

DESCRIPTION

NAVIGATION METHOD FOR MARINE VESSEL, NAVIGATION SYSTEM,
AND MARINE VESSEL

Technical Field

[0001]

The present invention relates to a method of stowing a ship with cargo and navigating the ship, a system capable of carrying out the method, and a ship to which the system is applied.

Background Art

[0002]

Generally, a ship for carrying cargos such as a container ship is designed to be capable of securing strength enough to withstand long-term operation while carrying as many cargos as possible. Specifically, for example, it is assumed that a ship will have been operated for 25 years under the North Atlantic wave environment, and the maximum load moment (design wave moment M_w (d)) that may be generated in the hull due to the wave conditions during that period is estimated. The maximum loading capacity of cargos is determined according to the difference in the design allowable load moment of the ship. In other words, the design tolerance (represented by M_a) of the load moment of the ship is

expressed by the following expression (1). Here, $M_s(d)$ represents a load moment (defined as a design still water moment) which is generated due to the dead weight of the ship, the weight of cargos, and the buoyancy in still water when cargos of an assumed maximum loading capacity are loaded.

$$M_a = M_w(d) + M_s(d) \dots\dots (1)$$

[0003]

In addition, under the operation of a ship, it is required that the sum of the real load moment caused by wave conditions in navigation and the real load moment caused by the dead weight of the ship, the weight of cargos and buoyancy does not exceed the tolerance of the hull. At that time, the load moment (defined as the real wave moment $M_w(r)$) which is generated due to the wave condition is conveniently estimated as $M_w(d)$, and then the amount of the cargos is determined. In other words, the amount of cargo to load in the ship is determined in a range satisfying the following expression (2) so that the total value of the load moment generated in still water when the cargos are loaded (defined as the real still water moment $M_s(r)$) and the design wave moment $M_w(d)$ does not exceed the design tolerance M_a of the ship.

$$M_s(r) \leq M_a - M_w(d) \dots\dots (2)$$

[0004]

For example, techniques described in the following Patent Literatures 1 and 2 have been proposed as a

technique for satisfying these conditions and supporting the safe operation of ships. These are techniques to be implemented from the viewpoint of ensuring safety in the operation of ships, and it can be said that Patent Literature 1 describes a technique for performing stowage of cargo while satisfying the above expression (2), and Patent Literature 2 describes a technique for performing marine navigation so that the real wave moment $M_w(r)$ does not actually exceed $M_w(d)$.

Citation List

Patent Literature

[0005]

Patent Literature 1: WO2006/003708A1

Patent Literature 2: JP 2019-12029A

Summary of Invention

Technical Problem

[0006]

Of course, ensuring the safety is the most important matter for ships carrying cargos, but it is also likewise important to increase the load capacity of cargos as much as possible. However, with respect to conventional ships, the increase of the load capacity is mainly considered at the time of design as well as ensuring the safety, but only the safety is almost focused in the operation phase. Therefore, under the actual circumstances, the navigation

is carried out while a margin is left for the load capacity. In other words, even when it is sufficiently possible to load more cargos with ensuring safety in view of design, the amount of cargo that can be loaded is underestimated because the importance is focused too much on safety, which has caused an obstacle to enhancement of transportation efficiency.

[0007]

In the present disclosure, in view of such circumstances, a ship navigation method, a navigation system, and a ship that are capable of easily enhancing the transportation efficiency of cargos while ensuring safety will be described.

Solution to Problem

[0008]

The present disclosure relates to a ship navigation method that estimates a real wave moment generated on a ship due to sea state on a voyage route based on sea state predicted on the voyage route, plans stowage of cargo based on a predicted value of the real wave moment, and navigates the ship while preventing a moment generated on the ship from exceeding a design tolerance.

[0009]

In the ship navigation method of the present disclosure, the difference between the predicted wave moment and a design wave moment is calculated as a

stowage margin, and it can be determined based on the stowage margin whether the stowage is modified or not.

[0010]

In the ship navigation method of the present disclosure, the moment generated on the ship is measured, and the ship can be navigated while preventing a value of a moment obtained based on a measured value of the moment generated on the ship from exceeding a threshold.

[0011]

In the ship navigation method of the present disclosure, the predicted wave moment for a sea route candidate is calculated, and the ship can be navigated while preventing the predicted wave moment from exceeding a threshold.

[0012]

In the ship navigation method of the present disclosure, an alarm can be issued to a crew member if a value of a moment obtained based on a measured value of the moment generated on the ship, or a predicted value of the moment generated on the ship exceeds a threshold.

[0013]

In the ship navigation method of the present disclosure, a measure to reduce a moment can be presented if a value of a moment obtained based on a measured value of the moment generated on the ship, or a predicted value of the moment generated on the ship exceeds a threshold.

[0014]

In the ship navigation method of the present disclosure, the measure to reduce the moment comprises presenting instructions for handling the ship can be presented.

[0015]

In the ship navigation method of the present disclosure, the measure to reduce the moment comprises presenting a sea route in which a value of the predicted wave moment is smaller than a threshold can be presented.

[0016]

Further, the present disclosure relates to a ship navigation system configured to be capable of executing the above-mentioned ship navigation method.

[0017]

Further, the present disclosure relates to a ship to which the above-mentioned ship navigation system is applied.

Effect of Invention

[0018]

According to the ship navigation method, the navigation system, and the ship of the present disclosure, it is possible to achieve an excellent effect that the transportation efficiency of cargos can be easily improved while ensuring safety.

Brief Description of Drawings

[0019]

FIG. 1 is a block diagram showing an example of a configuration of a ship navigation system according to an embodiment of the present invention;

FIG. 2 is a schematic side view showing an example of a sensor arrangement on a ship;

FIG. 3 is a schematic plan view showing an example of a sensor arrangement;

FIG. 4 is a graph showing an example of distributions of moments on the ship;

FIG. 5 is a flowchart showing an example of a process of making a stowage plan;

FIG. 6 is a flowchart showing an example of a process of navigating the ship;

FIG. 7 is a graph for showing the relationship between moments generated on the ship and measured moments; and

FIG. 8 is a diagram schematically showing an example of a guiding screen displayed on a display unit in the ship.

Description of Embodiment

[0020]

An embodiment of the present invention will be described below with reference to the accompanying drawings.

[0021]

FIG. 1 shows a configuration of a ship navigation system according to an example of the present disclosure. In the case of the present example, a system is configured in the form of straddling across a ship S and a land L, and transmits a stowage plan formed on the land L side to the ship S side while performing stowage of cargo based on this stowage plan in the ship S side and transmitting a stowage result to the land L side as needed.

[0022]

The land L side is provided with a voyage route selection unit 1, a wave data storage unit 2, a stowage planning unit 3, a stowage data storage unit 4, a wave moment calculation unit 5, a still water moment calculation unit 6, a stowage margin determination unit 7, a display unit 8, an operation input unit 9, and a communication unit 10. The ship S side is provided with a voyage route selection unit 11, a wave data storage unit 12, a stowage data storage unit 13, a wave moment calculation unit 14, a moment measurement unit 15, a measurement data storage unit 16, a moment margin calculation unit 17, a determination unit 18, a display unit 19, an alarming unit 20, an operation input unit 21 and a communication unit 22.

[0023]

The voyage route selection unit 1 on the land L side has a function of assisting the selection of a voyage

route of the ship S. The voyage route selection unit 1 is connected to an information service such as Sea-Navi (R), and based on conditions such as a departure point, a destination, a transit point, a water area, and the date and time, the voyage route selection unit 1 can extract candidates of the voyage route meeting the respective conditions, and present the candidates. The voyage route selection unit 1 may be configured to extract an appropriate voyage route from a library stored therein instead of using an external service such as Sea-Navi.

[0024]

The wave data storage unit 2 has a function of storing wave data related to various voyage routes, and can acquire wave data relating to a voyage route presented by the voyage route selection unit 1 as needed. The wave data stored in the wave data storage unit 2 may include forecast data acquired from an external organization such as the Meteorological Agency, may include past wave data, or may include both the data.

[0025]

The stowage planning unit 3 has a function of forming a stowage plan for cargos in the ship S, and can calculate the total weight of cargos to load in scheduled navigation, the amount of stowage of cargo in each internal compartment of the ship, and the like for the ship S based on each of conditions such as the type of

the ship S, the maximum loading capacity of the ship S, the design strength, and the types and amounts of cargos.

[0026]

The stowage data storage unit 4 has a function of storing data relating to the stowage plan for the cargos in the ship S (hereinafter, referred to as stowage data) formed by the stowage planning unit 3. The stowage data includes, for example, the total weight of the cargos in the planned navigation, the stowage amount in each internal compartment of the ship, the types of cargos to be loaded, the distribution of the dead weight in the ship S, the amount of ballast water filled in each ballast tank equipped in the ship S, etc.

[0027]

The wave moment calculation unit 5 has a function of referring to the wave data stored in the wave data storage unit 2 and calculating sea state predicted to be encountered on the voyage route (encounter sea state) which are presented by the voyage route selection unit 1. Further, the wave moment calculation unit 5 has a function of calculating an predicted value (referred to as a predicted wave moment $Mw(r)_{pv}$) of a wave moment (real wave moment $Mw(r)$) generated on the ship S on the corresponding voyage route based on the calculated encounter sea state and information on the ship S itself (dead weight, ship speed, outer plate shape, etc.).

[0028]

The still water moment calculation unit 6 has a function of calculating the dead weight of the ship S in still water, the weight of the cargos and the ballast water, and a real still water moment $M_s(r)$ generated on the ship S due to buoyancy based on the stowage data stored in the stowage data storage unit 4.

[0029]

The stowage margin determination unit 7 has a function of calculating a margin for stowage of cargo that can be additionally performed (referred to as a stowage margin ΔM) based on the predicted wave moment $M_w(r)_{pv}$ calculated by the wave moment calculation unit 5 and the real still water moment $M_s(r)$ calculated by the still water moment calculation unit 6. The calculation of the predicted wave moment $M_w(r)_{pv}$, the calculation of the real still water moment $M_s(r)$, and the calculation of the stowage margin ΔM will be described later.

[0030]

The display unit 8 is a display for displaying, as needed, information on a voyage route presented by the voyage route selection unit 1, the wave data stored in the wave data storage unit 2, the stowage data which is created by the stowage planning unit 3 and stored in the stowage data storage unit 4, information such as calculation results, etc. of wave moment calculation unit 5, the still water moment calculation unit 6, and the stowage margin determination unit 7, an interface screen

for inputting an operation to each unit, and other information.

[0031]

The operation input unit 9 is an interface for inputting an operation to each of the above-mentioned units, and includes, for example, a keyboard, a mouse, a touch panel type display, or the like. When the operation input unit 9 is a touch panel type display, the operation input unit 9 can also serve as some or all of the functions of the display unit 8.

[0032]

The communication unit 10 has a function of communicating with the outside of the system, and can communicate various information (for example, voyage route data, wave data, stowage data, etc.).

[0033]

The voyage route selection unit 11, the wave data storage unit 12, the stowage data storage unit 13, and the wave moment calculation unit 14 in the ship S have functions substantially similar to the functions of the voyage route selection unit 1, the wave data storage unit 2, the stowage data storage unit 4, and the wave moment calculation unit 5, respectively, on the land L. That is, the voyage route selection unit 11 has the function of assisting in selecting the voyage route of the ship S. The wave data storage unit 12 has the function of storing wave data associated with various voyage routes. The

stowage data storage unit 13 has the function of storing the stowage data generated by the stowage planning unit 3 on the land L. It is to be noted that the stowage data stored in the stowage data storage unit 13 includes the real still water moment $M_s(r)$ calculated by the still water moment calculation unit 6 on the land L. The wave moment calculation unit 14 has the function of referring to the wave data stored in the wave data storage unit 12 to compute sea state expected to be encountered in voyage routes presented by the voyage route selection unit 11 (encountered sea state).

[0034]

The moment measurement unit 15, which may be a strain sensor for example, has the function of measuring moments actually generated on the ship S. If the moment measurement unit 15 provided on the ship S is a strain sensor, the moment measurement unit 15 is placed at each of multiple positions along the length of the hull, as shown in Figs. 2 and 3. Each moment measurement unit 15 measures a strain generated on the ship S, thereby obtaining a moment generated on the ship S. In the figures, three transverse locations along the length of the hull each have four strain gauges (moment measurement units 15) at upper and lower positions on the right and left sides of the hull. It is to be noted that the configuration, number, and positions of the strain gauges or the moment measurement units 15 are not limited to the

example shown here but may be appropriately modified according to conditions such as the structure of the ship S.

[0035]

The measurement data storage unit 16 has the function of storing, as measurement data, measured values of the moment at each of different positions on the ship S measured by the moment measurement unit 15.

[0036]

The moment margin calculation unit 17 has the function of calculating the width of a margin (hereinafter called a moment margin M_m) left for a current value or a predicted value of the moment generated on the ship S against a designed value. Specifically, the moment margin calculation unit 17 has the function of referring to values such as a measured value of the moment (hereinafter called a measured moment $M(r)_{mv}$) stored as the measurement data in the measurement data storage unit 16, the value of the real still water moment $M_s(r)$ stored in the stowage data storage unit 13, and the predicted wave moment $M_w(r)_{pv}$ calculated by the wave moment calculation unit 14. The moment margin calculation unit 17 calculates the moment margin M_m by comparing the value of the moment measured on the ship S (the measured moment $M(r)_{mv}$) or the value of the moment predicted to be generated on the ship S with a design wave moment $M_w(d)$, a design still water moment $M_s(d)$, or

a design tolerance Ma at each of different positions on the ship S . The moment margin Mm may be expressed by Equations (3) and (4) below, for example. Mm_{mv} denotes a moment margin based on the measured value of the moment generated on the ship S , and Mm_{pv} denotes a moment margin based on the predicted value of the moment generated on the ship S .

$$Mm_{mv} = Ma - (Ms(r) + M(r)_{mv}) \quad (3)$$

$$Mm_{pv} = Ma - (Ms(r) + Mw(r)_{pv}) \quad (4)$$

[0037]

The above equations are merely exemplary. Equation (3), for example, may also take a form below, depending on what the measured moment $M(r)_{mv}$ represents (the measured moment $M(r)_{mv}$ will be described in detail below).

$$Mm_{mv} = Ma - M(r)_{mv} \quad (3)$$

[0038]

The determination unit 18 has the function of determining whether to issue an alarm and display an appropriate guiding screen, based on the value of the moment margin Mm calculated by the moment margin calculation unit 17.

[0039]

The display unit 19 is a display for displaying, as needed, information on a voyage route presented by the voyage route selection unit 11, the wave data, the stowage data, various data such as calculation results of various moments, an interface screen for inputting an

operation to each unit of the system, and other information.

[0040]

The alarming unit 20 has the function of issuing an alarm as necessary to people engaged in the navigation of the ship S, based on the determination by the determination unit 18. A designer may select an appropriate form of alarm, such as an audible alarm or a visual alarm, and determine the configuration of the alarming unit 20 accordingly. It is to be noted that the display unit 19 may implement the functions of the alarming unit 20.

[0041]

The operation input unit 21 is an interface for inputting an operation to each of the above-mentioned units, and includes, for example, a keyboard, a mouse, a touch panel type display, or the like. When the operation input unit 21 is a touch panel type display, the operation input unit 21 can also serve as some or all of the functions of the display unit 19.

[0042]

The communication unit 22 has the function of communicating with the outside of the system. The communication unit 22 enables various information items (e.g., voyage route data, wave data, and stowage data) to be exchanged with entities such as the communication unit 10 on the land L.

[0043]

The case where the system is configured to straddle the ship S side and the land L side and where the stowage plan is mainly formed on the land L side and the navigation plan based on the stowage is formed on the ship S side has been shown above. However, the system configuration is not limited to the example described above when the ship navigation system of the present invention is implemented. For example, in recent years when information processing and communication technology has been developed, most of the system can be constructed on the ship S, or each of the land L side and the ship S side can be provided with the same function regarding the stowage planning. In addition, the ship stowage planning system may have an appropriate configuration as long as it can implement the functions described below.

[0044]

The method for planning stowage of cargo by using the above system will be described. A subject matter of the present invention is to estimate the wave moment (real wave moment $M_w(r)$) generated during the navigation of the ship S and plan the stowage of cargo based on this estimation. In other words, in the conventional case, the stowage of cargo is performed with the difference between the design tolerance M_a and the design wave moment $M_w(d)$ set as the maximum loading capacity (see the above expression (2)). However, by using the predicted

value (predicted wave moment $Mw(r)_{pv}$) of the real wave moment $Mw(r)$ instead of the design wave moment $Mw(d)$, the design strength of the ship has a margin by the amount corresponding to the difference (stowage margin ΔM) between the design wave moment $Mw(d)$ and the predicted wave moment $Mw(r)_{pv}$, and this amount will be used for the stowage planning.

[0045]

As described above, the design wave moment $Mw(d)$ is set as a maximum wave moment which is expected to be generated on the ship S , for example, during a long-term operation period of the ship S . This value is a maximum value of the wave moment peculiar to each ship S , and the wave moment (real wave moment $Mw(r)$) which actually generated on the ship S in many actual navigations varies from navigation to navigation in a range which is equal to or less than the design wave moment $Mw(d)$. In other words, there is no safety problem even if the difference (stowage margin ΔM) is actively used in stowage planning, for example, a large amount of cargo is loaded by the amount corresponding to the stowage margin ΔM , and it is possible to enhance the transportation efficiency of cargos while maintaining safety.

[0046]

For example, it is assumed that the total value of the design wave moment $Mw(d)$ and the design still water moment $Ms(d)$ is distributed in the ship S as indicated by

a broken line in FIG. 4. Here, when the stowage of cargo is performed until the design still water moment $M_s(d)$ becomes maximum (so as to satisfy $M_s(r)=M_s(d)$) according to the conventional method, the total value of the real wave moment $M_w(r)$ and the real still water moment $M_s(r)$ is distributed to be lower than the total value of the design wave moment $M_w(d)$ and the design still water moment $M_s(d)$ as indicated by one-dotted line. In the present example, the difference between both the moments (the value corresponding to $M_w(d)-M_w(r)$) is calculated as the stowage margin ΔM and practically used.

[0047]

During the navigation of the ship S , at least part of the moment actually generated on the ship S is measured as the measured moment $M(r)_{mv}$. Voyage route selection and ship handling are performed appropriately so that a moment obtained based on the measured moment $M(r)_{mv}$ (the value of the moment obtained at each measurement point is indicated as a point in FIG. 4) does not exceed the design tolerance M_a (the sum of the design wave moment $M_w(d)$ and the design still water moment $M_s(d)$). In other words, the ship is navigated in such a manner that the predicted value (M_{mpv}) and the actually measured value ($M_{m_{mv}}$) of the moment margin in above Equations (3) and (4) do not fall below zero.

[0048]

To achieve such stowage and navigation, first, the predicted wave moment $Mw(r)_{pv}$ and the real still water moment $Ms(r)$ need to be calculated with sufficient accuracy. The process of calculating the values of these moments and making a stowage plan will be described with reference to a flowchart in FIG. 5.

[0049]

In order to estimate the real wave moment $Mw(r)$, it is necessary to select a voyage route and predict sea state encountered on the voyage route as a premise. Therefore, candidates of the voyage route are first extracted (step S1). The candidates of the voyage route are extracted by using the function of the voyage route selection unit 1, for example, by using an external service such as Sea-Navi, or from information on the voyage route stored in the voyage route selection unit 1. If conditions such as a departure point, a destination, a transit point and a water area are input, a voyage route meeting the respective conditions is extracted, and presented as a candidate.

[0050]

Subsequently, predicted sea state are acquired for the voyage route presented as the candidate (step S2). The function of the wave data storage unit 2 is used to refer to wave data in the same water area and the same season in the past. Alternatively, forecast data

provided by the Meteorological Agency or the like is referred to.

[0051]

The wave data acquired in step S2 includes the maximum wave height to be encountered by the ship S in the corresponding voyage route. The wave height most directly affects the comfort of navigation, the load generated on the ship S, and the like. Therefore, in step S3, a threshold value for the wave height (navigation avoidance limit) is set, and a voyage route which is estimated to have a wave height exceeding the navigation avoidance limit is excluded from the candidates. Then, a voyage route along which navigation is actually performed is selected from the remaining candidates, and determined (step S4).

[0052]

Further, the stowage planning unit 3 executes stowage planning for the ship S (step S5). The total load capacity of cargos, the load capacity of cargos in each compartment of the ship S, and the amount of ballast water filled in each ballast tank are determined, and stored as stowage data in the stowage data storage unit 4.

[0053]

The wave moment calculation unit 5 calculates a predicted wave moment $Mw(r)_{pv}$ based on the sea state predicted to be encountered in the selected voyage route (step S6).

[0054]

A case where a strip method is used as a method of calculating the predicted wave moment $Mw(r)_{pv}$ will be described. The load generated on the ship S can be evaluated by a vertical bending moment, and the vertical bending moment generated by waves can be expressed by the following expression (5). Here, H_s represents a wave height, χ represents a wave direction, and T_s represents a wave period.

$$Mw/H_s = R(\chi, T_s) \dots\dots (5)$$

[0055]

A sea state (H_s, T_s) is included in the wave data acquired in step S2. Therefore, these values (values estimated based on past data and forecasts) are substituted into the above expression (3) to calculate the value of Mw . Since the draft also affects the value of Mw and the draft fluctuates depending on the stowage of cargo, the stowage data is also referred to for the calculation of Mw . The maximum value of Mw thus obtained is used as the predicted value of the real wave moment $Mw(r)$, i.e., the predicted wave moment $Mw(r)_{pv}$ to be encountered during navigation. Of course, in addition to the strip method, various methods may be used for calculating the predicted wave moment $Mw(r)_{pv}$.

[0056]

On the other hand, the real still water moment $Ms(r)$ is determined by the stowage of cargo regardless of the

voyage route and the sea state. The still water moment calculation unit 6 refers to the stowage data of the stowage data storage unit 4 to calculate the real still water moment $M_s(r)$ (step S7).

[0057]

The stowage margin determination unit 7 calculates the difference between the predicted wave moment $M_w(r)_{pv}$ calculated in step S6 and the design wave moment $M_w(d)$ as the stowage margin ΔM (step S8). The stowage margin ΔM corresponds to an amount that may be further increased in stowage of cargo for the ship S in consideration of the design tolerance M_a of the load moment of the ship S and the condition of the voyage route.

[0058]

Here, stowage margins ΔM may be calculated for further voyage routes, and a voyage route may be selected by referring to these stowage margins. For example, this approach is effective if the stowage margin ΔM calculated at step S8 is not sufficiently wide and therefore considering another voyage route is desired, or if comparison among stowage margins ΔM of multiple voyage routes is desired. Because the voyage route selection at preceding step S4 did not take the stowage margin ΔM into account, the voyage route selection may be reviewed here after calculating the stowage margin ΔM .

[0059]

Once the stowage margin ΔM is calculated at step S8, the process proceeds to step S8a, where it is determined whether to consider another voyage route. If another voyage route is to be considered, the process returns to step S4, where a new voyage route different from the previous voyage route is selected from the candidates presented. Steps S6 to S8 are repeated for the selected new voyage route to calculate the stowage margin ΔM . It is to be noted that, if the stowage has not been modified, the real still water moment $M_s(r)$ remain unchanged. Therefore, in repeating the cycle from step S6 to step S8, step S7 for the second and following times does not need be performed but may simply use the value of the real still water moment $M_s(r)$ initially calculated at step S7.

[0060]

The stowage margin ΔM is thus calculated for each of one or more voyage routes. At any time point at which it is determined that no more voyage routes are to be considered, the process proceeds to step S8b, where the voyage route is determined from the candidate voyage routes by referring to the values of their stowage margins ΔM . For the voyage route determined, step S9 is performed. At step S9, it is determined whether to modify the stowage plan made at step S5, according to the magnitude of the stowage margin ΔM of the voyage route determined, the amount of cargo to be loaded, and other factors. If the stowage is not to be modified, the

stowage terminates. If the stowage is to be modified, the process proceeds to step S10. At step S10, the stowage planning unit 3 modifies the stowage plan, which is then stored as new stowage data in the stowage data storage unit 4.

[0061]

When the stowage of cargo is modified, the predicted wave moment $Mw(r)_{pv}$ generated on the ship S changes. Further, as a result of the change of the draft of the ship S, the real wave moment $Mw(r)$ may also change. Therefore, after the stowage plan is modified, the predicted wave moment $Mw(r)_{pv}$ and the real still water moment $Ms(r)$ are calculated again (steps S6 and S7) to calculate the stowage margin ΔM (step S8), and the stowage plan is modified according to the value of the stowage margin ΔM (steps S9 and S10). In this way, it is possible to easily perform modification of the stowage plan such as increase in amount of cargo to load, based on the value of the stowage margin ΔM . Further, by repeating this operation, the stowage plan is optimized so that the real still water moment $Ms(r)$ is maximized within a range satisfying the design tolerance Ma of the ship S.

[0062]

Voyage route information and necessary information such as wave data and stowage data are stored in each unit on the ship S side. The stowage data changed based

on the stowage margin ΔM is also transmitted to the ship S side via the communication units 10 and 22, and stored in each unit. Stowage of cargo is performed according to the new stowage data on the ship S side.

[0063]

Such a method can be carried out in various ships S in the form of simply increasing the amount of cargo to load within the range of the calculated stowage margin ΔM (increasing the real still water moment $M_s(r)$ by the weight of the cargo). However, an operation based on a slightly different method is effective especially when targeting container ships.

[0064]

Generally, in the case of ships, ballast water may be poured into the hull for the purpose of maintaining draft or correcting the load moment generated on the hull, but especially in container ships, a large amount of ballast water is frequently poured into the hull because the specific weight of the cargo is light. Therefore, when the ship S is a container ship and a large amount of ballast water is poured in a first stowage plan, the foregoing stowage planning method can be applied, for example, by the following procedure.

[0065]

First, the procedure of steps S1 to S8 shown in FIG. 3 is executed, and the amount of cargo to load is increased within the range of the calculated stowage

margin ΔM (steps S9 and S10). At this time, with respect to a compartment in which the amount of cargo to load is increased, the ballast water whose amount is equal to the increased amount of cargo is discharged. This causes the value of the real still water moment $M_s(r)$ to be hardly changed from that before the modification of the stowage plan, and causes the stowage margin ΔM to remain, so that it is possible to further modify the stowage plan and increase the amount of cargo to load.

[0066]

If it is assumed that the value of the real still water moment $M_s(r)$ does not change when the ballast water whose amount corresponds to the increased amount of cargo to load is reduced, it is theoretically possible to increase the amount of cargo to load without considering the stowage margin ΔM as in the present example. However, when the stowage of cargo is actually performed, the position of the ballast tank in the hull is different from the position where cargos are placed, so that even if the ballast water in a ballast tank located as close as possible to a compartment where the amount of cargo to load is increased is reduced, the value of the real still water moment $M_s(r)$ changes to some extent. For this reason, when an attempt is made to increase the amount of cargo to load without keeping the calculated stowage margin ΔM in mind, there is no standard for determining an allowable increase in the amount of cargo to load, so

that even if the ballast water is reduced, the possibility that the load capacity exceeds the tolerance as a result cannot be ruled out. If the stowage margin ΔM is used as in the present example, it is possible to safely increase the amount of cargo to load within a range that does not hinder.

[0067]

The stowage margin ΔM can be utilized in the form of using the stowage margin ΔM to reduce ballast water. In a container ship, ballast water may be poured for the purpose of correcting the load moment generated on the hull as described above, and in this case, the load of the ballast water acts in the direction of reducing the real still water moment $M_s(r)$. In other words, if the amount of the ballast water filled is reduced, the real still water moment $M_s(r)$ is increased, but the stowage margin ΔM calculated by the foregoing method is used for the increase of the real still water moment $M_s(r)$ to be caused by the reduction of the ballast water. In other words, the ballast water in the ship S may be discharged within the range of the stowage margin ΔM .

[0068]

Although the ballast water remains in the tank, such an operation is effective to such a case that it is impossible to load more containers due to restriction on cargo space or the like, or such a case that there is simply no more cargo to load. This operation makes it

possible to navigate a ship S which is a container ship in a state where the amount of ballast water is small, and it is possible to perform navigation having excellent fuel consumption with the reduced weight of the entire ship S. Of course, the above-mentioned "reduction of ballast water by the increased amount of cargo to load" and "reduction of ballast water within the range of the stowage margin ΔM " may be used in combination as appropriate. Alternatively, it goes without saying that only the amount of cargo to load is merely increased within the range of the stowage margin ΔM without reducing the ballast water.

[0069]

The stowage margin ΔM as described above can be utilized not only for stowage before navigation but also during navigation. That is, charging or discharging ballast water during navigation may be regarded as a kind of modification of stowage and therefore affects the moment generated on the hull. When charging or discharging ballast water is necessary during navigation, the ballast water can be advantageously charged or discharged within the stowage margin ΔM .

[0070]

Now, the process of navigating the ship S stowed according to the above process will be described with reference to a flowchart in FIG. 6.

[0071]

During the navigation of the ship S, the moment measurement unit 15 continually measures the moment generated at each of different positions on the ship S (step S11). The values obtained by the moment measurement unit 15 are stored as measurement data in the measurement data storage unit 16.

[0072]

The measured moment $M(r)_{mv}$ obtained by the moment measurement unit 15 will be described here.

[0073]

FIG. 7 illustrates an example of variations in the moment actually generated on the ship S. It is assumed here that the ship S with no cargo is stowed from time t_0 to time t_2 , and then starts being navigated at time t_3 .

[0074]

Moments generated on the ship S may be evaluated as vertical bending moments, such that moments due to sagging are negative, and moments due to hogging are positive. Generally, moments due to buoyancy tend to be positive; and moments due to the weight of cargo tend to be negative for cargo loaded at or near the center of the length of the hull, and tend to be positive for cargo loaded at or near either of both ends of the hull. With no cargo (time t_0), a positive moment is generated on the ship S due to buoyancy. Thereafter, as the ship S is stowed until time t_2 , the weight of cargo loaded into the ship S generates a negative moment as a whole. This

cancels the positive moment and further adds negative moments. The moment generated on the ship S at time t_2 is a still water moment observed on completion of the stowage. If the ship S is stowed according to the stowage plan, the moment generated on the ship S at this time point theoretically matches the real still water moment $M_s(r)$ ultimately calculated at step S7 in the process shown in FIG. 5. It is to be noted that the above-described moment variations with stowage is merely exemplary, and the moment does not necessarily vary as described above. For example, the total moment due to cargo may take a positive value, depending on the positions and amount of cargo.

[0075]

After the ship S starts being navigated (after time t_3), the real wave moment $M_w(r)$ is generated on the ship S. The real wave moment $M_w(r)$ continually changes during the navigation. Letting the base value be the value of the moment between time t_2 and time t_3 ($M_s(r)$), the real wave moment $M_w(r)$ is expressed as the difference with reference to the base line. If the real wave moment $M_w(r)$ is regarded as a vertical bending moment, the real wave moment $M_w(r)$ takes positive values when the ship is hogging, and takes negative values when the ship is sagging.

[0076]

During the navigation, the moment measurement unit 15 embodied as a strain gauge detects a measured value of the moment as the measured moment $M(r)_{mv}$, which depends on which time point is used as the reference in the above description. If the measured value is set to zero at the time point at which the moment due to cargo exactly cancels the moment due to buoyancy during the stowage (time t_1), the measured value (the measured moment $M(r)_{mv}$) obtained during the subsequent navigation (after time t_3) will be the sum of the real still water moment $M_s(r)$ and the real wave moment $M_w(r)$.

[0077]

In reality, however, it is difficult to identify time t_1 . Therefore, in practice, the measured value obtained by the moment measurement unit 15 is set to zero at some other time point. For example, the measured value may be set to zero during the cargo loading at a time point between time t_1 and time t_2 (shown as time t_a in FIG. 7). Then, the measured value obtained after time t_3 will be the sum of part of the real still water moment $M_s(r)$ (the value shown as M_{s2}) and the real wave moment $M_w(r)$. As another example, the measured value may be set to zero at a time point between time t_2 and time t_3 (shown as time t_b in FIG. 7). Then, the measured value obtained after time t_3 will consist of only the real wave moment $M_w(r)$.

[0078]

In either case, the moment being generated on the ship S can be known by obtaining the real wave moment $M_w(r)$ from the value of the measured moment $M(r)_{mv}$. That is, by recording the measured value at any time point between time t_2 and time t_3 as the base value, the real wave moment $M_w(r)$ being actually generated can be obtained as the difference between the base value and the value of the measured moment $M(r)_{mv}$ detected after time t_3 . For the real still water moment $M_s(r)$, the value ultimately calculated at step S7 in the process shown in FIG. 5 may be used. Thus, the moment being generated on the ship S can be obtained without relying on when the measured value is set to zero.

[0079]

At step S12, determination is made about the value of the moment obtained at step S11. Here, it is determined whether the value of a moment obtained based on the measured value (the measured moment $M(r)_{mv}$) measured by the moment measurement unit 15 exceeds a predetermined threshold. For example, the value of the real wave moment $M_w(r)$ is obtained based on the measured moment $M(r)_{mv}$ as described above, and the value obtained is compared with the threshold. An example of the threshold used for this determination may be the difference $(M_a - M_s(r))$ resulting from subtracting the real still water moment $M_s(r)$ from the design tolerance M_a . Alternatively, for added safety, the threshold used

may be set to an appropriate value somewhat smaller than $(Ma - Ms(r))$ so that the moment generated on the ship S does not actually exceed the design tolerance Ma .

[0080]

The values of the moments and the threshold used for the determination here are not limited to the above values but may be set as appropriate. For example, the sum of the real wave moment $Mw(r)$ obtained based on the measured moment $M(r)_{mv}$ and the real still water moment $Ms(r)$ may be compared with the design tolerance Ma or an appropriate threshold smaller than the design tolerance Ma . As another example, the determination may be based on whether the actually measured value Mm_{mv} of the moment margin Mm calculated by the moment margin calculation unit 17 according to above Equation (3) is smaller than zero (or a threshold set to an appropriate value that is somewhat greater than zero for added safety). It is to be noted that the equation for calculating Mm_{mv} may vary. For example, if the measured moment $M(r)_{mv}$ detected consists of only the real wave moment $Mw(r)$, Mm_{mv} is expressed as follows.

$$Mm_{mv} = Ma - (Ms(r) + M(r)_{mv})$$

As another example, if the measured moment $M(r)_{mv}$ detected is the sum of the real wave moment $Mw(r)$ and the real still water moment $Ms(r)$, Mm_{mv} is expressed as follows.

$$Mm_{mv} = Ma - M(r)_{mv}$$

[0081]

If the moment does not exceed the threshold, the process returns to step S11 to continue obtaining the measured moment $M(r)_{mv}$. If the value of the moment obtained based on the measured moment $M(r)_{mv}$ exceeds the threshold, the process proceeds to steps S13 and S14, where the alarming unit 20 issues an alarm or the display unit 19 guides ship handling. The details of steps S13 and S14 will be described below.

[0082]

As above, ship handling is supported based on the measured value of the moment (the measured moment $M(r)_{mv}$). Meanwhile, ship handling is also supported based on a predicted value of the moment (the predicted wave moment $Mw(r)_{pv}$, or the sum of the predicted wave moment $Mw(r)_{pv}$ and the real still water moment $Ms(r)$). The wave moment calculation unit 14 in the ship S refers to the voyage route selection unit 11, the wave data storage unit 12, and the stowage data storage unit 13, thereby obtaining: voyage route candidates selectable for reaching the destination from the current location; wave data predicted for each voyage route candidate; and stowage data (including the real still water moment $Ms(r)$) (step S15). The wave moment calculation unit 14 also obtains the measured moment $M(r)_{mv}$ (step S16) obtained by the moment measurement unit 15 at step S11.

[0083]

Based on the above data items obtained, the wave moment calculation unit 14 calculates the value of the wave moment $Mw(r)$ predicted for each voyage route candidate (the predicted wave moment $Mw(r)_{pv}$) (step S17). The predicted wave moment $Mw(r)_{pv}$ may be calculated by the above-described strip method or any other appropriate method. As needed, the equation for calculating the predicted wave moment $Mw(r)_{pv}$ may be modified with respect to the measured moment $M(r)_{mv}$, which is the measured value of the moment generated on the ship S , so that the predicted wave moment $Mw(r)_{pv}$ can be calculated more accurately.

[0084]

Determination is then made about the predicted value of the moment calculated (step S18). For example, it is determined whether the sum of the predicted value of the wave moment calculated by the wave moment calculation unit 14 (the predicted wave moment $Mw(r)_{pv}$) and the real still water moment $Ms(r)$ (i.e., the value of the moment predicted to be generated on the hull) exceeds a predetermined threshold. An example of the threshold used for this determination may be the design tolerance Ma . Alternatively, the threshold used may be set to an appropriate value that is somewhat smaller than the design tolerance Ma for added safety, in order to reduce the likelihood that the sum of the moments generated on the ship S in the voyage route to be selected actually

exceeds the design tolerance Ma . As another example, this determination at step S18 may be based on whether the predicted value Mm_{pv} of the moment margin Mm calculated by the moment margin calculation unit 17 according to above Equation (4) is smaller than zero (or a threshold set to an appropriate value that is somewhat greater than zero for added safety). Alternatively, the determination may be based on whether the predicted wave moment $Mw(r)_{pv}$ exceeds the design wave moment $Mw(d)$ or $(Ma - Ms(r))$ (or a threshold set to an appropriate value smaller than these values).

[0085]

If the moment does not exceed the threshold for every voyage route to be potentially selected, the process returns to step S15 to repeat the obtainment of data items and the calculation of the predicted wave moment $Mw(r)_{pv}$. If the predicted value of the moment exceeds the threshold, the process proceeds to steps S13 and S14.

[0086]

Steps S13 and S14 are thus reached if the value of the moment obtained based on the measured moment $M(r)_{mv}$ (which may be simply the measured moment $M(r)_{mv}$, or may be the real wave moment $Mw(r)$ obtained from the measured moment $M(r)_{mv}$, or may be the sum of the real still water moment $Ms(r)$ and the real wave moment $Mw(r)$) exceeds the threshold, or if the predicted value of the moment (which

may be the predicted wave moment $Mw(r)_{pv}$, or may be the sum of the predicted wave moment $Mw(r)_{pv}$ and the real still water moment $Ms(r)$ exceeds the threshold. The alarming unit 20 then issues an alarm notifying that the threshold is exceeded (step S13). Ship handling instructions or navigation instructions for causing the moment to be smaller than or equal to the threshold are also presented (step S14). The details of the alarm or the ship handling instructions or navigation instructions to be presented may be appropriately modified according to conditions, such as which moment exceeds the threshold and the extent to which the moment exceeds the threshold.

[0087]

For example, at step S13, an alarm is issued with a buzzer or a rotating light, or by other means. The alarm may notify that the sum of the moments being generated on the ship S ($Ms(r) + Mw(r)$) is approaching the design tolerance Ma , or that the moment predicted to be generated on the ship S in any voyage route to be taken can exceed the design tolerance Ma .

[0088]

At step S14, the display unit 19 displays measures to reduce the moment being generated or predicted to be generated on the ship S, for example changing the ship speed, or reorienting the hull to align with the wave direction. The display unit 19 may also display a guiding screen as shown in FIG. 7. In the shown example,

the guiding screen indicates that the moment can hereafter approach (or exceed) the tolerance in the voyage route labeled as R1, but not unlikely in the other voyage routes R2 and R3 for the present. A crew member may refer to this guiding screen to select one of the voyage routes R2 or R3. It is to be noted that the guiding screen shown here is merely exemplary. The guiding screen displayed may be appropriately modified according to required information and other conditions. For example, the guiding screen may show the safety rating of each voyage route based on the magnitude of the predicted value Mm_{pv} of the moment margin Mm .

[0089]

Once steps S13 and S14 are completed, the process terminates or may repeat steps S11 and S15, and the following steps.

[0090]

In implementing the method and systems described above, there is no need to modify the hull or other structures, for example in order to ensure safety or increase the load capacity, and it is possible to easily apply them to existing ships and enhance the transportation efficiency of cargos.

[0091]

As described above, in the ship navigation method of the present example, the real wave moment $Mw(r)$ generated on the ship S due to sea state on a voyage route is

estimated based on sea state predicted on the voyage route, stowage planning is performed based on the predicted wave moment $Mw(r)_{pv}$, which is a predicted value of the real wave moment $Mw(r)$, and navigation of the ship S is performed while preventing a moment generated on the ship S from exceeding the design tolerance Ma . In this way, the stowage is planned without using a design wave moment $Mw(d)$ unique to the ship S but by using the real wave moment $Mw(r)$, which may be smaller than or equal to the design wave moment $Mw(d)$. Further, the ship is navigated in a manner that the measured moment $M(r)_{mv}$ does not exceed the sum of the design wave moment $Mw(d)$ and the design still water moment $Ms(d)$. The efficiency of carrying cargo can thus be improved while maintaining safety.

[0092]

In the ship navigation method of the present example, the difference between the estimated value of the real wave moment $Mw(r)$ and the design wave moment $Mw(d)$ is calculated as the stowage margin ΔM , and it is determined based on the stowage margin ΔM whether the stowage of cargo is modified or not. In this way, the stowage plan can be easily modified based on the stowage margin ΔM .

[0093]

In the ship navigation method of the present example, the moment generated on the ship S is measured, and the ship can be navigated while preventing the value of the

moment obtained based on the measured value of the moment generated on the ship (measured moment $M(r)_{mv}$) from exceeding a threshold.

[0094]

In the ship navigation method of the present example, the predicted wave moment $Mw(r)_{pv}$ for the sea route candidate is calculated, and the ship can be navigated while preventing the predicted wave moment $Mw(r)_{pv}$ from exceeding a threshold.

[0095]

In the ship navigation method of the present example, an alarm can be issued to a crew member if the value of the moment obtained based on the measured value of the moment generated on the ship S , or the predicted value of the moment generated on the ship S exceeds a threshold.

[0096]

In the ship navigation method of the present example, the measure to reduce the moment can be presented if the value of the moment obtained based on the measured value of the moment generated on the ship S , or the predicted value of the moment generated on the ship S exceeds a threshold.

[0097]

In the ship navigation method of the present example, the measure to reduce the moment comprises presenting instructions for handling the ship can be presented.

[0098]

In the ship navigation method of the present example, the measure to reduce the moment comprises presenting the sea route in which the value of the predicted wave moment is smaller than a threshold can be presented.

[0099]

Since the ship navigation system of the present example is configured to be capable of executing the above-mentioned ship stowage planning method, the same action and effect as described above can be obtained.

[0100]

Since the ship of the present example is applied with the above-mentioned ship navigation system, the same action and effect as described above can be obtained.

[0101]

Therefore, according to the above example, it is possible to easily enhance the transportation efficiency of cargos while ensuring safety.

[0102]

It should be noted that the ship navigation method, the navigation system and the ship described in the present disclosure are not limited to the above-described example, and it goes without saying that various changes can be made without departing from the scope of the present invention.

Reference Signs List

[0103]

- 1 voyage route selection unit
- 2 wave data storage unit
- 3 stowage planning unit
- 4 stowage data storage unit
- 5 wave moment calculation unit
- 6 still water moment calculation unit
- 7 stowage margin determination unit
- 8 display unit
- 9 operation input unit
- 10 communication unit
- 11 voyage route selection unit
- 12 wave data storage unit
- 13 stowage data storage unit
- 14 wave moment calculation unit
- 15 moment measurement unit
- 16 measurement data storage unit
- 17 moment margin calculation unit
- 18 determination unit
- 19 display unit
- 20 alarming unit
- 21 operation input unit
- 22 communication unit
- L land
- S ship
- Ma design tolerance
- Mw(d) design wave moment
- Mw(r) real wave moment

$M_w(r)_{pv}$ predicted wave moment

$M(r)_{mv}$ measured moment

ΔM stowage margin

CLAIMS

1. A ship navigation method, comprising:
 - estimating a real wave moment generated on a ship due to sea state on a voyage route based on sea state predicted on the voyage route;
 - planning stowage of cargo based on a predicted wave moment, the predicted wave moment being a predicted value of the real wave moment; and
 - navigating the ship while preventing a moment generated on the ship from exceeding a design tolerance.
2. The ship navigation method according to claim 1, further comprising:
 - calculating, as a stowage margin, a difference between the predicted wave moment and a design wave moment; and
 - determining whether to modify the stowage based on the stowage margin.
3. The ship navigation method according to claim 1 or 2, further comprising:
 - measuring the moment generated on the ship; and
 - navigating the ship while preventing a value of a moment obtained based on a measured value of the moment generated on the ship from exceeding a threshold.

4. The ship navigation method according to any one of claims 1 to 3, further comprising:

calculating the predicted wave moment for a voyage route candidate; and

navigating the ship while preventing the predicted wave moment from exceeding a threshold.

5. The ship navigation method according to any one of claims 1 to 4, further comprising

issuing an alarm to a crew member if a value of a moment obtained based on a measured value of the moment generated on the ship, or a predicted value of the moment generated on the ship exceeds a threshold.

6. The ship navigation method according to any one of claims 1 to 5, further comprising

presenting a measure to reduce a moment if a value of a moment obtained based on a measured value of the moment generated on the ship, or a predicted value of the moment generated on the ship exceeds a threshold.

7. The ship navigation method according to claim 6, wherein presenting the measure to reduce the moment comprises presenting instructions for handling the ship.

8. The ship navigation method according to claim 6 or 7, wherein presenting the measure to reduce the moment

comprises presenting a voyage route in which a value of the predicted wave moment is smaller than a threshold.

9. A ship navigation system configured to be capable of executing the ship navigation method according to claim 1.

10. A ship to which the ship navigation system according to claim 9 is applied.