changing the rudder angle is reduced by reducing an upper limit of the speed of changing the rudder angle with the increase in the magnitude of the thrust.

9. The method according to claim **8**, further comprising:
making the upper limit constant when the magnitude of the thrust is less than or equal to a predetermined threshold.

10. The method according to claim **6**, wherein the marine propulsion device is the only marine propulsion device mounted to the watercraft.

11. A system for controlling a watercraft, the system comprising:
a marine propulsion device rotatable about a steering shaft;
a joystick operable by tilting and twisting to output an operating signal indicating a tilt amount and a twist direction of the joystick;
a selector operable to select one of a plurality of levels as a thrust level and output a setting signal indicating the thrust level; and
a controller configured or programmed to:
receive the operating signal and the setting signal;
control the marine propulsion device to output a thrust having a magnitude depending on the tilt amount that falls within a range up to a maximum thrust depending on the thrust level;
increase the maximum thrust with an increase in the magnitude of the thrust level;
change a rudder angle of the marine propulsion device such that the watercraft turns in a direction corresponding to the twist direction; and
reduce a speed of changing the rudder angle with the increase in the magnitude of the thrust level.

12. The system according to claim **11**, wherein the controller is configured or programmed to reduce the speed of changing the rudder angle such that a component of the thrust oriented in a right-and-left direction of the watercraft stays constant regardless of the increase in the magnitude of the thrust level.

13. The system according to claim **11**, wherein the controller is configured or programmed to reduce the speed of changing the rudder angle by reducing an upper limit of the speed of changing the rudder angle with the increase in the magnitude of the thrust level.

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