United States Patent

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[54] **SAILBOAT HYDROFOILS**
6 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** .... **114/39,** 114/66.5 H
[51] **Int. Cl.** **B63h 9/00,** B63b 1/18
[50] **Field of Search** .... 114/39, 66.5 H, 66.5 R

[56] **References Cited**

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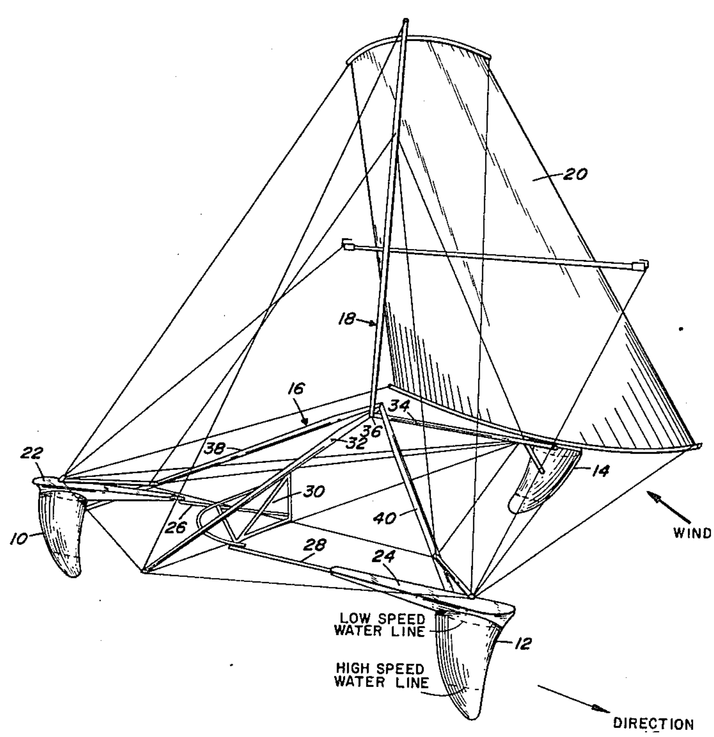
ABSTRACT: A hydrofoil craft having curved buoyant hydrofoils supporting a light frame which is driven by sail. During high winds the curved hydrofoils prevent the craft from "jumping" out of the water by creating a reverse or negative lift and in effect "hooking" the water.



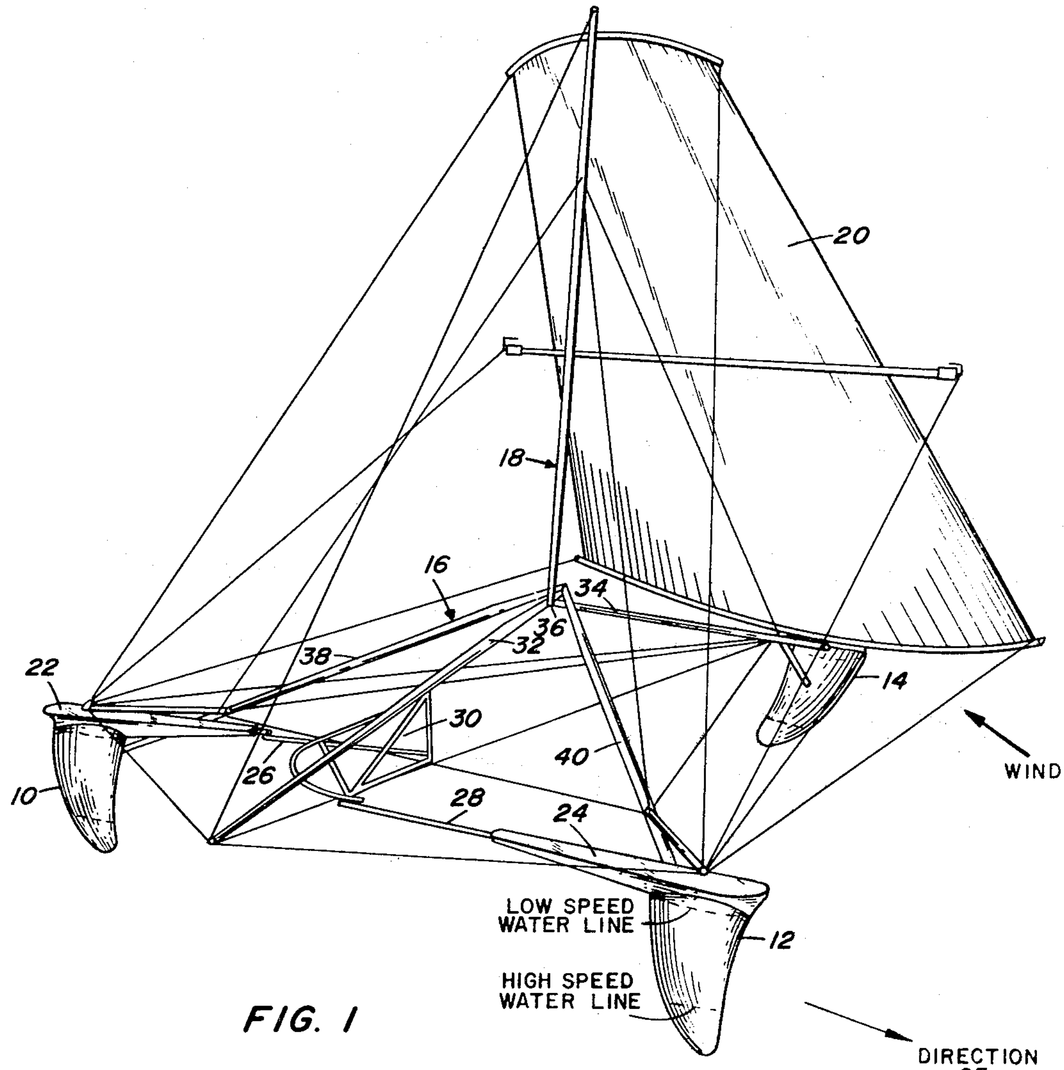


FIG. 1

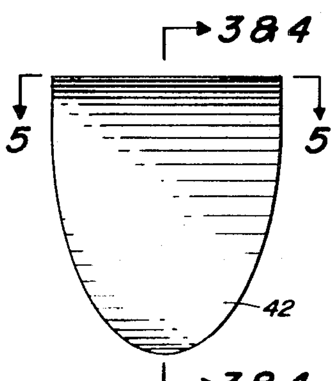


FIG. 2

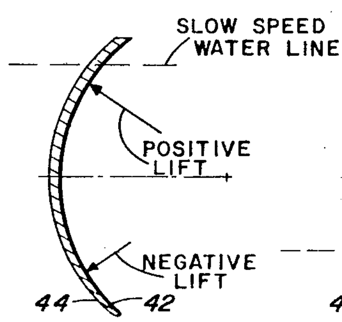


FIG. 3

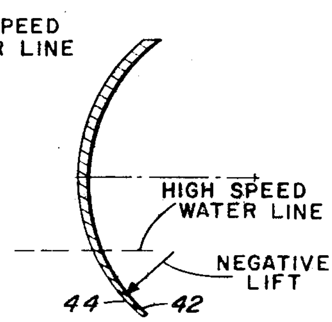


FIG. 4

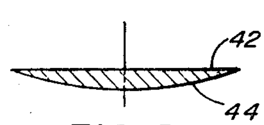


FIG. 5

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SAILBOAT HYDROFOILS

STATEMENT OF GOVERNMENT INTEREST

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.

BACKGROUND OF THE INVENTION

The present invention relates generally to improvements in hydrofoil sailboats and more particularly it pertains to sailboats having curved hydrofoils to improve sailing performance.

In the field of hydrofoil sailboats, it has been the general practice to employ hydrofoils that are straight along a vertical cross section and have a symmetrical foil-shaped end cross section. These foils have a flat inward surface and a curved outer surface. The passage of the foils through the water generates a lift force off of the curved surfaces which acts substantially perpendicular to the plane of the foil. The advent of the hydrofoil gave the capacity to raise the hull out of the water and thereby greatly reduce the drag of the hull. However, enough speed had to be attained to create a sufficient lift force to lift the hull from the water. Thus, such devices are only satisfactory if the wind is sufficiently strong to produce such a speed. However, during strong winds another obstacle to improved sailing performance has been encountered—lack of stability. The driving force acting at the center of pressure of the sail area creates a force tending to overturn the sailboat during high winds. Also, the sailboat tends to "jump" out of the water because the foils lift too far out of the water during these strong winds. To reduce or eliminate the overturning moment and the "jumping" behavior, various configurations of nonvertical sails and/or inclined submerged planes have been utilized. These attempts, though increasing stability, have not been completely successful because the foils still tend to lift too far out of the water.

The above disadvantages are overcome by the present invention which provides a hull-less craft having buoyant hydrofoils that are curved along a vertical cross section as well as having a flat inward surface and a curved outer surface.

SUMMARY OF THE INVENTION

The general purpose of this invention is to provide a highly stable hydrofoil sailboat with a greatly increased speed potential. The curved hydrofoils of the present invention permit the aerohydrofoil craft to operate in much higher winds with greater stability than ever before. The new foils yield high positive lift in low winds and, with increasing wind strength the foils automatically adjust to the changing conditions to provide the correct amount of immersion for the driving foils. During high winds the curved hydrofoils prevent the boat from "jumping" out of the water by creating a reverse or negative lift and in effect "hooking" the water.

To provide stability the two windward hydrofoils are shaped to automatically provide lift forces and restoring moments in accordance with wind strengths. One leeward foil automatically adjusts lift direction to provide restoring moments in proportion to overturning moments.

The buoyancy of the hydrofoils allows a hull-less hydrofoil watercraft to be used. The hydrofoils serve not only as lifting foils but also provide the necessary buoyancy normally contributed by the hull while the craft is at rest. This arrangement decreases drag and thereby greatly increases speed potential.

OBJECTS OF THE INVENTION

An object of the present invention is the provision of a hydrofoil sailboat with improved sailing performance.

Another object is to provide a hull-less hydrofoil craft with a greatly increased speed potential.

A further object of the invention is the provision of a highly stable sailboat to prevent overturning moments and "-jumping" in high winds.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the hydrofoil sailboat of this invention;

FIG. 2 illustrates a side elevation of a hydrofoil of the present invention;

FIGS. 3 and 4 show a section of the hydrofoil taken on the line 3—4 of FIG. 2 looking in the direction of the arrows; and

FIG. 5 is a sectional view of a hydrofoil taken along the end cross section on line 5—5 of FIG. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring in detail to FIG. 1 of the drawing, essentials comprise hydrofoils **10**, **12**, **14**, constructed and oriented to produce certain desired forces, a frame **16** for maintaining the hydrofoils in spatial relationship, and means for applying a propelling force to the frame and its attached hydrofoils, such as a mast **18** secured to the frame and a sail **20** secured to the mast. Hydrofoils **10**, **12** and **14** provide both the buoyant and dynamic support for the sailboat. The hydrofoils differ from those employed with hydrofoil boats having buoyant hulls in that they provide the entire buoyant supporting forces for the craft when it is at rest. When in motion, however, they produce lift forces, analogous to the lift forces produced by the hydrofoil of the hull-type hydrofoil boat and other stabilizing forces as will subsequently appear. This hull-less arrangement decreases drag and thereby greatly increases speed potential.

The frame **16** has the additional feature of being collapsible and therefore cane be stored and handled more conveniently. As shown in the drawing, mast **18** and spars **32** and **34** are hinged at **36** by a horizontal pin passing through ears in the spars. Spars **38** and **40** are hinged by a similar pin whose axis is perpendicular to the first horizontal pin. A screw, with the head shouldering on the second pin, passes through the second pin and engages threads in the first pin. Thus, by turning the single screw, the two pins are brought closer together, thereby erecting and stressing the entire aerohydrofoil frame. Removing the screw, completely frees the first pin from the second pin, allowing the entire structure to fold up and collapse into a small package.

Hydrofoil **14** and sail **20** are nonarticulating components, held to the frame with struts and wires in a fixed orientation. Hydrofoils **10** and **12** are each pivotally connected to the frame by struts **22** and **24**, respectively, and may be rotated simultaneously to desired positions by the use of push rods **26** and **28** and bell crank **30**. The structure and operation is described with greater particularity in a copending application, Ser. No. 3,738, in the name of Bernard Smith, filed on Jan. 19, 1970. Directional control is obtained by articulating hydrofoils **10** and **12** about vertical axes. Foil **14** and sail **20** are kept to leeward; foils **10** and **12** to windward. The drawing illustrates how foils **10** and **12** are manipulated for tacking to the right. Foil **12** is then the forward foil and is turned counterclockwise about 10° from a plane passing through the vertical pivot axes for foils **10** and **12**. On this tack foil **10** functions as the rudder. On the reverse tack foils **10** and **12** change functions. Foil **10** is turned clockwise about 10° and held substantially fixed and foil **12** becomes the rudder.

The forces acting upon the hydrofoils will now be described. As best illustrated in FIG. **5**, the foils each comprise a flat or high pressure side **42**, angularly disposed to the horizontal, and a curved or low pressure side **44**. When the boat is moving in the plane of the flat side there is produced a lift force perpendicular to the flat side at any point. The end cross-sectional shape of the foils is symmetrical about the midpoint, thus allowing the foils to move in either of opposite directions and produce the same lift.

Lift forces, however, are a function of speed and as the wind strength increases, the speed of the craft increases thereby creating greater lift forces and causing the upper portions of the foils to emerge from the water. In low winds, enough of the foil remains submerged in the water to provide stability and prevent the sailboat from "jumping" out of the water or from being overturned. However, in high winds, experience has shown that the prior art hydrofoils are lifted too far out of the water, which results in the sailboats "jumping" behavior and poor stability.

The above problems are solved by the present invention which provides a concave-convex curvature to the hydrofoil along its vertical cross section as seen in FIGS. 3 and 4. Curved foils have been found to prevent the "jumping" behavior of the hydrofoil craft in high winds without the sacrifice of speed in low winds and permit the craft to operate in much higher winds, with greater stability, then ever before.

In operation, the curved hydrofoils yield high positive lift in low winds. As seen in FIG. 3, at low speeds the curved foils is substantially submerged thus creating a positive lift force which acts on the top half of the curved foil and a negative lift force which acts on the bottom half of the foil. However, since the area of the top half of the foil is larger than the area of the bottom half (see FIG. 2), the positive lift is greater than the negative lift, as shown in FIG. 3 by the relative length of the vectors representing lift forces. Thus, the resultant lift force will be positive and tend to lift the foil out of the water even in low winds.

As the wind strength increases and the curved hydrofoils lift further out of the water, the positive lift force gradually decreases to zero. As seen in FIG. 4, when the hydrofoil is at the high-speed waterline, the only force which acts on the foil is a negative lift force. This force always keeps the hydrofoil partially submerged, even in high winds, and prevents the hydrofoil craft from "jumping" out of the water by the curved foils, in affect, "hooking" the water. In this manner, the foils automatically adjust to the changing wind strengths to provide the correct amount of immersion of the driving foils and proper stability for the hydrofoil craft.

Also, as seen in FIGS. 3 and 4, the horizontal component of the lift forces is always in a direction opposite to the horizontal component of the force acting on the sail 20. These forces tend to balance each other so that the hydrofoil craft can move in a direction approximately parallel to the plane of the sail 20 (the sail being at an angle as low as 15° to the wind) or plane of the foils 10 and 12.

Optimum results are obtained in high winds where the curved shape of the hydrofoils along a vertical cross section approximate a 60 to 75° arc of a circle. As seen in FIG. 2, all foils decrease in cross section in a direction toward their lower ends, a generally elliptical shape being illustrated with a long major axis as compared to the minor axis.

The load which may be carried by the craft may assume many different forms. In smaller versions of the craft this would comprise any suitable quarters to accommodate the operator or a crew. In larger versions, designed for transport, it would also include cargo space. In another application the cargo space would be provided by a second boat which would be towed or otherwise moved to the craft and then raised above the water and supported by the craft frame. At destination it would be lowered and floated to a pier or the like for unloading or other disposition.

While the propulsion means has been illustrated as an airfoil or sail, it is to be understood that the hydrofoils have utility with other forms of propulsion such as a motor-driven wind propeller and inboard and outboard motors. Also, it is to be understood that the curved hydrofoil of the present invention may be used on a hull-type aerohydrofoil craft. Therefore, the curved hydrofoils do not necessarily have to be buoyant.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings.

What is claimed is:

1. A hull-less boat comprising:

a frame for carrying a load;

a plurality of buoyant hydrofoils secured to said frame for supporting said frame above and out of contact with the water when said hydrofoils are immersed;

each of said hydrofoils being concavo-convex in vertical section to yield high positive lift at low speeds when the foils are substantially fully immersed and negative lift at high speeds when only the lower extremities of the foils are still immersed; and

means carried by the boat for propelling it.

2. A hull-less boat as defined in claim 1 wherein said propelling means comprises a fixed sail.

3. A boat in accordance with claim 1 wherein said hydrofoils are three in number; two of said hydrofoils being secured to the boat for pivotal movement about a vertical axis and the other one of said hydrofoils is rigidly affixed to the boat.

4. A boat in accordance with claim 3 wherein each of said hydrofoils have a symmetrical foil-shaped end cross section whereby the foils may move in either of opposite directions and produce the same lift.

5. A boat in accordance with claim 4 wherein two of said hydrofoils each have an inner flat surface and an outer curved surface and each disposed with said flat side in substantially the same plane whereby movement of the foils in said plane produces a lift force.

6. A hydrofoil having a concavo-convex in vertical section along its vertical cross section arranged below the frame of a watercraft and comprising an upper and lower curved portion constructed and arranged in such a manner that as the speed of the craft increases, the craft rises and the foil emerges until at top speeds the craft rides only on the lower curve portion of the foil which is adapted to "hook" the water and prevent the craft from "jumping" out of the water by the creation of a negative or reverse lift.

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