June 16, 1964 L. MEYERHOFF 3,137,265

DEVICE FOR CONTROLLING SHIP MOVEMENT

Filed Nov. 21, 1960 3 Sheets-Sheet 1

Fig. 1.

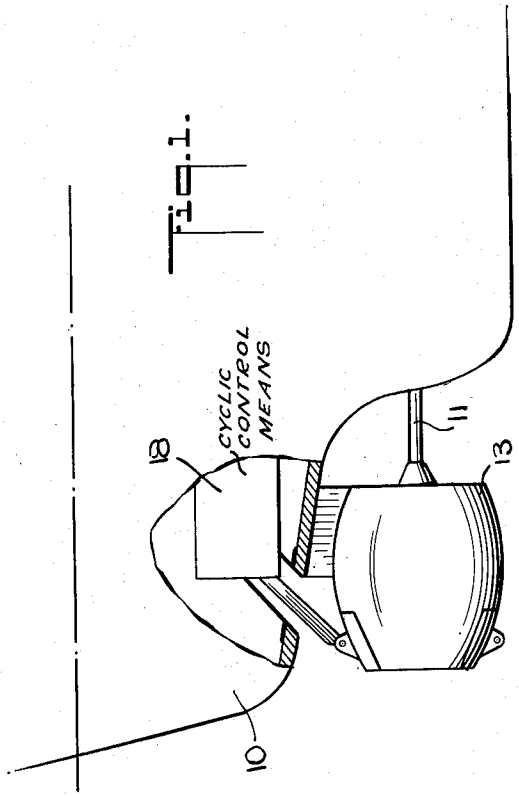


Fig. 2.

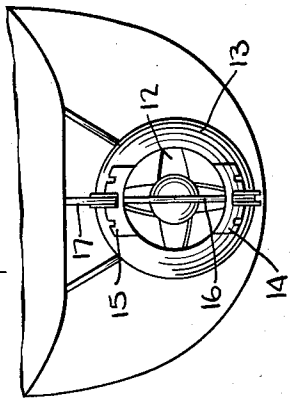


Fig. 3.

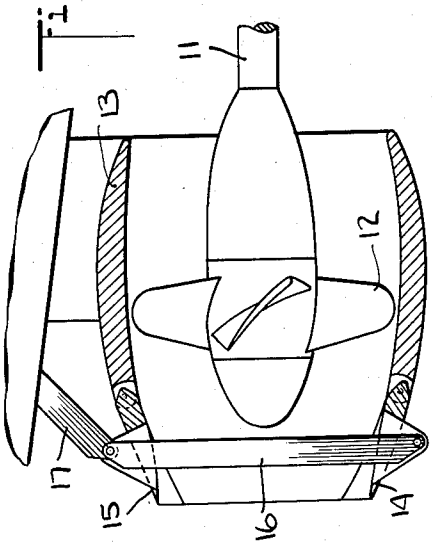


Fig. 4.

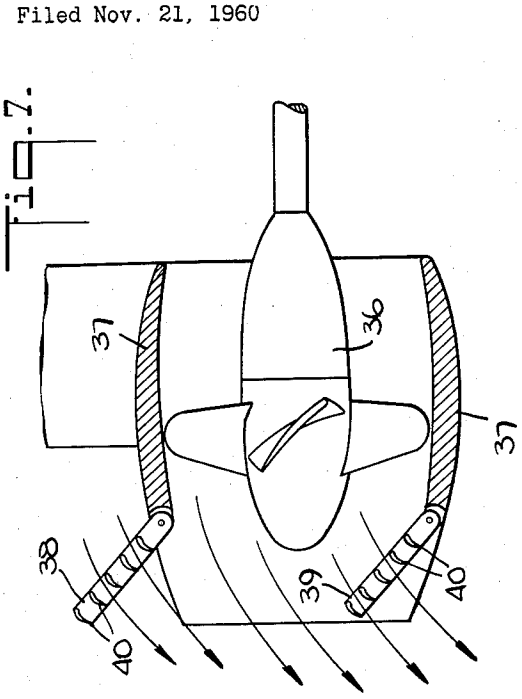
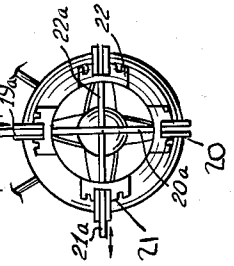


Fig. 4A.



INVENTOR.
LEONARD MEYERHOFF

BY Kenyon & Kenyon

ATTORNEYS

June 16, 1964 L. MEYERHOFF 3,137,265

DEVICE FOR CONTROLLING SHIP MOVEMENT

Filed Nov. 21, 1960 3 Sheets-Sheet 2

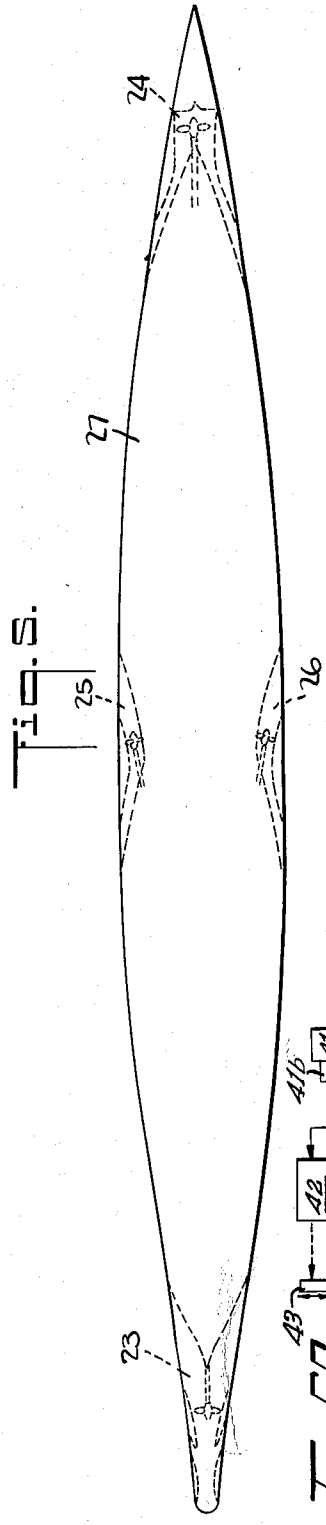


Fig. 5.

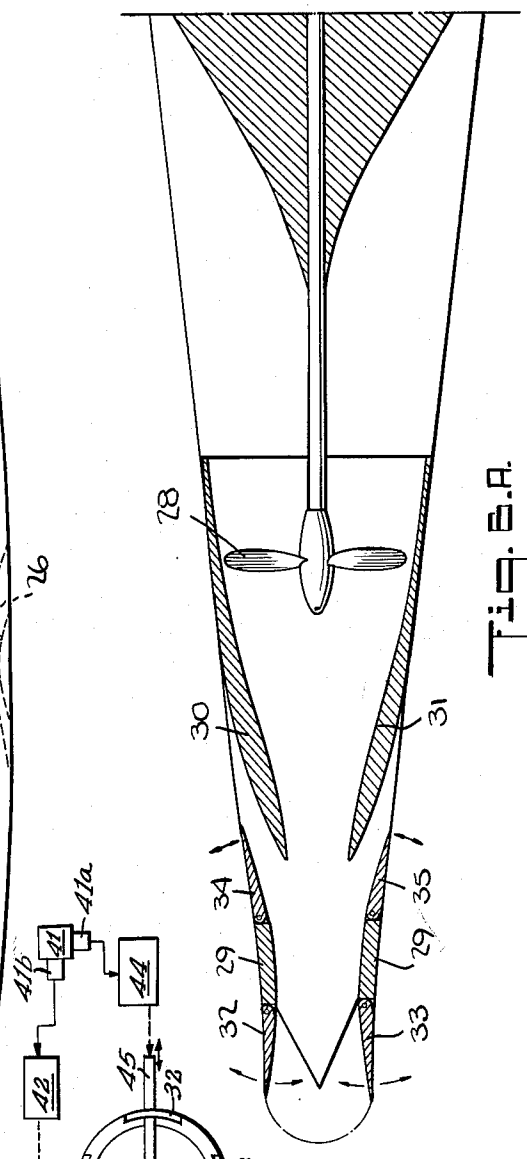


Fig. 6A.

Fig. 6B

INVENTOR.
LEONARD MEYERHOFF
BY Kenyon & Kenyon
ATTORNEYS

June 16, 1964 L. MEYERHOFF 3,137,265

DEVICE FOR CONTROLLING SHIP MOVEMENT

Filed Nov. 21, 1960 3 Sheets-Sheet 3

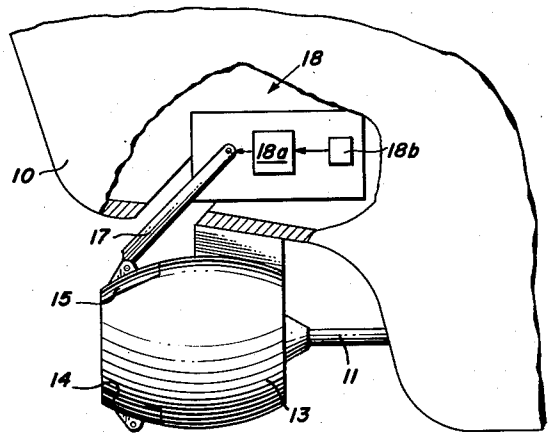


FIG.8A.

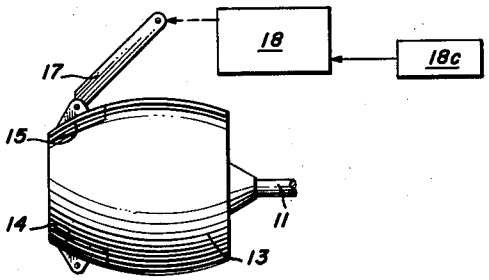


FIG.8B

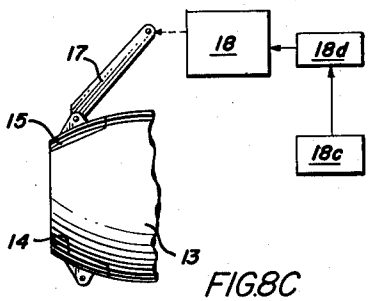


FIG.8C

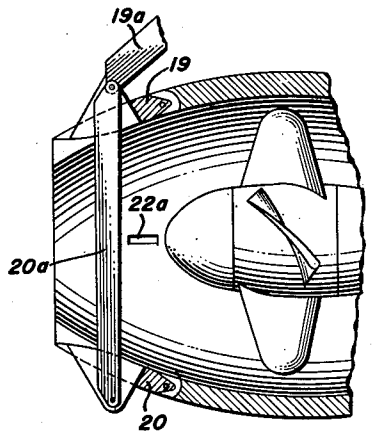


FIG.4B

INVENTOR
LEONARD MEYERHOFF

BY Kenyon & Kenyon
ATTORNEYS

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3,137,265

DEVICE FOR CONTROLLING SHIP MOVEMENT

Leonard Meyerhoff, Brooklyn, N.Y., assignor to Eastern Research Group, a partnership

Filed Nov. 21, 1960, Ser. No. 70,591
8 Claims. (Cl. 115—12)

This invention relates to a device suitable for controlling the movement of a ship. More particularly, this invention relates to the use of movable foil sections in conjunction with a duct to produce vertical or horizontal forces which act on a ship. The invention also relates to the use of the device of this invention to minimize wave drag.

There are several aspects involved in the movement of a ship through water. One of these involves the ability to the control the direction of movement of a ship in the sense of being able to properly steer the ship in order to maintain a course. Another problem concerns the elimination of rolling and a third relates to elimination of the pitching motion of a ship generally caused by waves transverse to the direction of propulsion of the ship.

An additional difficulty which is encountered concerns the heaving of a ship in rough or heavy seas. This problem is related to pitching, a ship encountering one or the other or both depending upon the relationship between the length of the ship and the condition of the seas.

A troublesome and costly problem which is encountered in ship propulsion relates to the energy which goes to the formation of a wave by the bow. The energy involved in the wave formation is not manifested in the speed of the ship and, therefore, represents a loss of efficiency.

Numerous methods of steering have been developed over the years. An advance in this respect is the use of a duct as disclosed in U.S. Patent No. 2,139,594, issued to L. Kort on December 6, 1938, to produce a stream of water whose direction may be controlled. Thus, by the normal reaction forces associated with a directionally controlled stream of water, the direction of the ship's movement may be controlled. In his patent, Kort also recognizes that such a duct may be used on a submarine to control the vertical movement.

The problems of heaving and pitching have received much attention, but control of these motions are largely unsolved. Overcoming these undesirable motions is an important consideration in improving the performance and seaworthiness of a ship. Thus, for example, rough water speeds may be increased if the pitching motion of a ship may be controlled. Efficiency is also increased since the propeller may be maintained fully under water at all times and operated closer to its design point. In this connection, the matching of the propeller to the engine may be made more precise if the conditions under which the ship is to operate may be fixed within narrow limits. Additionally, pitch-quenching is a very important factor in ships used for military purposes. It is to be readily appreciated that missile launching and aircraft launching and retrieving are made much more accurate if the pitching motion of a ship may be controlled during such operations.

The foregoing remarks apply equally well to rolling motion.

Accordingly, it is an object of this invention to provide a device suitable for substantially reducing the pitching, rolling and heaving motions of a ship.

It is another object of the present invention to provide a device for steering a ship.

It is another object of this invention to provide a device suitable for use in minimizing wave drag and thereby substantially decrease the power loss otherwise associated with this phenomenon.

It is a further object of this invention to provide devices for substantially reducing the pitching, heaving and rolling motions of a ship which is responsive to means which determines the necessary amount of compensation.

It is another object of this invention to provide a device suitable for controlling the vertical or horizontal movement of a submarine or other undersea craft.

It is a further object of this invention to provide a means for propelling a semi-submerged vessel which substantially eliminates the characteristic surface wave formation associated with such movement.

In accordance with one embodiment of the present invention, one or more pairs of foil-shaped members or flaps are pivotally connected to a duct surrounding the propeller of a ship. The foil-shaped members of each pair are parallel to each other and are disposed at opposite ends of a diameter of the downstream opening of the duct. One pair of foil-shaped members is preferably disposed in a substantially horizontal plane, i.e., approximately parallel to the plane of the water line of the ship, and the other pair of members is preferably disposed in a substantially vertical plane, i.e., approximately perpendicular to the plane of the water line of the ship. The first pair of members is capable of imparting vertical movement, and the second is capable of imparting horizontal movement.

When the propeller is in rotation, a stream of water is fed to the foil-shaped members through the duct. By varying the incidence of the foil-shaped members or flaps, the stream of water may be used to impart to the ship either an upward or downward movement, and/or a sideways movement, the former for stability purposes and the latter for steering. The movement thus produced results from the combination of two forces. The first of these forces is due to the reaction force produced by the expulsion of a stream of water and the second is the lift resulting from the use of foil-shaped flaps.

The device of this invention may be disposed at different points on a ship in order to accomplish the various objects set forth above. Thus, for example, pitching may be overcome by positioning a device either at the stern, where the propeller is conventionally positioned, or at the bow.

Reduction of heaving requires that two devices be used, one at the bow and one at the stern.

To reduce the rolling type of motion, it is necessary to position two devices amidships on the respective sides of the ship.

Reduction of wave drag requires positioning a device of this invention at the bow of a ship. The reduction of wave drag is further aided by a similar device at the stern. As described in detail below, the induction of flow through the bow minimizes wave formation at the bow, thereby increasing the propulsion efficiency.

In a second embodiment of this invention, a pair of members employed for controlling the pitching motion of the ship, for example, are connected to a control means. This control means may be one of two general types. In one aspect of this invention, the first control means is set to provide a cyclical, pivotal movement to the pair of foil-shaped members to provide a cyclical vertical force acting on the ship of sufficient magnitude to substantially counterbalance the cyclical vertical motion caused by the condition of the water through which the ship is moving. Alternatively, the control means senses and is responsive to the condition of the surface of the water in the vicinity of the ship, and in turn controls the cyclical pivotal movement of the foil-shaped members to counteract the effects of the surface condition of the water through which the ship is moving.

A pair of foil-shaped members which are employed for controlling the direction of movement of the ship in a

horizontal plane, that is the steering of the ship, are connected to a second control means, for example, the conventional steering mechanism of the ship.

The invention will be more fully understood when described in conjunction with the drawings in which

FIG. 1 is a side elevational view partly in section of a device of this invention;

FIG. 2 is an end elevational view of the device of FIG. 1;

FIG. 3 is an enlarged side elevational view, partly in section, of the device of FIG. 1;

FIG. 4A is an end elevational view of a device of this invention embodying two pairs of foil-shaped members;

FIG. 4B is a side elevational view of a device of this invention embodying two pairs of foil-shaped members.

FIG. 5 is a plan view of a ship employing four of the devices of the present invention;

FIG. 6A is an enlarged elevational view, partly in section, of a modification of the device shown in FIG. 1;

FIG. 6B is an elevational section view showing the control system for the two pairs of foil-shaped members, and

FIG. 7 is a schematic view, partly in section of a cascade device of this invention.

FIG. 8A is a schematic representation of the system wherein a gyro device or the like controls the foil-shaped members.

FIG. 8B is a schematic representation of a system in which the device responsive to the water surface condition controls the foil-shaped members.

FIG. 8C is a schematic representation of the system shown in FIG. 8B and including a time-delay means.

With respect now more particularly to FIG. 1, there is depicted a side elevational view of a device of this invention. Shown in FIG. 1 is the rear portion of a ship **10**. Attached thereto is shaft **11** to which the ship's propeller **12** is affixed. Shown in section is duct **13**. Duct **13** is disposed to produce a stream of water having a velocity relative to the ship **10**.

Attached to duct **13** are foil-shaped members **14** and **15**. Members **14** and **15** are pivotally connected to duct **13**, as, for example, by a hinge. In the embodiment depicted, foil-shaped members **14** and **15** are pivotally connected to each other by means of member **16**. Member **15** is pivotally connected to shaft **17** which, in turn, is connected to cyclic control means **18**. Reciprocable movement of the shaft **17** produces a corresponding movement in the vertical direction of foil-shaped members **14** and **15**.

Shaft **17** is caused to reciprocate by cyclic control means **18**. Thus, cyclic control means **18** and shaft **17** may be connected by a cam type of linkage whereby rotation of the cam would produce a reciprocal movement of the shaft **17**. Instead of a cam arrangement, hydraulic means or means embodying a screw and nut principle may be suitably employed, for example. This movement of shaft **17** produces a corresponding movement in foil-shaped members **14** and **15**.

Consider the situation in which a stream of water emanates from duct **13** due to rotation of propeller **12**. The cyclical movement of foil-shaped members **14** and **15**, in the nature of a flapping action, would deflect the stream of water first in an upward direction and then in a downward direction. Such movement of the stream of water in turn produces reaction forces thereby producing a cyclical, vertical movement of the stern of the ship with respect to the bow. Such movement is actually a pitching movement and the timing of the cycle of members **14** and **15** is chosen to counteract the pitching motion caused by movement of the ship through waves.

In one embodiment, cyclic control means **18** is pre-set to provide a symmetrical reciprocable movement of shaft **17**. The schedule of cyclic control means **18** is fixed in accordance with water conditions to reduce pitching to a minimum.

In the pitch-quenching device shown in FIG. 1, the force produced by deflection of the stream accounts for 65% of the total effect. The remaining 35% of the countereffect obtains as a result of the pressure differences arising from the use of foil-shaped sections. The values of 65% and 35% can be varied in either direction depending on the combined design of propeller and duct. In addition to the added lift, the use of flaps permit rapid changes to be made in the direction of the pitch-quenching force. It is this latter characteristic which makes the use of foil-shaped members so valuable for pitch-quenching.

A second embodiment of the present invention involves the use of a cyclic control means **18** which produces a reciprocal motion of shaft **17** in accordance with the pattern of the surface of the water in the vicinity of the ship. Thus, for example, radar or similar type devices **18***c* are employed to scan the configuration of the surface of the water in the immediate vicinity of the ship or ascertain the impending wave condition and this surface configuration is transformed into a movement of shaft **17** which counteracts the pitching effects of the water FIG. 8B.

Alternatively, a sensing device such as a gyroscope **18***b* is employed to sense deviations caused by the pitching motion of the ship and to translate such deviations by means of servo **18***a* into mechanical motion of such magnitude and duration as to quench the pitching motion of the ship when transmitted to the foil-shaped members **14** and **15** through shaft **17** FIG. 8A.

Another method for controlling the schedule of the cyclical motion of the foil-shaped members involves the use of a sensing device in combination with a memory device or time-delay means **18***d* (FIG. 8C). Thus, the sensing device would determine the magnitude and frequency of the pitching motion of the ship and would also convert this information to a form suitable for storage. Since the conditions of the surface of a large body of water do not change rapidly, the use of a control means including a time-delay would be advantageous in eliminating any tendency of the system to hunt.

FIG. 2 is an end elevational view of the device shown in FIG. 1.

FIG. 3 is an enlarged view of FIG. 1.

FIG. 4A is an end elevational view of a device of this invention employing two pairs of foil-shaped members, namely, **19** and **20**, and **21** and **22**. Members **19** and **20** perform the same function as those numbered **14** and **15** in FIG. 3.

FIG. 4B is a side elevational view of the device shown in FIG. 4A and including members **19***a* and **21***a* connected to members **20***a* and **22***a*, respectively.

Foil-shaped members **21** and **22** are used to steer the ship by producing a moment about the ship's vertical turning axis. The linkage of members **21** and **22** to the steering mechanism of the ship may be similar to that shown in FIG. 1 for members **14** and **15** and is not shown in the drawings. Thus, by movement of the steering mechanism, the stream of water emanating from nozzle **13** is directed at an angle to the direction of motion of the ship. This in turn produces a reaction force in a horizontal plane which will cause the ship to move in the desired direction, thus effecting a steering operation.

In the instance of a ship operating entirely under water, the two pairs of foil-shaped members shown in FIG. 3, may be employed in combination to produce a change in movement in any direction.

FIG. 5 depicts a ship **27** employing four devices of the present invention. One device **23** is positioned at the stern, another device **24** at the bow, and two devices **25** and **26** amidships.

Device **23** is similar to that described in conjunction with FIGS. 1 through 4.

Devices **25** and **26** are employed primarily to counteract rolling. These devices are connected to control means, not shown, which senses, for example, by gyroscopic means, the roll of the ship. The flaps of the respective devices are then controlled in a manner which tends to counteract the rolling tendency of the ship. In addition,

the streams of water emanating from devices 25 and 26 aid in propelling the ship in the desired direction.

Device 24, positioned at the bow, serves several purposes. It operates in conjunction with device 23 to overcome pitching, both devices 23 and 24 being controlled to provide the desired pivotal movement about a transverse axis through the ship's center of gravity.

Device 24 also operates in conjunction with devices 23, 25 and 26 to control heaving. Since the ship as a whole moves in a vertical direction as a result of heaving, it is necessary to employ at least two forces, either situated at opposite ends of the ship, or at opposite sides of the ship's beam to overcome this motion. It is evident that the overall combination of devices 23, 24, 25 and 26 may be used to overcome heave.

There is a continuous induction of water through device 24. As shown in the drawings, there is a propeller in device 24 so that the induced water can be used for propulsion. Alternatively, the induced water is allowed to enter an opening in the bow and is then merely pumped out through openings provided aft of the bow. In either instance, the induction of water at the bow minimizes wave drag.

The induced water causes the pressure distribution on the bow to be altered. In this effect, the induction of water at the bow allows large quantities of water to flow relatively unimpeded into the ship. This movement prevents the water from forming the strong wave pattern normally associated with ships at high Froude numbers.

As stated above, device 23 also serves to reduce wave drag. At the stern, the ejection of water also inhibits the formation of the wave normally associated with the flow at the rear. Due to the large quantity of fluid in the retarded layer of flow at the stern (the boundary layer), the wave making effect of the stern is generally less than the bow. Hence, the suppression effect is greatest at the bow.

The water which enters device 24 provides a propulsive thrust when returned to the ambient stream. It is important to return the water in such manner as to minimize wave formation. As shown in FIG. 5, the water is diverted into two streams. It is to be understood that foil-shaped members are provided for each of the two streams as shown in FIG. 4. Two exit streams are used to avoid a turning moment which would be imparted to the ship if all of the water were returned on one side.

Devices 25 and 26 are also useful for wave drag suppression. The intake and exit locations of devices 25 and 26 have the strongest effect at certain Froude numbers. The wave drag suppression of this system will be effective for the entire range of ship speeds, and when applied to extremely fast ships which normally move at speeds of over 40 knots this system will be effective over the entire range.

FIG. 6A is a plan view of a device of this invention which is modified to provide additional features. Shown in FIG. 6 is a propeller 28 and stationary duct 29. Also depicted are stationary vanes 30 and 31. Two pairs of foil-shaped members 32 and 33 and 34 and 35 are employed. These members are connected in the fashion described above.

In normal operation, members 34 and 35 are held in contact with vanes 30 and 31, respectively. In this condition, members or flaps 32 and 33 perform the anti-pitching, -heaving and-rolling functions described above.

Gyro device 41 by means of roll channel 41*a* and servo 44 can control link 45 connected to vanes 32 and 33 (FIG. 6B). Similarly pitch channel 41*b* of gyro 41 by means of servo 42 can operate link 43 to control members 32 and 33.

If it is desired to increase the propulsive power by increasing the rate of rotation of the propeller, flaps 34 and 35 may be moved away from vanes 30 and 31. This permits increased water intake through the spaces between flaps 34 and 35 and vanes 30 and 31 due to Venturi effect. Such increased flow produces a corresponding increase in the lift of flaps 32 and 33. The effectiveness of this Venturi effect is greater if the propulsion system is located in the ship's boundary layer.

Should it suddenly be desired to brake the ship, this may be accomplished by moving flaps 32 and 33 toward each other so as to effectively block off the normal downstream exit of the water stream. In conjunction with this, flaps 34 and 35 are moved away from vanes 30 and 31.

Thus, a stream of water is forced out between vanes 30 and 31, and flaps 34 and 35. This stream has an opposite effect on the movement of the ship since the reactive force is in a direction opposite to that of the stream when it passed between flaps 32 and 33. Accordingly, a braking force is exerted on the ship.

This method of braking is much more responsive than prior methods which depended on reversal of propeller rotation.

The configuration shown in FIG. 6 is also suitable for braking a ship. It is to be appreciated that two additional pairs of flaps, arranged as shown in FIG. 4, may be used in conjunction with pairs 32 and 33, and 34 and 35.

The devices of this invention are also suitable for use on semi-submerged vessels. These vessels operate with the main hull approximately several feet below the surface of the water. Although submerged, a wave is formed on the surface. This effect is virtually eliminated at depths of about two hull diameters or more. However, the semi-submerged ship must operate relatively close to the surface. By using a device of this invention at the bow of semi-submerged vessels, the characteristic surface disturbance is substantially eliminated. Use of additional devices aft will increase the effectiveness of wave suppression.

In the examples described above, the pairs of foil-shaped members have been depicted as being in either a substantially vertical direction or a substantially horizontal direction. It is to be appreciated that the pairs of members, if more than one pair is used, need not be disposed as shown in FIG. 4, but may be inclined at an angle.

In all of the variations of the devices of this invention, it is to be understood that the foil-shaped members may be employed in cascade to provide increased action. FIG. 7 depicts the use of a cascade system.

Shown in FIG. 7, is a propeller 36, duct 37 and vanes 38 and 39, each of which has mounted thereon foil-shaped members 40. The movement of water past the foil-shaped members 40 is shown by the directional arrows in FIG. 7. As shown in FIG. 7, vanes 38 and 39 are inclined in an upward direction. The flow past the foil-shaped members provides an upward lifting force due to the air-foil effect. Accordingly, it is noted that vanes 38 and 39 are moved in an opposite direction to the foil-shaped members of FIGS. 1 through 6 to produce the same direction of lifting force.

There are several advantages of using a cascaded system as shown in FIG. 7. In the first place, the action of vanes 38 causes the water flowing outside of duct 37 to be turned in a downward direction as shown by the arrows. The downward movement of this stream of water serves to deflect the stream of water produced by propeller 36 which flows through duct 37. Accordingly, additional upward lift is obtained due to the jet effect of a large body of downwardly moving water.

Another advantage of the system shown in FIG. 7 relates to the amount of power needed to pivot vanes 38 and 39, as compared with that necessary to move the flaps of the other embodiments. In the other embodiments, the movement of the air-foil sections is generally in a direction opposite to that of the force produced by the air-foil sections themselves. In other words, the power necessary must be sufficient to overcome the lifting force produced by the flaps. On the other hand, in the system shown in FIG. 7, the lifting force is approximately per-

pendicular to the air-foil sections, or in other words, parallel to the vanes 38 and 39. The force required to pivot vanes 38 and 39 is approximately perpendicular to the lifting force. Accordingly, the power necessary to pivot vanes 38 and 39 is relatively independent of the lifting force produced by the air-foil sections 40 and vanes 38 and 39 and need only overcome the drag of the vanes.

In the embodiments shown in the drawings, the two members of a pair are shown connected to each other, there being only one connection between the members and the source of motivation. It is to be understood that an alternative structure may suitably involve connection of the motivating or control means to each of the members individually to produce the same result.

It will also be appreciated that another alternative structure may involve connection of a control means to each of the members individually to provide for opening or closing of the orifice formed by these members to adapt such opening to the flow therethrough in the most efficient manner. Such adjustable exit area improves off-design propeller operation. Rough seas or wave drag with increasing speeds cause off-design propeller operation by causing greater drag at a given speed. Adjustable exit area brings the pressure at the duct exit to ambient value and leaves less kinetic energy in the water stream. Adjustability also keeps the same flow pattern at the propeller to avoid flow losses. In effect, the system is made to behave as if an adjustable pitch propeller is incorporated.

In the prior art, it was known to use stabilizing wings or fins attached to the hull of a ship to overcome pitching (see Model Experiments with Fixed Bow Antipitching Fins, by G. P. Stefun, Journal of Ship Research, October 1959). Such fins may be employed in conjunction with the devices of this invention by attaching them to the nozzle surface.

The embodiments described above in conjunction with the drawings are intended merely as illustrative of the present invention. Variations may be made therein within the skill of the art without departing from the spirit and scope of this invention.

I claim:

1. In a ship, first means producing a stream of water, second means attached to said ship for guiding said stream, third means connected to said ship and disposed in the path of said stream adjacent one end of said second means, said third means being adapted to deflect said stream in a desired direction having a vertical component, and cyclic control means connected to said third means to cause said third means to cyclically deflect said stream of water whereby corresponding cyclical forces acting on said ship are provided in directions opposed to those of the cyclically deflected stream of water.

2. In a ship, means producing a stream of water, means attached to said ship for guiding said stream, at least one pair of foil-shaped members connected to said ship and disposed in the path of said stream adjacent one end portion of said guiding means, said members being pivotable about respective axes which are substantially perpendicular to the direction of flow of said stream and at an angle to the vertical, cyclic control means attached to said members and operative to cyclically pivot said pair of members about said axes to cyclically deflect said stream of water, whereby the cyclical forces created act on said ship.

3. A device for controlling the motion of a ship comprising means producing a stream of water, means attached to said ship for guiding said stream, means attached to said ship and disposed in the path of said stream, adjacent one end portion of said guiding means being pivotable about a substantially horizontal axis and adapted to deflect said stream of water in a vertical plane, cyclic control means attached to said last-named means to cyclically pivot said last-mentioned means about said axis thereby cyclically deflecting said stream of water in a vertical plane, whereby the forces produced by the deflected stream act on said ship.

4. A device for controlling the movement of a ship comprising means producing a stream of water, duct means attached to said ship guiding said stream of water, and means including at least one pair of flaps spaced one from another and pivotally connected adjacent the exit of said duct means about an axis at an angle to the vertical, said flaps being adapted to deflect said stream of water, and cyclic control means to cyclically pivot said flaps whereby the forces created act on said ship.

5. The device of claim 4 in which said flaps are foil-shaped.

6. A device for controlling the movement of a ship comprising first means producing a stream of water, second means attached to said ship guiding said stream of water, said second means having a downstream side with a cross-sectional opening substantially corresponding in form to the other portions of said guiding means, at least one pair of horizontally disposed foil-shaped members pivotally connected to the downstream side of said second means, said members being positioned at opposite boundaries of said stream, and cyclic control means connected to said members to cyclically pivot said members and thereby cyclically deflect said stream.

7. A device for controlling the movement of a ship comprising first means producing a stream of water, second means attached to said ship guiding said stream of water, at least one pair of foil-shaped members pivotally connected to the downstream side of said second means about an axis at an angle to the vertical, said members being positioned at opposite boundaries of said stream, sensing mechanism responsive to the condition of the surface of the water in the immediate vicinity of said ship, and cyclic control means responsive to said sensing mechanism to cyclically pivot said pair of members.

8. A device for controlling the movement of a ship comprising first means producing a stream of water, second means attached to said ship guiding said stream of water, at least one pair of foil-shaped members pivotally connected to the downstream side of said second means, about an axis at an angle to the vertical, said members being positioned at opposite boundaries of said stream, a sensing device responsive to the deviations caused by the pitching motions of said ship, and cyclic control means responsive to said sensing device to cyclically pivot said pair of members to counteract said deviations.

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