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2,892,435

METHOD FOR CONTROLLING ROLLING MOVEMENTS OF A SHIP

Filed Feb. 17, 1954

3 Sheets-Sheet 1

Fig. 2

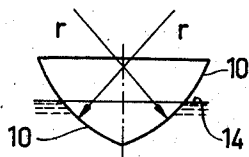


Fig. 1

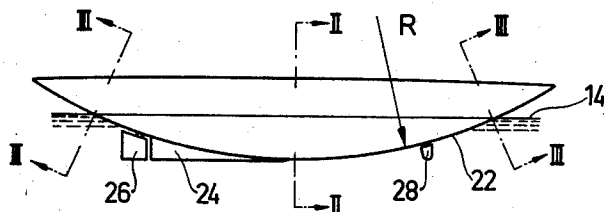


Fig. 3

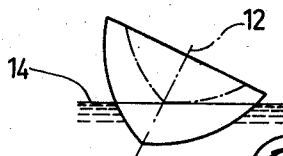


Fig. 9

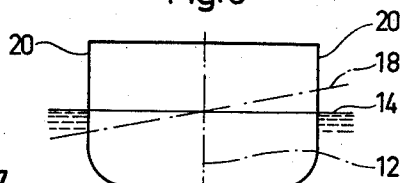


Fig. 7

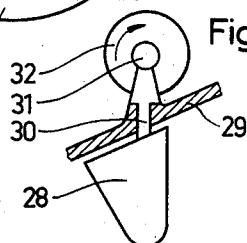


Fig. 8

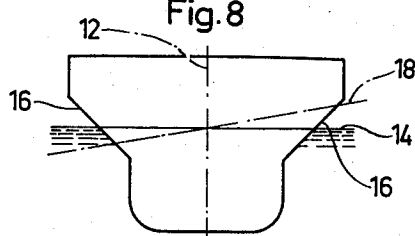


Fig. 6

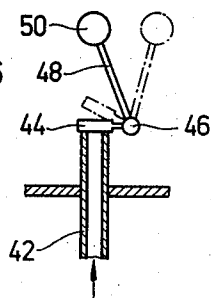


Fig. 4

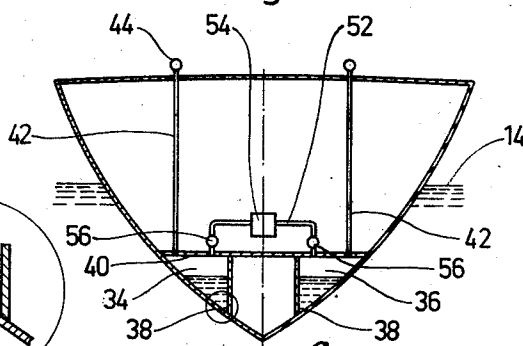
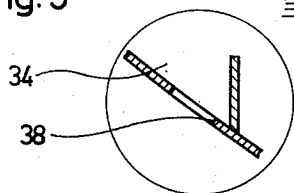


Fig. 5



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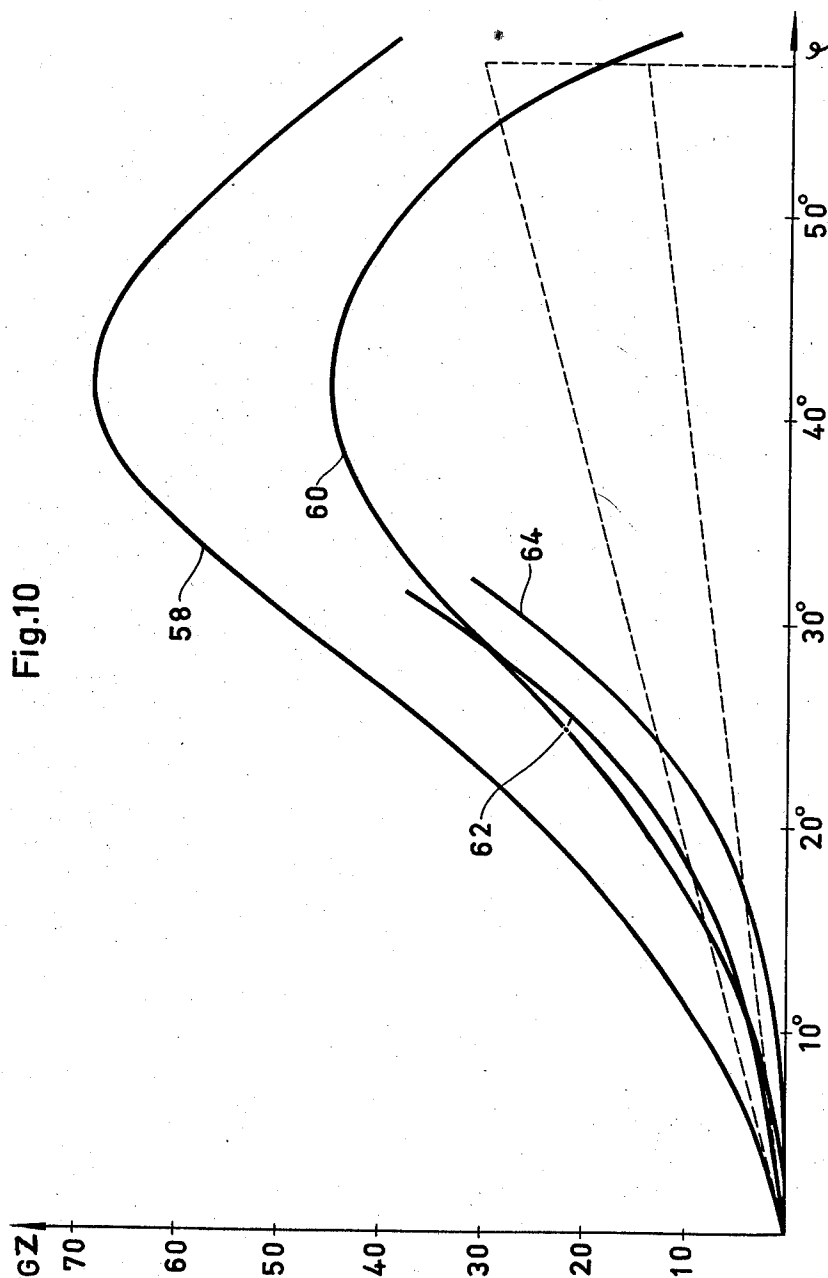
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METHOD FOR CONTROLLING ROLLING MOVEMENTS OF A SHIP

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Fig. 11

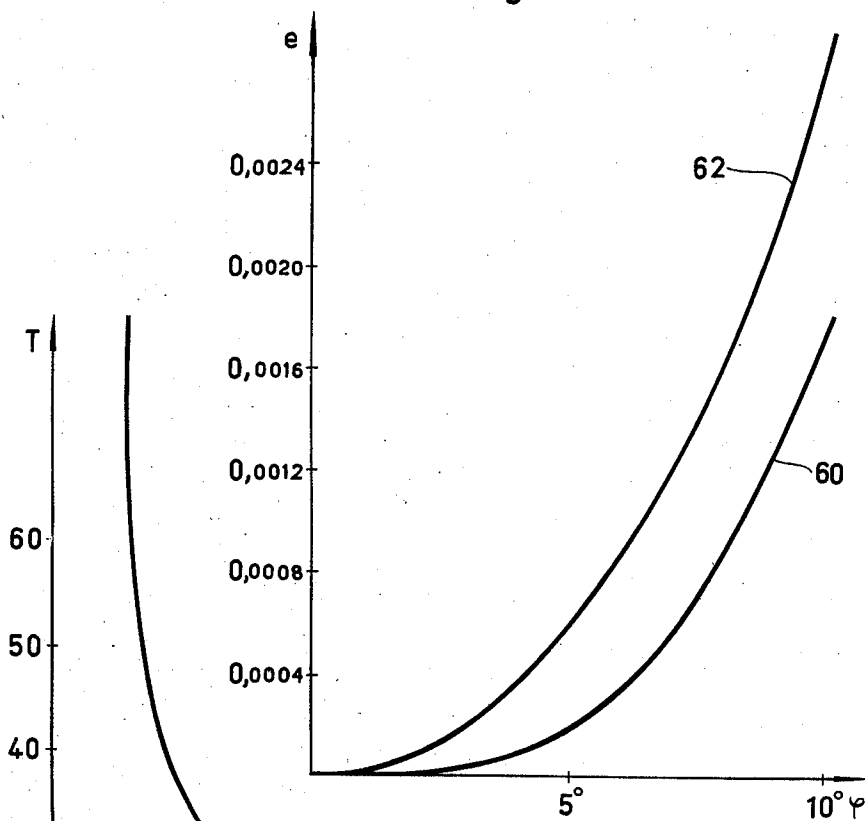
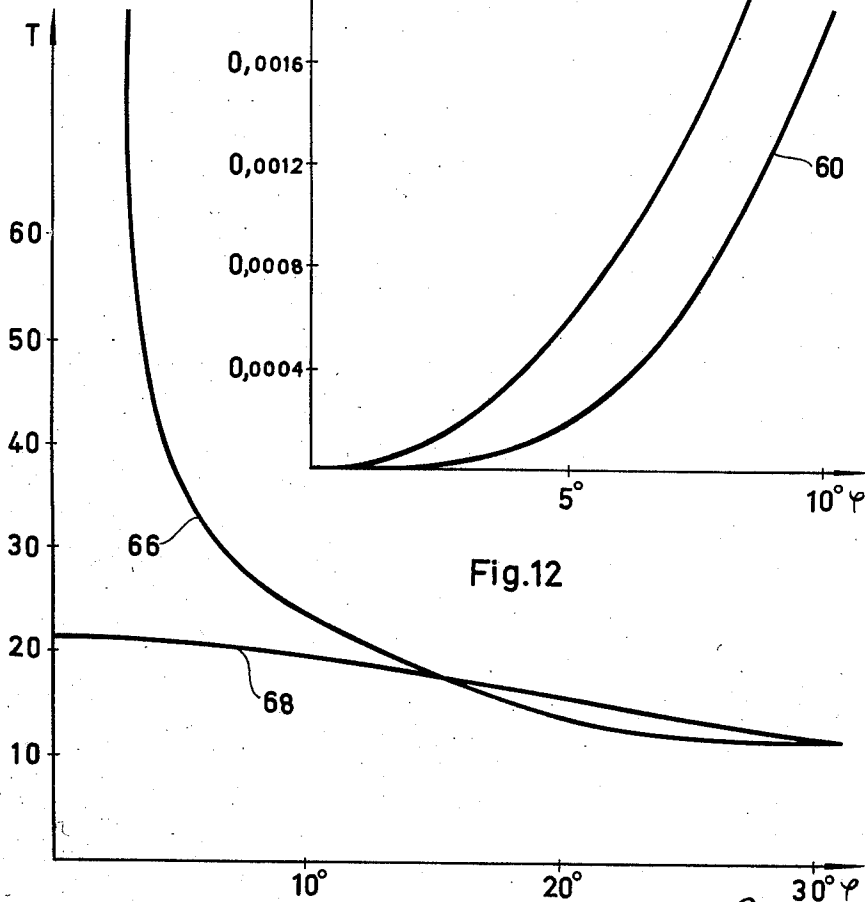


Fig. 12



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2,892,435

## METHOD FOR CONTROLLING ROLLING MOVEMENTS OF A SHIP

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Application February 17, 1954, Serial No. 410,858

Claims priority, application Sweden February 20, 1953

1 Claim. (Cl. 114—122)

My invention relates to ships and more particularly to anti-rolling means for such ships.

In spite of the extraordinary development of shipping experienced with the introduction of engine-operated ships, nevertheless the various types of ships hitherto brought into use have all been marked by a common weakness or imperfection consisting in their tendency to roll through continuously repeated angular movements about a longitudinal axis.

Even ultra modern ships now built, show qualities inferior to those of earlier constructions with respect to their increased tendency to roll.

Many propositions have been tried with a view to reducing the rolling of ships. According to one proposition, the ship is provided with water tanks, generally placed at the bottom of the ship on both sides of the fore and aft center line thereof, said tanks having for their object to be alternately filled and emptied in order to move the center of gravity of the ship in a lateral direction thereby counteracting the rolling of the ship. This way does not lead to any favourable result.

It is also known to adjust the metacentric height of the ship by means of water tanks or stowing of the cargo in the ship. The oscillatory period of the rolling of the ship can thereby be prolonged and the resonance avoided between the rolling and the waves. This procedure is better than the former, but frequently results in a dangerous instability of the ship. The movements of the ship become softer through the reduced metacentric height with less violent rolling, but at the same time the ship becomes more cranky. If, for example, the ship has to make a substantial sheer, a very powerful lurch will occur, which has proved to be an obvious inconvenience, particularly in large passenger boats.

One main object of my invention is to provide anti-rolling means in ships adapted to maintain rolling movements at a minimum particularly when sailing through a turbulent sea.

Further objects and advantages of my invention will be apparent from the following description considered in connection with the accompanying drawings, which form part of this specification and of which:

Fig. 1 is a side elevational view of a ship constructed according to my invention.

Fig. 2 is a cross section of the hull proper of the ship taken on the line II—II of Fig. 1.

Fig. 3 shows the hull of the ship in the same section as in Fig. 2 but in an inclined position relative to the surface of the water, a section on the lines III—III of Fig. 1 also being indicated with chain-dotted lines in this figure.

Fig. 4 is a cross section through the hull of the ship corresponding to Fig. 2 but on a larger scale.

Fig. 5 shows a detail of Fig. 4 on a larger scale.

Fig. 6 shows a valve on a still larger scale.

Fig. 7 is a longitudinal section of a portion of the forepart of the hull, carrying a bow rudder forming part of my invention and illustrated together with its actuating members.

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Fig. 8 is a cross section of the hull of a ship embodying a modification of my invention.

Fig. 9 is a cross section of the hull of a ship of the conventional type.

Figs. 10 to 12 present curve diagrams.

The hull of the ship illustrated in the Figs. 1—4 is shown in the British patent to Ljungström No. 521,734. In cross section, the hull substantially has the form of a V, the legs 10 of which constitute circular arcs with the radius  $\phi$ . The ship may be built with ribs or frames, all of which have the same radius of curvature. In its longitudinal direction the hull has the form of a partial body of revolution, the center of which is located amidships above the ship, as is indicated by the radius R.

When a ship of this and analogous types swings about its longitudinal axis so as to cause its longitudinal vertical plane 12 passing through the center line of the ship to take an inclined position as is indicated in Fig. 3, the area of a surface defined by the longitudinal vertical plane 12 and the hull at the water-line 14 will increase, calculated from said longitudinal vertical plane 12 in the direction of the swinging motion, the area of such surface on the opposite side of said plane being reduced correspondingly at the same time. The same effect is attained with a hull form made according to Fig. 8, the side portions 16 of which converge in a downward direction. These side portions need only have an extension in the vertical direction corresponding to the angles of list to be calculated with so as to ensure the water-line substantially to be located adjacent said portions. The chain-dotted line 18 indicates the position of the water-line at a certain list of the ship. In this case, too, the area of the above defined surface at the water-line has been increased in the listing direction, as seen from the longitudinal plane 12 relative to the opposite side. In the conventional hull of a ship with parallel sides 20, on the other hand, the proportion between the two areas above defined will not be changed, as will easily be understood from Fig. 9. Again, if the loading of the ship is reduced, its breadth in the water-line decreases when constructed according to my invention, but will remain unchanged when constructed with the form shown in Fig. 9. The advantages attained with the form of the hull according to my invention will become still more evident by the following explanation.

The forepart 22 of the hull has, in addition to the obtuse intersectional angle of the sides 10 of the hull at the keel, a depth or cross-sectional area below the water-line decreasing continuously toward the bow. This form of the forepart, which in the illustrated embodiment is curved upwardly, may begin from approximately amidships. The afterpart of the hull may have substantially the same form as the forepart but is provided with a keel 24 projecting rearwardly toward the rudder 26.

The forepart 22 is provided with a rudder 28 carried by a shaft 30 penetrating through the bottom 29 of the ship. The shaft 30 is connected through a transmission 31 with a gyro-rotor 32, the axis of rotation of which extends athwart-ships. Said gyro-rotor operates so as on a rolling movement of the ship to the right, for example, to automatically turn the rudder 28 so as to cause the ship to change its course in the same direction. Such a gyro may be constructed in any known manner and be adapted to actuate the rudder by means of a servo-motor.

I prefer additionally to build the ship with bottom tanks 34 and 36 communicating directly with the sea through relatively large openings 38. Extending from the upper limiting wall 40 of the tanks are conduits 42 provided with top valves 44. When the valves 44 are opened, air present in the bottom tanks will rapidly escape therefrom and water will enter the tanks through the openings 38. The valves may be constructed for automatic con-

trol and for this purpose be pivoted about a shaft 46 (Fig. 6) and provided with an arm 48 carrying a weight 50. Such valves will operate automatically, for example upon a sheer or yaw of the ship, the valve being raised due to the listing of the ship, thus opening a communication with the ambient atmosphere so as to cause the tank controlled by said valve to be filled by water replacing the air permitted to escape. The actuation of the valves thus results from the listing movement of the ship but it is also dependent on the centrifugal force.

The tanks 34 and 36 may also be interconnected by a conduit 52. Said conduit includes a compressor 54 and valves 56. By means of the compressor 54 air may be introduced into either tank or into both tanks at the same time while displacing a corresponding quantity of water out of the ship. It is also possible to pass air through the conduit 52 from one tank to the other, the quantity of water being increased in the former and reduced in the latter tank.

When a wave initiates a rolling movement of the ship about its longitudinal axis in one direction, the front rudder 28 causes an immediate change of course in the same direction, which results in a neutralization in an early stage of the rolling movement. When at the next moment the waves tend to roll the ship in the opposite direction, the front rudder 28 reacts and initiates a change of course directly opposite to the former, the balance of the deviations from the principal course thus being restored. The ship will only perform a very slight change of course to meet every wave, such changes always interrupting and neutralizing the rolling movement, so that the latter becomes negligible, if perceptible at all to the passengers.

The capability of the ship to perform the continuous deviations from the main course in response to each wave is largely due to the particular form of the ship's hull described above. The following table indicates the speeds and wave periods of sea waves having different lengths:

| Wave length          | Wave speed<br>in knots | Wave period<br>in seconds |
|----------------------|------------------------|---------------------------|
| 50' = 15.25 m. ....  | 9.5                    | 3.1                       |
| 100' = 30.5 m. ....  | 13.4                   | 4.4                       |
| 200' = 61 m. ....    | 19.0                   | 6.2                       |
| 400' = 122 m. ....   | 26.8                   | 8.8                       |
| 600' = 183 m. ....   | 32.8                   | 10.8                      |
| 800' = 244 m. ....   | 37.9                   | 12.5                      |
| 1,000' = 305 m. .... | 42.8                   | 14.0                      |
| 2,000' = 610 m. .... | 60.0                   | 19.8                      |

The ship must thus be capable of reacting within the wave periods to the impulses imparted thereto by the rudder 28.

According to traditional concepts, the hull of a ship of the type illustrated in Figs. 1-3 will perform the minimum of disturbing rolling when loaded as deeply as with a displacement of 2000 tons, for example, to have a metacentric height between 0.14 and 0.3 meter. If the load is reduced, the ship becomes more cranky. The capacity of the tanks 34 and 36 is selected so as to give to the ship when the tanks are substantially clear of water, a metacentric height approaching 0. Said height may be advantageously negative, in which latter case the ship is brought into an unstable position of equilibrium and, when lying still, is imparted a slight list toward one or the other side. The ship will then have two stability centers near each other, which result is obtained by a negative metacentric height of a few centimeters. In this way the ship will, within a listing range of a plurality of degrees, attain a position of equilibrium controllable by the bottom tanks and capable of being adjusted from normal stability to a floating indefinite position adapted to be influenced by exceedingly small forces, such as a moment of a few hundreds of kilograms in a ship having a displacement of 2000 tons. The position of equilibrium is then also influenced by small forces, for instance, by a

change of the center of gravity of the ship in the lateral direction caused by passengers walking from one railing of the ship to the other.

Assuming a ship being formed as a cylinder or spool floating on the water, all reactions of the ship to the attacks of the waves will be directed through the axis of rotation of the spool. With a metacentric height of 0 such ship would consequently remain entirely uninfluenced by the attack of the waves on its sides. The ship would then move entirely undisturbed by the surrounding sea as far as angular movements about the longitudinal axis are concerned.

The hull formed according to Figs. 1-3 by circular arcs approaches the properties of the cylinder in such respect, since the dynamic forces produced by the surrounding sea constitute the normal to the circularly shaped sides of the ship and may be caused to attack near the metacenter of the ship. The less the force resultant produced by the sea deviates from the metacenter, or the closer it coincides with the static force resultant produced by the water pressure, the lower the metacentric height can be chosen, without the ship being disturbed too much by the dynamic play of forces.

Fig. 10 shows curves indicating the static stability of ships constructed according to my invention and for ships of conventional construction. These curves have been drawn up, like the following curves, for a ship having a displacement of 2000 tons. The abscissa in Fig. 10 indicates the listing angle  $\phi$  of the ship, and the ordinate indicates the erecting lever GZ in centimeters. The curve 58 relates to a hull constructed according to my invention with a metacentric height equalling 30 centimeters, while the curve 60 relates to a hull with a metacentric height of 0. The conventional hull with a metacentric height equalling 14.4 centimeters is represented by the curve 62 and the conventional hull with a metacentric height of 0 by the curve 64. As will be apparent from the curves the hull constructed according to my invention and having a metacentric height of 0 with respect to static stability ranks equal with the conventional hull having a metacentric height of 14.4 centimeters. The type of hull used according to my invention thus permits of a lower metacentric height than does the conventional hull in order to possess the same stability.

Fig. 11 relates to the dynamic stability which for the hull embodying my invention and having a metacentric height equalling 0 is indicated by the curve 60, and which for the statically comparable conventional hull with a metacentric height of 14.4 centimeters is indicated by the curve 62. In this case too, the abscissa indicates the listing angle  $\phi$ , while the ordinate indicates the so-called dynamic lever  $e$ . It will appear from Fig. 11 that the quantity of work accumulated by a listing and equalling  $e$  times the displacement is smaller in the hull made according to my invention than in the conventional hull. This involves a considerably smaller force being required according to my invention to restore the ship to an upright position upon initiation of a listing movement than is required in a ship of conventional construction. Said figure shows further that the difference between the hulls is particularly evident for listing angles below  $5^\circ$ . The value of the work required for counteracting a rolling movement of the ship is understood to be for the ship represented by the curve 60 to be only a fraction of the work required for the ship represented by the curve 62, as far as small listing angles are concerned.

With greater listing angles, such as angles reaching or even surpassing  $30^\circ$ , when the risk of capsizing is of importance, the stability of the hull constructed according to my invention is, on the other hand, at least as good as that of the conventional hull, as will be easily understood from the two figures explained above. The downwardly converging cross-sectional shape of the hull will thus be understood to designate a hull creating stability curves of the character illustrated in said figures.

It will be understood from the above explanation that the form of hull used according to my invention is highly suited to eliminate rolling of the ship by means of the front rudder 28. The force required to counteract the listing initiated by the wave will be small and may, therefore, be produced by the rudder 28 without difficulty. Paradoxically as it may seem, the ship is made cranky in order to attain a stable motion uninfluenced by the waves. The metacentric height may even be negative, in which case the center of gravity is located above the metacenter. The ship moves forwardly in the same way as a bicycle, where the front wheel corresponds to the rudder 28 and where the supporting points are located below the center of gravity. With a lateral load, such as a gust of wind, acting on the cyclist and tending to incline the bicycle to the right, the cyclist automatically turns the front wheel somewhat in the same direction, and the balance is immediately restored.

To attain the capability of instantaneous reaction to the rudder 28 required to control the rolling of the ship by small lateral changes of course, the above described shape of the forepart of the ship is also of importance. The forepart thus facilitates rapid changes of course of the ship to maintain its balance. In this respect the forepart shaped according to my invention substantially differs from the conventional stem or bow portion with a vertical profile penetrating deeply into the water.

Another factor having an influence on the motion of the ship through the waves is the oscillatory period of the ship in a rolling motion. As already stated the oscillatory period increases with a decreasing metacentric height of the ship. With a constant metacentric height the oscillatory period is longer at smaller listing angles than at larger ones. In this respect also the hull constructed according to my invention is superior to the conventional hull, as will be understood from Fig. 12, where the abscissa indicates the listing angle  $\phi$  and the ordinate the oscillatory period  $T$  calculated in seconds. Curve 66 relates to an arc-shaped hull having a metacentric height of 0, while curve 68 relates to the conventional hull having a metacentric height equalling 14.4 centimeters and possessing an equal static stability. According to the curve 66 the oscillatory period decreases strikingly with an increasing listing angle. Thus the hull constructed according to my invention has no tendency of getting into resonance with the oscillatory period of the waves, which is presumed to be constant or at any rate to be altered very slowly.

Rubber suspension is well known to be an exceedingly effective means for the damping of vibrations such, for example, as are imparted to adjacent parts by a high speed engine. This damping quality of the rubber results from its modulus of elasticity not remaining unchanged by the oscillatory amplitude but rapidly being changed in response thereto. The rubber thus does not lend itself to synchronous oscillations, and a ship according to my invention shows the same damping quality with regard to an actuation by the surrounding sea.

As it is consistent with common practice to have the rudder of a ship controlled by a gyroscope or gyro-compass over a servomotor in order to keep the course of the ship in the direction of the voyage, the time control of the gyroscope reacting to the speed of angular movements performed by the rudder 26 is adjusted, according to the invention, so as to operate in a slower and preferably many times slower pace between two angular end positions of the rudder than does the gyro-controlled bow rudder 28 located under the forepart of the ship. These measures are necessary to prevent the rapid immediate actuation created by the rolling movements of the ship from being intermixed and getting into phase with the movements of the main rudder of the after-part.

The bow rudder is thus a rapidly operating balancing member of the ship, which as a rule produces small forces to create very small angular deviations to both sides, whereas the main rudder is intended to steer the ship in the desired course.

The gyro-control of the rudder 28 may be put out of operation and said rudder instead be operated manually. The ship may thus be prepared, for instance, for a powerful sheer to port by a manually initiated preparatory turn to starboard by the rudder 28, which turn to starboard causes overbalancing to port, before the more or less sharp sheer to port is made by both rudders 26 and 28. In this way, a lurch that would be unpleasant to the passengers is avoided. During the preparatory turn to starboard, the port tank or tanks may be filled with water, whereas water is discharged from the starboard tank or tanks.

As will be understood from the preceding explanation, the water tanks 34 and 36 do not have for their object directly to counteract the rolling of the ship, their main object being to raise and to lower the center of gravity of the ship in order to impart to the ship a maximum of soft motion in response to the nature of the waves. However, the tanks may be used to counterbalance a one-sided load, for instance due to the wind or the passengers gathering on one side of the ship. In this case the suitable position of the center of gravity is attained by a corresponding variation of the contents of the tanks under consideration.

The rudder 28 may be actuated by means other than gyroscopes, for instance by a pendulum, responding to oblique positions of the ship. The tanks may be located at various places in or on the ship, thus including location on deck. The change of the metacentric height may also be caused by a weight transfer within the ship.

While several more or less specific embodiments of the invention have been shown, it is to be understood that this is for purpose of illustration only, and the invention is not to be limited thereby, but its scope is to be determined by the appended claim.

What I claim is:

A method of controlling and counteracting the rolling movements due to wave action of a ship having a roll-sensitive hull substantially V-shaped in cross section and having a keel line arcuate from a point substantially amidships to the bow thereof and responsive to a rudder disposed adjacent the bow for stabilizing purposes, said method comprising automatically creating and applying a lateral force to the hull adjacent the bow in response to and proportional to a rolling movement of the portion of the hull above the longitudinal axis of roll in one direction, said force being applied transversely to the hull and substantially in alignment with the roll axis, said force tending to move the bow laterally in the direction of said rolling movement, whereby to decrease the rolling of the ship due to wave action.

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