United States Patent

[11] 3,556,035

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[21] Appl. No. **794,589**
[22] Filed **Jan. 28, 1969**
[45] Patented **Jan. 19, 1971**
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[54] **SAILING VESSEL**
14 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **114/39,** 114/66.5
[51] **Int. Cl.** **B63b 35/00,** B63b 1/26
[50] **Field of Search** 114/39, 66.5, 102, 103

[56] **References Cited**

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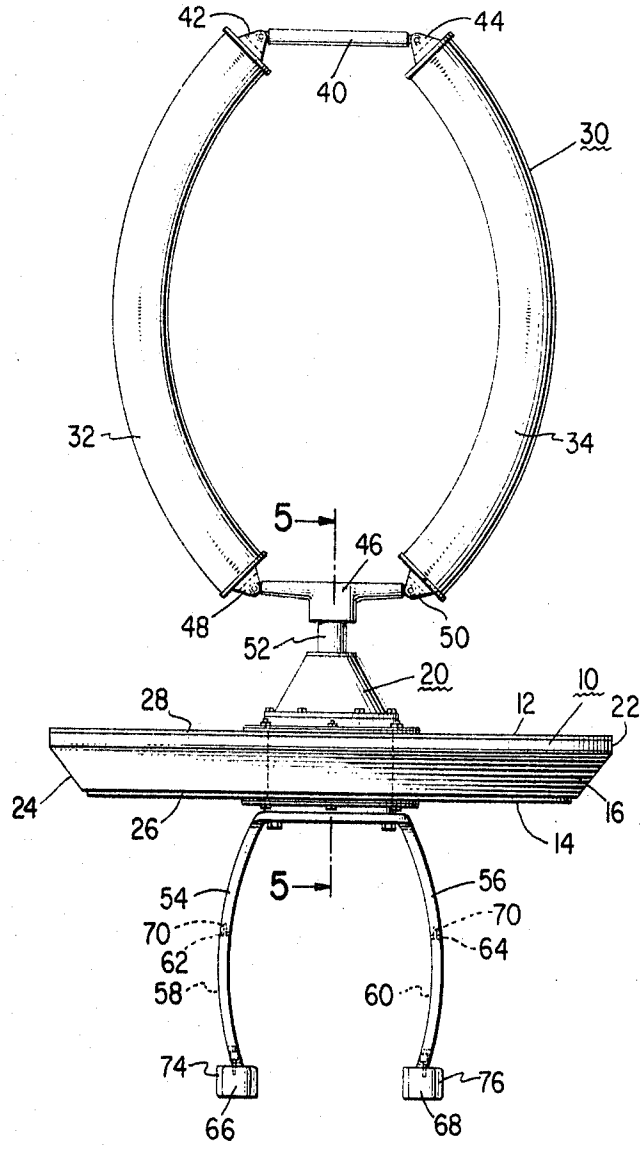
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ABSTRACT: A sailing vessel is provided which includes an improved sail and an improved hydrofoil. The sail and the hydrofoil are each rigid and each has streamlined cross sections.



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SHEET 1 OF 2

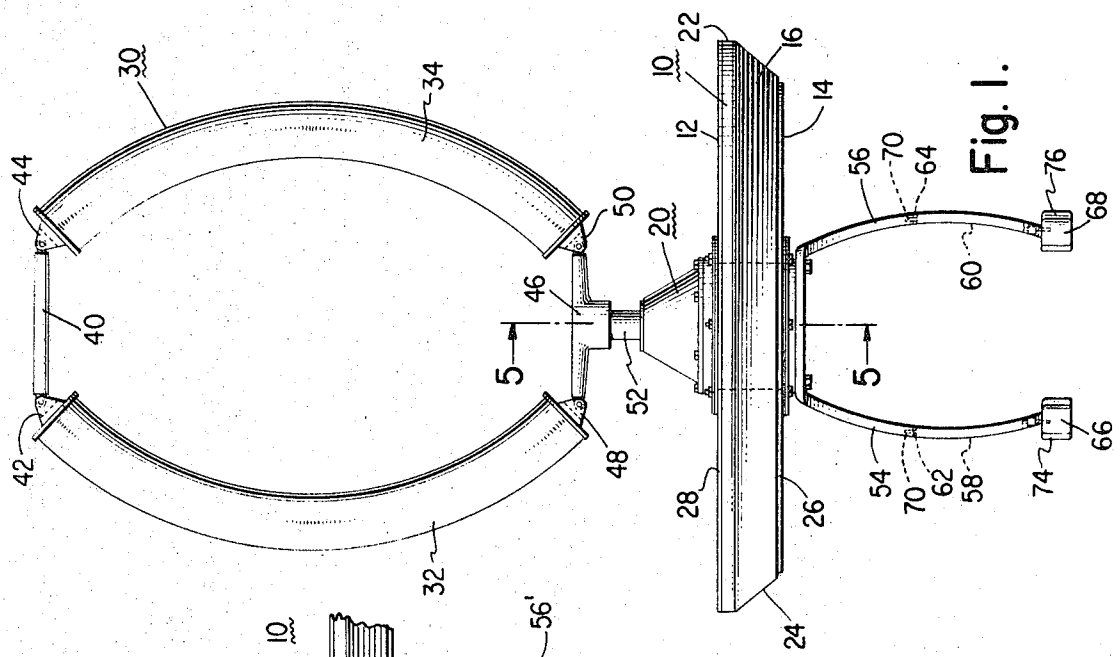


Fig. 1.

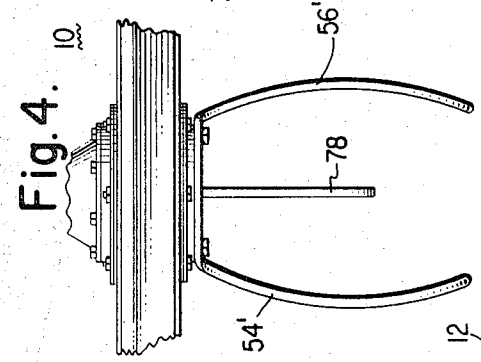


Fig. 4.

Fig. 2.



Fig. 3.

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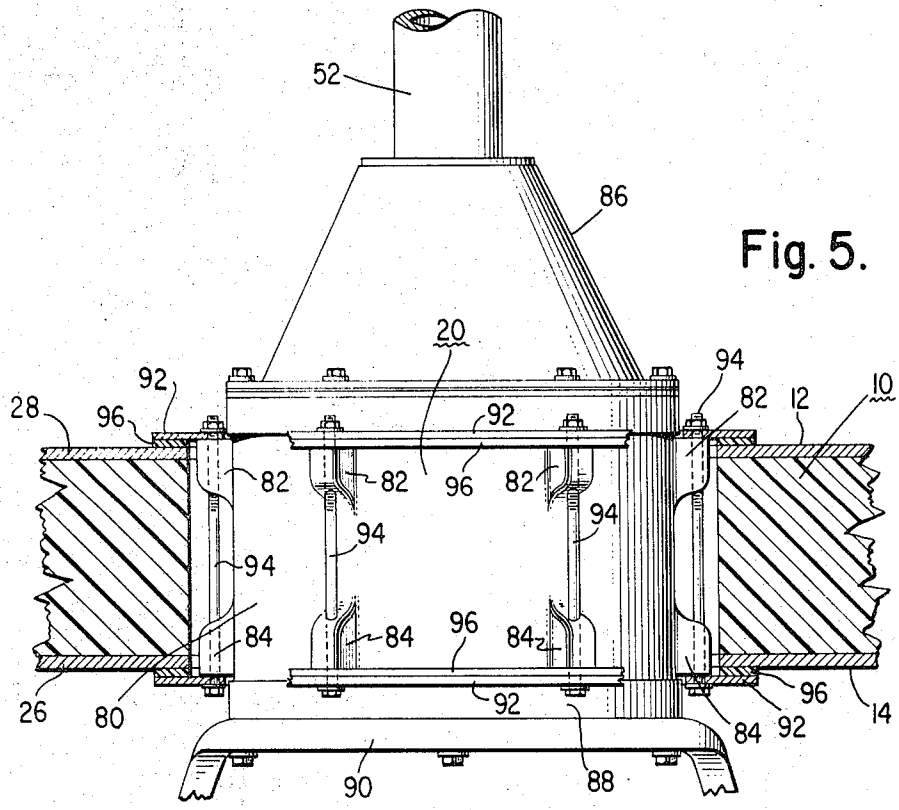


Fig. 5.

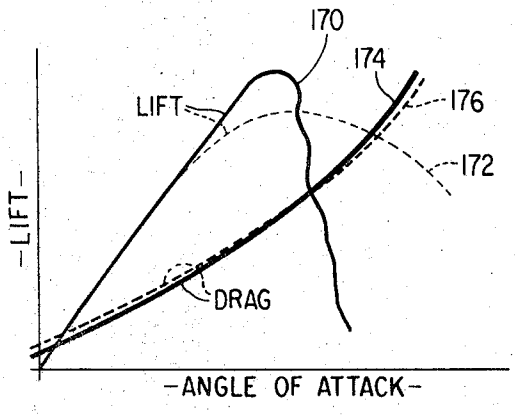


Fig. 6.

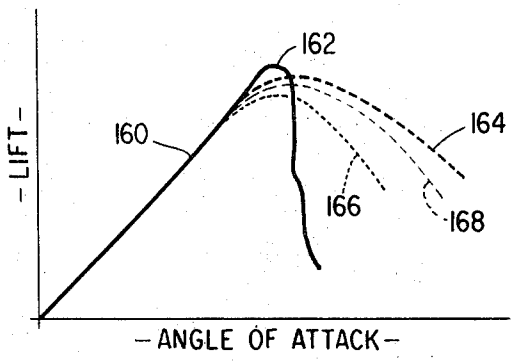


Fig. 7.

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SAILING VESSEL

This invention relates to sailing vessels and more particularly to the sails and to the hydrofoils of said vessels.

The disclosed sailing vessel may be unattended sailing vessel carrying detection devices, which must remain in a certain area of the ocean. When a moored buoy, which carries detection devices, is provided, the buoy must not only be large enough to provide sufficient buoyancy to support the payload comprising the detecting and communication devices but the buoy must also be large enough to support the mooring system that extends from the buoy to an anchor or to a weight at the bottom of the ocean. If the buoy is to be positioned over a deep region of the ocean, the mooring system may be very heavy, even though it is immersed in water and the mooring system will apply loads to the buoy, whereby the buoy must be very large and expensive to support the payload and the mooring system. On the other hand, a freely floating platform or an unattended or uncontrolled sailing vessel which does not have provisions to keep it at a particular region in the ocean will not remain in the region for a very long time, whereby the information transmitted by the uncontrolled platform or vessel will not originate from the same region. Means may be provided to cause the vessel to remain in the same particular region of the ocean. If a sailing vessel is unattended, the sail thereof must require a minimum of attention, and it must be able to provide effective propulsion or lift under all sailing conditions. It is also advantageous for the hydrofoil portion of the vessel to be effective under all sailing conditions.

In accordance with the invention, the sail or airfoil for the vessel is sufficiently rigid or rigidized, as by providing internal pressure within a flexible outer skin, so that it will not be deformed in normal use. The sail has the configuration of a closed curve, such as a circle, an ellipse, an oval, or one or more portions thereof, and the sail is streamlined in cross section. The sail is rotatably mounted on a floating platform or float, or hull which may have any convenient shape, circular for example, when observed from the top. Radio or internal means are provided to provide control signals to orient the sail with respect to the hull. A hydrofoil, which is fixed to the bottom of the hull, may be similar in configuration and cross section to the sail. The hull may be flexible, if desired, so as to yield due to water loading such as provided by wave action. The payload is supported within or on the hull in a weatherproof manner. In the case where the hull is flexible, the airfoil and hydrofoil may be so connected as to be rigid with respect to each other. The airfoil-hydrofoil structure would then be mounted on the hull by means of a flexible coupling between the rigid airfoil-hydrofoil structure and the flexible hull.

The invention will be better understood upon reading the following description in connection with the accompanying drawing in which:

FIG. 1 is a front elevational view of a sailing vessel made in accordance with this invention,

FIG. 2 is a side elevational view of the sailing vessel of FIG. 1,

FIG. 3 is a cross section of the airfoil of the vessel of FIGS. 1 and 2 taken at line 3–3 of FIG. 2,

FIG. 4 is a broken away view of a sailing vessel similar to the one of FIGS. 1 and 2 including however a modified hydrofoil and rudder,

FIG. 5 is a broken away view of the sailing vessel of FIGS. 1, 2 and 3 showing the connection between the sail and the hydrofoil to the hull of the vessel, and

FIGS. 6 and 7 are curves which are useful in describing the operation of the described vessels.

Turning first to FIGS. 1 and 2, the float or hull 10 may be circular when viewed from the top. As better shown in FIG. 5, the hull 10 may comprise a thin upper resilient annular sheet 12 of a material such as metal and a thin, lower, smaller resilient annular sheet 14, which may also be of metal. A thicker sheet 16 of buoyant material such as a plastic foam may be positioned between the sheets 12 and 14. The sheet 16 may be hollowed out to provide storage for a payload in a manner not shown. The three sheets 12, 14 and 16 may have a hole therethrough to include a support 20 for the airfoil-hydrofoil assembly (which includes the support 20) as will be more fully explained. The upper part 22 of the hull 10 may be circular and the lower 24 thereof may be in the shape of a frustum of a cone, the bottom of the hull 26 being flat and parallel to the top or deck 28 thereof, except as noted hereinafter. A sail 30 is mounted on the center of the hull 10 by means of the support 20, as will be described. The sail 30 comprises a structure that is sufficiently rigid so that in normal operation of the described vessel, its shape does not change. The sail 30 comprising two similar curved airfoils 32 and 34 which each extend through an arc of less than 180°. The airfoils 32 and 34 are so shaped and positioned that the concave portions thereof are towards each other and are in substantially the same plane. However, the curved airfoil sections 32, 34 may be disposed otherwise. For example, the convex sides may face each other. Or if the concave sides face each other, the sections 32, 34 may be joined directly to each other at the top or at the bottom or at both ends. The cross section of the airfoils 32, 34 are streamlined in that the front end or leading edge 36 (see FIG. 3) is rounded and that the rear or trailing edge 38 is sharpened. While the airfoils are shown as being hollow, they may be of solid construction. The cross section of each of the airfoils 32 and 34, being streamlined, are symmetrical about a center axis that extends through an edge 38. As shown in FIG. 1, the tops of the airfoils 32 and 34 are fixed to each other by a bar 40 and by respective brackets 42 and 44 which are fixed to the upper ends of the airfoils 32 and 34. The bottoms of the airfoils 32, 34 are fixed to each other by a bar 46, and by respective brackets 48 and 50 which are fixed to the bottom ends of the airfoils 32 and 34, the center of the bar 46 being fixed to a rotatable shaft 52. If desired, an airfoil such as 32 but extending through 360° may be used instead of the described sail structure, this modified sail being fixed to the top of the shaft 52. The shaft 52 extends into the structure 20. Motor means (not shown) may be provided in the structure 20 to rotate the shaft 52, and therefore the sail 30, with respect to the structure 20.

As shown in FIGS. 1 and 2, a pair of curved hydrofoils 54 and 56 are fixed to the structure 20. The hydrofoils 54 and 56 are curved and the concaved sides thereof extend towards each other. The cross section of the hydrofoils 54 and 56 may also be streamlined, as is the cross section of the airfoils 32 and 34, however the hydrofoils 54 and 56 may be much thinner than the airfoils 32 and 34. A pair of rudders 58 and 60 may be set into respective notches 62 and 64 in the trailing edges of the hydrofoils 54 and 56 and may be turned with respect thereto by motors 66 and 68 on pins 70 and 72 by means of gearings 74 and 76, if desired.

If desired, a rudder 78 may be provided extending downwardly from the rear of the structure 20, as shown in FIG. 4, in which case the accompanying hydrofoils 54' and 56' have no notches therein and no motor or gearing need be attached to the bottoms of the hydrofoils 54' and 56'.

The structure 20 is better shown in FIG. 5. The purpose of the structure 20 is to hold the sail 30 and the hydrofoils 54 and 56 (or 54' or 56') in relatively fixed position with respect to each other while permitting resilient connection of the structure 20 to the hull 10 and also while permitting rotation of the sail 30 with respect to the structure 20.

As shown in FIG. 5, the structure 20 may comprise a central ring 80 having pairs of upper 82 and lower 84 ears extending radially therefrom. The top of the ring 20 may be closed by a frustoconical member 86 through which the shaft 52 extends. The bottom of the ring 20 is closed by a plate 88 to which a bar 90 which joins the upper ends of the hydrofoils 54 and 56 (or 54' or 56') may be fixed as by bolts. Clamping rings 92, 92 are fixed to the top and to the bottom of the ears 82 and 84 by bolts 94, the rings 92, 92 extending radially to overlap the sheets 12 and 14. Respective annular resilient pads 96 extend between the plates 92, 92 and the sheets 12 and 14, whereby the hull 10 is resiliently movable to a small degree with respect

to the structure **20**. Furthermore, due to its construction as noted above, the hull **10** itself is flexible and conforms to a limited extent to the waves to the extent permitted by the flexing of the sheets **12** and **14**.

The sail comprising the airfoils **32** and **34** are rigid or rigidized and are dirigible as pointed out above, whereby they will retain their preferred shape and may be rotated to give propulsions of the vessel in the desired direction to keep the vessel in the desired area or region of the ocean. The lift or propulsive effect vs. the angle of attack of the described sail **30** and of other known sails may be compared by reference to FIG. **7**. In FIG. **7**, the solid line **160** shows that the lift of a straight flat airfoil increases linearly with the angle of attack until the peak **162** is reached at the critical angle. At a larger angle of attack the lift falls off very quickly. The angle of attack is defined as the angle between the relative wind vector and the zero lift line of the sail. For a sail **30** which includes the two curved shaped airfoils **32** and **34** as shown and described, the peak of lift is lower as shown by curve **164** than for a straight flat airfoil, but the fall off of lift is much smaller after the critical angle is reached whereby a vessel having a sail such as the sail **30** can sail efficiently over a greater range of wind directions for a single sail setting than the vessel having a straight airfoil. The standard cloth sail produces a lift in accordance with the curve **166**. It is seen that the rigid sail herein described has lift characteristics more like a cloth sail than a straight rigid airfoil sail. The curve **168** results when a rigid sail is used in which the elements **32** and **34** are elliptical rather than round.

Similarly, the curve of FIG. **6** compare the lift and drag of the hydrofoils **54** and **56** with flat hydrofoils. It will be seen that as the angle of attack of the flat hydrofoil, illustrated by the curve **170**, increases, at or near the angle of stall, the lift or resistance to lateral motion (side force) by the vessel suddenly decreases. With the hydrofoils **54** or **56** (**54'** or **56'**) shown in FIGS. **1**, **2** and **4**, the lift indicated by the curve **172** is not as great as that of the flat hydrofoil, but the lift stays high over a wide range of angles of attack, whereby the vessel having hydrofoils **54** and **56** gets away more quickly from a standing start because the active hydrofoils **54** and **56** (**54'** and **56'**) pass out of the static region more quickly than a flat hydrofoil as the speed of the craft increases, and retains a more nearly uniform lift over a wide range of angles of attack, whereby a vessel having hydrofoils such as the hydrofoils **54**, **56** (**54'** or **56'**) is more stable in the water than a vessel having flat hydrofoils. The curves **174** and **176**, which represent the drag provided by a flat hydrofoil and by the described hydrofoils show that the drag is not greatly increased by using the described hydrofoils, and the drag may even be lower at higher angles of attack due to the lower induced drag of the described hydrofoils.

I claim:

1. A sailing vessel comprising:

a hull having a top and a bottom surface;

a rigid sail having an elongated, vertically oriented arcuate portion mounted for rotation on the top surface of said hull about a vertical axis, said sail further having a streamlined cross section in a horizontal plane comprising a substantially rounded leading edge and a substantially sharpened trailing edge; and

means for rotating said sail with respect to said hull.

2. The sailing vessel according to claim **1** further comprising a hydrofoil fixed to the bottom of said hull and extending away therefrom.

3. The sailing vessel according to claim **2** wherein said hydrofoil comprises a first and a second portion, each portion of said hydrofoil having the configuration of at least a portion of a closed curve.

4. The sailing vessel according to claim **1** wherein said sail further comprises a first and a second elongated member, each elongated member having a vertically oriented arcuate portion, said first and second members being symmetrically oriented about a vertical axis.

5. The sailing vessel according to claim **4** wherein said sail further comprises:

first means for joining the end of said first elongated member which is furthest from the top of said hull to the corresponding end of said second elongated member; and

second means for joining the other end of said first elongated member which is closest to the top of said hull to the corresponding end of said second elongated member.

6. The sailing vessel according to claim **1** wherein the area between the top and the bottom of said hull is substantially filled with a buoyant material.

7. The sailing vessel according to claim **1** wherein said hull is substantially circular in cross section in a plane parallel to the top of said hull.

8. The sailing vessel according to claim **7** wherein the diameter of the substantially circular cross section of said hull is greater in a horizontal plane near the top of said hull than the diameter of the substantially circular cross section of said hull in a horizontal plane near the bottom of said hull.

9. The sailing vessel according to claim **8** wherein a first resilient sheetlike member having an annular opening is fixed to the top of said hull and a second resilient sheetlike member having an annular opening is fixed to the bottom of said hull, the annular openings of said first and second resilient members being coaxial along a vertical axis through said hull, and wherein said hull has an annular opening from the top to the bottom of said hull coaxial with the annular openings of said first and second resilient members.

10. A sailing vessel comprising:

a hull having a top and a bottom surface, said hull further having a substantially circular cross section in a horizontal plane;

a rigid sail rotatably mounted on the top surface of said hull, said sail further comprising a first and a second elongated member, each member having a vertically oriented arcuate portion, each sail member being symmetrically oriented about a vertical axis, each member further having a streamlined cross section in a horizontal plane comprising a substantially rounded leading edge and a substantially sharpened trailing edge; and

means for rotating said sail with respect to said hull.

11. The sailing vessel according to claim **10** further comprising a hydrofoil fixed to the bottom of said hull and extending away therefrom.

12. The sailing vessel according to claim **11** wherein said hydrofoil comprises a first and a second portion, each portion of said hydrofoil having the configuration of at least a portion of a closed curve.

13. A sailing vessel comprising:

a hull having a top surface and a bottom surface, the top surface being parallel to the bottom surface, said hull having a substantially circular cross section in a plane which is parallel with the top surface, said hull further having the area between said top surface and said bottom surface substantially filled with a buoyant material;

a first resilient sheetlike member fixed to the top surface of said hull and a second resilient sheetlike member fixed to the bottom surface of said hull, for providing a floatable wave resistant hull structure;

a rigid sail rotatably mounted on the top surface of said hull, said sail comprising a first and a second elongated member, each elongated member having a vertically oriented arcuate portion, said first and second sail members being symmetrically oriented about a vertical axis, each sail member further having a streamlined cross section in a horizontal plane comprising a substantially rounded leading edge and a substantially sharpened trailing edge;

first means for joining the end of said first elongated member which is furthest from the top of said hull to the corresponding end of said second elongated member;

second means for joining the other end of said first elongated member which is closest to the top of said hull to

the corresponding end of said second elongated member; and

means coacting with said second joining means for rotating said sail with respect to said hull.

14. The sailing vessel according to claim 13 further comprising a hydrofoil, said hydrofoil being fixed to the bottom of said hull and extending away therefrom and having a first and a second portion, each portion of said hydrofoil having the configuration of at least a portion of a closed curve.