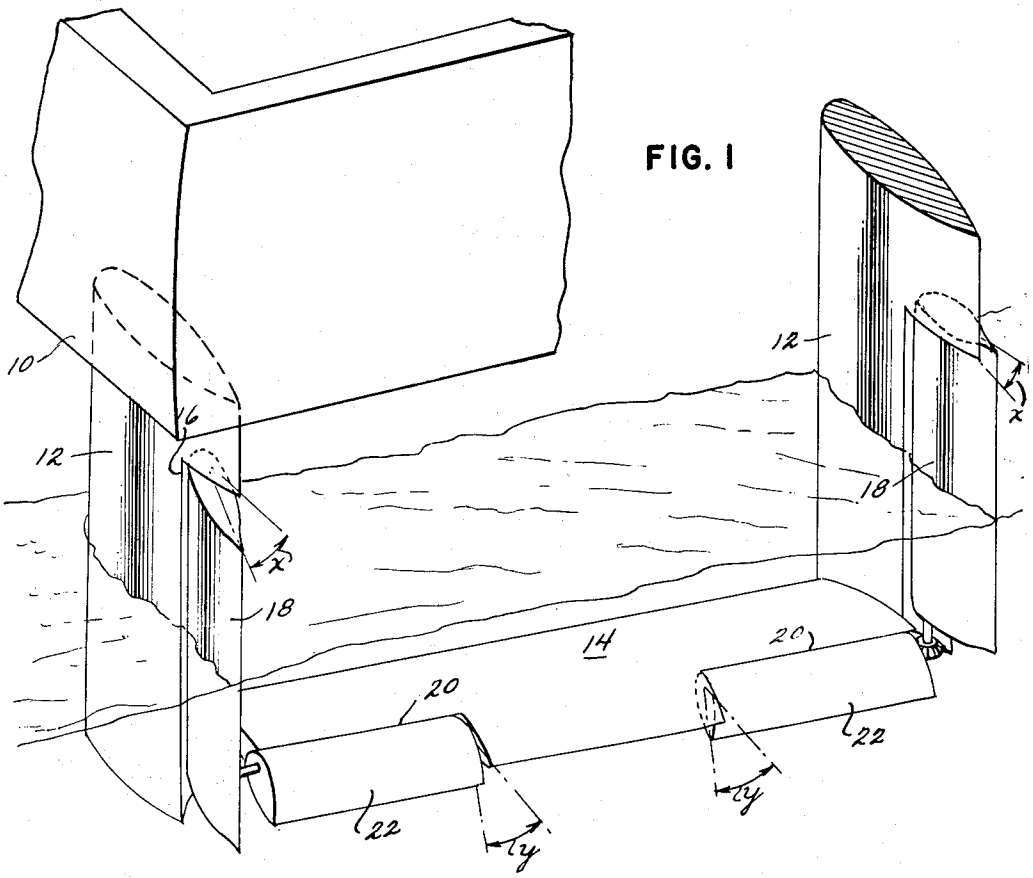
June 12, 1956 P. A. SCHERER ET AL 2,749,871

FLAP DEPTH CONTROL FOR HYDROFOIL CRAFT

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FIG. 1



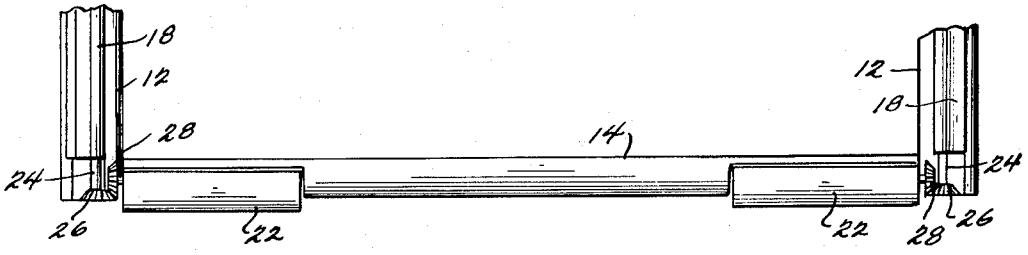


FIG. 2.

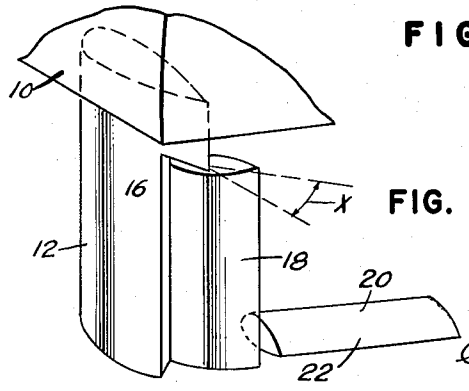


FIG. 1A

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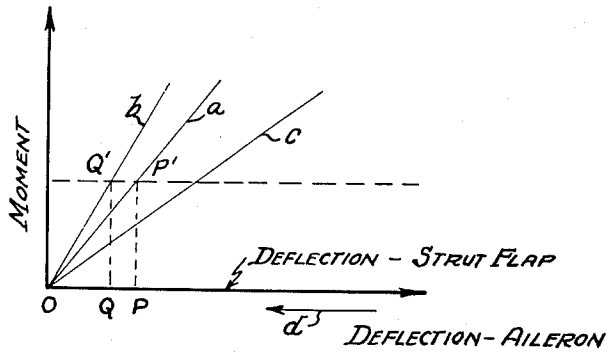
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FLAP DEPTH CONTROL FOR HYDROFOIL CRAFT

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FIG. 3



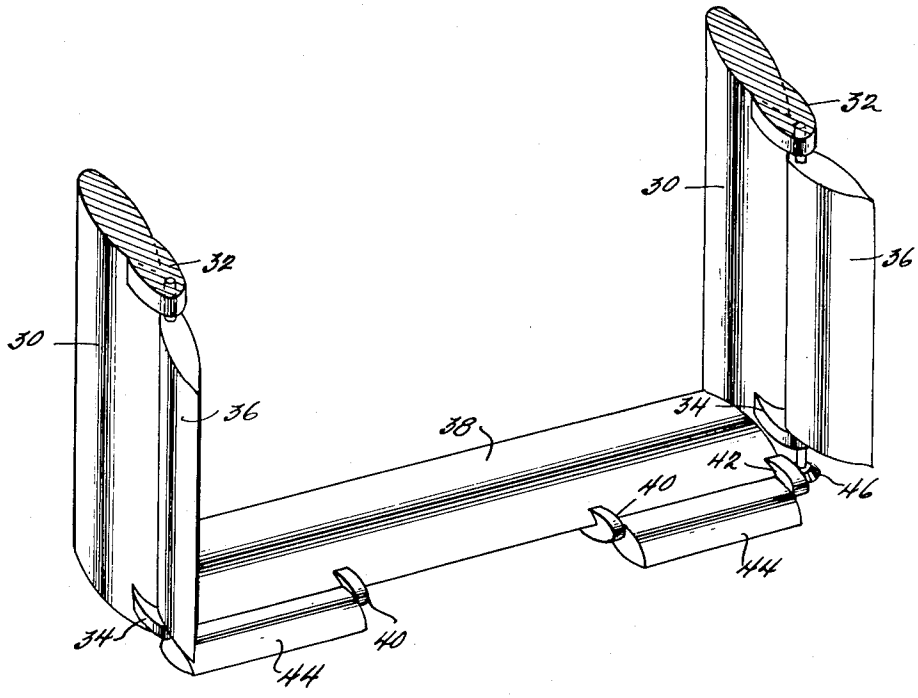


FIG. 4.

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2,749,871

FLAP DEPTH CONTROL FOR HYDROFOIL CRAFT

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Application September 12, 1952, Serial No. 309,224

11 Claims. (Cl. 114—66.5)

This invention pertains to hydrofoil craft, and more particularly to improvements in the mechanism for achieving proper depth control (submergence) of the hydrofoil.

The term "hydrofoil craft," as is well understood in the art, refers to water-borne vessels whose main hull or cargo structure is, during normal operation, supported well above the surface of the water by means of a submerged foil or foils, connected to the hull by one or more normally vertical supporting struts. Such craft offer numerous advantages over other types of surface craft, among which are increased efficiency, speed and maneuverability. For optimum operation, however, it is necessary to provide for maintaining the depth of submergence of the hydrofoil itself at the proper value, and various means for accomplishing this result have been proposed.

It is a principal object of the present invention to provide a hydrofoil depth control arrangement which will operate automatically to maintain the submergence of the main foil at the desired or design level, and such that accidental or fortuitous deviation from this level will be automatically corrected.

A further object of the invention is to provide an arrangement of the above type in which all of the operating parts of the depth control mechanism can be located at or near the main foil and its vertical struts, so that no control mechanisms extending upward to the hull are required.

Another object of the invention is to achieve an automatic depth control of the above type by very simple mechanical means which are self-operating in the sense that no special power supply is required; the energy required for operation of the mechanism is derived from the energy of the travelling vessel.

Yet another object of the invention is to provide a depth control for hydrofoils which is especially well adapted for small craft, in which the lift to drag ratio is of secondary importance, and in which the simplicity of construction and operation of the control system are particularly desirable.

A further object of the invention is to provide a craft of this type with a plurality of sets of related vertical flaps and ailerons, so disposed that a degree of automatic levelling of the craft is obtained, e. g., in athwartships and/or fore-and-aft directions.

The above and other objects and advantages of the invention will best be understood from the following detailed specification of certain preferred and exemplary embodiments thereof, given for purposes of illustrating the principles of the invention, and from the accompanying drawings, in which:

Fig. 1 is a view in perspective, with parts broken away, of a preferred form of the invention, shown in operating condition,

Fig. 1*a* is a fragmentary perspective view, similar to Fig. 1, but showing the vertical flaps deflected inwardly,

Fig. 2 is an end view, in elevation, of the same structure,

Fig. 3 is a moment diagram illustrating the principle of the invention, and

Fig. 4 is a view similar to Fig. 1 but showing a modified form of the invention.

In general, the present invention accomplishes automatic depth control of the main hydrofoil by providing movable vertical flaps on or at the main vertical supporting struts, and connecting these flaps for control of the positioning of a pair of ailerons pivoted on or near the ends of the main hydrofoil. The vertical heights of the vertical flaps are such that, with the craft in a normal state of submergence of the main foil, the flaps cut the surface of the water, and matters are arranged so that, when the instantaneous submergence of the craft is that for which the foil system is designed (which condition may be called briefly "the design point"), the vertical flaps are slightly deflected outwardly from the straight position. Also, the ailerons on the main foil are arranged to be not deflected at all or else slightly deflected downward at the design point, and connections are provided between the flaps and their respective corresponding ailerons so that an increase of flap deflection will correspond to a decrease in the downward deflection of each aileron.

Referring now more particularly to the embodiment of the invention shown in Figs. 1 and 2, the hull or main structure of a hydrofoil craft is shown in chain lines and designated generally by reference numeral 10. The particular configuration or design of the hull is not indicated in detail, since it forms no part of the present invention, it being understood that in normal operation or flight this hull is supported clear of the surface of the water. In the embodiment shown, this support is provided by a pair of vertical struts 12, suitably profiled in accordance with well-known hydrodynamic principles, and connected at their lower ends by the main hydrofoil 14. As is well known, this hydrofoil is designed to provide, during forward motion of the draft, sufficient lift to maintain the hull 10 above the water surface; the forward motion may be achieved in various ways, such as by air or water screws, which again do not form part of the present invention and hence need not be shown or described in detail.

In the operation of craft such as just described, different conditions of air and water, and variations in the forward speed of the craft, result in changes in the effective lift of the foil 14, so that it is desirable to provide means by which the submergence of the foil, and hence the height of the hull above the effective water surface, may be maintained approximately constant.

Each of the struts 12 in Fig. 1 has a portion of its trailing edge cut out as indicated at 16, and in the space produced there is pivotally mounted a flap 18, whose profile may correspond more or less to that of the cut-out section of the strut. The pivotal axes of these flaps may be vertical, and each flap has a vertical height such that, in normal operation, a portion of the flap extends above the water-line, as shown in Fig. 1. Opposite extremities of the trailing edge portions of the main hydrofoil 14 are also cut away, as indicated at 20, and ailerons 22 are pivoted on horizontal axes in these cut-outs. The ailerons 22 as such are those commonly used for lateral control and control of submergence, and may be profiled to correspond to the shape of the foil 14.

In accordance with the present invention, means are provided for correlating the movements of the flaps 18 and the ailerons 22. Thus, and as has been intimated, matters are so arranged that flaps 18 are slightly outwardly deflected when the foil 14 is at normal submergence, and hence during forward motion they will be subject to a torque about their vertical axes. As best seen in Fig. 2, each flap has a vertical axle or shaft 24, and is connected with its corresponding aileron 22 so that rotation of either flap will also rotate the correspond-

ing aileron independently of the other. For example, and as shown, the connection may comprise bevel gears 26 and 28 on the shafts of the flaps and ailerons respectively, and this connection is arranged so that an increase in flap deflection produces a decrease in the deflection of the corresponding aileron. It is of course to be understood that the bevel gearing shown is merely for purposes of illustration, since the connection between flap and aileron may comprise other types of gearing, cams, levers and equivalent means. Also, the transmission ratio of the gearing or connection need not be 1:1. To protect the gearing and prevent fouling, suitable housings for the gearings will be provided, these being omitted from the drawings for clarity.

The operation of the invention will best be understood from a consideration of the diagram in Fig. 3, which is based upon a 1:1 gearing between flaps and ailerons, and upon the assumption that the pivot axes of the flaps are well forward of their aerodynamic centers. The ordinates in this diagram are values of the torque exerted upon the flap axles, and the abscissas represent flap deflections. The horizontal dash line represents the aileron torque, which will be independent of aileron deflection if the ailerons are pivoted on their aerodynamic centers, which is here presumed merely in order to clarify the explanation. The line *a* of the diagram represents the relation between flap deflection and flap moment at the design point; that is, when the instantaneous submergence is that for normal operation. Line *b* represents the relation when the submergence is greater than design submergence, while line *c* represents the relation when the submergence is smaller than normal. From the diagram, and considering first the case in which the actual submergence is equal to the design submergence, it will be seen that a stable equilibrium is achieved when the flap moment equals the aileron moment (these two elements being coupled for opposite deflectional changes), or when the flap moment line *a* intersects the horizontal aileron moment line; that is, at point P'. The value of strut-flap deflection corresponding to this condition is indicated at point P. If, instantaneously, the flap deflection should too small (for instance), and hence the aileron deflection too large, as compared with equilibrium, the aileron moment will exceed the flap moment, and will accelerate the system in such a direction that the aileron deflection will be reduced until equilibrium is again reached. The arrow *d* in Fig. 3 signifies that the aileron deflection decreases when flap deflection increases.

Supposing now that the actual submergence momentarily exceeds the design submergence, the amount of the flap under water will be increased, increasing the flap torque, and equilibrium will be shifted to point Q' on line *b*. The aileron deflection (point Q) will therefore be increased, which is what is required to restore the correct submergence. A similar analysis shows that a decrease in submergence with respect to the design point will reduce aileron deflection (line *c*) and also restore the correct submergence. The lift of the flaps does not need to be large. The flaps themselves should be fairly large, and hence lightly loaded, in order to avoid spray where they pierce the surface.

It has been stated above that the normal ("design") position of the flaps 18 is slightly outwardly of the fore-and-aft axes of the corresponding struts 12; this is indicated in Fig. 1 by the angles *x*, the angles *y* indicating the corresponding aileron deflections. The outward deflection of the flaps will tend to reduce the induced drag of the hydrofoil 14. However, in some cases it might be preferable to use flaps which are deflected inwardly, as shown in Fig. 1*a*; if turns are made, the rudder action will then be amplified by the flap-deflections, rather than counteracted. In the embodiment described, the foil 14 is assumed to be forward of the center of gravity of the craft as a whole.

The flaps 18 and ailerons 22 in the embodiment of

Figs. 1 and 2 have been described respectively as movable sections of the main struts and foil; however, it is clear that either the flaps or the ailerons, or both, could equally well be independent foils. Thus, where the term "hydrodynamic member" is employed herein, this refers either to foil or flap mounted co-extensively with the strut and forming a part of the streamline configuration thereof or alternatively a movable foil which is physically set apart from said strut. As shown in Fig. 4, for example, the supporting struts 30 could be provided with upper and lower mounts 32 and 34 between which the vertical flaps 36 are pivoted. Likewise, the main foil 38 could be provided with supports, lugs or the like 40 and 42, between which the ailerons 44 are pivoted as independent foils. A connection 46 between flap and aileron, operating as described in the first embodiment, is also shown in this figure.

It has been stated above that the flaps 18 and 36 are pivoted well forward of their aerodynamic centers; with this arrangement, any failure of the connections or linkages to the ailerons will merely permit them to return to zero-lift condition, so that they "fail safe." It was also stated that for simplicity of the disclosure, the ailerons were considered as pivoted in their aerodynamic centers; however, as a practical matter, these also could be pivoted forward of the aerodynamic center, so that fail-safe operation of the ailerons as well will be achieved.

While, for purposes of the present disclosure, the connected flaps and ailerons have been treated as the sole means for control of submergence, supplemental manual or automatic control could also be utilized in conjunction therewith. Thus, the vertical control surfaces could be used to superimpose a relatively small force upon a larger force exerted by a spring or like device, the latter force being substantially constant.

In the above discussion, matters have been treated as though changes in submergence occurred uniformly at both lateral sides of the craft; that is, that both struts 12 in Fig. 1 moved (or tended to move) upward or downwardly at the same time, the craft maintaining a level condition athwartships. Clearly, since the operation of the flap and aileron combination at each side of the craft is independent of the operation of the combination at the other side, the arrangement will also provide automatic levelling of the craft in the event some occurrence should alter the equality of submergence of the two vertical struts. Such an occurrence might be, for example, a shift in the loading of the craft, although other factors such as wave action might tend to create such a condition. The invention therefore provides an automatic levelling feature which will be of distinct advantage in many cases. Also, if, for example, there are two main hydrofoils displaced in the fore-and-aft direction, the independence of the separate pairs of vertical flaps and their corresponding ailerons will provide a degree of fore-and-after level control. In short, the device as disclosed not only controls total lift supplied by foil 14, but also differential lift forces on each of the vertical struts such as 12.

While the invention has been disclosed herein in connection with particular embodiments and specific structural details, it is clear that numerous changes and modifications could be made by those skilled in the art, without departing from the spirit of the invention and the scope of the appended claims.

We claim:

1. A hydrofoil craft comprising a hull, at least one hydrofoil connected thereto, an aileron adjustably mounted on said hydrofoil, a movably mounted hydrodynamic member carried by said craft in position to pierce the surface of the water during operation of the craft, said member having its chord line angularly deflected from the forward direction of said craft during operation at a predetermined design value of submergence and means interconnecting said hydrodynamic member

and said aileron for adjusting the angle of attack of said aileron responsive to torque on and movement of said hydrodynamic member to control the submergence of said main hydrofoil.

2. A hydrofoil craft as claimed in claim 1 and wherein an aileron is adjustably mounted at each end of said hydrofoil, a pair of said hydrodynamic members, each said aileron being adjustable through the said interconnecting means responsive to torque on respective ones of said hydrodynamic members.

3. A hydrofoil craft comprising a hull, at least one hydrofoil, at least one hydrodynamic strut connecting said hull and said hydrofoil, ailerons adjustably mounted at opposite ends of said hydrofoil, a hydrodynamic member carried by said strut in position to pierce the surface of the water during operation of said craft, said vertical member having its chord line angularly deflected from the forward direction of said craft during operation at a predetermined design value of submergence, and connections between said hydrodynamic member and said ailerons to adjust the deflections of said ailerons in accordance with the torque exerted upon said hydrodynamic member.

4. A hydrofoil craft as claimed in claim 3 and wherein said hydrodynamic member has its chord line deflected outwardly from the forward direction of said craft.

5. A hydrofoil craft as claimed in claim 3 and wherein said hydrodynamic member has its chord line deflected inwardly from the forward direction of said craft.

6. A hydrofoil craft comprising a hull, a hydrofoil, a pair of struts connecting said hull and said hydrofoil, ailerons adjustably mounted at opposite ends of said hydrofoil, a hydrodynamic member carried by each of said struts in position to pierce the surface of the water during operation of said craft and being pivotally mounted, said hydrodynamic members having their chord lines deflected angularly from the forward direction of said craft during operation at a predetermined design value of submergence, and connections between each

hydrodynamic member and its corresponding aileron to adjust the deflections of said ailerons in accordance with the torques exerted upon said hydrodynamic members and the resultant rotation thereof.

7. A hydrofoil craft in accordance with claim 6, in which each of said hydrodynamic members is pivoted upon a vertical axis forward of its aerodynamic center.

8. A hydrofoil craft in accordance with claim 6, in which said hydrodynamic members constitute movable sections of their respective struts.

9. A hydrofoil craft in accordance with claim 6, in which said ailerons constitute movable sections of said hydrofoil.

10. A hydrofoil craft in accordance with claim 6, in which said connections comprise means for increasing the deflection of each aileron in response to an increase in the torque developed by its corresponding hydrodynamic member and the resultant rotation thereof.

11. In a hydrofoil craft comprising a hull and at least one hydrofoil suspended from said hull, independent sets of lift-control elements mounted at spaced apart portions of said hydrofoil, each set comprising a surface-piercing hydrodynamic member and an aileron connected thereto for rotation in accordance with the moment of said hydrodynamic member, each said hydrodynamic member having their chord lines angularly deflected from the forward direction of said craft during operation at a predetermined design value of submergence, whereby differences in submersion of different parts of said hydrofoil are independently compensated by said sets of elements.

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