Dec. 28, 1965 SUETSUGU NOMURA ETAL 3,225,728

HULLED BODY EQUIPPED WITH WAVE-RIDING DEVICE

Original Filed Dec. 11, 1961 2 Sheets-Sheet 1

Fig. 1.

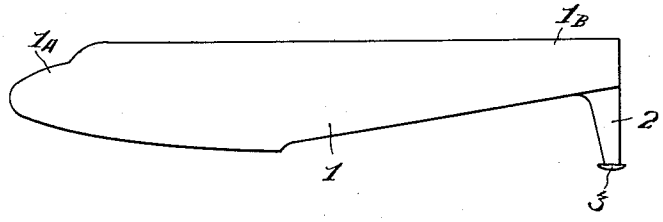


Fig. 2.

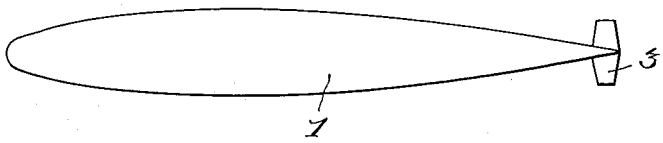


Fig. 3.

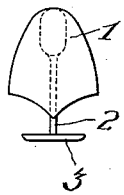
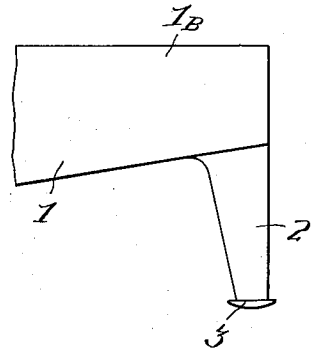


Fig. 4.



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Fig. 5.

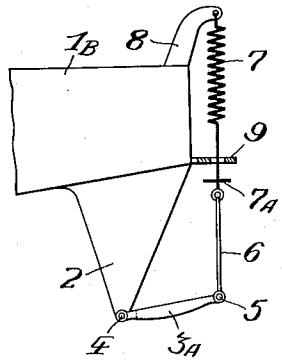


Fig. 6.

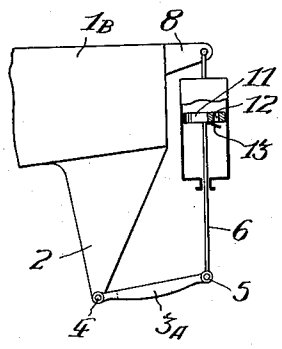


Fig. 7.

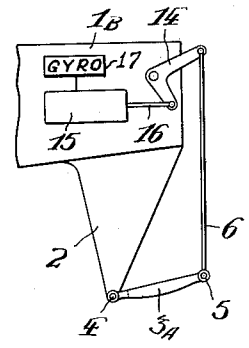


Fig. 8.

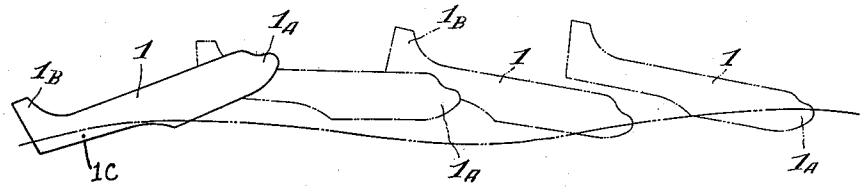
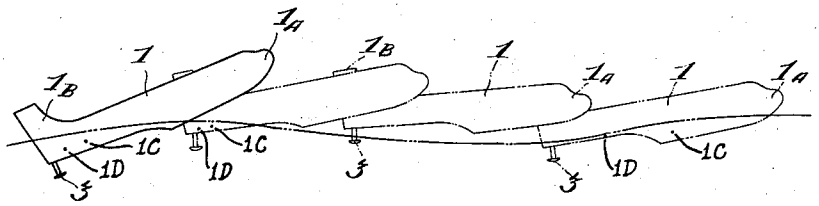


Fig. 9.



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HULLED BODY EQUIPPED WITH WAVE-RIDING DEVICE

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Continuation of application Ser. No. 158,291, Dec. 11, 1961. This application Oct. 8, 1963, Ser. No. 314,810

7 Claims. (Cl. 114—66.5)

This application is a continuation of application Serial Number 158,291 filed December 11, 1961, now abandoned.

The present invention relates to hydrofoil apparatus for use with such craft as amphibious aircraft, hydroplanes or boats and more particularly to such craft having a stepped hull.

The invention comprises hydrofoil means positioned below the stern of the hull rearwardly of its center of buoyancy and arranged to hold the stern down so that the bow or nose of the craft is prevented from dipping below the surface of an oncoming wave.

Various objects, features and advantages of the invention will become apparent from the following description together with the accompanying drawing forming a part hereof.

Referring to the drawing:

FIGURE 1 is a side elevational view of a hull equipped with a hydrofoil in accordance with the invention, illustration of the control system for the hydrofoil being omitted.

FIGURE 2 is a plan view of the hull shown in FIG. 1.

FIGURE 3 is a front elevational view of the hull of FIG. 1.

FIGURE 4 is an enlarged fragmentary side elevational view of the stern portion of the hull of FIG. 1.

FIGURE 5 is an enlarged fragmentary view similar to FIG. 4 and showing a spring controlled hydrofoil applied to the stern portion of the hull illustrated in FIGS. 1, 2 and 3.

FIGURE 6 is a view similar to FIG. 4 showing a damped hydrofoil.

FIGURE 7 is a view similar to FIG. 4 showing a hydrofoil controlled by a servomotor.

FIGURE 8 shows the operation of a stepped hull from which the hydrofoil of the invention has been omitted.

FIGURE 9 illustrates, by comparison with FIG. 7, the improved operation which is obtained by the use of the controlled hydrofoil of the invention.

Referring now to FIG. 1 through FIG. 4, the submerged hydrofoil or wing 3 is attached rigidly to the free lower end of the supporting post 2 which extends downwardly from the stern 1B of hull 1 rearwardly of the center of buoyancy of the hull. The center of buoyancy is indicated in FIG. 9 at 1C. The center of buoyancy is located at the center of gravity of the water which is displaced by the hull 1 and the force of buoyancy which keeps the hull afloat may be considered as being applied at the point 1C. Under stable floating conditions, for any object, the center of buoyancy is located directly above the center of gravity of the object. The hydrofoil 3 assumes an effectively horizontal position. In order to attain the object of this invention, the downward component of the force acting on the hydrofoil 3 is an important factor and, in this connection, it is advantageous to have the underside of hydrofoil 3 appropriately curved with respect to the direction of forward movement.

When an ordinary amphibian or hydroairplane glides on the wavy surface of water, the stern of its fuselage will rise above the water and the bow will pitch down rapidly causing the nose or bow to dive into the approaching upwardly inclined surface of the next oncoming wave, thus providing a very poor wave-riding performance, as illustrated in FIG. 8. With the submerged wing or hydrofoil 3 provided below the stern, however, the stern section 1B of the fuselage is pulled downwardly. This downward pull, accompanied by the continuously applied upwardly directed force if flotation acting at the center of buoyancy, results in a torque or couple acting about a transverse axis 1D intermediate the stern 1B and the center of buoyancy 1C which urges the nose of the craft upwardly above the rising front of the next oncoming wave. By thus preventing the stern 1B from rising above the water surface a markedly improved wave-riding performance is obtained as shown in FIG. 9.

Each of FIGS. 5 through 7 show the submerged hydrofoil 3A connected to the lower free end of supporting post 2 by a horizontal pivot shaft 4 so that the negative angle of lift of hydrofoil 3A may be varied and suitably controlled.

In FIG. 5, a pivotal connection 5 interconnects the trailing edge portion of a transversely extending hydrofoil member 3A and a vertically movable link rod 6. A helical tension spring 7 is connected at its upper end to a supporting bracket 8 fixed to the upper part of the stern portion 1B of the hull 1. The lower end of the spring 7 is connected to the upper end of the link rod 6. A stop member 7A is disposed above the upper end of the link rod 6, being carried by the lower end portion of the spring 7. Upon contraction of the tension spring 7 accompanying upward movement of the link rod 6, the stop member 7A will engage the lower surface of a fixed stop member 9 secured to the stern portion 1B of the hull 1. The stop members 7A and 9 thus limit the maximum angle of inclination of the hydrofoil 3 to an angle which produces a predetermined maximum downward pull on the stern portion 1B for any particular velocity of the hull 1.

The tension of the spring 7 is such that downward movement of the trailing edge portion or clockwise rotation of the hydrofoil 3, as viewed in FIG. 5, may be produced by increasing velocity of forward movement of the hydrofoil member 3 through the water above a predetermined minimum velocity. The spring 7 exerts an effectively constant upward pull through the link rod 6 upon the trailing edge of the hydrofoil 3. As a result, there is a substantially constant downward pull exerted on the stern 1B of the hull 1, commencing with a predetermined minimum velocity which is sufficient to displace the stop member 7A downwardly out of engagement with the fixed stop member 9. For velocities exceeding this predetermined minimum velocity, the hydrofoil 3A will tend to assume an angular position which offers the least resistance to its passage through the water, the position of least resistance being modified by the substantially constant upward pull of the spring 7. The downward pull on the stern portion 1B of the hull 1 will thus remain constant throughout a range of velocities commencing with a predetermined minimum velocity sufficient to produce downward movement of the stop member 7A from the fixed stop member 9, the upper limit being determined by the maximum speed of the hull 1.

In FIG. 6, a damping device consisting of an air cylinder 10 and piston 11 is shown. The air cylinder 10 is suspended from the support arm 8 of the stern while the piston 11 is connected with the upper end of link rod 6 which serves as a piston rod. In this piston 11, there is a through hole 12, fitted with a leaky check valve 13. Where this device is used, hydrofoil 3 will be pushed down or rotated clockwise by the water when the stern tends to rise. The trailing edge of hydrofoil 3, together with piston 11, will tend to move downwardly with respect to

the cylinder 10; but, since the leaky check valve 13 remains closed for this movement, the air in the bottom chamber within the cylinder presents a large initial resistance to the downward motion of the piston, and the hydrofoil 3 will not immediately yield to the downward push of water and therefore the tendency of the stern to rise rapidly will be greatly reduced. If the stern tends to dip down, the check valve 13 will open permitting piston 11 to move freely upwardly and hydrofoil 3 to turn upward or counterclockwise with but little hindrance. In other words, the stern can pitch down without much interference being caused by the hydrofoil.

FIG. 7 illustrates the case in which the hydrofoil movement is to be automatically controlled in accordance with the ups and downs of water surface as well as of the hulled body. The operating cylinder 15 with its piston rod 16, shown in the figure, is to be actuated by the signal transmitted from the sensing part of such a device as the electromagnetic gyro equipment 17. The motion of piston rod 16 is transmitted to the hydrofoil 3 through the bell-crank 14 and link rod 6.

A hull equipped in accordance with this invention is extremely effective and superior in terms of the wave-riding performance, and existing hulls can be readily and conveniently modified to utilize the invention.

While we have shown and described what we believe to be the best embodiments of our invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In combination with an elongated hull adapted to float upon water and to move longitudinally thereupon; a downwardly extending supporting member having its upper end fixed to the stern portion of said hull, the lower end of said supporting member being free; a transversely extending hydrofoil member positioned below said hull rearwardly of the center of buoyancy of said hull to be normally immersed in said water; means pivotally connecting the leading edge portion of said hydrofoil member to the free end portion of said supporting member for angular displacement of said hydrofoil member about an axis perpendicular to the longitudinal axis of said hull; and control means supported by said hull and connected to the trailing edge portion of said hydrofoil member for altering the angle of inclination which said hydrofoil member would otherwise assume during movement through said water if said trailing edge were free, said angle of inclination of said hydrofoil member during forward movement of said vessel through said water producing a downwardly directed pull on said stern portion rearwardly of said center of buoyancy to produce a torque about an axis extending transversely of said hull intermediate said stern portion and said center of buoyancy, said torque tending to elevate the nose portion of said hull, the magnitude of said downwardly directed pull being controllable by said control means.

2. The combination according to claim 1, wherein said control means opposes downward movement of said trailing edge portion.

3. The combination according to claim 1, wherein said control means comprises spring means yieldingly urging said trailing edge portion upwardly to produce said downwardly directed pull.

4. The combination according to claim 1, wherein said control means comprises cylinder and piston means interconnecting said trailing edge portion and said hull, said cylinder and piston means including check valve means permitting effectively free upward movement of said trailing edge portion and opposing downward movement thereof.

5. The combination according to claim 4, wherein said check valve means is leaky to permit retarded downward movement of said trailing edge portion.

6. The combination according to claim 1, wherein said control means comprises servomotor means adapted for response to gyroscopic stabilization means.

7. In a vessel comprising an elongated hull adapted to float upon water and to move forwardly thereupon, in combination: a downwardly extending elongated supporting member having its upper end fixed to the stern portion of said hull, said supporting member being located on the longitudinal axis of said hull and being shaped to offer a minimum resistance to said forward movement when said supporting member is immersed in said water; a hydrofoil member positioned at the lower end of said supporting member, said hydrofoil member being normally immersed in said water rearwardly of the center of buoyancy of said hull; means pivotally connecting the leading edge portion of said hydrofoil member to said supporting member for angular displacement of said hydrofoil member about an axis located below the level of said water rearwardly of said center of buoyancy and extending perpendicularly to said longitudinal axis; stop means limiting upward movement of the trailing edge of said hydrofoil member, the angle of inclination of said hydrofoil member, when the upward movement of its trailing edge is limited by said stop means, causing forward movement of said hydrofoil member through said water to produce a maximum downwardly directed force acting on said hydrofoil member to urge the stern of said vessel downwardly accompanied by an upwardly directed force acting at said center of buoyancy, said downwardly and upwardly directed forces producing a torque acting about an axis extending transversely of said hull intermediate said stern portion and said center of buoyancy, said torque urging the nose of said hull upwardly; and spring means yieldingly urging said hydrofoil member toward said angle of inclination wherein upward movement of said trailing edge is limited by said stop means, said spring means exerting a substantially constant upward pull upon said trailing edge whereby an effectively constant downward pull is exerted on the stern portion at all speeds exceeding a predetermined minimum speed.

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