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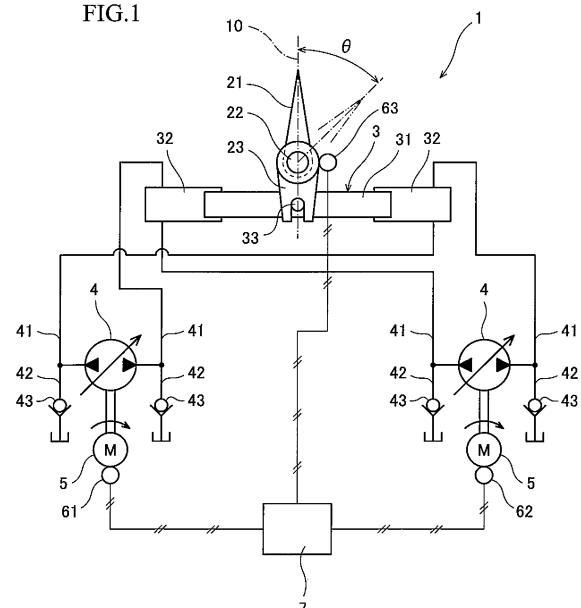
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(54) **SHIP STEERING MACHINE**

(57) A ship steering gear (1) according to one embodiment includes: a hydraulic actuator (3) that rotates a rudder stock (22) coupled to a rudder plate (21); two axial piston hydraulic pumps (4) that are connected to the hydraulic actuator (3) such that a closed circuit is formed between the hydraulic actuator (3) and the hydraulic pumps (4); and two electric motors (5) that drive the hydraulic pumps (4). The ship steering gear (1) further includes: first detectors (61, 62) that detect electric power, or electric currents, supplied to the electric motors (5); a second detector (63) that detects a rudder angle θ that is an angle of the rudder plate (21) relative to a center line (10) of a hull; and a torque calculator (7) that calculates a torque applied to the rudder stock (22) based on the electric power, or the electric currents, detected by the first detectors (61, 62) and the rudder angle θ detected by the second detector (63).

FIG.1



Description**Technical Field**

5 [0001] The present invention relates to a ship steering gear.

Background Art

10 [0002] Conventionally, there is a known ship steering gear including a hydraulic actuator that rotates a rudder stock coupled to a rudder plate. For example, Patent Literature 1 discloses a ship steering gear including two ram-cylinder-type hydraulic actuators that rotate a rudder stock via a tiller. Each of the hydraulic actuators includes a ram and a pair of cylinders. The ram is provided with a pin that engages with the tiller. Both ends of the ram are inserted in the pair of cylinders, respectively.

Citation List**Patent Literature**

20 [0003] PTL 1: Japanese Laid-Open Patent Application Publication No. 2017-149181

Summary of Invention**Technical Problem**

25 [0004] When a rudder angle, which is an angle of the rudder plate relative to the center line of the hull, is not zero degrees, a torque that turns the hull is applied to the rudder stock regardless of whether the rudder stock is rotating or is stopped. Also, even when the rudder angle is zero degrees, a torque may be applied to the rudder stock due to influences such as the tide and swinging motions (rolling, pitching, and yawing) of the hull. Therefore, there is a demand for identifying the torque that is applied to the rudder stock.

30 [0005] In view of the above, an object of the present invention is to provide a ship steering gear that is capable of identifying a torque that is applied to a rudder stock.

Solution to Problem

35 [0006] In order to solve the above-described problems, a ship steering gear according to the present invention includes: a hydraulic actuator that rotates a rudder stock coupled to a rudder plate; an axial piston hydraulic pump that is connected to the hydraulic actuator such that a closed circuit is formed between the hydraulic actuator and the hydraulic pump; an electric motor that drives the hydraulic pump; a first detector that detects electric power, or an electric current, supplied to the electric motor; a second detector that detects a rudder angle that is an angle of the rudder plate relative to a center
40 line of a hull; and a torque calculator that calculates a torque applied to the rudder stock based on the electric power, or the electric current, detected by the first detector and the rudder angle detected by the second detector.

[0007] According to the above configuration, the torque calculator calculates the torque applied to the rudder stock, and thereby the torque can be identified. In addition, since electrical sensors can be used as the first detector and the second detector, the torque can be calculated with a simple configuration.

45 [0008] The torque calculator may calculate the torque by using an operation coefficient. The operation coefficient that the torque calculator uses to calculate the torque while the rudder stock is stopped may be less than the operation coefficient that the torque calculator uses to calculate the torque while the rudder stock is rotating. The inventors of the present invention have found that the relationship between the electric power supplied to the electric motor and the torque applied to the rudder stock varies significantly depending on whether the rudder stock is rotating or is stopped.
50 Therefore, the torque can be precisely calculated by using, in the calculation of the torque, an operation coefficient whose value varies depending on whether the rudder stock is rotating or is stopped.

[0009] For example, the hydraulic actuator may rotate the rudder stock via a tiller fixed to the rudder stock. The hydraulic actuator may include: a ram provided with a pin that engages with the tiller; and a pair of cylinders, in which both ends of the ram are inserted, respectively.

55 [0010] For example, the torque calculator may calculate the torque applied to the rudder stock based on the following equation:

$$T = m \cdot K \cdot (W - W_0) / (\omega \cdot \cos\theta), \text{ where}$$

T is the torque [N · m] applied to the rudder stock;

m is the operation coefficient;

K is an efficiency of the electric motor;

W is the electric power [W] detected by the first detector, or is electric power [W] calculated based on the electric current detected by the first detector;

W₀ is electric power [W] supplied to the electric motor when a delivery flow rate of the hydraulic pump is zero;

ω is an angular velocity [rad/s] of the rudder stock, the angular velocity ω_0 being equal to 1 while the rudder stock is stopped; and

θ is the rudder angle [rad] detected by the second detector.

Advantageous Effects of Invention

[0011] The present invention makes it possible to identify the torque that is applied to the rudder stock.

Brief Description of Drawings

[0012] FIG. 1 shows a schematic configuration of a ship steering gear according to one embodiment of the present invention.

Description of Embodiments

[0013] FIG. 1 shows a ship steering gear 1 according to one embodiment of the present invention. The ship steering gear 1 includes a hydraulic actuator 3, which rotates a rudder stock 22 coupled to a rudder plate 21.

[0014] In the present embodiment, the hydraulic actuator 3 is a ram-cylinder-type hydraulic actuator that rotates the rudder stock 22 via a tiller 23 fixed to the rudder stock 22. Although the number of hydraulic actuators 3 is one in the present embodiment, the number of hydraulic actuators 3 may be two, which are disposed parallel to each other, with the rudder stock 22 positioned therebetween.

[0015] Specifically, the hydraulic actuator 3 includes: a rod-shaped ram 31, which extends in a direction orthogonal to the axial direction of the rudder stock 22; and a pair of cylinders 32, in which both ends of the ram 31 are inserted, respectively. At the middle of the ram 31, a pin 33 is provided on the center line of the ram 31. The pin 33 engages with the tiller 23.

[0016] To be more specific, the tiller 23 is provided with a groove that is open in a direction away from the rudder stock 22, and the pin 33 is inserted in the groove. The pin 33 and the tiller 23 collectively serve as a link mechanism between the rudder stock 22 and the ram 31.

[0017] In the present embodiment, two hydraulic pumps 4 are adopted as sources of pressure that moves the hydraulic actuator 3. Alternatively, the number of hydraulic pumps 4 may be one. The two hydraulic pumps 4 are connected to the hydraulic actuator 3 such that a closed circuit is formed between the hydraulic actuator 3 and the hydraulic pumps 4.

[0018] Each of the hydraulic pumps 4 is an axial piston hydraulic pump, in which pistons are reciprocally held by a cylinder block that rotates (the axial direction of each piston is parallel to the axial direction of the cylinder block). Each hydraulic pump 4 supplies hydraulic oil to one cylinder 32, and recovers the hydraulic oil from the other cylinder 32.

[0019] In the present embodiment, each hydraulic pump 4 is a variable displacement swash plate pump whose swash plate is tiltable from the center to both sides. The tilting direction and tilting angle of the swash plate are changed by an unshown regulator in accordance with an output from an unshown operating device operated by a ship operator. The hydraulic pumps 4 are driven by respective electric motors 5. In the present embodiment, the rotation speed of each electric motor 5 is constant.

[0020] Alternatively, each hydraulic pump 4 may be a variable displacement bent axis pump. Further alternatively, each hydraulic pump 4 may be a fixed displacement pump; each electric motor 5 may be a servomotor; and the rotation direction and rotation speed of each hydraulic pump 4 may be changed in accordance with an output from an unshown operating device.

[0021] Each hydraulic pump 4 includes a pair of supply/discharge ports, and these supply/discharge ports are connected to the pair of cylinders 32 by a pair of supply/discharge lines 41. In this manner, a closed circuit is formed between the hydraulic actuator 3 and the two hydraulic pumps 4. In order to replenish the closed circuit with the hydraulic oil, a tank line 42 provided with a check valve 43 is connected to each supply/discharge line 41.

[0022] The ship steering gear 1 further includes a torque calculator 7, which calculates a torque T applied to the rudder stock 22. For example, the torque calculator 7 is a computer including memories such as a ROM and RAM, a storage

such as a HDD, and a CPU. The CPU executes a program stored in the ROM or HDD. The torque calculator 7 may be an analog operational circuit.

[0023] The torque calculator 7 is electrically connected to a pair of first detectors 61 and 62 and a second detector 63. In the present embodiment, the first detectors 61 and 62 are power sensors, and detect electric power W1 and W2, respectively, which are supplied to the two electric motors 5. The second detector 63 is an angle sensor, and detects a rudder angle θ , which is an angle of the rudder plate 21 relative to a center line 10 of the hull.

[0024] In the present embodiment, the second detector 63 is provided on the tiller 23. Alternatively, the second detector 63 may be provided on the rudder stock 22. Further alternatively, the ram 31 may be provided with a stroke sensor, and a stroke detected by the stroke sensor may be converted into the rudder angle θ . The rudder angle θ may be detected in such a manner. In other words, a stroke sensor and a converter may collectively serve as the second detector 63.

[0025] The torque calculator 7 calculates the torque T [N · m] applied to the rudder stock 22 based on the electric power W1 and W2 [W] detected by the first detectors 61 and 62 and the rudder angle θ [rad] detected by the second detector 63. In the present embodiment, the torque calculator 7 calculates the torque T based on an equation 1 shown below.

$$T = m \cdot K \cdot (W - W_0) / (\omega \cdot \cos\theta) \quad (\text{equation 1}),$$

where

m is an operation coefficient;

K is an efficiency of the electric motor 5;

W is a total value [W] of the electric power W1 and W2;

W0 is a total value [W] of electric power supplied to both the electric motors 5 when the delivery flow rates of the hydraulic pumps 4 are zero; and

ω is an angular velocity [rad/s] of the rudder stock 22, the angular velocity ω being equal to 1 while the rudder stock 22 is stopped.

[0026] The value of the operation coefficient m varies depending on whether the rudder stock 22 is rotating or is stopped. To be more specific, the operation coefficient m to be used while the rudder stock 22 is stopped is less than the operation coefficient m to be used while the rudder stock 22 is rotating. For example, the operation coefficient m to be used while the rudder stock 22 is rotating is preset within a range from 0.6 to 1.0, and the operation coefficient m to be used while the rudder stock 22 is stopped is preset within a range from 0.1 to 0.5. For example, the efficiency K of the electric motor 5 is 0.85 to 0.95. The angular velocity ω of the rudder stock 22 is obtained by performing differentiation on the rudder angle θ .

[0027] As described above, in the ship steering gear 1 of the present embodiment, the torque calculator 7 calculates the torque T applied to the rudder stock 22, and thereby the torque T can be identified. In addition, since electrical sensors can be used as the first detectors 61 and 62 and the second detector 63, the torque T can be calculated with a simple configuration.

[0028] In particular, the value of the operation coefficient m to be used in the calculation of the torque T varies depending on whether the rudder stock 22 is rotating or is stopped. This makes it possible to precisely calculate the torque T.

(Variations)

[0029] The present invention is not limited to the above-described embodiment. Various modifications can be made without departing from the scope of the present invention.

[0030] For example, in the above-described embodiment, the first detectors 61 and 62 are power sensors. Alternatively, the first detectors 61 and 62 may be current sensors, and may detect electric currents A1 and A2, respectively, which are supplied to the two electric motors 5. In this case, the torque calculator 7 calculates the electric power W1 and W2 supplied to both the electric motors 5 based on the electric currents A1 and A2 detected by the first detectors 61 and 62. The torque calculator 7 adds up the electric power W1 and W2 to calculate total power W.

[0031] The hydraulic actuator 3 need not be of a ram cylinder type, but may be a rotary vane actuator including a rotary shaft that is coupled to the rudder stock 22 by a coupling. Alternatively, the hydraulic actuator 3 may be a trunk piston actuator, in which the distal end of a rod extending from a piston disposed in a cylinder is coupled to the tiller 23 by a pin.

[0032] Regardless of whether the hydraulic actuator 3 is a rotary vane actuator or a trunk piston actuator, the torque T applied to the rudder stock 22 can be calculated based on an equation below.

$$T = m \cdot K \cdot (W - W_0) / \omega$$

Reference Signs List

[0033]

1	ship steering gear
10	center line
21	rudder plate
22	rudder stock
23	tiller
3	hydraulic actuator
31	ram
32	cylinder
33	pin
4	hydraulic pump
5	electric motor
61, 62	first detector
63	second detector
7	torque calculator

Claims

1. A ship steering gear comprising:

a hydraulic actuator that rotates a rudder stock coupled to a rudder plate;
 an axial piston hydraulic pump that is connected to the hydraulic actuator such that a closed circuit is formed
 between the hydraulic actuator and the hydraulic pump;
 an electric motor that drives the hydraulic pump;
 a first detector that detects electric power, or an electric current, supplied to the electric motor;
 a second detector that detects a rudder angle that is an angle of the rudder plate relative to a center line of a
 hull; and
 a torque calculator that calculates a torque applied to the rudder stock based on the electric power, or the electric
 current, detected by the first detector and the rudder angle detected by the second detector.

2. The ship steering gear according to claim 1, wherein

the torque calculator calculates the torque by using an operation coefficient, and
 the operation coefficient that the torque calculator uses to calculate the torque while the rudder stock is stopped
 is less than the operation coefficient that the torque calculator uses to calculate the torque while the rudder
 stock is rotating.

3. The ship steering gear according to claim 2, wherein

the hydraulic actuator rotates the rudder stock via a tiller fixed to the rudder stock, and
 the hydraulic actuator includes:

a ram provided with a pin that engages with the tiller; and
 a pair of cylinders, in which both ends of the ram are inserted, respectively.

4. The ship steering gear according to claim 3, wherein

the torque calculator calculates the torque applied to the rudder stock based on the following equation:

$$T = m \cdot K \cdot (W - W_0) / (\omega \cdot \cos\theta),$$

where

T is the torque [N · m] applied to the rudder stock;

m is the operation coefficient;

K is an efficiency of the electric motor;

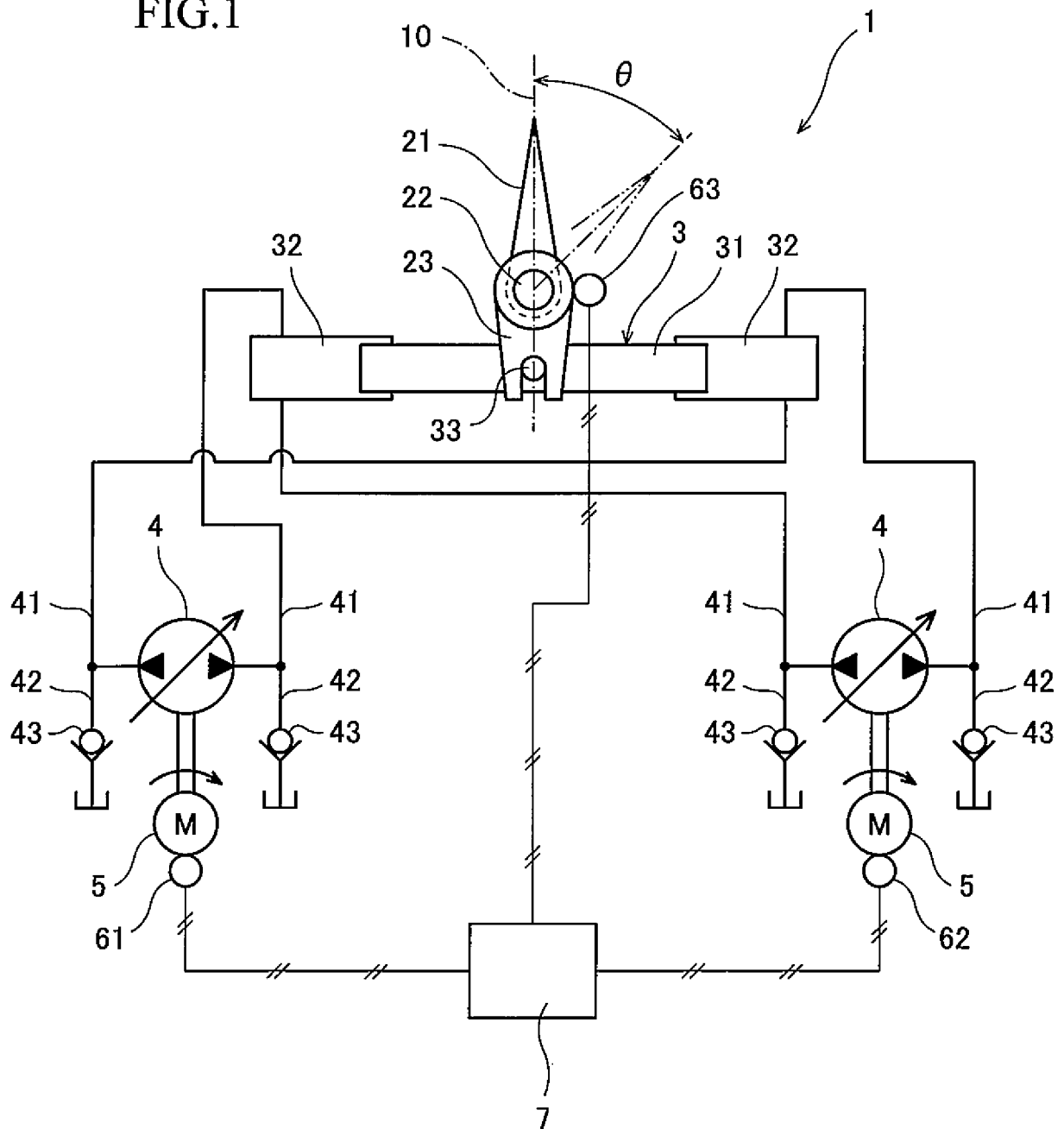
W is the electric power [W] detected by the first detector, or is electric power [W] calculated based on the electric current detected by the first detector;

W0 is electric power [W] supplied to the electric motor when a delivery flow rate of the hydraulic pump is zero;

ω is an angular velocity [rad/s] of the rudder stock, the angular velocity ω_0 being equal to 1 while the rudder stock is stopped; and

θ is the rudder angle [rad] detected by the second detector.

FIG.1



INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F15B11/028 (2006.01) i, F15B11/08 (2006.01) i, B63H25/30 (2006.01) i
FI: B63H25/30F, F15B11/028Z, F15B11/08C

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. F15B11/028, F15B11/08, B63H25/30

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2001-10590 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 16.01.2001 (2001-01-16), paragraphs [0001]-[0059], fig. 1-7	1 2-4
Y A	WO 01/19670 A1 (MAROL CO., LTD.) 22.03.2001 (2001-03-22), page 20, line 22 to page 33, line 12, fig. 8-10	1 2-4
A	JP 2017-144917 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 24.08.2017 (2017-08-24)	1-4
A	JP 2011-111127 A (HONDA MOTOR CO., LTD.) 09.06.2011 (2011-06-09)	1-4
A	JP 2000-168691 A (KAWASAKI HEAVY IND LTD.) 20.06.2000 (2000-06-20)	1-4

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2020/026351

JP 2001-10590 A	16.01.2001	(Family: none)
WO 01/19670 A1	22.03.2001	US 6820567 B1 column 12, line 62 to column 20, line 19, fig. 8-10
JP 2017-144917 A	24.08.2017	(Family: none)
JP 2011-111127 A	09.06.2011	US 2011/0117798 A1
JP 2000-168691 A	20.06.2000	(Family: none)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2017149181 A [0003]