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Danahy

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[54] **FLEXING HYDROFOIL**

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[52] **U.S. Cl.** ..... **114/66.5 H**

[51] **Int. Cl.** **B63b 1/18**

[58] **Field of Search** ..... 114/66.5 R, 66.5 H

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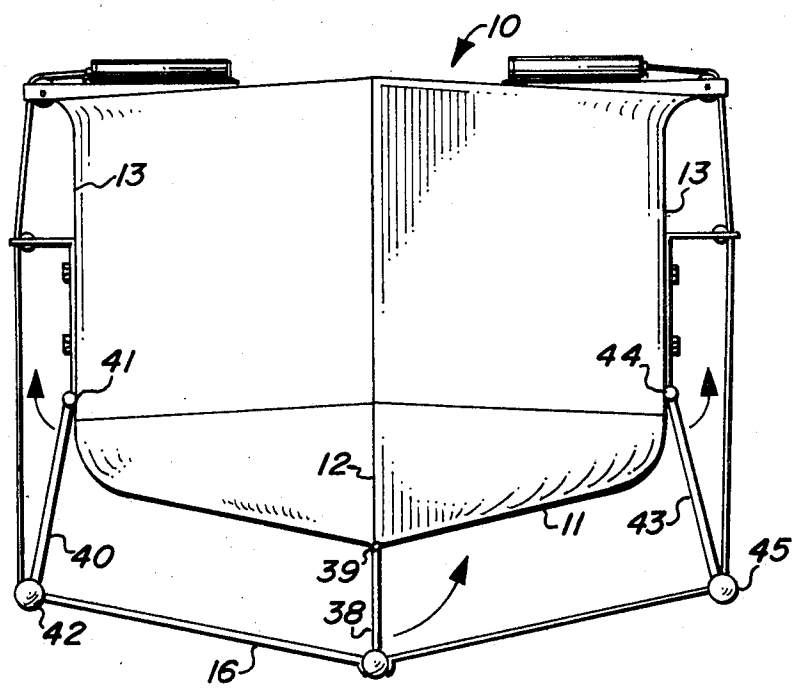
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[57] **ABSTRACT**

This specification discloses a flexing hydrofoil that consists essentially of a thin flexible blade that is secured to the underside of a boat hull transversely thereof and in spaced relation thereto by three or more struts together with tensioning cables connected to the ends of the blade. Provision may also be made for the blade to be moved into engagement with the hull when the hydrofoil is to be ineffective.

The present invention relates to hydrofoils that are mounted on a boat hull and is concerned primarily with a flexing hydrofoil that includes as a characteristic and essential element a flexing blade.

12 Claims, 8 Drawing Figures



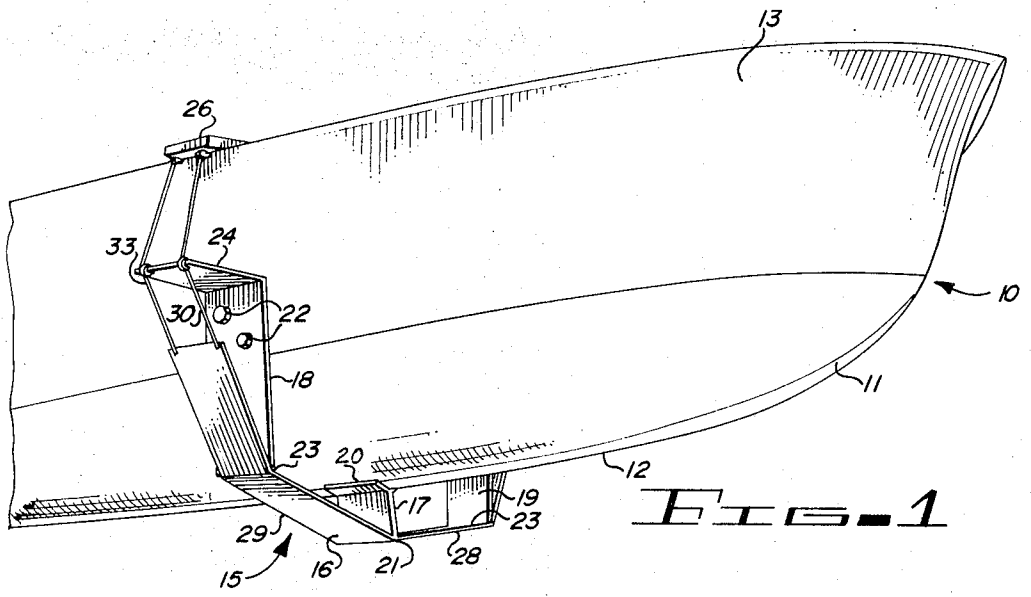

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Fig-1

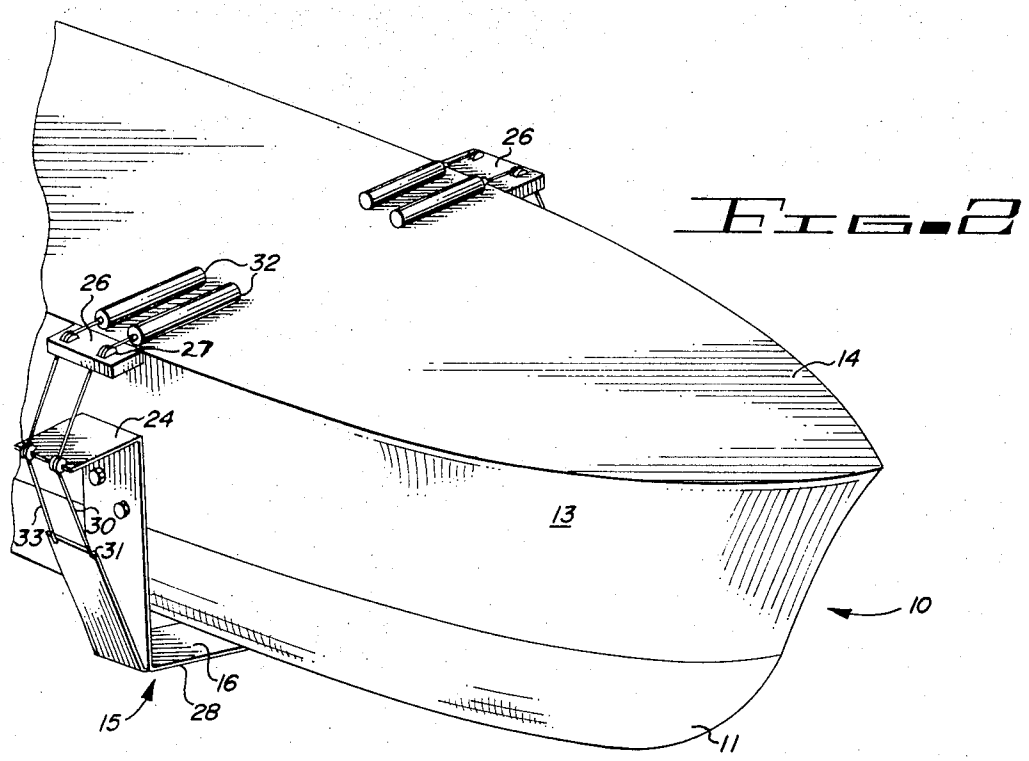

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Fig-2

Fig-3

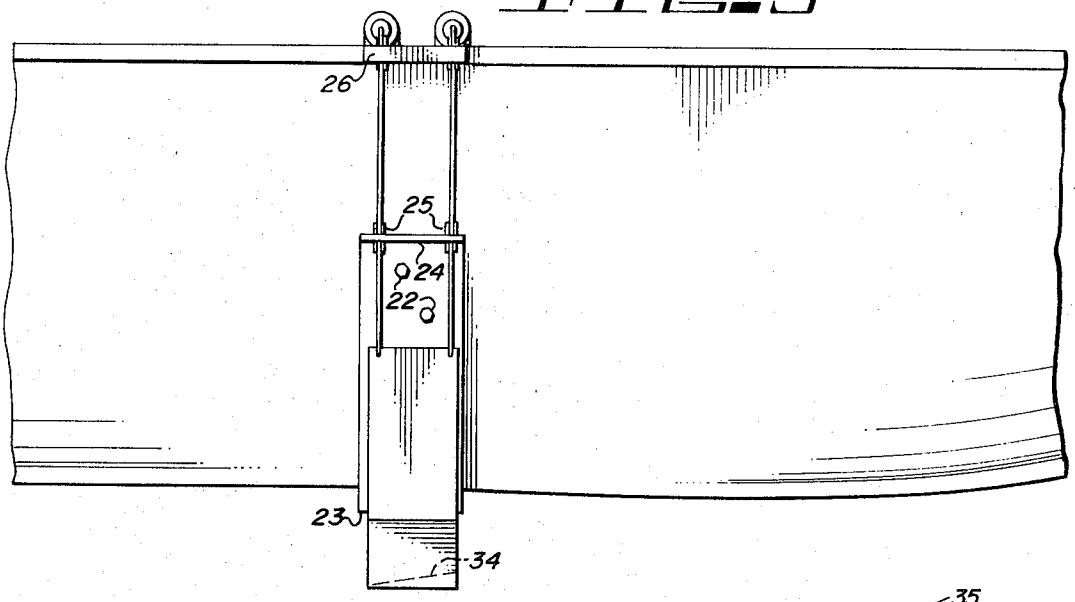
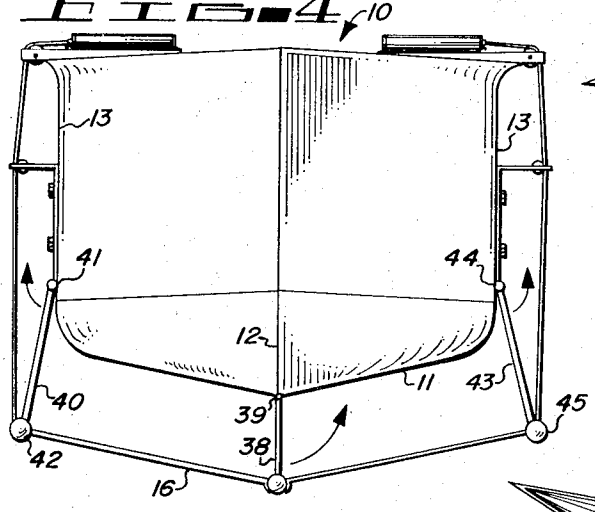


Fig-4



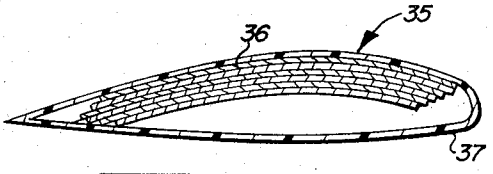
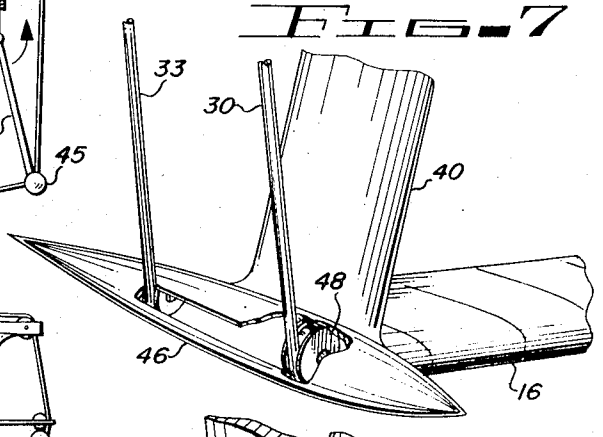


Fig-6

Fig-7



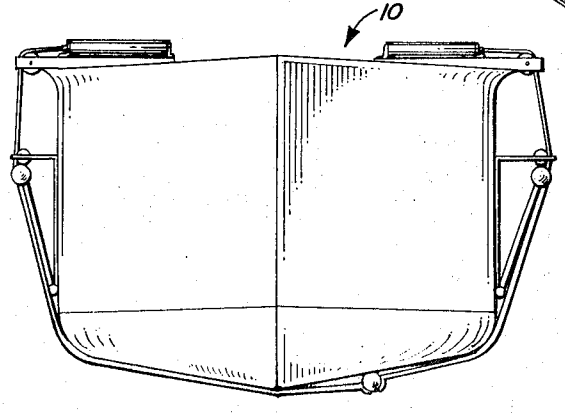


Fig-5

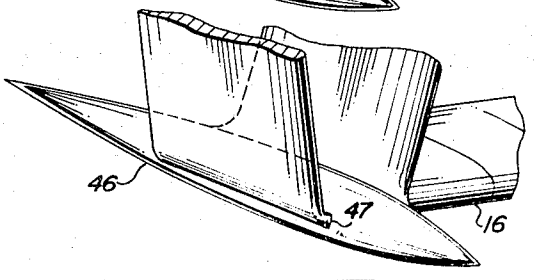


Fig-8

FLEXING HYDROFOIL

ORIGIN OF THE INVENTION

The invention described herein was made by a member of the Armed Forces of the United States and may be manufactured and used by or for The Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

In the known hydrofoils of the type with which this invention is concerned, the foil is designed as a rigid beam which must have sufficient section modulus to resist bending. This means that while the upper sectional area is in compression, the lower sectional area is in tension and any material near the neutral axis is not loaded to any appreciable extent. This means that the ratio between the weight of the foil to the required lift is relatively high.

A hydrofoil has a leading edge and a trailing edge. At present, there is no known hydrofoil which includes means to vary the tension on these edges to adjust the angle of attack of the foil and thereby alter its resultant lift capabilities.

The known art is also singularly lacking in a hydrofoil which is susceptible of being moved into a position closely adjacent to the hull of a boat when its lifting effect is not required.

OBJECTS OF THE INVENTION

With the foregoing conditions in mind, the present invention has in view the following objectives:

1. To provide a foil that is of considerably lighter weight than known foils for any particular lift requirement.

2. To provide a hydrofoil in which the ratio of foil weight to lift requirement is low as compared to known foils.

3. To provide, in a hydrofoil of the type noted, a thin flexible blade that is mounted transversely of a boat hull in spaced relation thereto.

4. To provide, in a hydrofoil of the kind described, means for applying and controlling tension to the leading and trailing edges of the blade, and thereby controlling the foil angle of attack, the foil lifting force and the stress level in the foil.

5. To provide a hydrofoil having inherent shock absorbing characteristics.

6. To provide, in a hydrofoil including a flexible blade and struts for mounting the blade in effective position in spaced relation to the hull of a boat, mechanism for storing the blade in ineffective position against the hull.

7. To provide, in a hydrofoil of the type described, the capability to monitor the tension in the foil at both leading edge and trailing edge and thereby indicate the stress level in the foil, the lifting load on the foil, the deflection of the foil, and the angle of attack of the foil.

Various other more detailed objects and advantages of the invention such as arise in connection with carrying out the above ideas in a practical embodiment will, in part, become apparent and, in part, be hereafter stated as the description of the invention proceeds.

SUMMARY OF THE INVENTION

The foregoing objects are achieved by providing a hydrofoil comprising a thin flexible blade that is mounted in spaced relation to the hull of a boat and transversely thereof by three or more struts. Tension means for the leading and trailing edges of the blade may be provided in the form of cables, each of which is secured to the ends of the blade adjacent to said edges with the other ends of the cables being connected to energy absorbing devices such as springs or pneumatic or hydraulic cylinders. The upper ends of the struts are hingedly connected to the boat hull with the outboard struts having their lower ends in sliding engagement with the blade whereby the blade may be retracted into a collapsed position relative to the hull.

An alternate means of altering tension in the thin flexible blade is to attach the ends to struts which, as a function of their hydrodynamic loading and elastic properties, may bend and twist in a limited degree thereby altering the tension within the flexing foil blade.

For a full and more complete understanding of the invention, reference may be had to the following description and the accompanying drawings wherein:

FIG. 1 is a perspective of the forward end of the hull of a boat looking at the underside thereof and depicting a flexing hydrofoil applied thereto in accordance with the precepts of this invention;

FIG. 2 is another perspective of the forward end of the boat hull looking at the top thereof and illustrating the tension devices for the blade;

FIG. 3 is a view in side elevation of that portion of a boat hull to which the hydrofoil is attached;

FIG. 4 is a front elevation of a modification in which the foil is retractable but illustrating the foil in effective position;

FIG. 5 is a front elevation similar to FIG. 4 showing the foil retracted;

FIG. 6 is a detailed cross-section on an enlarged scale of a modified blade which is loosely laminated;

FIG. 7 is a detailed perspective on an enlarged scale of the outboard strut of the device of FIGS. 4 and 5; and

FIG. 8 is a detailed perspective showing the blade as it is pulled through a nacelle.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and first more particularly to FIGS. 1, 2 and 3, a hull of a boat is shown at 10 and includes a curved bottom 11 presenting what might be called a keel line 12, sides 13 and a deck 14.

A hydrofoil is identified generally at 15. It comprises a thin flexible blade 16 of an appropriate metal and struts which support blade 16 in spaced relation to bottom 11. There are three of these struts which are identified as a center strut 17 and outboard struts 18 and 19.

In a more simplified embodiment of the invention, the struts are secured to hull 10 by the following arrangements. Center strut 17 carries at its upper end a pair of flanges 20 which engage bottom 11 on opposite sides of keel line 12. The lower end of strut 17 engages blade 16 substantially midway its ends as indicated at 21.

The upper ends of outboard struts 18 and 19 are attached to sides 13 in any preferred manner such as by hinges or as by bolts 22 which may be removable and hence impart removability to struts 18 and 19. The lower ends of struts 18 and 19 engage blade 16 along the lines at 23 and this engagement may be slidable to

a small degree. These lines 23 define the effective length of blade 16 which functions as a foil.

Each of struts 18 and 19 is formed with an outwardly extending flange 24 which is oriented at some angle to the strut and the outer end of which is formed with a pair of openings in each of which is rotatably mounted a pulley 25. Outstanding from deck 14 at its side edges are a pair of tongues 26, each of which has a pair of apertures 27. Each of the latter is provided with some form of friction reducing device such as a lining of hard metal or a pulley comparable to pulleys 25.

Blade or foil 16 has a leading edge 28 and a trailing edge 29. A cable 30 has one end anchored to the end edge of blade 16 closely adjacent to leading edge 28 as shown at 31. Cable 30 passes upwardly through one of the openings in flange 24 and about the pulley 25 therein. It then assumes an upward inwardly inclined direction through an aperture 27 in a tongue 26 and thence inwardly along the upper surface of the tongue where its other end is secured to an energy absorbing or tension controlling device represented diagrammatically at 32. The latter may be a spring or an hydraulic or a pneumatic mechanism.

It will be understood that there is a cable 30 at each end of blade 16 for the leading edge 28 which is connected thereto and assumes the same path described above. A second pair of cables 33 are connected to the ends of blade 16 adjacent to its trailing edge 29 and passed about pulley 25, through apertures 27 and their ends secured to energy absorbing or tension controlling devices 32.

By adjusting the tension on cables 30 and 33, the angle of attack of blade 16 as determined by leading edge 28 and trailing edge 29 may be varied. This is depicted by the broken line 34 at the bottom of FIG. 3. It is also understood that blade 16 may be removed by disconnecting its ends from cables 30 and 33, thereupon it may be stored in a convenient manner such as by being coiled into a roll. Center strut 17 is also preferably removable in that it is held in blade-supporting position by the tension on the blade. However, if desired, center strut 17 may be attached to bottom 11 in a more permanent manner as by bolts (not illustrated) or by a hinge to permit folding up against the bottom of the hull. Outboard struts 18 and 19 also may be removed by displacing bolts 22, or, if attached by a hinge, these struts 18 and 19 may be folded up against the hull.

As shown in FIGS. 1, 2 and 3, blade 16 is simply a thin flexible blade of metal. However, it may be of a loosely laminated construction, as illustrated in FIG. 6 which depicts the laminations in an exaggerated manner. Thus, a laminated blade is referred to generally at 35. It comprises laminae 36 of thin sheet metal which are encased in a sheath 37 of plastic or similar flexible covering. Blade 16 of the embodiment of FIGS. 1, 2 and 3 may also be formed with a camber comparable to the curved cross-section of a Venetian blind. Similarly, a laminated blade could be composed of cambered laminae.

It is contemplated that the hydrofoil of this invention be susceptible of being stored against the hull when not in use. One arrangement for achieving this end is illustrated somewhat diagrammatically in FIGS. 4 and 5. In these views, boat 10 has the same bottom 11 with keel line 12 and sides 13.

A center strut 38 has its upper end hingedly connected to bottom 11 on keel line 12 at 39. Its lower end is fixedly secured to blade 16 with the construction permitting a relatively swinging movement between strut 38 and blade 16. This movement may be provided by the flexing properties of the blade.

An outboard strut 40 has its upper end pivotally connected to a side 13 at 41. Its lower end is slidably connected to blade 16 at 42. The other outboard strut 43 has its upper end hinged to a side 13 at 44 and its lower end slidably connected to blade 16 at 45.

One form of sliding connection which may be used for connections 42 and 45 is illustrated in FIGS. 7 and 8. Thus, a nacelle 46 is rigidly secured to the lower end of the outboard strut. FIGS. 7 and 8 show the strut 40 with the nacelle 46 thereon formed with a slot 47. The outboard end portion of blade 16 assumes an upward direction as shown in FIG. 8. Cables 30 and 33 have their ends secured to the end of blade 16 and to reduce the frictional resistance to movement of blade 16 as it makes the turn at nacelle 46 the latter is provided with pulleys 48 which function in the manner of conventional pulleys when cables 30 and 33 ride thereon and then serves as rollers on which blade 16 rides.

FIG. 4 depicts the hydrofoil in effective position. When it is to be collapsed against hull 10, as shown in FIG. 5, strut 40 is swung upwardly into the position of FIG. 5. As this action takes place, pulley 48 in the nacelle 46 at the end of strut 40 rides on cables 30 and 33. An upward pull on the cables at the other end of blade 16 pulls center strut 39 against bottom 11 and at the same time causes blade 16 to slide through slot 47 of the nacelle 46 at that side. The pull on the cables will also swing strut 43 about its pivot 44 into the upraised position. Blade 16 is now in a position in which it is substantially in engagement with bottom 11.

The flexible foil may develop inherent behavior characteristics if the outboard ends are fixedly attached to struts hydrodynamically designed to either bend or twist or both bend and twist depending upon depth of strut submergence and speed through the water, i.e., the hydrodynamic forces imposed on the strut must result in elastic deflection of the strut and such deflection can be in the form of bending and/or twisting of the strut. That is to say that struts 18 and 19 may be shaped like a wing section so that water flow past the strut will develop transverse (athwartships) loads causing the strut to deflect in an elastic manner thereby imparting a change in the tension in the flexible foil. Depending upon the configuration of the strut and the arrangement of the attachment of the strut to the hull, the strut may similarly twist as the hydrodynamic loads are developed upon the strut. A twisting motion of the strut will alter the tension relationships between the leading and trailing edges and thereby alter the angle of attack of the foil.

While preferred specific embodiments of the invention are herein disclosed, it is to be clearly understood that the invention is not be be limited to the exact construction, devices and mechanisms illustrated and described because various modifications of these details may be provided in putting the invention into practice.

What is claimed is:

1. For use with a boat hull having a bottom and sides, a hydrofoil comprising:

a. a thin flexible metallic blade having a leading edge, a trailing edge and end edges;

b. a center strut having an upper end in engagement with said bottom centrally thereof and a lower end engaging said blade;

c. a pair of outboard struts each having an upper end portion secured to one of said sides and a lower end engaging said blade;

d. two pairs of cables, one pair at each side of said hull, a cable of each pair being connected to one end of said blade adjacent to said leading edge with the other cable of that pair being connected to said blade end adjacent to said trailing edge, and

e. means for applying various degrees of tension to said cables to cause said blade to flex between port and starboard ends in different amounts from said leading to trailing edges and thereby vary the angle of attack of said blade.

2. The hydrofoil of claim **1** together with guide means for said cable on the hull sides and in which said tensioning means includes energy absorbing devices on said hull.

3. The hydrofoil of claim **2** together with devices for controlling the tension.

4. The hydrofoil of claim **2** in which said guide means comprises outwardly extending flanges on the upper ends of said outboard struts and tongues extending outwardly of said hull from the tops of the sides thereof.

5. The hydrofoil of claim **4** in which said flanges are formed with holes through which said cables pass, and pulleys are carried by said flanges at said holes over which said cables ride.

6. The hydrofoil of claim **1** in which said blade is removable from said hull.

7. The hydrofoil of claim **6** in which said struts are removable from said hull.

8. The hydrofoil of claim **1** in which said blade is of a laminated construction.

9. The hydrofoil of claim **1** in which said struts are hingedly connected at their upper ends to the bottom and sides respectively, the lower end of the center strut is fixedly secured to said blade and the lower ends of the outboard struts are slidably connected to said blade.

10. The hydrofoil of claim **9** in which the slidable connections are provided by nacelles at the lower ends of said outboard struts with the nacelles having slots through which said blade passes.

11. The hydrofoil of claim **1** in which the blade is collapsible into a position in which it substantially engages the bottom of the hull.

12. The hydrofoil of claim **1** in which the outboard struts bend and/or twist elastically thereby altering the tension within the foil blade.

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