May 1, 1962 J. BADER 3,031,999

ADJUSTABLE HYDROFOIL

Filed Oct. 7, 1959 2 Sheets-Sheet 1

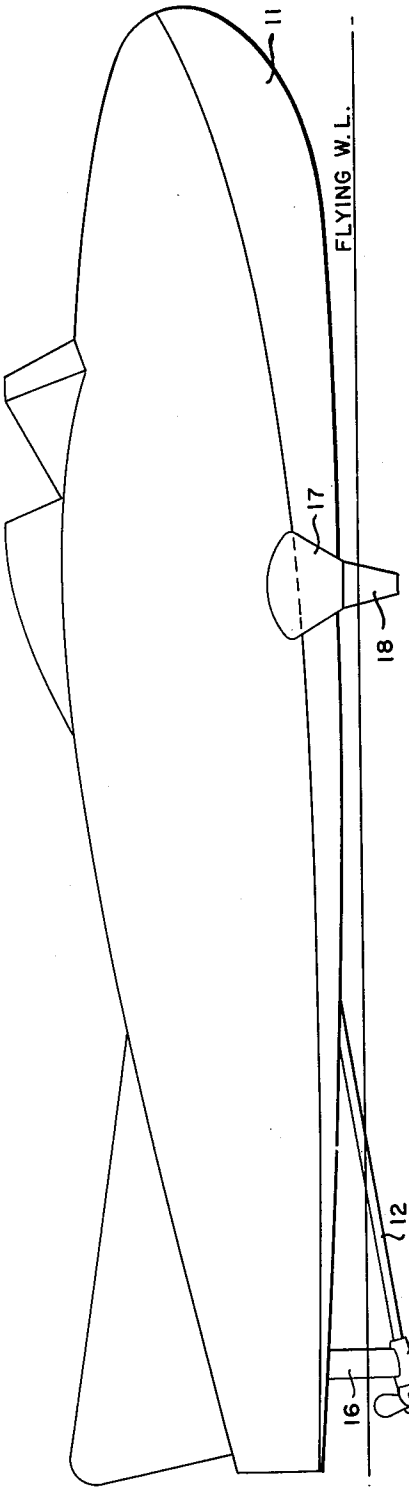


FIG. 1.

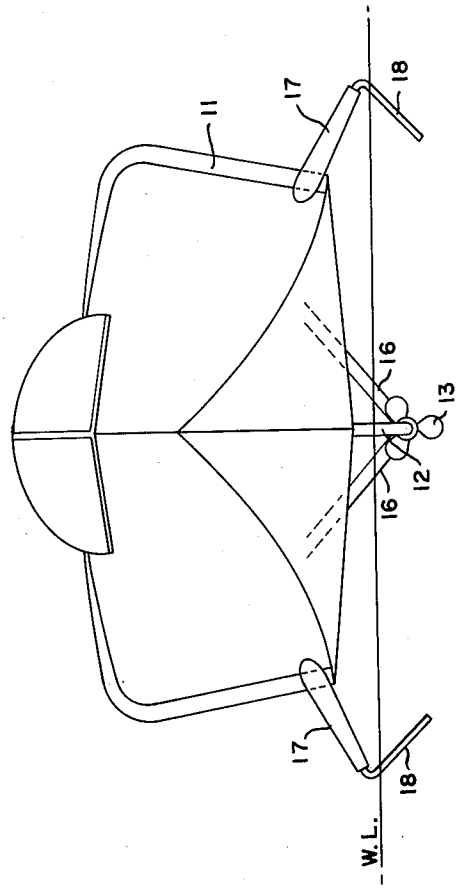


FIG. 2.

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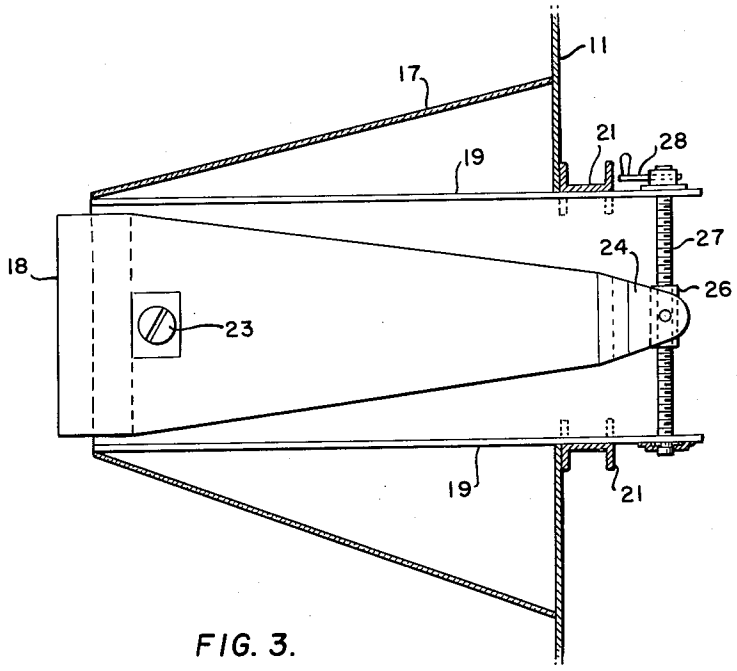


FIG. 3.

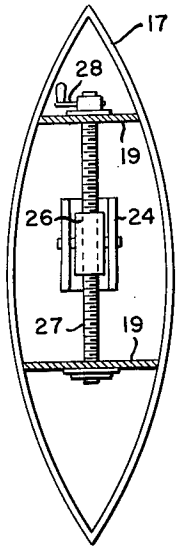


FIG. 5.

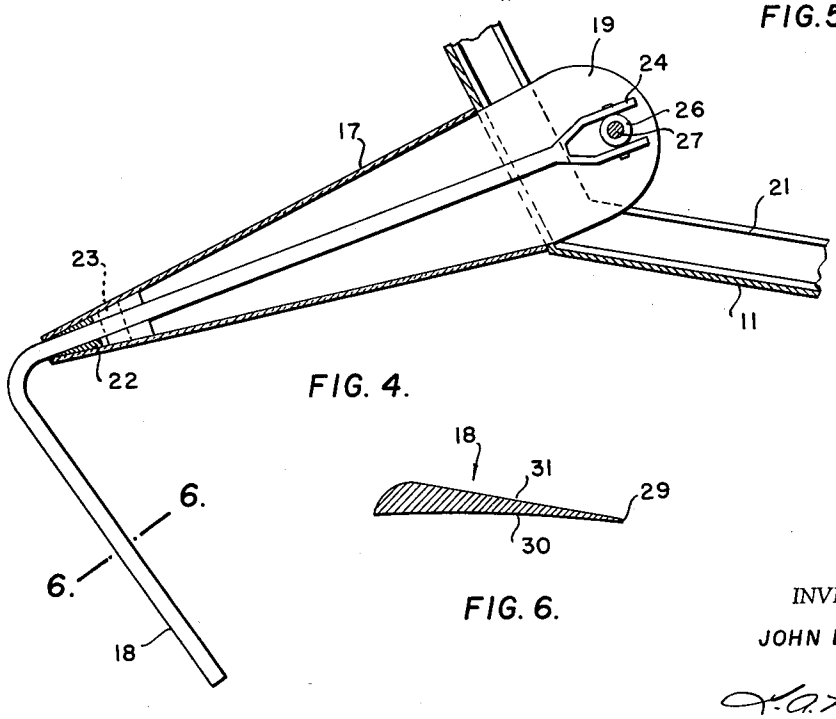


FIG. 4.

FIG. 6.

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ADJUSTABLE HYDROFOIL

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to adjustable hydrofoils and more particularly to an adjustable hydrofoil system for high speed craft wherein the propeller struts act as after foils and the angle of attack of the forward foils is adjustable.

It is well known in the design of high speed boats that the performance of such craft can be greatly improved with the use of hydrofoils. In general, hydrofoils on the forward portion of the hull are cantilevered outward directly from the hull. The after portion of such a craft usually has a second fixed hydrofoil mounted on the after portion of the hull and a propeller supporting structure carried below the hull to place the propeller below the flying water line.

As a hydrofoil boat comes up to flying speed, maximum lift is required to allow take-off since the drag on the boat prevents reaching maximum speed until after take-off. After flying speed has been reached the reserve lift which was required for take-off is no longer necessary and excessive angle or area of the hydrofoils is detrimental in that excessive drag is produced. For this reason, fixed angle hydrofoils do not allow optimum operation.

Further, with regard to the conventional hydrofoil boat described above, the propeller supporting structure, which necessarily extends into the water, creates additional drag which also detracts from optimum operation of the craft.

In some craft, no after hydrofoil is provided; in this case the planing action of the hull is relied upon to provide lift aft. Again, however, a supporting structure must be provided for the propeller and again additional drag is imposed by the supporting structure.

Another disadvantage which is incurred by the use of cantilevered foils projecting outward directly from the hull is lack of stability when foil-borne. The stability of a foil borne boat can be approximated by drawing perpendiculars to the foils at the points where the foils intersect the water. For stability, the intersection of such lines from each side should be above the center of gravity of the boat.

There are also in use several types of hydrofoil boats wherein the hydrofoils are cantilevered from the hull but are made adjustable so that the angle of attack may be varied. This partially solves the problem by providing optimum lift under varying conditions. However, these known devices require complicated control systems and necessarily suffer from structural deficiencies. In general, the problem of maintaining stability remains.

The present invention provides a pair of forward foils which are made adjustable by simple mechanism and are supported away from the hull by sponsons securely connected to the hull framing. The after hydrofoil is the propeller mounting structure shaped in the form of a lifting hydrofoil. The lift of the after hydrofoil is varied by adjusting the angle of attack of the forward foils and thereby varying the trim of the boat. The system has a minimum of drag while providing adjustable lift and a greater degree of stability than can be obtained with known craft.

It is thus an object of this invention to provide an adjustable hydrofoil which is strong but light in weight.

Another object is the provision of a relatively simple mechanism for adjusting the lift of a hydrofoil system by changing its angle of attack.

A further object is to provide a hydrofoil system wherein the propeller struts form the after hydrofoil.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a side elevational view of a craft utilizing a preferred embodiment of the invention;

FIG. 2 is a front elevational view of the embodiment of FIG. 1;

FIG. 3 is a top plan view, partly in section, of the support and adjusting mechanism for the forward foils of the embodiment shown in FIG. 1;

FIG. 4 is a front view, partly in section, of the details shown in FIG. 3;

FIG. 5 is an end view, partly in section, of the details shown in FIG. 3; and

FIG. 6 is a cross-sectional view taken on the line 6—6 of FIG. 4 showing the shape of the forward hydrofoils.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1 (which illustrates a preferred embodiment) a hull **11** adapted to be propelled through the water by a propeller **13** mounted at the end of a propeller shaft **12**. Supporting propeller **13** at a bearing **14** are a pair of hydrofoil shaped supports **16** fixed to hull **11** near the stern.

Affixed to the forward portion of hull **11** are a pair of sponsons **17** which support main hydrofoils **18**. As can be seen in FIGS. 3 through 5, sponsons **17** are rigidly supported by a pair of internal webs **19** secured to the internal framing **21** of hull **11**.

Hydrofoil **18** extends through sponson **17**, being clamped at its outer end in a clamp bearing **22** and pivotable around a pin **23**. The inner end of the hydrofoil forms a lever arm having a fork **24** which is pivotably connected to a nut **26** positioned between the two fork members. Nut **26** engages a worm **27** which spans the distance between sponson webs **19** at a point inside the hull.

Worm **27** is adapted to be rotated by means of a crank **28**. Alternatively the worm may be rotated by means of a motor or the like (not shown) or in place of a worm a hydraulic cylinder might be used to adjust the position of fork **24**.

It will be realized that at low speeds, hydrofoil equipped boats operate with virtually the same draft as conventional craft. However, as the boat gathers speed the hydrofoils lift the hull clear of the water.

At rest, a portion of hull **11** of the present invention lies below the waterline. As propeller **13** is driven, the boat moves forward through the water and begins to gain speed. Obviously with a large portion of the hull in the water plane, a great drag is experienced making acceleration difficult. For this reason, the hydrofoils are adjusted for maximum lift to raise the hull clear of the water.

Worm **27** is turned moving nut **26** and with it the forked end **24** of foil **18**. The foil pivots around pin **23** and slides in bearing **22**. The pivoting action of foil **18** adjusts the lifting portion to give a large angle of attack and maximum lift. This causes the forward section of the boat to rise from the water at relatively low speeds. To further aid the forward hydrofoils in initial lift the sponsons **17** are also designed to act as lifting hydrofoils before take-off.

The supports **16** for propeller **13** are also in the form of lifting hydrofoils. As the forward portion of the boat is lifted clear of the water, the angle of attack of the propeller support members is increased giving them greater lift and causing the after portion of the hull to rise above the water when sufficient speed is reached. Since the supports act as lifting hydrofoils the additional drag incurred with conventional propeller supports is reduced considerably.

With the entire hull above the water line as seen in FIGS. 1 and 2, the angle of attack on the forward foils which speeded take-off becomes unnecessary and causes additional drag. To remedy this, worm **27** is rotated in the opposite direction to cause the foil to pivot around pin **23** and decrease the angle of attack thus allowing still greater speed.

In order to lessen the drag still more, the cross-section of the forward foil as seen in FIG. 6 is a supercavitating section.

The supercavitating section is based on the principle that an infinitely thin hydrofoil having a given small angle of attack and sufficient speed will have a cavitation bubble on the negative pressure side of the foil extending from the leading edge to a point beyond the trailing edge. The cavity, of course, will be infinitely thin at the leading edge and increase in thickness until it reaches the point of collapse. It has been found that material may be added to the negative pressure side of the foil to give it increased strength as long as the thickness of the foil at any point is less than the thickness of the cavity. Of course this has a practical limitation at the leading edge since an infinitely thin leading edge is impossible in practice, but in tests it has been found that a section with practical dimensions can still be used to great advantage.

The principal advantage of the supercavitating foil section is in a reduction of the friction which would otherwise be produced by turbulence and small cavities on the negative pressure side of the conventional foil.

The section shown in FIG. 6 is designed so that a cavity will form at leading edge **29** and encompass the entire negative pressure side **31** of the foil while no cavitation will be experienced by the pressure side **30**. It will be realized that since foils **18** extended through the surface of the water air will be carried into the cavity thus creating full cavitation at lower speeds and further reducing drag.

It will also be noted from FIGS. 2 and 4 that the hydrofoils enter the water at an angle. It is known in the art that the stability of a foil borne boat can be determined by drawing perpendiculars to the foils at the flying water line. For stability the intersection of the perpendiculars should be above the center of gravity of the boat. The present invention utilizes sponsons to space the forward foils from the centerline of the boat and the foils have an inboard slope thus lending a large degree of stability to the craft.

It will be realized that a large amount of stress appears at the joint between sponsons **17** and foils **18** since the foils are centilevered from the sponsons. However, clamp **22** in addition to allowing pivotal motion of foil **18** also distributes the stress over a relatively large area compared with the area of a welded connection at this point and reduces the cross-section of the foil which would be required for the same maximum allowable stress if a welded connection were utilized.

Although a specific sponson shape is shown in the figures it will be realized that a variety of sponson shapes may be utilized with the invention, and the hull shape may also be varied. For example, the conventional three point type of racing hull might be utilized with the hydrofoils attached to the side sponsons of the hull.

Thus there has been described a preferred embodiment of a hydrofoil equipped boat which incorporates simplicity of operation with optimum stability, lift, and drag characteristics.

Obviously many modifications and variations 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. A hydrofoil craft comprising a hull having an internal frame, a forward portion, and an after portion; a propeller, propeller support means mounted on the after portion of said hull said propeller support means having the shape of a lifting hydrofoil; a pair of angle-shaped forward hydrofoils, a pair of hydrofoil support means for mounting said forward hydrofoils, each of said hydrofoil support means comprising a web member having a first end and a second end and secured at said first end to said internal frame of said hull, a sponson having the shape of a lifting hydrofoil and being attached to said hull and said web member, a clamp-bearing clamping one of said hydrofoils and being fixedly mounted at said second end of said web member, and a pivot pin passing through one of said hydrofoils and said sponson whereby one leg of said angle-shaped hydrofoil passes through said clamp bearing and is in rotatable engagement with said pivot pin; and adjusting means for rotating said one leg of said hydrofoil about said pivot pin whereby the angle of attack of said hydrofoil may be varied.

2. The invention as defined in claim 1 wherein said one leg of said hydrofoil has a forked end and said adjusting means comprises an internally threaded ball-nut secured between the two portions of said forked end, a screw passing through said ball-nut, and means for turning said screw.

3. A hydrofoil craft for operation in water comprising a hull having a forward portion and an after portion, a propeller, hydrofoil shaped support means for mounting said propeller on the after portion of said hull, a pair of forward hydrofoils, adjustable means for mounting said forward hydrofoils on opposite sides of the forward portion of said hull, a hydrofoil shaped sponson over each of said adjustable means whereby said hydrofoil shaped sponson aids initially in lifting said hull clear of said water, said adjustable means including a pair of lever arms each having an inner end extending from one of said forward hydrofoils through one of said sponsons and means for moving said inner end of said lever arm in a direction longitudinally of said hull to thereby adjust the angle of attack of said hydrofoils.

4. The invention as defined in claim 3 wherein said forward hydrofoils have an inboard slope.

5. The invention as defined in claim 4 wherein said forward hydrofoils have a supercavitating cross-section.

6. A high speed boat comprising a hull having an internal framework, a pair of hydrofoils each having a supercavitating cross-section and each having an adjusting arm extending into said hull at opposite sides thereof, a pair of sponsons each shaped as a lifting hydrofoil and each pivotally clamping the outer end of said adjusting arm and enclosing the portion of said adjusting arm between said clamped portion and said hull, said sponsons being supported by the internal framework of said hull, and means for pivoting said adjusting arms by movement of the inner ends of said arms longitudinally of said hull to adjust the angle of attack of said hydrofoils.

7. The invention as defined in claim 6 wherein said sponsons project outboard from said hull and said hydrofoils have an inboard slope.

8. A hydrofoil craft comprising a hull having an internal frame, a forward portion and an after portion; a propeller, a propeller shaft mounting said propeller, a pair of hydrofoil shaped propeller supports attached at their outer ends to said after portion of said hull, the inner ends of said propeller supports supporting said propeller shaft; a pair of forward hydrofoils each comprising a supporting portion disposed in angular relationship to

a lifting portion having a supercavitating cross-section and an inboard slope, a pair of hydrofoil support means for mounting said forward hydrofoils, each of said hydrofoil support means comprising a web member secured at one end to the internal frame of said hull, a sponson having the shape of a lifting hydrofoil and being attached to said hull and said web member, a clamp bearing fixedly mounted at the other end of said web member and slidably clamping one of said forward hydrofoils, and a pivot pin passing through said one of said hydrofoils and said sponson whereby the hydrofoil may be pivoted around said pivot pin; said supporting portion of said one of said hydrofoils having a forked end, an internally threaded ball nut pivotably mounted between the two portions of said forked end, an adjusting screw passing through said ball nut in engagement therewith, and means for turning said adjusting screw.

9. The invention as defined in claim 3 wherein said lever arm is forked at its inner end and said means for moving said inner end of said lever arm comprises an internally threaded ball-nut secured between the two portions of said forked end, a screw passing through said ball-nut in engagement with the internal threads thereof, and means for turning said screw.

10. The invention as defined in claim 6 wherein said means for pivoting said adjusting arms comprises a forked end on each of said adjusting arms, an internally threaded ball-nut pivotally secured between the two portions of said forked end, a screw passing through said ball-nut in engagement with the internal threads thereof, and means for turning said screw.

11. A high speed boat comprising a hull having an

internal framework, a pair of forward hydrofoils each having an adjusting arm extending into said hull at opposite sides thereof, a pair of sponsons each shaped as a lifting hydrofoils and each pivotally clamping the outer end of said adjusting arm and enclosing the portion of said adjusting arm between said clamped portion and said hull, said sponsons being supported by the internal framework of said hull, means for pivoting said adjusting arms by movement of the inner ends of said arms longitudinally of said hull to adjust the angle of attack of said forward hydrofoils, a pair of angularly disposed lifting hydrofoil shaped support members each having one end thereof attached to said hull, and a propeller housing affixed to the opposite ends of said support members.

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