Oct. 11, 1949. W. P. CARL, JR 2,484,687

RIGID SAIL CONSTRUCTION FOR BOATS OR THE LIKE

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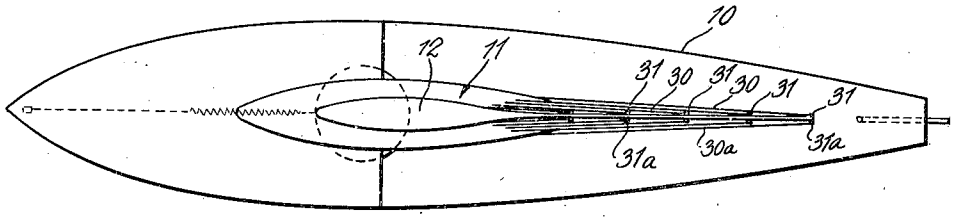


Fig. 1.

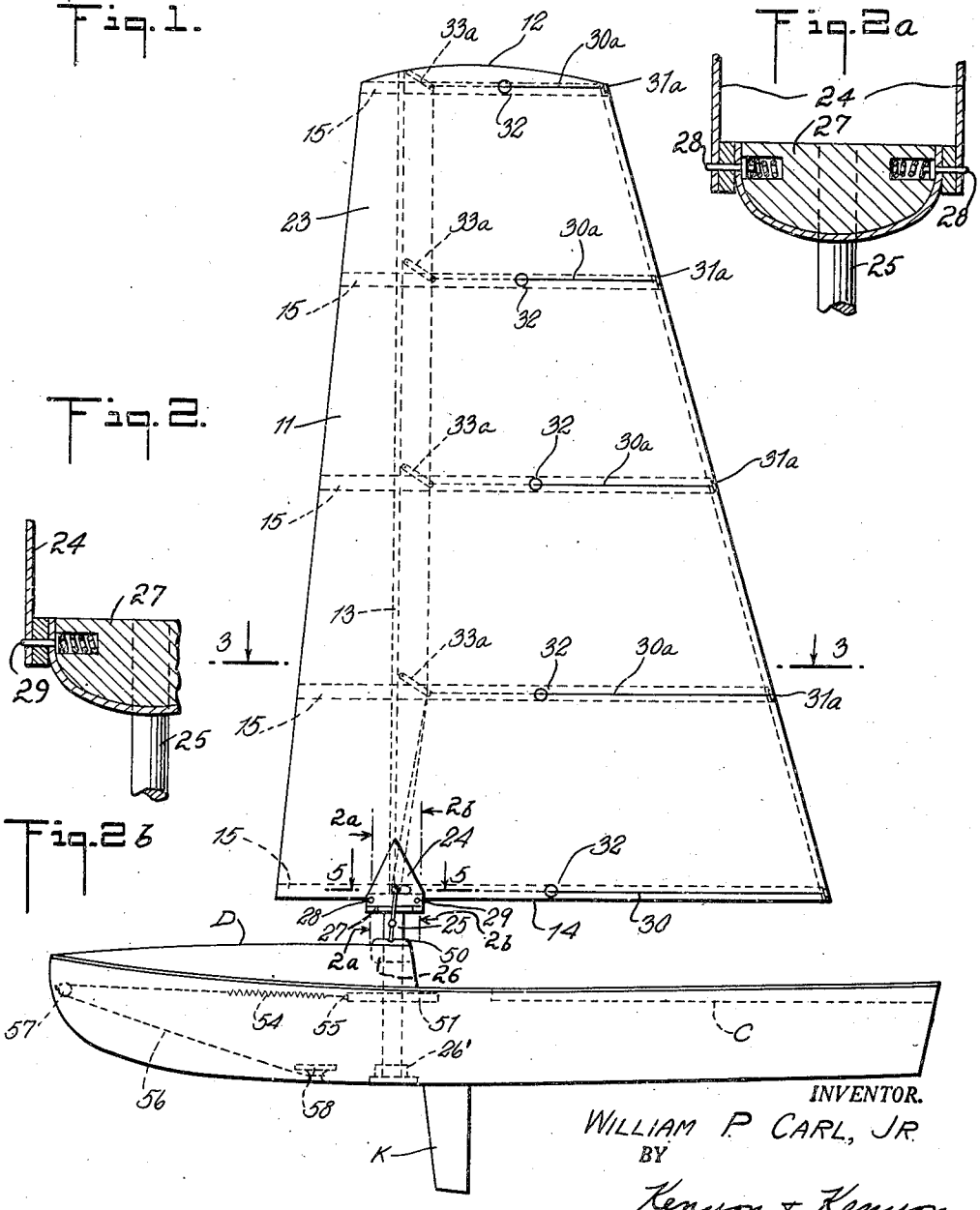


Fig. 2.

Fig. 2b

Fig. 2a

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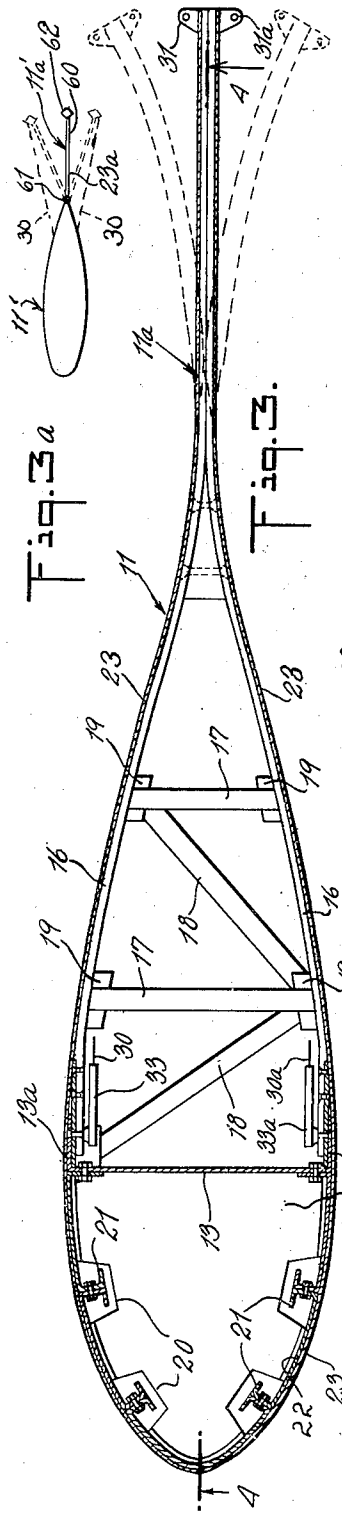


Fig. 3a

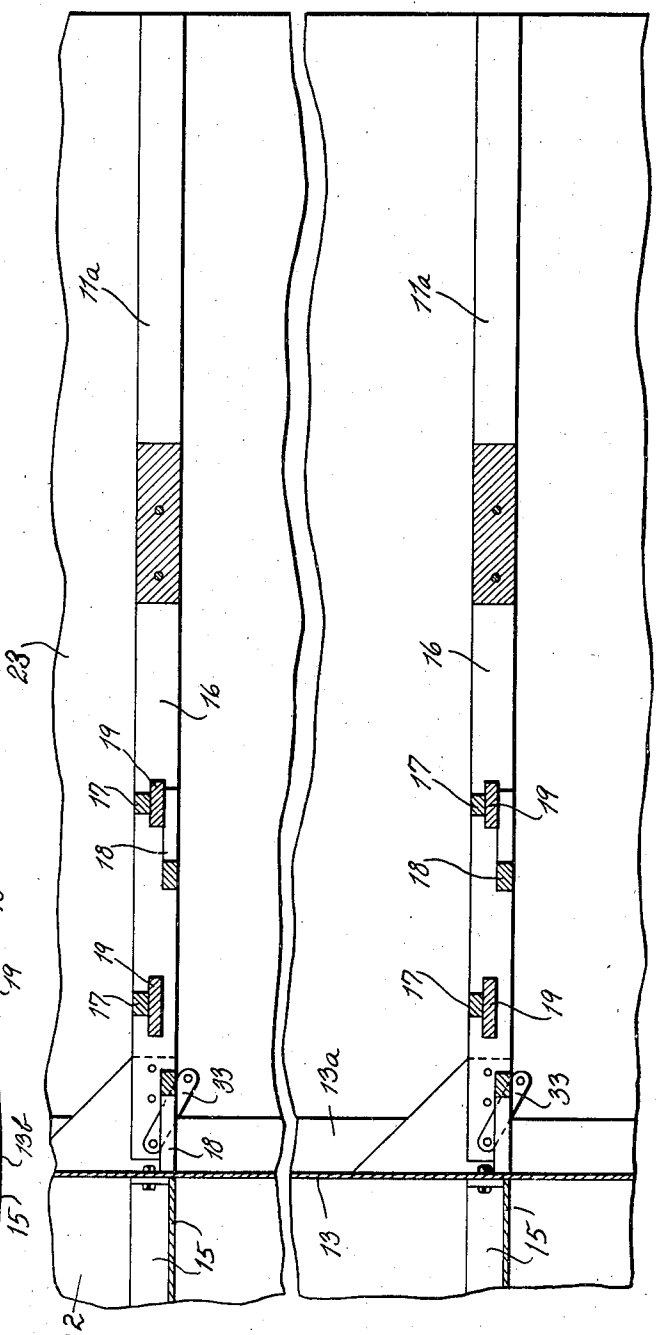


Fig. 3.

Fig. 4.

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Filed Aug. 30, 1945 3 Sheets-Sheet 3

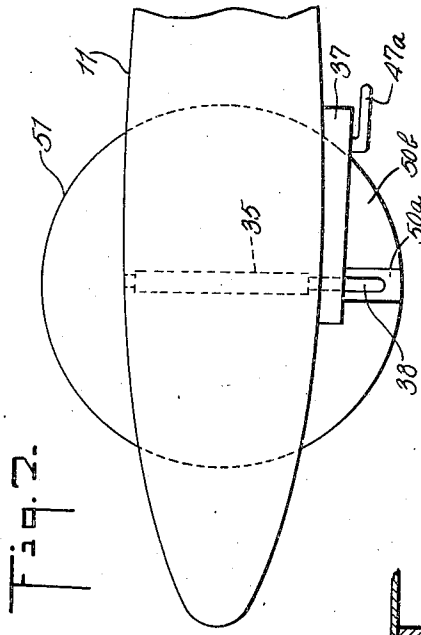


Fig. 7.

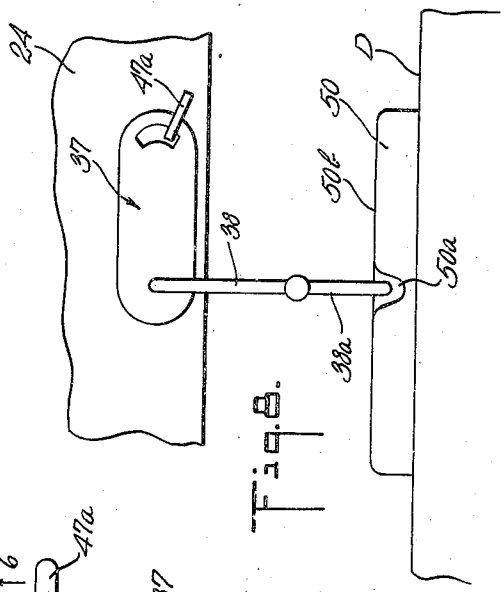


Fig. 8.

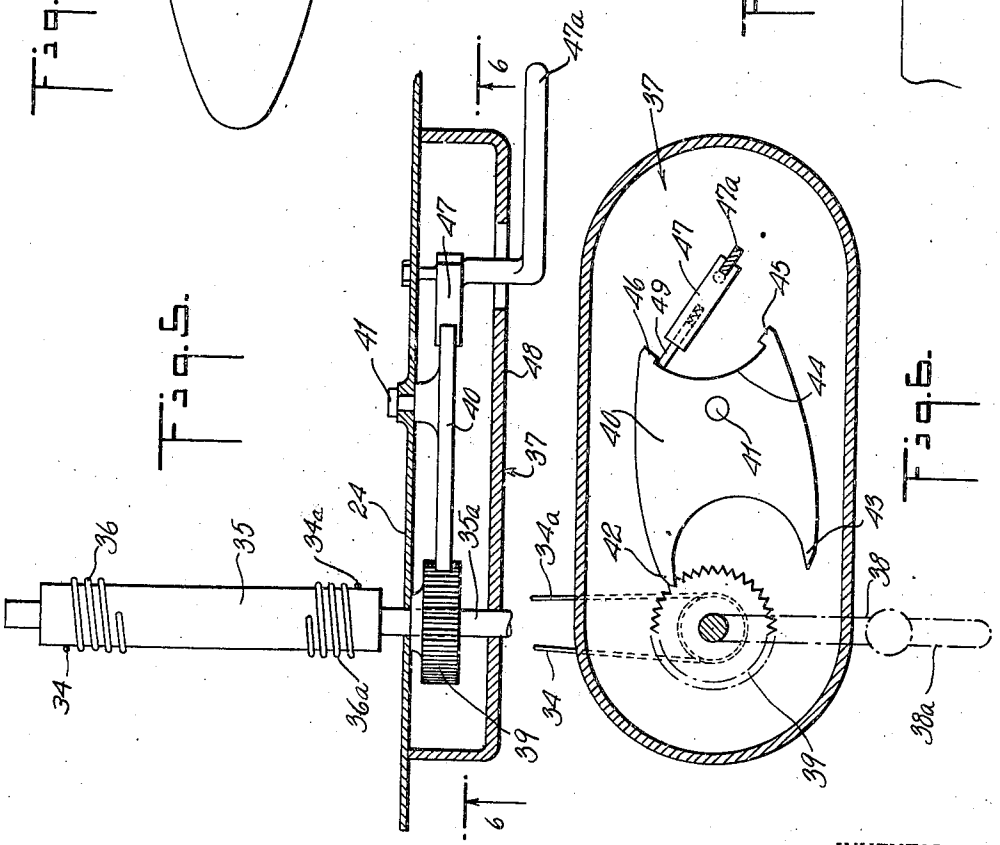


Fig. 5.

Fig. 6.

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UNITED STATES PATENT OFFICE

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RIGID SAIL CONSTRUCTION FOR BOATS OR THE LIKE

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Application August 30, 1945, Serial No. 613,494

6 Claims. (Cl. 114—103)

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This invention relates to sailboats, or the like, and in particular to their sails and the control of said sails.

The art of sailing, as it exists today, is the result of a very slow evolution from the square sail through the fore and aft gaff-boom rig to the fore and aft Marconi rig. Current conventional sails have several glaring aerodynamic faults:

1. A great deal of aerodynamic twist.
2. Mast interference.
3. Low critical flutter speed, i. e., when the wind reaches a certain velocity, the sail will flap like a flag and have to be shortened.
4. Large tip losses, i. e., when sails are cut in the shape of a triangle, as most conventional sails are, the area near the corners of the sail are not providing as much lift per square foot as they would if a trapezoidal, elliptical or semi-circular shape were used.

Other faults of the conventional sailing rig are:

5. The mast is usually stayed at very inefficient angles, throwing tremendous columnar loads into the mast which necessitates a very complicated system of stays, tending to spring the ship's hull bottom, and induce great loads on the ship's sides.
6. The sail must be controlled by ropes through a system of pulleys. Decks and cockpits are cluttered with ropes and cleats.

An object of my invention is to provide a sail construction and control that will eliminate the foregoing defects or faults.

Still another object of the invention is to provide sail structure in which the mast is eliminated as such and in which a substantially rigid sail replaces it that is a self-sufficient hollow structure covered with stressed skin that will take both the bending moments and torsional loads imposed upon it.

Still a further object of my invention is to provide a sail which has essentially a good airfoil section with a part of the trailing portion, approximately thirty per cent of the chord, that may be cambered by flexing or hinging. Hinging the trailing portion makes it possible to change the angle of the trailing portion with respect to the airfoil's chord. This effectively cambers the airfoil. By control of this camber, the maximum driving force can be obtained, as is well known to aerodynamicists, i. e., a high value of lift to drag ratio is obtainable from an airfoil with a high value of lift.

Another object of the invention is to provide sail structure that can conveniently be folded back into the boat when not in use.

Yet another object of the invention is to provide simple means for controlling camber and the attitude of the sail with respect to the plane of symmetry of the boat so that the sail will

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trim correctly to any point of sailing and any wind velocity.

To the accomplishment of the foregoing, and such other objects and features as may hereinafter appear, this invention consists in the novel construction and arrangement of parts hereinafter to be described in detail and then sought to be defined in the appended claims, reference being had to the accompanying drawings forming a part hereof, which show, merely for the purposes of illustrative disclosure, preferred embodiments of the invention, it being expressly understood, however, that changes may be made in practice within the scope of the claims without digressing from the inventive idea.

In the drawings in which similar reference characters denote corresponding parts:

Figure 1 is a top plan view of a boat equipped with the sail of my invention;

Fig. 2 is an elevational view of the boat and sail;

Fig. 2*a* is a transverse sectional view on an enlarged scale taken along line 2*a*—2*a* of Fig. 2 and viewed in the direction of the arrows;

Fig. 2*b* is a transverse fragmentary sectional view on an enlarged scale taken along line 2*b*—2*b* of Fig. 2 and viewed in the direction of the arrows;

Fig. 3 is an enlarged transverse sectional view of the sail of Fig. 2 along line 3—3 thereof and viewed in the direction of the arrows;

Fig. 3*a* is a similar view of a modified sail construction;

Fig. 4 is an enlarged section taken along line 4—4 of Fig. 3 and viewed in the direction of the arrows;

Fig. 5 is an enlarged sectional view taken along line 5—5 of Fig. 2, viewed in the direction of the arrows and illustrating part of the camber control mechanism;

Fig. 6 is a sectional view taken along line 6—6 of Fig. 5 and viewed in the direction of the arrows;

Fig. 7 is an enlarged fragmentary top plan view of the sail and camber control; and

Fig. 8 is an elevational view of the same.

Referring to the drawing, 10 denotes a sailboat of conventional construction with which the sail 11 of my invention is used.

The sail 11 viewed in elevation (Fig. 2) has substantially the trapezoidal form and an airfoil section of normal taper (approximately 2–1) and has a faired tip 12.

The loads on such a given airfoil are computed for a safe wind and boat velocity in the same manner as for an airplane wing. From the computed loads, the structure is determined. The sail 11 includes a shear web 13 which in the embodiment shown has substantially U-section and extends longitudinally through the sail in

its widest part from the root chord or bottom edge 14 to the faired tip 12. Preferably this web 13 is of aluminum alloy (Alclad) or other suitable material. Leading edge formers 15 preferably of the same material are secured to the web 13 at intervals along its length and extend transversely forwardly of the latter. Aft of the shear web 13 and in alignment with the formers 15 are ribs 16, cross strips 17 and diagonals 18 preferably of spruce cap strips connected by non-hydroscopic fibreboard gussets 19 or the like. The ribs 16 and formers 15 when assembled have substantially the airfoil sectional shape shown in Fig. 3. It will be noted that the ribs 16 in their trailing portions are joined together without spacing to form the trailing cambering portion 11*a* of the sail.

The formers 15 which are plates having the shape seen in plan in Fig. 3 and upstanding side flanges seen in Fig. 4 are provided with peripheral recesses 20 in which I-beam section stringers 21 formed from a stressed sectional metallic skin 22 are received and supported. These formers are covered with the sectional stressed skin 22 preferably of aluminum alloy (Alclad) or other suitable material whose joints form the stringers 21 and are fastened to the shear web 13. The formers and skin 22 provide a metal stressed skin leading edge for the structure with the skin 22 forming a metallic sheath for the leading edge.

The entire structure is covered with a stressed skin formed of suitable airplane fabric 23 such as Flightex fabric and doped with conventional doping compounds forming the sail 11 with its combining trailing portion 11*a*.

Aluminum alloy (Alclad) gussets 24 (or of other material) are secured suitably to opposite sides of the shear web 13, the ribs 16 and to the aluminum skin 22 adjacent the root chord 14, overhanging the lowermost edge thereof so that the sail 11 may be hingedly mounted to a pivot or rotatable shaft 25 in the boat so that the sail may rotate about an axis perpendicular to its airfoil sections.

The shaft 25 runs from the sail's root chord 14 through a bearing 26 of bronze or the like in the deck D of the boat down into a thrust and moment bearing 26' bolted or otherwise secured, for example, to the keel K of the boat 10. A crosshead 27 is fixed to the upper end of the shaft or pivot 25. This cross head 27 forms a platform over whose opposite sides the gussets 24 overhang. The crosshead is provided with spring loaded oppositely extending horizontal securing pins 28 and 29 which are positioned to extend into openings in the gussets 24 and serve to anchor the sail 11 to said cross head 27 and hence to the pivot 25. The complete structure of the sail 11 and shaft or pivot 25 is thus completely cantilevered and the sail may rotate about an axis perpendicular to its airfoil sections and to the boat through a full 360°. When it is desired to fold the sail into the boat, it is rotated 180° from the position shown in Fig. 2. Spring loaded pins 29 may then be pressed to clear the gussets 24 and the sail rotated about hinge pins 28 as an axis to the non-use position in the boat. At such time, the cambering portion 11*a* will lie at the top and the leading edge of the sail will then be received in a sail crotch C provided in the boat deck. To remove the sail entirely, the spring loaded pins 28 are also depressed to clear them, from the openings in gussets 24.

The sail 11 has its portion 11*a* cambered, for example, in the following way. Cables 30, 30*a* are attached respectively to a plurality of supports 31, 31*a* at opposite sides of the trailing end of the cambering portion 11*a* of the sail. These cables 30, 30*a* lead through suitable openings 32 in the sail cover 23 respectively to bell cranks 33, 33*a* pivotally supported at opposite sides to the lips 13*a*, 13*b* of the shear web 13 in the sail. A pair of bus cables 34, 34*a* are connected respectively to all the bell cranks 33 and all the bell cranks 33*a*. These bus cables lead to a transversely extending drum 35 around which they are wound in opposite directions as at 36, 36*a* so that rotation of drum 35 in one direction tightens one of the bus cables and eases off the other while its rotation in the opposite direction has the opposite effect. The corresponding action of the bus cables 34, 34*a* alternately tightens or eases off the corresponding cables 30, 30*a*, causing flexing of portion 11*a* and its cambering in the direction of the tightened cables 30 or 30*a* as shown in Fig 3. In other words, the portion 11*a* is alternately flexed and cambered to the right or to the left of the normal unflexed full line position of Fig. 3 toward one of its two dotted flexed positions, depending upon whether cables 30 or 30*a* have been tightened by the rotation of drum 35 in the required direction.

The drum 35 is supported between the gussets 24 extending outwardly of the sail 11 and extending at one end 35*a* through a two way or double acting ratchet mechanism 37 to a crank handle 38, the latter for manual manipulation. The two way or double acting ratchet mechanism 37 includes a toothed ratchet wheel 39 rigidly carried on the extension 35*a* of the drum 35. A double acting pawl 40 is pivotally supported at 41, for example, from the gusset 24. The prongs 42, 43 of the pawl 40 are so located thereon with respect to the pivot 41 that in one position of the pawl 40 prong 42 will engage the ratchet wheel 39 to permit rotation of the latter in one direction while preventing counter rotation, and so that in a second or neutral position both prongs 42, 43 will be clear of said ratchet wheel 39 to permit rotation of the latter and shaft 35*a* and drum 35 in either direction, and so that in a third position tooth 43 will engage said ratchet wheel 39 to permit rotation of the latter in the opposite direction to that when pawl 42 engages it and prevents counter rotation.

The pawl 40 may be retained in any of its three mentioned positions. To this end, it is provided with the arcuate cam surface 44 having limit stops 45 and 46 at opposite ends. A ratchet control lever 47 is pivotally supported in the gusset 24 and the cover 48 of the bi-ratchet mechanism. This lever 47 is manipulated by a lever 47*a*. An arm of this lever 47*a* has a spring loaded pin 49 which bears against the cam surface 44 between the stops 45 and 46, so that when lever 47*a* is rotated in one direction the pin 49 rests against the stop 46 and forces prong 42 into engagement with the teeth of ratchet wheel 39. When 49 rests against stop 45, the prong 43 is forced into engagement with the teeth of ratchet wheel 39. When pin 49 bears on the cam surface 44 in alignment with pivot 41, both prongs 42 and 43 are clear of the teeth of ratchet wheel 39.

The two way or double acting ratchet mechanism 37 just described enables one through proper positioning of its control lever 47*a* to set it (*a*) for ratcheting in a clockwise direction, (*b*) for ratcheting in an anti-clockwise direction, and (*c*) for neutral or disconnection which allows the

drum 35 to be turned in either direction. The neutral position is utilized for automatic cambering.

An automatic camber control is provided by extending the handle or crank 38 of drum 35 at 38a (Fig. 8). This extension 38a is adapted to co-operate with a cam 50 fixed to the deck D. The cam is concentric with the pivot or shaft 25 and has a depressed portion 50a into which the end of extension 38a projects when the sail 11 lies parallel with the fore and aft direction of the boat. When the sail 11 swings out of this position, the end of extension 38a rides out of depression 50a onto surface 50b of the cam and causes appropriate rotation of drum 35 to tighten the corresponding bus cable 34 or 34a and effect automatic cambering of the portion 11a of the sail toward the center line of the boat. Thereafter, if desired, the camber can be increased by flipping the crank 47a to desired ratcheting position and rotating arm 38 further in the same direction. When automatic camber control alone is desired, the crank 47a is maintained in neutral position.

The rotation of sail 11 about the axis of the shaft 25 is controllable either manually or automatically. Manual control is effected through lever-like means such as a bull wheel 51 or the like rigidly affixed to the shaft 25 and a friction brake of any conventional form (not shown). Automatic control is effected either through a rubber bungee cord, or, in the alternative, by a metal coil spring 54 secured at one end to a hook 55 on the bull wheel 51 and at the other end to a cord 56 which is passed around a pulley 57 secured suitably to the boat. The free end of the cord 56 is attachable to a cleat 58 rigidly secured to the boat so that the cord tension may be adjusted. Any desired variation of spring force can be secured by allowing the cord 56 to wrap around suitably shaped cams (not shown) instead of the bull wheel and by varying its tension.

When tension is placed in the cord 56 by tightening up the cord, the sail 11 is restrained from revolving in either direction both by the lever arm of the radius of the bull wheel 51 and the tension of the spring 54. Now when the boat 10 is headed off the wind, the pitching moment on the sail 11 increases, and, by adjusting the tension for any given strength of wind, the sail 11 will trim to the proper position. As the boat 10 is headed further off the wind, the moment of the sail increases proportionately and the sail will trim automatically to a greater angle with respect to the boat's axis. Thus, for any given wind velocity, the boat 10 can be sailed through a complete circle without touching the sail 11. Going about and jibbing are executed smoothly and without the usual violent sail flapping.

This control feature has the following unique advantages over the old conventional method:

1. It does not require constant watching and control of ropes.

2. It is a safety feature because if, with a sudden gust, the moment increases on the sail 11, the sail automatically changes its angle of attack so as to relieve the heeling moment.

3. It is a more efficient method of trimming a sail, because, when sailing along and struck with a gust, the immediate change of angle of attack changes what would have been an increased heeling force into a greater driving force.

4. By manual control, the sail can be used as a brake for landing.

5. By manual control, the sail can be positioned so that the boat can be sailed backwards.

A slightly modified form of sail 11' is shown in Fig. 3a. Therein the cambered portion 11a of Fig. 3 is eliminated. In place thereof, a pivoted trailing flap 11a consisting of dope-covered fabric 23a on a frame 60 is hinged suitably to the said sail 11' at 61, which is the point where the cambered portion 11a of Fig. 3 would normally begin. This flap is equipped with trailing edge prisms 62 so that the hinge moment of the flap increases with the angle of attack or in other words the flap has what is known as a positive

$$\frac{dC_h}{d\alpha}$$

which is the ratio of hinge moment coefficient to angle of attack. When the ratio is negative, the stability of the sail about the axis around which the sail rotates is increased. This flap 11a is manipulated by the same cable controls used to manipulate cambered portion 11a of Fig. 3. All other structural details described for the sail 11 remain the same. In addition, if desired, the flap 11a' could consist of sailcloth that could be lowered and raised using conventional track and slides as desired in the hinged frame 60, which is cable-controlled in the same way as cambered portion 11a of Fig. 3.

The structure thus described provides:

1. A rigid sail of airfoil section and stressed skin construction.

2. A rigid sail employing no mast.

3. A rigid sail of airfoil section with variable controllable camber.

4. A variable controllable camber mechanism that can be either manual or automatic.

5. A rigid sail which is hinged to a pivot at the sail's root chord for lowering.

6. A control mechanism for maintaining the sail at correct trim for any point of sailing and any wind velocity.

7. A sail in which the forward portion is rigid and the rear portion can be dropped.

In addition to the foregoing, a number of other important advantages exist in my sail constructions. These may be summarized as follows:

My sail constructions are entirely self-supporting, and require no halyards.

The leading edge of my sail constructions has the stiff metal sub-skin which has as one function the prevention of any scallop formation, or any departure from airfoil cross-sectioned configuration, in those portions of the sail between ribs. This is important for efficient sailing.

In the trailing edge of my sail constructions there is a link provided between ribs, which prevents the covering from cupping or pocketing at the trailing edge.

With the sail constructions of my invention, the cupped sides of the afterpart of the sail have a positive

$$\frac{dC_h}{d\alpha}$$

where Ch is the hinge moment and α is the angle of attack, so that the sail tends to float at zero lift, or, in other words, trim and remain in line with the direction of the wind. This is in contrast with sails having, at that part of the sail, a convex section or triangular section, both of which have a negative

$$\frac{dC_h}{d\alpha}$$

in which case the hinge moment coefficient decreases with increasing angle of attack, and the

sail will float or trim into or against the breeze at positive lift even if the sail is pivoted ahead of its center of pressure. This tends to keep the sail from trimming at zero lift.

The truss construction in my sails is very efficient. The transverse or cross-strips 17 do not theoretically take any load and are very light members used to halve the unsupported length of the outside frame 16 which quarters the stress.

It will be noted moreover that the axis of rotation of my sail is in front of the aerodynamic center of pressure of the sail, thereby eliminating any tendency for the boat to upset and so that the sail automatically trims at zero lift. In contrast, in sails which are pivoted behind the aerodynamic center of pressure the sail will not pay out and relieve itself in a breeze but will tend to line itself up with the boat and upset it. My sail is stable while sails pivoted behind the aerodynamic center of pressure are unstable, i. e., lack "weathercock stability."

While specific embodiments of the invention have been described, it will be understood that changes may be made in structural detail within the scope of the claims. There is no intention, therefore, of limitation to the exact details shown and described. For example, the angle of the axis upon which the sail pivots need only be such that the sail may, taking into account the characteristics of its cross-section, trim at zero lift, which angle is herein referred to as substantially perpendicular to the boat; and the size and type of the boat hull is immaterial.

What is claimed is:

1. A rigid sail of symmetrical airfoil section for a boat or the like, having a trailing portion lying in the chord plane of the sail and whose angle with respect to airfoil chord may be varied, cable means secured to the trailing portion at a plurality of points for trimming the latter to either side of a normal position, sets of pivoted members to which said cable means are secured, and cable means secured to said sets of pivoted members for operating the sets in opposite directions to secure effective airfoil cambering in the desired direction.

2. A rigid sail of symmetrical airfoil section for a boat or the like, having a trailing portion lying in the chord plane of the sail and whose camber or angle with respect to airfoil chord may be varied, cable means secured to the trailing portion at a plurality of points for cambering the latter to either side of a normal uncambered position, sets of levers pivotally supported within the sail and to which said cable means are secured, cable means secured to said sets of pivoted levers for operating the sets simultaneously in opposite directions, and means for actuating said last-named cable means.

3. A rigid sail of symmetrical airfoil section for a boat or the like, having a trailing portion lying in the chord plane of the sail and whose camber may be varied, cable means secured to the trailing portion at a plurality of points for cambering the latter to either side of a normal uncambered position, sets of levers pivotally supported within the sail and to which said cable means are secured, cable means secured to said sets of pivoted levers for operating the sets simultaneously in opposite directions, means for actuating said last-named cable means, double acting ratchet means between said actuating means and said last-named cable means for maintaining the cambering of said trailing portion in desired position, and means for operating said double acting ratchet means.

4. A rigid sail of airfoil section for a boat or the like, having a trailing portion whose camber may be varied, cable means secured to the trailing portion at a plurality of points for cambering the latter to either side of a normal uncambered position, sets of levers pivotally supported within the sail and to which said cable means are secured, cable means secured to said sets of pivoted levers for operating the sets simultaneously in opposite directions, and cam means for automatically actuating said last-named cable means.

5. A rigid sail for a boat or the like, including a shear web, formers secured to the leading side of said web, ribs secured to the trailing side thereof and terminating in camberable trailing portions, said formers and ribs providing airfoil sections, a metallic skin covering the formers to provide a stressed metallic sheath for the leading edge of the sail, a fabric covering for the sail overlying the said sheath and said ribs, and means for cambering said trailing portions.

6. A rigid sail for a boat or the like, including a shear web, formers secured to the leading side of the web, ribs secured to the trailing side of said web and terminating in camberable trailing portions, said formers and ribs providing airfoil sections, a metallic skin covering the formers to provide a metallic sheath for the leading edge of the sail, a doped fabric covering for the sail overlying said sheath and said ribs, cables secured to said ribs for flexing the latter to camber their trailing portions, and means for operating said cables.

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