

⑩



Europäisches Patentamt
European Patent Office
Office européen des brevets

⑪ Publication number:

**0 174 189
B1**

⑫

EUROPEAN PATENT SPECIFICATION

④⑤ Date of publication of patent specification: **31.05.89**

⑤① Int. Cl.⁴: **B 63 B 21/22**

⑦① Application number: **85306266.9**

⑦② Date of filing: **04.09.85**

⑤④ Automatic anchor watching control system.

③⑩ Priority: **04.09.84 JP 185695/84**
10.09.84 JP 190422/84

④③ Date of publication of application:
12.03.86 Bulletin 86/11

④⑤ Publication of the grant of the patent:
31.05.89 Bulletin 89/22

⑧④ Designated Contracting States:
DE GB

⑤⑥ References cited:
GB-A-2 119 551
US-A-3 810 081
US-A-3 905 011
US-A-3 974 792

⑦③ Proprietor: **KAWASAKI JUKOGYO KABUSHIKI
KAISHA**
1-1 Higashikawasaki-cho 3-chome
Chuo-ku Kobe-shi Hyogo-ken (JP)

⑦③ Proprietor: **SUMITOMO HEAVY INDUSTRIES,
LTD**
2-1 Ohtemachi 2-chome Chiyoda-ku
Tokyo 100 (JP)

⑦③ Proprietor: **NIPPON KOKAN KABUSHIKI
KAISHA**
1-2 Marunouchi 1-chome Chiyoda-ku
Tokyo 100 (JP)

⑦③ Proprietor: **HITACHI ZOSEN CORPORATION**
6-14 Edobori 1-chome Nishi-ku Osaka-shi
Osaka 550 (JP)

⑦③ Proprietor: **MITSUBISHI JUKOGYO KABUSHIKI
KAISHA**
5-1, Marunouchi 2-chome Chiyoda-ku
Tokyo 100 (JP)

⑦③ Proprietor: **SHADAN HOJIN NIPPON ZOSEN**
KENKYU KYOKAI
8th Floor Senpaku Shinko Building 1-15-16
Toranomon
Minato-ku Tokyo (JP)

⑦② Inventor: **Miyazaki, Seiji**
18-31 Nishiokamoto 2-chome
Higashinada-ku Kobe (JP)

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European patent convention).

EP 0 174 189 B1

EP 0 174 189 B1

⑦ Inventor: **Mayu, Hirokazu**
1-24-301, Takasu-cho 2-chome
Nishinomiya (JP)
Inventor: **Imamura, Hiroshi**
1-5-301 Ichinotani-cho 1-chome
Suma-ku Kobe (JP)
Inventor: **Origane, Takafumi**
1-1-1708 Hasaka-dori 4-chome
Hyogo-ku Kobe (JP)
Inventor: **Takada, Kazumi**
26-29 Teramae 2-chome
Kanazawa-ku Yokohama (JP)
Inventor: **Chiba, Ryuji**
1600-64 Okura-cho
Machida (JP)
Inventor: **Katayama, Fusaichi**
1-6-13 Hachiman-dai
Arao (JP)
Inventor: **Hibi, Terumi**
5-1- Marunouchi 2-chome
Chiyoda-ku Tokyo (JP)

⑦ Representative: **Hayward, Denis Edward Peter**
et al
Lloyd Wise, Tregear & Co. Norman House
105-109 Strand
London WC2R 0AE (GB)

Description

The present invention relates to an automatic anchor watching control system for preventing dragging or dredging of an anchor of a ship at anchor.

Anchor watching or maintaining the anchor bearing of a ship at anchor is an important task. When the anchor securely holds in the sea bottom, the position of the ship is determined by the length of the anchor chain and the external forces.

Under such condition, the collision of the ship with another ship or obstacles can be avoided by selecting a proper anchorage point with the location of the ship relative to other ships and obstacles taken into consideration.

If an external force being exerted on the ship exceeds the holding force which is determined by the anchor, anchor chain and sea bottom soil, dragging or movement of the anchor in the sea bottom will happen.

It is known to measure the tension in an anchor by means of a chain angle sensing device (US—A—3810081).

Once dragging occurs, the dragging will continue, unless the external force is reduced rapidly, and may result in an accident such as a collision.

In conventional practice, changes in the direction of the bow relative to a fixed object on the ground are observed, and if the ship moves without changing this direction, the ship will be judged to be dragging its anchor. Further, the ground position is determined by a position-finding method to detect whether the ship is dragging its anchor or not (US—A—3905011), and when the ship is dragging its anchor, certain measures may be taken to secure holding of the anchor, said measures including extension of the anchor chain to increase the holding power, operation of the main engine to generate thrust, and at the same time, use of check helm, and operation of the bow thruster.

According to the above-mentioned conventional anchor watching method, the judgement whether the ship is dragging its anchor, the judgement of the magnitude of the holding force of the anchor, anchor chain and sea bottom soil, and of the magnitude of external forces being exerted on the ship, are made solely on the experience of the ship's crew rather than on accurately engineered (numerical) estimates, and the anchor watching operation is effected through windlasses, the main engine, etc., controlled by the crew. The effectiveness of the anchor watching thus depends on the crew's activity, and there is a possible problem of insufficient anchor watching due to lack of capability or perception of the crew.

The present invention was conceived in view of the above situation. The primary objective of the present invention is to achieve an anchor watching system which automatically detects, with appropriate detectors, the environmental conditions of the ship at anchor, including sea

phenomena, weather, and condition of the sea bottom, and automatically operates the main engine or the like in a timely manner according to the condition of the ship, so as to maintain the proper anchoring of the ship.

According to the present invention, there is provided an automatic anchor watching control system for ships and the like, comprising detecting means permitting the calculation of the maximum holding force of the anchor and anchor chain, detecting means permitting calculation of the external forces acting on the ship, means responsive to the calculated values of maximum holding force and externally-acting forces for calculating forces (if any) that need to be applied to the ship to maintain the actual anchor chain tension below the maximum holding force, and means for outputting control signals corresponding to said forces to be applied to the ship to the ship's propulsion means and/or the ship's turning gear.

In the preferred form, the system further comprises means for detecting dragging of the ship's anchor and means for generating control signals to be outputted to the ship's propulsion means and/or the ship's turning gear to arrest the dragging. For this purpose there may be means for calculating the distance from the ship to the anchor, means for calculating the present distance of the ship from the position of the anchor when first cast, and means for comparing these two calculated values.

Preferably, the means for calculating the distance from the ship to the anchor comprises detectors for detecting the let-out anchor chain length, the water depth and the anchor chain tension, and means for performing computations upon the signals received from said detectors in accordance with theoretical anchor chain catenary formulae.

The means for calculating the present distance of the ship from the position of the anchor when first cast may comprise means for integrating with respect to time the ship's velocity or acceleration from the time of anchor casting to the present.

Also in the preferred form, the means for calculating the maximum holding force of the anchor and anchor chain comprises detectors for detecting the type of sea bottom soil, the anchor chain tension, the let-out anchor chain length and the water depth, means for calculating the length of anchor chain lying on the sea bottom, and means for summing the holding force due to the anchor itself in the type of soil detected and the holding force due to said anchor chain length lying on the sea bottom.

The means for calculating the external forces acting on the ship may comprise detectors for wind direction and velocity and tidal current.

Accordingly, as the tension in the anchor chain is maintained at or below the maximum holding force, the anchor of a ship with the present system will be continuously maintained in a proper condition to prevent dragging.

It should be noted that ship's turning gear herein is to be construed as steering gear and/or a bow thruster.

A preferred embodiment of the present invention will now be described in the following with reference to the accompanying drawings, in which:—

Figure 1 shows the general arrangement of an automatic anchor watching system of the present invention and various units of the ship to be controlled by said system;

Figure 2 is a block diagram showing the arrangement of the automatic anchor watching system and its auxiliary devices;

Figure 3 shows the relationship of forces operating on the hull in a ship equipped with the anchor watching control;

Figure 4 is an explanatory diagram of the anchor chain catenary;

Figures 5 and 6 are flow charts illustrating the computations made and controls given in the anchor watching system;

Figures 7 and 8 are explanatory diagrams showing the non-dragging condition and the dragging condition.

As illustrated in Figures 1 and 2, the present anchor watching system includes a variety of detectors and control units, and various components such as the main engine are controlled by the system.

As shown in Figure 1, a control unit 2, a gyrocompass 3 and a control console 4 (hereinafter called the control panel) are installed in the bridge control room 1 located in the upper aft superstructure of the ship. A pair of windlasses 5, arranged port and starboard, and remotely controlled from the control panel 4, are located at the bow on the upper deck, and an anchor chain 6 to be let out from each windlass 5 passes through a respective hawsepipe 7 to emerge at the respective side of the ship. An anchor 8 is connected to the end of each anchor chain 6.

An anchor chain tension detector 9, which detects the tension in the anchor chain by means of a load cell or the like, is provided in at least one anchor chain 6 being let out from one windlass 5. The windlass 5 is also provided with a let-out anchor chain length detector 10 which detects the length of the anchor chain let out by the windlass by counting the number of revolutions of the windlass. Further, the windlass 5 is provided with an anchor casting signal transmitter 31 (Figure 2) which detects the commencement of anchor casting. The detection signals from these detectors 9, 10 and 31 are arranged to be outputted to the control unit 2. An anchor chain angle detector 11 (for example, a device using an image sensor a TV camera, or the like), for detecting the angle θ (see Figure 3) of the anchor chain 6 with respect to the centre line of the hull in the horizontal plane, is provided above and athwart the hawsepipe 7, and the detection signal from this detector is also outputted to the control unit 2.

Further, a sea bottom soil detector 12, consisting of an ultrasonic generator 12a for transmitting

a specified ultrasonic wave form towards the sea bottom and an ultrasonic receiver 12b for receiving the reflected wave form, is provided in the bottom of the hull, and its detection signal is arranged to be outputted to the control unit 2. The sea bottom soil detector 12 also operates as a water depth detector 13.

A tidal current detector 14 for detecting the direction and velocity of the tidal current, used in the computation of the external forces on the hull, is provided in the bottom of the hull at the bow, and the detection signal is arranged to be outputted to the control unit 2. A salt concentration detector 15 for detecting the salt concentration of the water, and a water temperature detector 16 for detecting the water temperature, are provided in the bottom of the hull toward the aft end, and their detection signals are also arranged to be outputted to the control unit 2 to compensate the detection data from the ultrasonic type detectors 12, 13, 14 for changes in water salt concentration and temperature.

On both sides of the hull at both the bow and aft ends, four sets of draft gauges 17 for electrically detecting the draft are installed, and their detection signals are also arranged to be outputted to the control unit 2.

A wind direction and velocity detector 18 for detecting the direction and velocity of the wind, used in the calculation of the external forces on the hull, is provided above the bridge, and its detection signals are arranged to be outputted to the control unit 2. A Doppler sonar speedmeter (Figure 2), for measuring the absolute ground velocity of the ship in a shallow sea anchorage area, is provided in the bottom of the ship, and its detection signal is arranged to be outputted to the control unit 2.

A water ballast pump 19, the main ship's engine 20, the ship's steering gear 21, and a bow thruster 22 are provided with control means 19a, 20a, 21a, and 22a respectively, capable of receiving control signals from the control unit 2. The control means 19a constitutes ship's draft control means also controlling a ballast water drain valve.

As shown in Figure 2, the control unit 2 consists of a detection signal receiving unit 23, a central processing unit 24, a timer 25, a read only memory (ROM) 26, a random access memory (RAM) 27, a data setter 28 and a control signal output unit 29.

The detection signal receiving unit 23 receives the detection signals from the detectors 3, 9 to 18, 23, 24, 30 and 31, applies any necessary analogue-to-digital conversion, amplification or waveform shaping to these detection signals, and outputs them to the central processing unit 24. The unit 23 also receives from the central processing unit 24 signals that are generated by processing said detection signals. The signals processed by the detection signal receiving unit 23 are stored in the RAM 27 via the central processing unit 24. The ROM 26 stores a variety of computation programs to be executed in the central processing unit 24, which will be

explained later (see the flow charts of Figures 5 and 6).

The timer 25 outputs an actuation signal at a specified time cycle to the central processing unit 24, and according to this actuation signal computation is executed at the specified time cycle.

The data setter 28 is for inputting to the central processing unit 24 such data, additional to the data obtained from the variety of detection signals, as may be required for a variety of calculations such as those concerning the anchor chain catenary, the maximum holding force and external forces on the hull. This data may include the principal dimensions of the hull, i.e. length, breadth and depth (L, B and D), the dimensions of the superstructure, anchor chain unit weight (Wc), chain type and dimensions, hawsepipe frictional force, and vertical distance (d) from the water line to the hawsepipe. Some data, such as the draft and water depth, may in the alternative be detected by independent detectors and manually inputted to the data setter 28.

The control signal output unit 29 receives control signals from the central processing unit 24, applies any necessary digital-to-analogue conversion or amplification, and outputs signals to the windlass control means 5a, the main engine control means 20a, the bow thruster control means 22a, the steering gear control means 21a, and the draft control means 19a.

Thus, the control unit 2 is connected, as shown in the block diagram of Figure 2, to the various detectors 3, 9 to 18, 23, 24, 30 and 31 on the one hand, and to the various control means, including the main engine control means, on the other hand, and it uses the detection signals from said various detectors 3, 9 to 18, 30 and 31, and the data set in beforehand, for determining whether the ship is dragging its anchor or not. When the ship is not dragging its anchor, the control unit 2 computes the maximum holding force which can be applied by the anchor 8 and the anchor chain 6, and the external forces (wind force and tidal force) on the hull. To maintain the anchor chain tension T_0 at or below the maximum holding force, the control unit may output a control signal to the windlass control means 5a to let out more anchor chain 6, and/or it may output a control signal to the draft control means 19a to charge or drain the hull ballast water and thereby lessen the wind force or the tidal force, and/or it may output a control signal to the main engine control means 20a to use the propulsive force of the propeller for anchor watching control, and/or together with the use of the propeller it may output a control signal to the steering gear control means 21a to control the helm angle, and/or it may output a control signal to the bow thruster control means 22a to control the turning propulsive force of the bow thruster.

On the other hand, when the ship is dragging its anchor, the control unit determines by computation the direction and distance of dragging and outputs control signals corrected according to the dragging condition to the main engine control

means 20a, the bow thruster control means 22a, and so forth.

Now, the process of computation in the central processing unit 24 of the control unit during anchor watching will be explained with reference to the flowcharts of Figures 5 and 6.

First, with reference to Figure 5, the subflow-chart for determination of dragging will be explained. Blocks S1 to S12 indicate operations in the process. The process commences at S1. The central processing unit is initialized at S2. The count "n" of dragging is set at $n = 1$ at S3. At S4, an anchor casting signal from the anchor casting signal transmitter 31 is received, and the anchor casting start time t is set at $t = 0$. At S5, according to the clock signals from the timer 29 (see Figure 2), a calculation command signal is outputted, for example, every five minutes after anchor casting. With the calculation command signal present, a test is made to determine whether the current period is a calculation period or not, and when it is a calculation period the central processing unit shifts to S6. When it is not a calculation period, the unit shifts back to S5 and repeats the calculation period check until a calculation period is reached.

At S6, the detection data obtained from various detectors and stored in the RAM 27, and the preset data set beforehand by the data setter, are inputted and the process shifts from S6 to S7.

At S7, a test is made to determine whether the letting-out of the anchor chain 6 has been completed or not by examining whether the signal from the let-out anchor chain length detector 10 is steady or not. When the letting-out has been completed, the process shifts to S8.

At S8, the let-out anchor chain length C is calculated from the detection signal from the let-out anchor chain length detector 10, and according to anchor chain catenary theory, as illustrated in Figure 4, the anchor chain catenary length S , the horizontal distance Y of the anchor chain catenary, and the length of the straight portion Z of the anchor chain on the sea bottom are calculated, and the horizontal distance X from the ship to the anchor 8 is calculated.

At S9, the horizontal distance R from the original anchor casting position to the present ship position (Figures 7 and 8) is calculated. The calculation at S9 may be executed as an interrupt.

At S10, the dragging distance $\Delta R = (R - X)$ is calculated, and at S11 a test is made whether the dragging distance ΔR exceeds a relatively small preset value A (for instance, $A = 20$ m). This preset value A is designed to absorb errors such as the detection errors of detectors 9, 10, 17, 30 etc., and the distance required by the anchor to dig into the sea bottom. When the dragging distance ΔR is not more than the present value, the ship is judged not to be dragging its anchor, and the process shifts back to S5 to repeat the steps starting from S5.

On the other hand, when the dragging distance ΔR exceeds the preset value A , the ship has been dragging its anchor. The process shifts to S12,

and at this step ΔR_n is substituted for ΔR . At the next step S13, ΔR_n is compared with the value of ΔR of the preceding cycle (namely, $\Delta R_{n-1} \cdot R_0 = 0$). When ΔR_n is larger than the value of the preceding cycle, the ship is dragging its anchor and the process shifts to S14, at which the values of ΔR , R_x , R_y , R , X (see Figure 8), and if necessary an alarm, are displayed on the control panel indicator 32 (see Figure 2). The process shifts to S15, and the value of the count "n" of dragging is incremented. On the other hand, at S13, when the value does not exceed the previous value, the ship is judged not to be dragging its anchor and the process shifts back to S5 to repeat the steps starting from S5.

The above-mentioned subflowchart is executed at the specified time cycle independently of the main flowchart which will be explained later. The results are used by interrupt as calculation data for the main flowchart (information on whether the ship is dragging or not) (see Figure 6) and correction data for the results of computation.

Next, the calculation procedure for anchor watching control to be executed in the central processing unit 24 will be explained briefly with reference to the main flowchart of Figure 6. Blocks S1 to S9 indicate operations in the process.

The process commences at S1. The central processing unit is initialized at S2. At S3, when the actuation signal from the timer 25 is inputted, the process shifts to S4 and a variety of data stored in the RAM 27 is inputted. At S5, the information on the presence or absence of dragging obtained according to the subflowchart is used to test whether the ship is dragging its anchor or not. When the ship is dragging its anchor, the process shifts to S8, and the data of the dragging (distance and direction) are inputted. Next, the process shifts to S9, and the various data inputted are used to calculate the external force F on the hull. At S10, the required orthogonal components of the anchor watching control force F_p and F_s (see Figure 3) are computed. During this computation, corrections are made for the dragging distance ΔR and the direction of dragging. In other words, in contrast to the case of non-dragging, a correction of the control outputs (for instance, the control outputs to the main engine and the bow thruster) is made corresponding to the state of dragging. At S11, control signals corresponding to the corrected F_p and F_s are outputted. Next, the process shifts from S11 back to S4 to repeat the steps described above in the exercise of anchor watching control.

On the other hand, at S5, when the ship is holding position (non-dragging condition), the process shifts to S6 at which the maximum holding force T_{max} is calculated. At the following step S7, a test is made whether the anchor chain Tension t_0 (strictly speaking, the detected anchor chain tension plus the frictional force of the hawsepipe) is smaller than the maximum holding force T_{max} . When the anchor chain tension is smaller (or when there is no danger of dragging), the process shifts to S12 and terminates. When

the anchor chain tension is equal or larger (or when there is a danger of dragging), the process shifts to S9. At S9, the external force F on the hull is calculated, and at S10 the required anchor watching component forces F_p and F_s are calculated. At S11, control signals corresponding to F_p and F_s are outputted, and the process then shifts from S11 back to S4 to repeat the steps mentioned above.

The present automatic anchor watching system is arranged to execute tasks in its central processing unit 24 according to the flowcharts as outlined above. The detection of dragging, calculation of the anchor chain catenary, calculation of the maximum holding force obtainable with the anchor 8 and the anchor chain 6, calculation of external forces acting on the hull, calculation of anchor watching control propulsive forces, etc. are made in said central processing unit 24 as explained below.

(I) The detection of dragging is by means of the speedmeter 29 and gyrocompass 3. In other words, the dragging condition is tested by whether the horizontal distance X from the ship to the anchor determined by the anchor chain catenary theory is equal to the horizontal distance R from the anchor casting position to the present ship position determined by the speedmeter 29 and the gyrocompass 3. (If the ship is not dragging its anchor, X is equal to R ; see Figure 7).

To be more specific, the horizontal distance R is determined by first establishing a system of coordinates and performing time integration of the velocity components of the ship, obtained by means of the speedmeter and the gyrocompass, from anchor casting to the present. In other words, as it is possible, with the use of a Doppler sonar speedmeter, to detect the absolute ground velocity of the ship in a shallow sea area where anchorage can be made, the present (at time $t = t$) position of the ship (R_x , R_y) is as follows; the anchor casting position is set as the origin ($(0,0)$, $t = 0$) as shown in Figure 7.

$$R_x = \int_0^t V_x(t) dt, R_y = \int_0^t V_y(t) dt \quad (1)$$

$$R = [R_x^2 + R_y^2]^{1/2} \quad (2)$$

where

$V_x(t)$: The velocity of the ship in the direction of the X axis of the specified system of coordinates obtained from the measured velocity at time t and the data of the gyrocompass.

$V_y(t)$: The velocity of the ship in the direction of the Y axis of the specified system of coordinates obtained from the measured velocity at time t and the data of the gyrocompass.

The horizontal distance R from the anchor casting position to the present position of the ship is thus obtained with high accuracy.

When the ship is not dragging its anchor, the horizontal distance X from the ship to the anchor 4 is roughly equal to the horizontal distance R

from the anchor casting point to the present position of the ship (see Figure 7).

In contrast, when the ship is dragging its anchor, the horizontal distance R from the anchor casting point to the present ship position is greater than the horizontal distance X from the ship to the anchor 4, and (R-X) is the distance of dragging (see Figure 8). As the value of (R-X) is a vector that can be divided into an X-axis component and a Y-axis component, the direction of dragging as well as the distance of dragging can be determined.

R can also be obtained by using accelerations ($a_x(t)$, $a_y(t)$) to be detected by accelerometers, rather than the ship velocities ($V_x(t)$, $V_y(t)$) detected by the speedmeter 8 as described above.

(II). The maximum holding force and the horizontal distance X are determined by obtaining the anchor chain catenary on the basis of the theoretical formulae for anchor chain catenary.

The anchor chain catenary is calculated in the following manner using main parameters such as the let-out anchor chain length C, anchor chain tension T_o , and water depth H all obtained as detection data (see Figure 4).

$$S = f_1(T, H, D, Wc) \quad (3)$$

where

S: Catenary length of the anchor chain catenary;

T: Horizontal component of anchor chain tension;

H: Water depth;

d: Vertical distance between the water surface and the hawsepipe; and

Wc: Anchor chain unit weight.

$$\phi = f_2(T_o, H, D, Wc) \quad (4)$$

where

ϕ = Angle of elevation at the top end of the anchor chain; and

$$T = T_o \cos \phi \quad (5)$$

$$Y = f_3(T, Wc, S) \quad (6)$$

where

Y: Horizontal length of anchor chain catenary.

$$Z = C - S \quad (7)$$

where

Z: Length of straight portion of the anchor chain on the sea bottom.

$$X = Y + Z \quad (8)$$

where

X: Horizontal distance from the ship to the anchor.

For T_o , the detected anchor chain tension plus the frictional force of the hawsepipe is used. The functions f_1 , f_2 and f_3 express the functional

relationships obtained from anchor chain catenary theory. Since these theoretical formulae are well known, a detail explanation is omitted.

(III). On the basis of the length of the straight portion Z of the anchor chain on the sea bottom obtained in the above-mentioned manner, the sea bottom soil p obtained as detection data, and data inputted as preset data, the maximum holding force $T_{o\max}$ which can be exerted by the anchor 8 and the chain 6 is obtained by the following formula:

$$T_{o\max} = (T(p) + T(Z)) \quad (9)$$

$T(p)$ is the holding force of the anchor itself determined by the sea bottom soil p and the known type and dimensions of the anchor. $T(Z)$ is the holding force of the anchor chain 6 determined by the length Z of the straight portion of the anchor chain resting on the sea bottom and the anchor chain unit weight Wc.

(IV). The external force F acting on the hull and its angle α (see Figure 3) are determined from the direction of the tidal current, the direction and velocity of the wind, and the draft all obtained as detection data, and the dimensions of the hull ($L \times B \times D$) and superstructure inputted as preset data.

L: Length of the hull;

B: Width of the hull; and

D: Depth of the hull.

The angle of the anchor chain θ is obtained as detection data, and the angle ϕ is obtained by the calculation of the anchor chain catenary.

(V). As shown in Figure 3, the conditions for maintaining the position of the hull without moving, or the conditions of anchor watching, are determined by the balance of forces in the longitudinal and transverse directions as follows:

$$F \sin \alpha = F_s + T \sin \theta \quad (10)$$

$$F \cos \alpha = F_p + T \cos \theta \quad (11)$$

$$T = T_o \cos \phi \quad (12)$$

$$T_o \leq T_{o\max} = T(p) + T(Z) \quad (13)$$

where

F: External force due to wind and tidal current;

T: Horizontal component of anchor chain tension;

F_p : Anchor watching control propulsive force in the longitudinal direction of the hull which is obtained by driving the propeller by means of the main engine; and

F_s : Anchor watching control propulsive force in the horizontal direction perpendicular to the centre line of the hull which is obtained by driving the bow thruster and/or by checking helm.

Accordingly, from the formulae (10) to (13) and the theoretical formulae of the anchor chain catenary theory, values of F_p and F_s which satisfy said formulae (10) to (13) are obtained.

When the ship is dragging its anchor, the values

F_p and F_s are corrected according to the condition of dragging (distance and direction of dragging).

In addition to balancing the forces in the longitudinal and transverse directions as described above, balancing the moments around a vertical axis may be considered. In this case, it may be possible to balance the moments by using the transverse propulsive force of the bow thruster 22. For a ship without the bow thruster 22, it may be possible to balance the moments by letting out more anchor chain to increase the maximum holding force T_{0max} and using the steering gear to check helm and generate a transverse propulsive force.

Further, to reduce the external forces, it may be possible, when the wind is strong, to increase the draft to reduce the side area of the ship above the water surface, or when the tidal force is strong, to decrease the draft to reduce the side area of the ship below the water surface.

When the external force F acting on the hull is determined, it is desirable to use data such as the height, direction and period of the waves, and height, direction and period of swell both to be detected by draft gauges, although these data are not specifically considered in the above-described embodiment.

The anchor watching control propulsive forces F_p and F_s are thus determined, and control signals for generating the longitudinal propulsive force F_p and the transverse propulsive force F_s are outputted by the central processing unit 24 via the control signal output unit 29 to the main engine control means 20a, the bow thruster control means 22a and/or the steering gear control means 21a.

Control signals may be applied to all of the above-mentioned means 20a, 21a and 22a, or to any two of them, or to any one of them, at a particular time.

In some cases, to let out the anchor chain 6 more to increase the maximum holding force T_{0max} , a control signal is also outputted to the windlass control means 5a, or to reduce the effects of the tidal current or wind force, a control signal for increasing or draining the ballast is outputted to the draft control means 19a.

As the automatic anchor watching control system of the present invention is arranged, as explained above, to avoid dependence of anchor watching on human perception, and to determine, by calculation, the maximum holding force of the anchor, the external forces acting on the ship, and the anchor chain tension from a variety of data detected by various detectors, and to automatically actuate anchor watching control means so as to constantly keep the anchor chain tension below the maximum holding force, the system is capable of preventing dragging.

Further, as the automatic anchor watching control system of the present embodiment uses feedback which can quickly detect incipient dragging due to, for example, a sudden change in the soil of the sea bottom, and modify the control outputs according to the dragging condition, the

system makes possible automatic control of anchor watching with very high reliability.

Accordingly, the crews of ships are freed from the anchor watching operation which requires the experience of many years and is complicated in execution, and anchor watching can be executed independently of the capacity of the crews.

Since the dragging detection unit constituting a part of the automatic anchor watching system of the present embodiment uses a dragging detection method in which the horizontal distance from the ship to the anchor, determined from the anchor chain catenary and the let-out anchor chain length, is compared with the horizontal distance from the anchor casting point, which is obtained by time integration of the ship's velocity or acceleration from anchor casting to the present position of the ship, fixed facilities on the ground or ashore are not required and the detection can be made with equipment mounted on the ship alone. As apart from the performance of the detectors, the principal source of error is merely the distance required by the anchor to dig into the sea bottom, the system can detect dragging in its very early stage.

Claims

1. An automatic anchor watching control system for ships and the like, comprising detecting means (12, 9, 10, 11) permitting the calculation of the maximum holding force of the anchor and anchor chain (6), detecting means (18, 14, 17) permitting the calculation of the external forces acting on the ship, means responsive to the calculated values of the maximum holding force and externally-acting forces for calculating the forces (if any) that need to be applied to the ship to maintain the actual anchor chain tension below the maximum holding force, and means (2, 3, 4) for outputting control signals corresponding to said forces to be applied to the ship to the ship's propulsion means (22) and/or the ship's turning gear (21).

2. A system according to Claim 1, further comprising means for detecting dragging of the ship's anchor and means for generating control signals to be outputted to the ship's propulsion means and/or the ship's turning gear to arrest the dragging.

3. A system according to Claim 2, wherein the means for detecting dragging comprises means for calculating the distance from the ship to the anchor, means for calculating the present distance of the ship from the position of the anchor when first cast, and means for comparing these two calculated values.

4. A system according to Claim 3, wherein the means for calculating the distance from the ship to the anchor comprises detectors (10) for detecting the let-out anchor chain length, the water depth (13) and the anchor chain tension (9), and means for performing computations upon the signals received from said detectors in accordance with theoretical anchor chain catenary formulae.

5. A system according to Claim 3 or Claim 4, wherein the means for calculating the present distance of the ship from the position of the anchor when first cast comprises means for integrating with respect to time the ship's velocity or acceleration from the time of anchor casting to the present.

6. A system according to Claim 3 or Claim 4 or Claim 5, wherein the output control signals are corrected according to the direction and distance of dragging.

7. A system according to any one of the preceding claims, wherein the detecting means, permitting the calculation of the maximum holding force of the anchor and anchor chain comprises detectors (12) for detecting the type of sea bottom soil, the anchor chain tension (9), the let-out anchor chain length (10) and the water depth (13), means for calculating the length of anchor chain lying on the sea bottom, and means for summing the holding force due to the anchor itself in the type of soil detected and the holding force due to said anchor chain length lying on the sea bottom.

8. A system according to any one of the preceding claims, wherein the means for calculating the external forces acting on the ship comprise detectors (18, 14) for wind direction and velocity and tidal current.

9. A system according to Claim 8, wherein the means for calculating the forces to be applied to the ship are arranged to compute orthogonal components of force parallel to and perpendicular to the longitudinal centre line of the ship.

10. A system according to any one of the preceding claims, further comprising means for outputting control signals to ship's draft control means for varying the ship's draft and hence the external forces on the ship, and/or to windlass control means for varying the let-out anchor chain length, and means for detecting the horizontal angular direction of the anchor chain with respect to the ship.

Patentansprüche

1. Selbsttätiges Ankerbeobachtungs- und kontrollsystem, für Schiffe und dgl., gekennzeichnet durch Detektoreinrichtungen (12, 9, 19, 11), durch die die Haltekraft des Ankers und der Ankerkette (6) berechnet werden kann, Detektoreinrichtungen (18, 14, 17), durch die die auf das Schiff einwirkenden Aussenkräfte berechnet werden können, Einrichtungen, die zur Berechnung der Kräfte (falls vorhanden), die auf das Schiff angewandt werden müssen zur Aufrechterhaltung der tatsächlichen Ankerkettenspannung unter der maximalen Haltekraft, auf die berechneten Werte der maximalen Haltekraft und der von außen einwirkenden Kräfte ansprechen und durch Einrichtungen (2, 3, 4) zur Ausgabe von Steuersignalen, die den Kräften entsprechen, welche an den Antrieb (22) und/oder an die Drehvorrichtung (21) des Schiffes zu legen sind.

2. System nach Anspruch 1, gekennzeichnet zusätzlich durch Detektoreinrichtungen, durch die ein Schleifen des Schiffsankers erfaßt wird, und Einrichtungen, durch die Steuersignale erzeugt werden, die zur Behebung des Schleifvorgangs an den Schiffsantrieb und/oder an die Drehvorrichtungen des Schiffes abgegeben werden.

3. System nach Anspruch 2, dadurch gekennzeichnet, daß die Einrichtungen zum Ermitteln des Schleifens Mittel, durch die der Abstand vom Schiff zum Anker berechnet wird, Mittel, durch die der gegenwärtige Abstand des Schiffes von der erstmaligen Ankerstelle her berechnet wird, und Mittel aufweisen, durch die die zwei berechneten Werte miteinander verglichen werden.

4. System nach Anspruch 3, dadurch gekennzeichnet, daß die Mittel Berechnung des Abstandes des Schiffes zum Anker Detektoren (10), durch die die herausgegebene Ankerkettenlänge, die Wassertiefe (13) und die Ankerkettenspannung (9) ermittelt werden, und Einrichtungen aufweisen, durch die reagierend auf die von den Detektoren empfangenen, Signale Berechnungen gemäß der theoretischen Kettenformeln (catenary formulae) für Ankerketten durchgeführt werden.

5. System nach Anspruch 3 oder 4, dadurch gekennzeichnet, daß die Mittel zum Berechnen des gegenwärtigen Abstandes des Schiffes von der erstmaligen Ankerstelle Einrichtungen aufweisen, durch die zeitabhängig die Geschwindigkeit und Beschleunigung des Schiffes von der Zeit des Ankerwerfens bis zur Gegenwart integriert wird.

6. System nach Anspruch 3 oder 4, dadurch gekennzeichnet, daß die Ausgangssteuersignale gemäß der Schleifrichtung und -entfernung berechtigt werden.

7. System nach einem der vorhergehenden Ansprüche 1 bis 6, dadurch gekennzeichnet, daß die Detektoreinrichtungen, durch die die maximale Kraft des Ankers und der Ankerkette berechnet werden können, Detektoren (12), durch die die Beschaffenheit des Seebodens, die Ankerkettenspannung (9), die ausgegebene Ankerkettenlänge (10) und die Wassertiefe (13) ermittelt werden können, Mittel, durch die die am Seeboden liegende Ankerkettenlänge berechnet wird, und Mittel aufweisen, durch die die durch den Anker selbst bedingte Haltekraft in der Art des ermittelten Seebodens und die durch die auf dem Seeboden liegende Ankerkettenlänge bedingte Haltekraft summiert werden.

8. System nach einem der vorhergehenden Ansprüche 1 bis 7, dadurch gekennzeichnet, daß die Einrichtungen zum Berechnen der auf das Schiff einwirkenden Aussenkräfte Detektoren (18, 14) für Windrichtung und -geschwindigkeit sowie für Tidenströmung aufweisen.

9. System nach Anspruch 8, dadurch gekennzeichnet, daß die Einrichtungen zum Berechnen der an das Schiff anzulegenden Kräfte ausgelegt sind, die parallel und senkrecht zur Längsmittellinie des Schiffes bestehenden orthogonalen Kräftekomponenten zu berechnen.

10. System nach einem der vorhergehenden Ansprüche 1 bis 9, gekennzeichnet zusätzlich durch Einrichtungen, durch die Steuersignale an die Tiefgangsteuereinrichtung zur Veränderung des Tiefgangs des Schiffes und somit der auf das Schiff einwirkenden Aussenkräfte und/oder an die Ankerspillsteuereinrichtung zur Veränderung der Ankerkettenlängenausgabe gegeben werden, und durch Mittel zur Ermittlung der horizontalen Winkelrichtung der Ankerkette gegenüber dem Schiff.

Revendications

1. Système Automatique de commande de surveillance d'une ancre pour bateaux ou analogues, comportant des moyens de détection (12, 9, 10, 11) permettant de calculer la force maximum de maintien d'une ancre et de sa chaîne, des moyens de détection (18, 14, 17) permettant de calculer les forces extérieures agissant sur le bateau, des moyens réagissant aux réponses aux valeurs calculées de la force maximum de maintien et des forces extérieures pour calculer les forces (s'il y en a) devant être appliquées au bateau pour maintenir la tension réelle de la chaîne d'ancre en dessous de ladite force maximum de tension, et des moyens (2, 3, 4) pour émettre des signaux de commande correspondant auxdites forces qui doivent être appliquées au bateau, au moyen de propulsion (22) du bateau et/ou au moyen (21) d'orientation du bateau.

2. Système selon la revendication 1, comprenant en outre des moyens pour détecter le rippage de l'ancre du bateau et des moyens pour générer des signaux de commande devant être émis vers les moyens de propulsions du bateau et/ou les moyens d'orientation du bateau pour arrêter le rippage de l'ancre.

3. Système selon la revendication 2, dans lequel les moyens pour détecter le rippage de l'ancre comprennent des moyens pour calculer la distance séparant le bateau de l'ancre, des moyens pour calculer à tout moment la distance séparant le bateau de la position qu'occupait l'ancre lorsqu'elle a été mouillée pour la première fois, et des moyens pour comparer ces deux valeurs.

4. Système selon la revendication 3, dans lequel les moyens pour calculer la distance séparant le bateau de l'ancre comportent des détecteurs (10) pour déterminer la longueur de la chaîne d'ancre larguée, la profondeur du fond (13) et la tension (9) de la chaîne d'ancre, et des moyens pour effectuer des calculs à partir des signaux en

provenance desdits détecteurs en application de formule théorique de chaîne d'ancre en suspension caténaire.

5. Système selon la revendication 3 ou 4, dans lequel les moyens pour effectuer le calcul de la distance instantanée du bateau par rapport à la position première de l'ancre lorsqu'elle a été mouillée, comprennent des moyens pour intégrer en fonction du temps la vitesse ou accélération du bateau à partir du moment du mouillage jusqu'à l'instant considéré.

6. Système selon la revendication 3, 4 ou 5, dans lequel les signaux de commande émis sont corrigés en fonction de la direction et de la distance du rippage de l'ancre.

7. Système selon l'une quelconque des revendications précédentes, dans lequel les moyens de détection permettant le calcul de la force maximum de maintien de l'ancre et de la chaîne d'ancre comprennent des détecteurs (12) pour détecter la nature du sol du fond de la mer, la tension (9) de la chaîne d'ancre, la longueur (10) de chaîne larguée et la profondeur (13) de l'eau, des moyens pour calculer la longueur de chaîne reposant sur le fond de la mer et des moyens pour faire la somme de la force de maintien due à l'ancre elle-même en fonction du type de sol détecté et de la force de maintien due à ladite longueur de chaîne reposant sur le fond de la mer.

8. Système selon l'une quelconque des revendications précédentes, dans lequel les moyens pour calculer les forces extérieures agissant sur le bateau comprennent des détecteurs (18, 14) pour détecter la force et la direction du vent et des détecteurs pour déterminer la force et la direction du courant par exemple du courant de marée.

9. Système selon la revendication 8, dans lequel les moyens pour effectuer le calcul des forces devant être appliquées au bateau sont disposés de façon à calculer les composants orthogonaux de la force parallèle et perpendiculaire à la ligne centrale longitudinale du bateau.

10. Système selon l'une quelconque des revendications précédentes, comprenant en outre des moyens pour émettre des signaux de commande au moyen de commande du tirant d'eau du bateau afin de faire varier le tirant d'eau du bateau et en conséquence les forces extérieures agissant sur le bateau, et/ou au moyen de commande du guindeau de façon à faire varier la longueur de la chaîne mouillée, et des moyens pour détecter l'angle que fait la chaîne par rapport au bateau.

Fig.1.

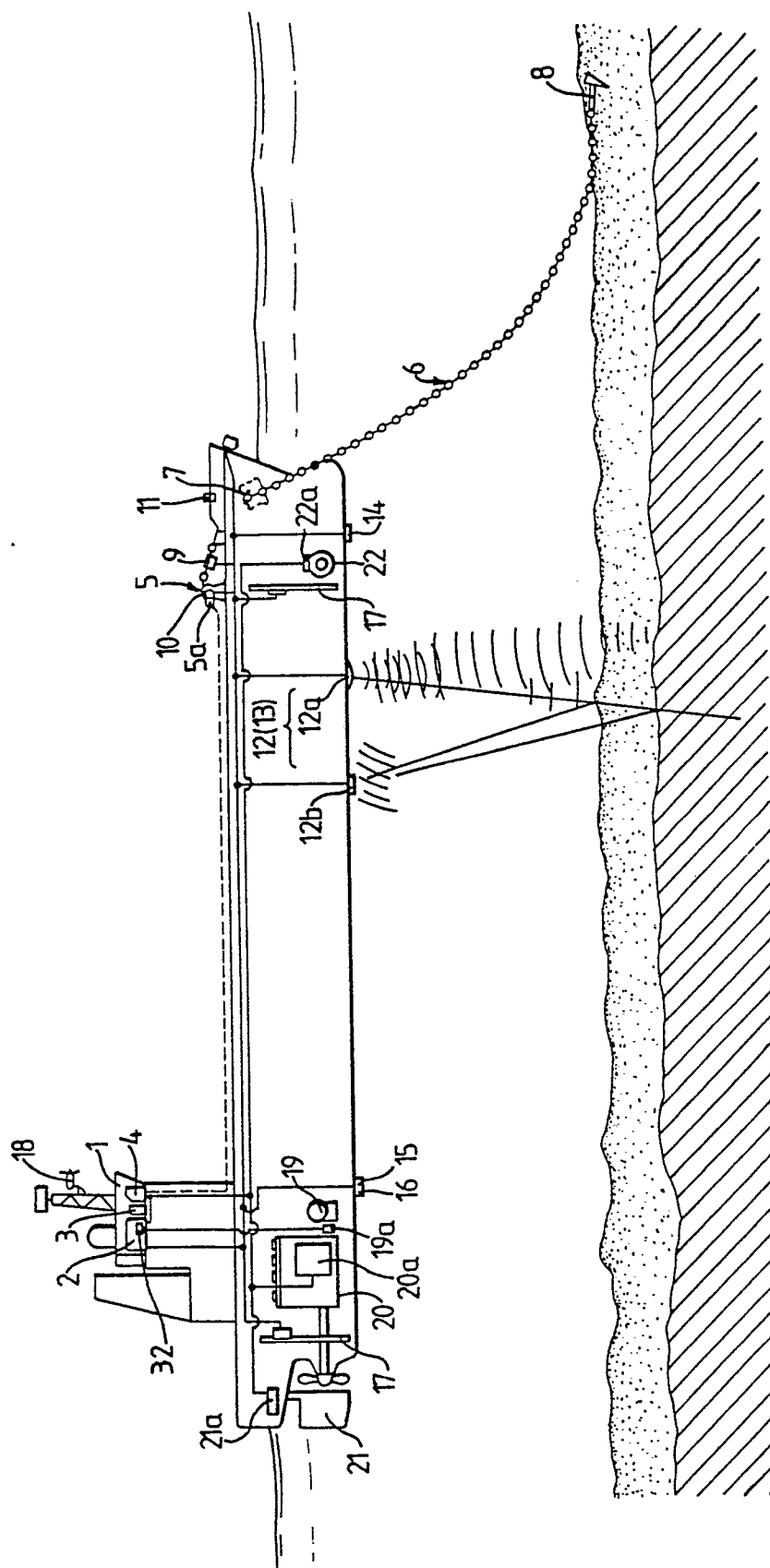


Fig.2.

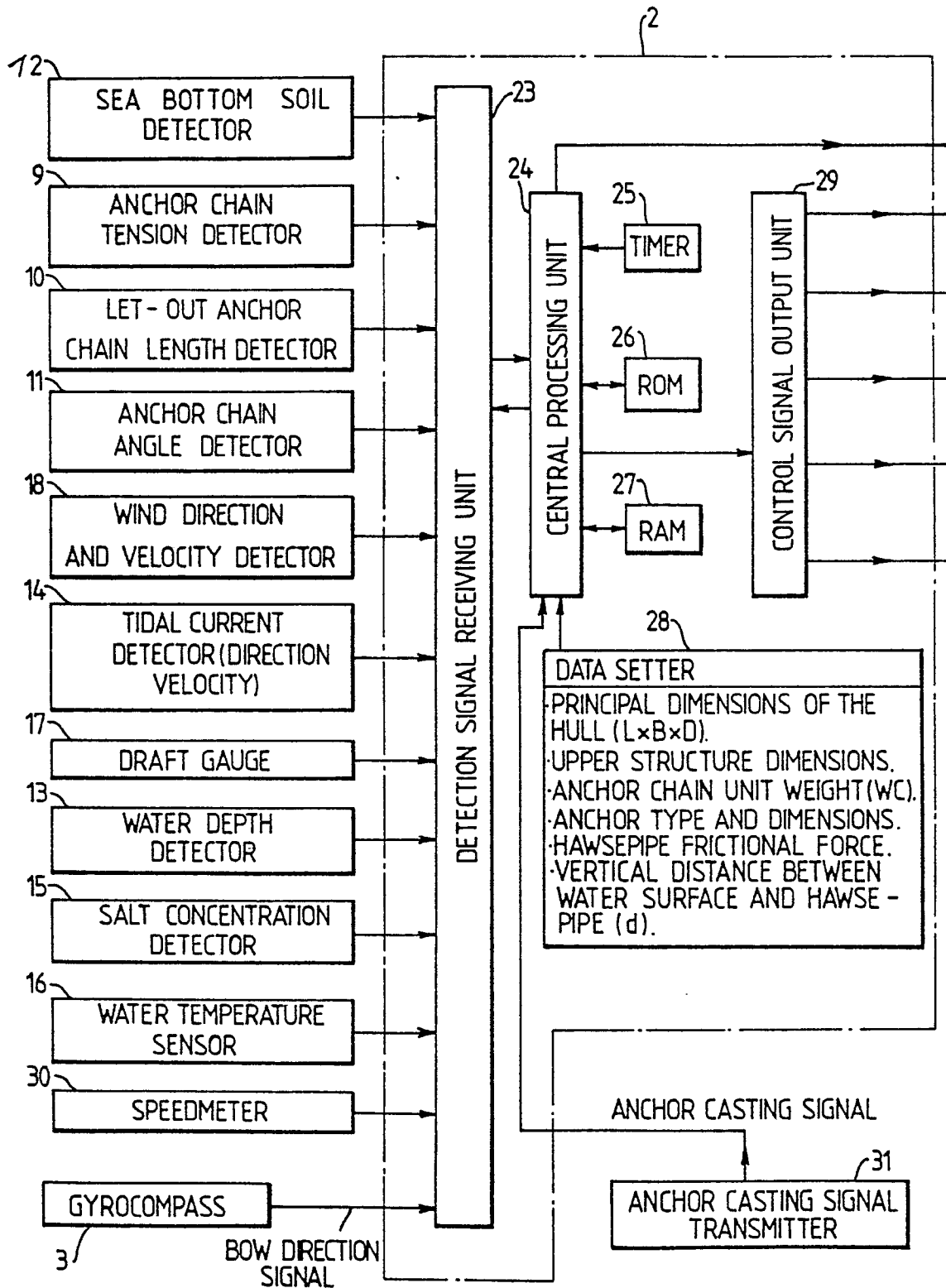


Fig. 2. cont.

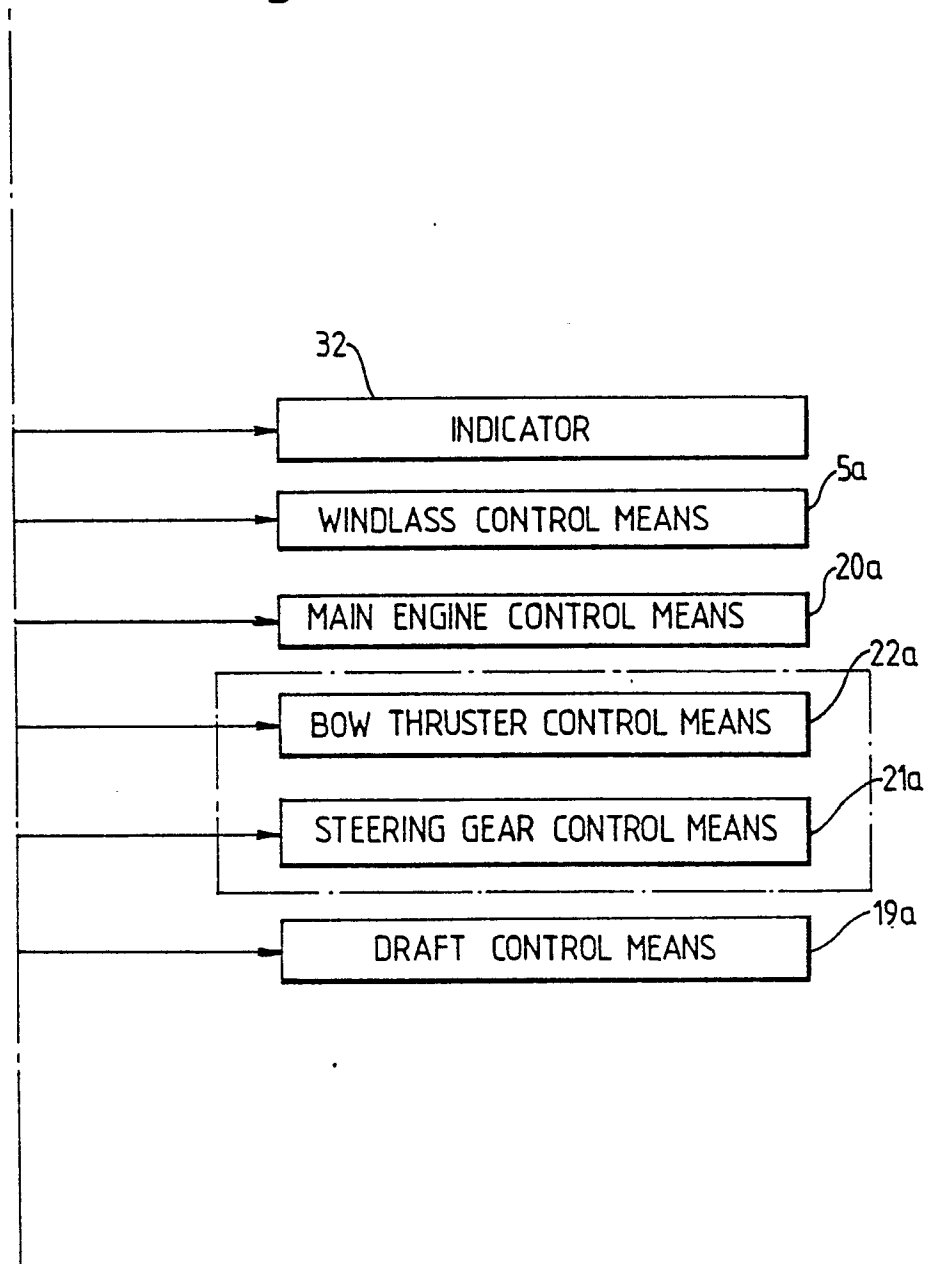


Fig.3.

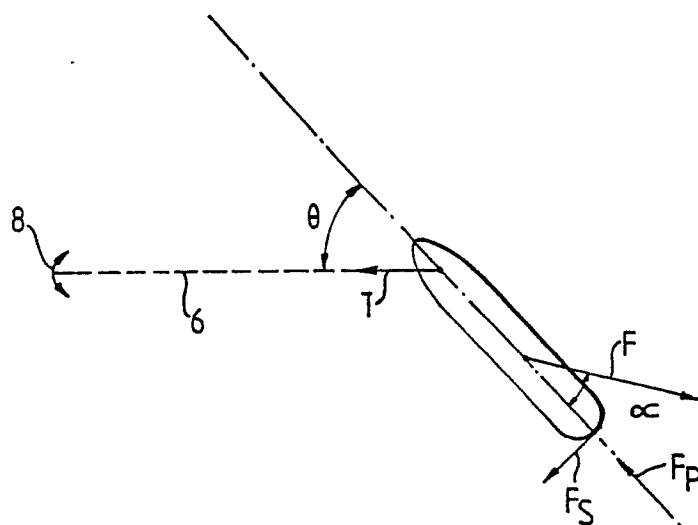
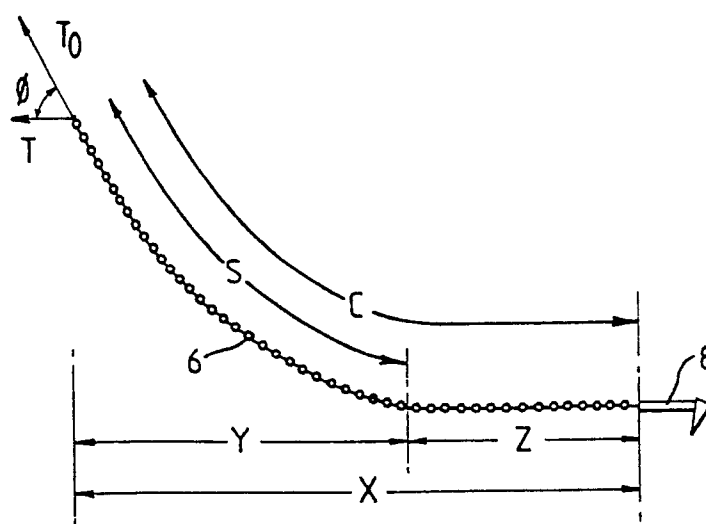


Fig.4.



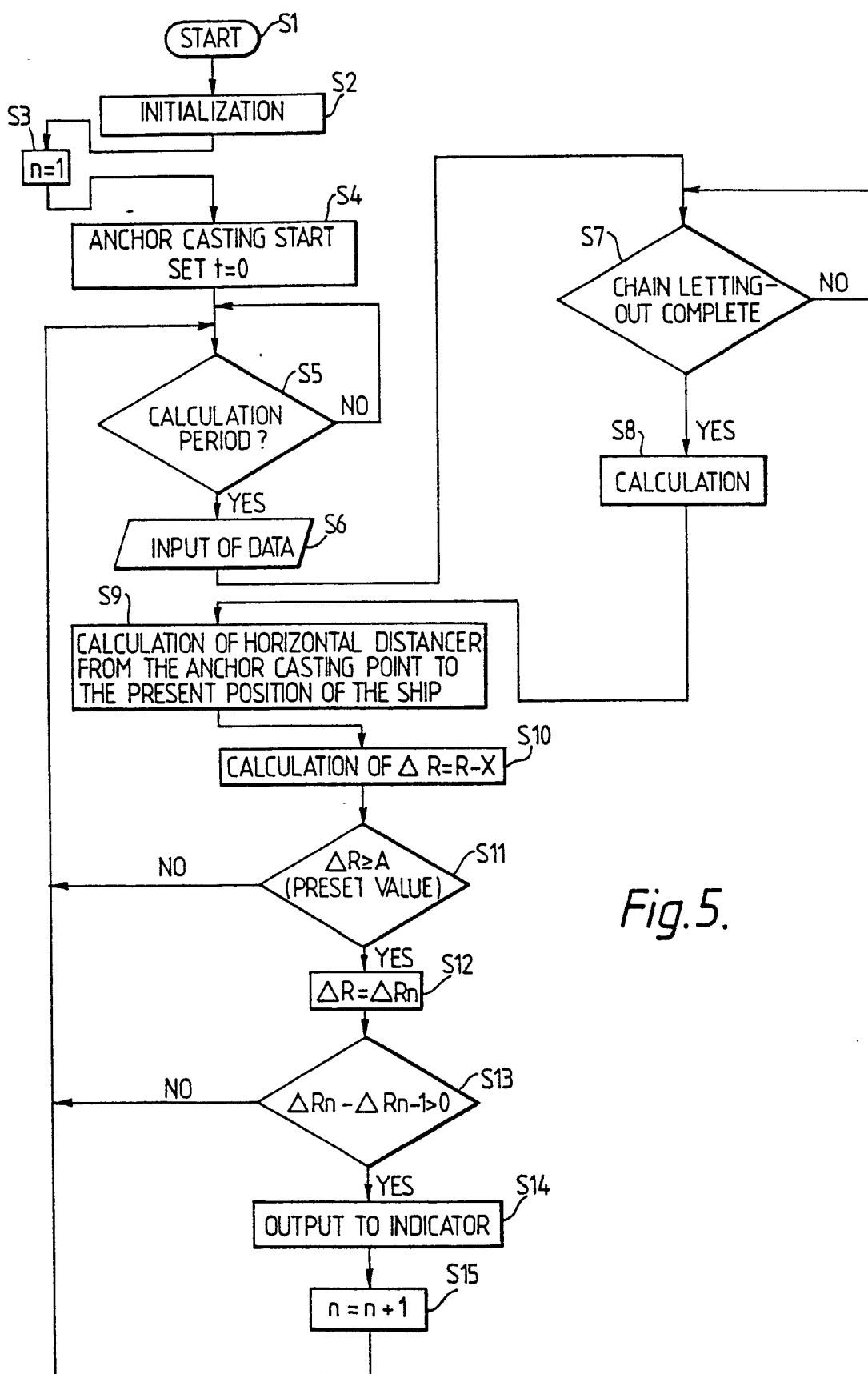


Fig.5.

Fig.6.

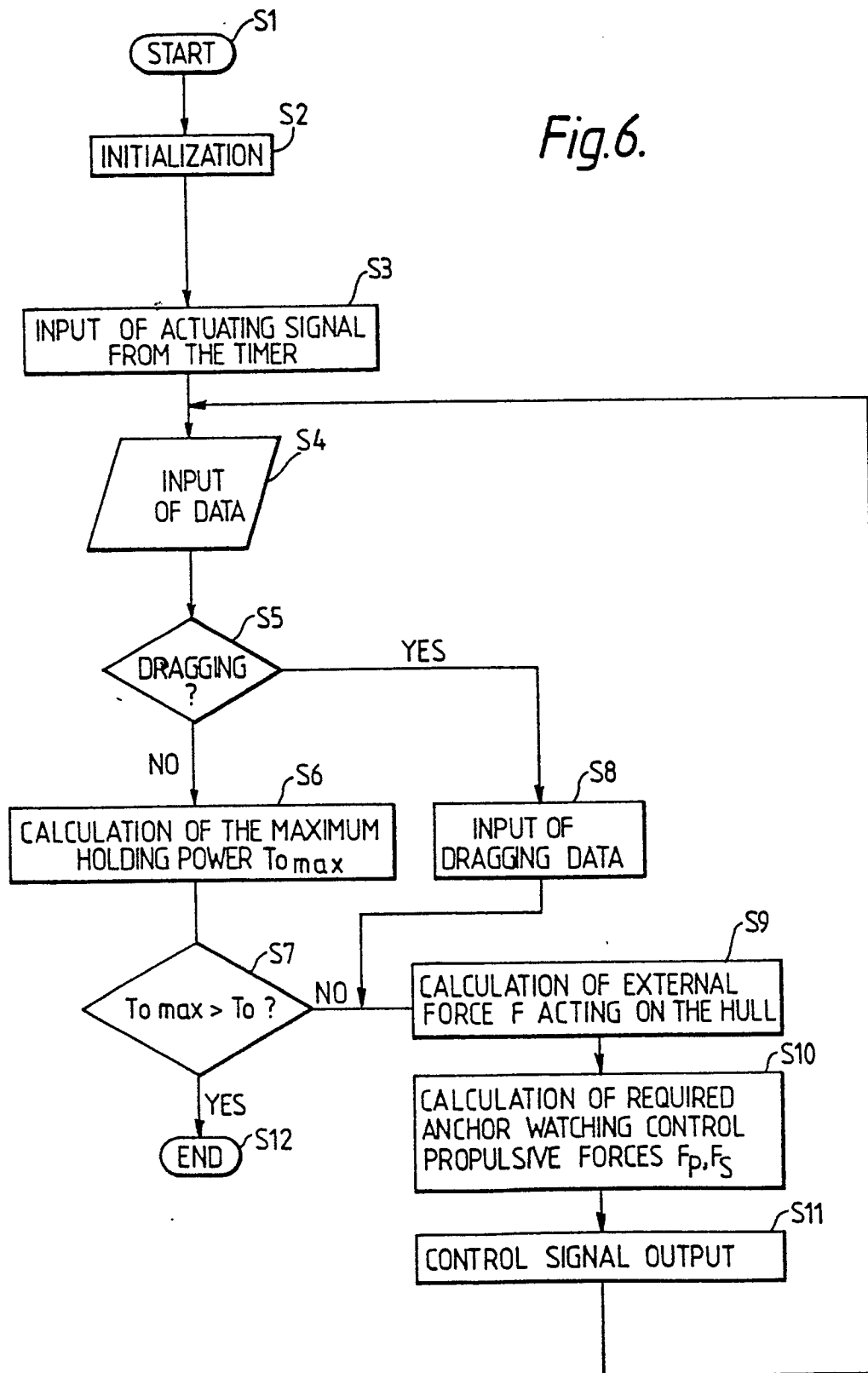


Fig.7.

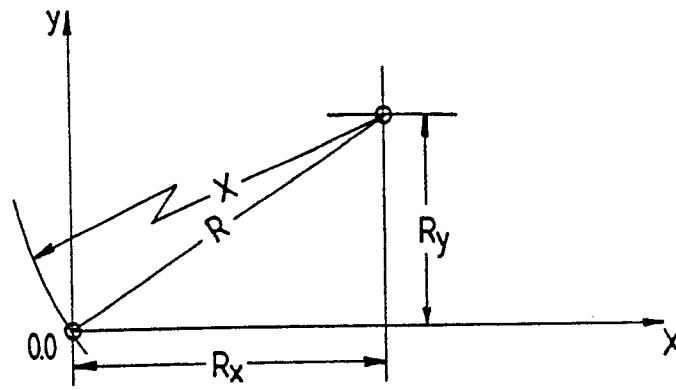


Fig.8.

