PASSIVE STABILIZER SYSTEM FOR A BOAT AND THE LIKE

Filed Dec. 18, 1962

FIG. 1

FIG. 2

FIG. 3

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Filed Dec. 19, 1962, Ser. No. 245,476
9 Claims. (Cl. 114—125)

The present invention relates to a passive type stabilizer system for a vessel or boat and the like and more particularly to such a system provided with weir means therein.

Flume-type stabilizers, to reduce the roll of vessels, can through use of one design or another, be applied to ships and boats of all sizes, and all degrees of "stiffness" in the water, from the largest ocean liner to a small motorboat.

An example of a large ocean liner which has been stabilized from the flume-type passive tank is the large, luxury passenger ship the SS Matsonia; this is a ship of 26,000 long tons displacement, and a natural period of roll of about 18 seconds. An example of a small motorboat which can be stabilized by a flume-type passive tank is a Chris-Craft 27-foot express cruiser; of about 7,150 pounds displacement, and a natural period of roll, when not underway, of about 2.20 seconds. In these two examples the range of displacements is roughly 8200 to 1, and the range of natural periods is 8.2 to 1.

Basically, the flume-type stabilizer is one which operates as though it were a giant U-tube. This giant U-tube is of a size to extend clear across the ship, at or near maximum beam of the ship. The complete unit consists of two wing tanks, one on each side of the ship, and an interconnecting tank in the form of an open channel, generally called the flume. This system of tanks is partially flooded with water or other liquid, to a predetermined static level, z.

The predetermined level of water is calculated to be that level which will cause the natural period of the stabilizer, i.e. the period for one cycle of transfer of water between wing tanks, to be equal to, or substantially equal to, the natural period of roll of the ship. In this way, dynamic transfer between wing tanks is caused to be larger than the corresponding static transfer would be, whenever, and only whenever, the frequency of excitation of the stabilizer is somewhat above, or somewhat below, or equal to, the natural frequency of roll of the ship.

The natural frequency of a flume-type stabilizer is calculated by converting the flume system into its equivalent, i.e. the conventional U-tube system, and then calculating the natural frequency of this equivalent system in a conventional way. This treatment of the flume system is known as the U-tube analogy. This method of treatment comes from the fact that as water is transferred across the ship, from one wing tank to its opposite wing tank, the volume of water in the flume remains essentially unchanged in the process, as long as each wing tank is able to continue to supply, and in turn, to receive, the transfer of water that this condition of operation imposes.

As soon as the U-tube analogy has been completed for a flume-type stabilizer, the system can be simplified further, by being reduced to a U-shaped line. This U-shaped line is one which joins the axis of the water in the cross-connection (i.e. a horizontal line) with the axis of water in each wing tank, taken up to the free surface only (i.e. two vertical lines, one for each wing tank).

This U-shaped line has a characteristic weighted length S', and this weighted length establishes the natural frequency of the system, by the relation that this frequency is the quantity \( \sqrt{64.4/S'} \), that is the square root of the quotient, twice the constant of gravity, over the weighted length S'.

The best design of a simple flume-type stabilizer for large ships is one such that when the predetermined static depth of water z, has been made about one-half deck height, and the free surface area of each wing tank has been made about one-third or two-thirds of the total vessel free surface area of the system, the system will be correctly proportioned, as an efficient, well tuned system. This is well established, by design calculations and by tests at sea.

A small motorboat is relatively more stiff in the water than a large ship. This peculiarity of small craft is necessary for avoiding excessive heel when a large shift in weight occurs, as when persons aboard congregate on one side. The metacentric height of a large passenger ship is about 3.80 feet, and the metacentric height of the 27-foot motorboat is much less for example, 2.17 feet. Froude scaling of the ocean liner to a model having the same displacement as the motorboat gives a metacentric height of the model of 0.85 foot, and a natural period of roll of the model of 4.0 seconds. The motorboat is more stiff in the water than this, by a factor of about 2.5.

With respect to the design of acceptable flume-type stabilizers for small boats, the desired stabilizers are designed preferably by going to a type of design inherently more suitable for boats, than the design found acceptable for large ships.

This preferred design for small boats is that which interrupts the flow across the vessel, to an extent such that what one has is essentially a system of two U-tubes, arranged in tandem across the vessel. In this way, the weighted length of each U-tube is about half what the weighted length otherwise would be.

This is amply for tuning the stabilizer to the boat.

Tuning of a flume-type stabilizer is one problem, but the effective use of weight of water is another problem. This is to say, it does not make for an attractive design of stabilizer to have complete separation of the foregoing U-tubes in tandem. A complete blocking of the flow between U-tubes would seriously limit what stabilizing moment would be developed. This is in view of the fact that acceptable weight of water for a stabilizer installation is pretty much a fixed quantity. For instance, in the case of a particular design of stabilizer and 2 degrees roll of the boat, the moment which would be developed if the flow between U-tubes had been completely blocked is only 42 percent of the moment that is developed with what transfer between U-tubes is provided by the design. This extra moment developed is the margin needed to make the stabilizer performance attractive, and the installation feasible.

In the foregoing design of stabilizer, the type of constriction used to limit the flow between the two U-tubes is a submerged weir. This weir is located at the plane of separation of the two U-tubes, that is, in the way of centerline plane of the boat. A nozzle could be used in place of the weir, but a submerged weir is much more efficient because the flow over the weir is more nearly linear with amplitude of roll, than is the case for a nozzle.

As soon as some flow between U-tubes arranged in tandem across a boat is provided by a particular design or flume-type stabilizer, it becomes important to be able to assess how much relaxation of character of flow has been provided by the interconnection of U-tubes. Too much relaxation of character of the flow would mean that the system had been transformed back to what essentially is a single U-tube extending clear across the boat.

The test of whether with a particular design of stabilizer, one has essentially two U-tubes in tandem, or a single
U-tube depends on whether or not with the boat upright, the head of water in way of centerline plane of the boat is essentially that which would exist if the flow were completely blocked at this point, or is essentially zero. The trick of good design is to permit some transfer between U-tubes, but not so much that no head exists at the weir when the boat has become upright.

In the case of small boats, the foregoing problem is solved by locating the stabilizer high in the boat, such as on the cabin top, or built into the roof of the bridge. This has the effect of introducing a large dynamic component, or component with the gravity component, so that the resultant head at weir, the head due to apparent gravity, is very large. The short period of roll of the ship is very beneficial for getting large dynamic effect. The large head produced even though the roll may be moderate means that the flow can be heavily damped by the weir, and still allow passage of a significant quantity of water. If the weir were not in place, the flow across this station might, in fact, be too significant for comfort, that is excessive. This analysis tells us that while the type of stabilizer that is suitable for small boats may be very limited useful for long-period ships, the stabilizer is of great usefulness, and the indicated method, for short-period ships.

It is an object of the present invention to provide a simple passive stabilizer system including tank means which define the outer boundary of the stabilizer system and have the outer portions included in the stabilizer system disposed entirely within the tank means including weir means, hydrostatic pressure plate means and throat means.

The need for providing stabilizing means or systems for large vessels for attenuating the motion of the ship due to wave action has long been recognized and there have been a variety of devices and designs directed at reducing this undesirable motion in a seaway. Roll stabilization, the aim of the present invention, has continued to be a problem to be reckoned with although various devices for reducing roll are in operation today on many types of crafts.

Many vessels use one type or another of antroll fins externally projecting from the sides of the vessel to create large resistances to rolling action. Some of these fins are fixed while others are controllable, but fail to prevent roll in heavy seas at speeds below about 15 knots. On ships designed for low speeds, such as missile tracking vessels while on station, antrolling fins are ineffective.

Other passive systems of stabilizing the roll of a ship including a system of tanks for shifting the center of gravity of a vessel to create a righting moment to rolling or heeling action has also been tried. These systems utilized, generally, a pair of closed tanks, one located on each side of the ship and connected by a U-shaped crossover tube which was completely filled with water while in operation and also by an air duct connected between the tops of the tanks and having a valve for controlling the flow of air between the tanks.

These stabilizers were tried on a number of vessels but were found to suffer from several serious disadvantages. One disadvantage was the excessively noisy operation. The controllable air flow between the tanks acted as a damping system to prevent too rapid an exchange of water between the tanks. To sustain sufficient pressure in the line for adequate damping, the flow of air that is to be contricted port is maintained very high velocities and was exceptionally noisy.

The system required that the lowest level of water in a tank during transfer could not fall below the top of the crossover duct otherwise the air damping of the system would not be operable. In accordance with the present invention a passive stabilizing system is provided that eliminates many of the disadvantages encountered heretofore and which stabilizer system is compact and suitable for installation high in a boat and which is inconspicuous.

It is another object of the present invention to provide a passive stabilizing system that utilizes but a single stabilizing tank means which tanks means has incorporated therein weir means (vertical plate) and hydrostatic pressure plate means (horizontal plates) which in effect subdivide the single tank means into small starboard and port wing tanks or sections, and larger starboard and port wing tanks or sections which have their inner ends or inboard sides adjacent the weir means.

It is another object of the present invention to provide passive stabilizer system that can be used in small boats where other systems would not be feasible particularly active stabilizers using fins that project outwardly from the hull of the boat, since these stabilizers would be too costly to install and to operate and would require auxiliary power which is commonly not available on small boats. Also fin type stabilizers would not be practical due to congested marinas, docks and narrow inlets and channels to the docks and marinas so that there would be possible snagging or entanglement of the fins with other small craft.

It is another object of the present invention to provide a compact and packaged type passive stabilizer system that can be readily installed by an individual small craft or small boat owner and which does not require a skilled worker or mechanic in order to affix it to the small craft.

It is another object of the present invention to provide a passive stabilizing system for reducing the roll of a boat or a ship which is especially adapted for small craft and the like, and particularly for ships having a short natural period of roll such as, for example, a period of 2 to 8 seconds duration.

It is another object of the present invention to provide a simple and yet effective passive stabilizer system that may be added to supplement existing conventional stabilizer systems now on boats, to be used as a trimmer for small roll.

It is another object of the present invention to provide a simple and compact passive stabilizer system comprising a single tank means that has a large righting moment derived for small rolls of a boat due to the amplification characteristics of the system.

It is another object of the present invention to provide a single tank means for a passive stabilizer system in which the interior of all portions of the tank are in communication with every other portion therein at all times, and thereby eliminates any excessively noisy operation and any need for crossover tubes required in passive systems used heretofore.

It is yet another object of the present invention to provide a simple and compact passive stabilizer system which will fit into and be readily incorporated in a small craft such as motor boats and small cabin craft that could not accommodate the large volume type passive stabilizer systems used heretofore and generally used on ocean going vessels.

It is another object of the present invention to fulfill a need for equipping small craft and motor boats with a packaged passive stabilizer system which is economical so that they can be incorporated in existing small craft and motor boat cruisers the ownership of which is rapidly increasing.

It is another object of the present invention to provide a compact type passive stabilizer system for use with small craft which develops a righting moment to reduce or attenuate the roll of the small craft that can only be reproduced by conventional type passive systems now in existence that are 2 to 3% times greater in size than of the stabilizing system of the present invention.

Various other objects and advantages of the present...
invention will be readily apparent from the following detailed description when considered in connection with the accompanying drawing forming a part thereof and in which:

FIGURE 1 is a side elevation of a small craft embodying the passive stabilizer system of the present invention.

FIGURE 2 is an enlarged plan view of the passive stabilizer system of the present invention with the top removed and the walls in section and

FIGURE 3 is a side elevational view partly in section of the stabilizer tank means embodied in the present invention.

Referring to the drawings the reference numeral 10 generally designates a small craft or boat including a hull 11 and a cabin 12 superimposed on the deck 13 of the hull and provided with an open bridge 14 adjacent the aft part of the cabin 12. A mast 15 is disposed on the top of the cabin 12 in spaced relationship as indicated at 16, with the forward end of the bridge or cockpit 14.

The passive stabilizing system generally designated 17 is secured by any well known means to the top of the cabin 12. Members provided in the assembly complete the bridge 14 and the mast 15 as clearly shown in FIGURE 1. The passive stabilizing system 17 generally comprises an elongated tank transverse or completely enclosed member 18 that is substantially rectangular in configuration with vertical side walls 19 extending transversely across the top opposite end walls 20 extending longitudinally of the boat, a horizontal bottom 21 and a horizontal roof or top member 22. The overhead or top 22 is provided with an inlet connection 23 (FIGURE 1) having a cap member thereover for filling or introducing liquid into the interior of the tank.

As shown in FIGURE 1, the stabilizer tank extends transversely of the hull and cabin to a point substantially adjacent the starboard and port sides of the hull. A vertical weir 25 is secured to the bottom 21 of the tank and extends horizontally between the side walls 19 thereof. The weir is secured to the bottom and walls 19 of the tank by welding or other suitable means and has its longitudinal axis designated 26 coaxial with the longitudinal axis of the tank so that the weir is symmetrically disposed with respect to the end walls 20 of the tank. The hydrostatic pressure plates members 27 which are substantially rectangular in shape are disposed within the chamber of the tank on opposite sides of the weir 25. The plate members 27 are disposed in horizontal planes and are spaced or stacked as indicated at 28 vertically of the tank or a depth of 4 inches. The lower plates 27 are also spaced above the bottom 21 of the tank as indicated at 28, a distance equal to the vertical spaces 28 between two adjacent stacked plates while the uppermost plates 27 are disposed below the top 22 a greater distance than spaces 28. The plates 27 extend between the tank side walls 19 as shown in FIGURE 2 and abut these walls. The plates are mounted on vertical hollow tubular members 30 spaced an equal distance apart from one another as indicated at 31, with the members 30 disposed adjacent the walls 19 being spaced closely thereto and forming spaces substantially smaller than 31. The tubular members 36 are in alignment with one another, and have their axis coinciding with a longitudinal axis indicated at 32 extending parallel to the axis 26 of the weir 25 and the center line or longitudinal axis of the ship hull 11 which coincides with the longitudinal weir axis 26. The center 33 of the tank is spaced some distance outward of and on opposite sides of weir 25.

The horizontal space between two adjacent tubular members 30 and vertical space between two stacked adjacent plates 27 form nozzles or throat sections 33. By way of example, plates 27 are spaced vertically with respect to each other one inch apart, while they are spaced horizontally with respect to each other 2 inches wide, thus forming nozzles having a cross sectional area of 1 inch by 2 inches.

The members 30 and pressure plates 27 and the members 30 are laterally spaced from the end walls 20 of the tank so as to provide therebetween sections or portions 34 in the tank which form small starboard and port wing tanks. The sections, portions or spaces 34 in the tank are separated by the walls 19 of the chamber between the inner side or inboard ends of the plates 27 and members 30, and the weir 25 provide two larger inboard wing tanks adjacent the starboard and port sides of the boat. It is to be noted that the smaller starboard and wing tanks 34 are in communication with the larger starboard and wing tanks 35 and the weir 25 at all times, and that all of the tanks, sections, chambers or compartments within the main tank 17 always communicate with each other so that in effect the single overall tank 17 is subdivided into a plurality of smaller chambers or zones therein, as above described.

In operation as the boat rolls due to wave action, the water is transferred from one section or portion of the tank 17 by the force of gravity and local sway to another section or portion of the tank, but the kinetic energy thereof is damped by the restrictions or nozzles or throat sections 33. Figure 2 provides a damper as well as being damped by the weir therein. This transference of water imparts a stabilizing moment to the boat in opposition to roll. The pressure plates and nozzles formed thereby and weir means cooperate to enable the transferring liquid to impart the optimum stabilizing moment notwithstanding the substantially short period of boat roll as described above.

The hydrostatic pressure plates or fins and the weir form a throat or nozzle of essentially constant cross-sectional independently of the amount of roll, and the weir provides a damper to the water which gives approximate linear transfer.

The initial tuning of the invention is governed by the effect of cross-section of the tank and the effect of cross-sectional area of the nozzles and the size of the weir, but this may be readily varied by merely changing the level of liquid in the tank. The weir may have its upper end terminate substantially at the water line or liquid level in the tank or below the water line, but the weir should always be spaced a substantial distance from the top of the tank so that all portions of the tank 17 adequately communicate with one another. The height of the weir should be at least equal to half the depth of the water, for example, if a 4 inch depth or level of water is to be disposed in the tank then the weir should be at least 2 inches high and never less than this depth for such a construction. On the other hand, with a level of 4 inches of water in a tank a depth of 4 inches of water in a tank the weir should be 3 inches high. This is necessary so that the weir creates a sufficient head to obtain the desired result of reducing the roll of the ship or boat.

In one embodiment of the invention, the passive stabilizer system of the present invention was designed to be installed on a 27 foot overall length 1951 Super-Express Chris-Craft cruiser. The tank 17 has a depth of 7 1/2 inches, while the width of the tank walls 20 is 1 1/2 inches and the distance of the smaller or outboard wing tanks 34 between the walls 20 and the vertical axis through the pressure plates is 14 inches. The length of the larger inboard wing tanks 35 between the vertical axis of the pressure plates and the vertical axis of the weir is 23 inches so that the overall width of the tank and wall 19 is 74 inches. The weir is one inch in thickness and extended upwardly in the tank or has a height of 2 1/2 inches. The depth of water in the tank is 3 1/2 inches and the vertical spacing 28 between the pressure plates or fins is 1 inch with the lower plate being spaced 1 inch from the bottom 21 of the tank. The width of the throat section 33 between 2 adjacent members 30 is 2 1/4 inches wide and the displacement of the boat is 7,150 pounds with a metacentric height of 2,165 feet, at zero speed. The boat has a natural period of 2.20 seconds and a beam of 8 feet.
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4¾ inches. The boat is to be provided with the cabin top installation as shown in the drawings, and the tank disposed on top of the cabin.

Under these conditions the moments developed, for a 2 degree resonant roll, with fresh water in the stabilizer tank would be as follows:

<table>
<thead>
<tr>
<th></th>
<th>Foot pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer between wing tanks</td>
<td>63.8</td>
</tr>
<tr>
<td>Transfer over weir</td>
<td>88.5</td>
</tr>
<tr>
<td>Hull damping, zero speed estimated</td>
<td>54.0</td>
</tr>
</tbody>
</table>

Total: 206.3

Weight allowance for stabilizer water: Fresh water = 106 pounds (1.5 percent of displacement).

The invention described herein provides a means of roll reduction in situations where conventional roll reducing techniques fail. It has been found that the stabilizer means of the present invention provide a compact passive stabilizer system which includes a single tank subdivided into outer and inner wing tanks with hydrostatic pressure plate or flaps therein, and weir means that can be readily installed as a packaged unit high in a boat and which tank is sufficiently small so as to be inconspicuous thereon and not to detract from the overall design of the boat.

It is further apparent that the present invention provides a passive stabilizing system in which no compromise is necessary regarding tuning and other characteristics even though it is of a compact design and relatively small when compared with conventional stabilizing systems now in use.

Although the present invention is especially suitable for boats and ships having a short natural period of roll as for example, a period of 2 to 8 seconds duration it can also be used for any other type of boat or ship. Further, the stabilizer system is of such a compact nature that it can be readily installed without requiring reconstruction or redesign of existing boats and if desired it may be installed in a boat to supplement a conventional stabilizer system therein so that the present invention can be used as a trimmer for small roll since it develops a large moment due to its amplification characteristics.

The invention described herein develops a righting moment therein comparable to other stabilizer systems now in use that are 2 to 2½ times the size of the present invention and thereby provides a compact unit and sleek design for small boats in which the larger conventional units could not be installed without major redesign and reconstruction of the boat.

It will be realized that many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In combination a boat having a substantially short period of roll and a stabilizer system therefore including an elongated tank extending transversely of said vessel, said tank being substantially rectangular in cross section, said cross section being substantially constant throughout the tank, a plurality of horizontal hydrostatic flat plate members disposed in stacked spaced relationship in opposite ends of said tanks and spaced from the opposite end walls of the tank to provide outer wing compartments in the tank, weir means disposed along the center line of said tank and extending transversely of the main axis of said tank, said weir means mounted on the bottom of said tank and extending upwardly from the bottom a distance at least equal to one half the depth of liquid within said tank, said plate members and weir means providing inner wing compartments between the weir means and the plate members on both sides thereof, and a body of liquid disposed in said tank for transfer from one end to the other of the tank.

2. The combination of claim 1 wherein said plate members are mounted on vertical members spaced apart from one another, and the cross sectional area between horizontal plate members and said vertical members forms throat means.

3. The combination of claim 1 wherein said vessel is provided with a cabin on the hull and which projects thereof, and said elongated tank is superimposed on top of said cabin.

4. The combination of claim 2 wherein said plate members are stacked in spaced relationship one inch apart, and the lowest plate member in the tank is spaced one inch from the bottom of the tank and the vertical members are spaced approximately two and three quarter inches apart, and said tank has a depth of seven and one half inches, a length of seventy four inches and a width of eleven and one half inches.

5. The combination of claim 3 wherein said cabin is provided with a cockpit and said tank is disposed forwardly of and adjacent said cockpit.

6. The combination of claim 2 wherein said weir means extends to a position no higher than the surface of said liquid body.

7. In combination a boat having a substantially short period of roll and a stabilization system therefor comprising an elongated liquid containing means having ends and a longitudinal axis extending transversely to said boat, a pair of at least two vertically disposed elongated members, each of said pair of elongated members mounted at either end of said elongated liquid containing means and spaced longitudinally from said ends thereof, said elongated members being spaced laterally from each other and extending the substantially full height of said liquid containing means, horizontally disposed pressure plate means mounted on said elongated members and cooperating with said elongated members to form a plurality of nozzle means for damping the energy of transferring fluid therethrough, said pressure plate means comprising at least two flat plates, and weir means mounted transversely on the bottom and on the longitudinal center of said elongated liquid containing means, and a body of liquid disposed in said liquid containing means.

8. The combination as set forth in claim 7, said flat plates of said pressure plate means being spaced vertically from each other and from the top and bottom of said liquid containing means.

9. The combination as set forth in claim 8, wherein said elongated liquid containing means comprises a tank having a substantially rectangular cross section throughout.

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