

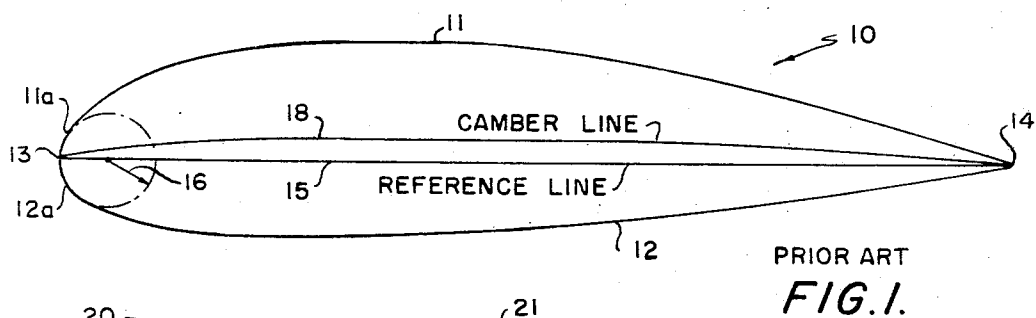
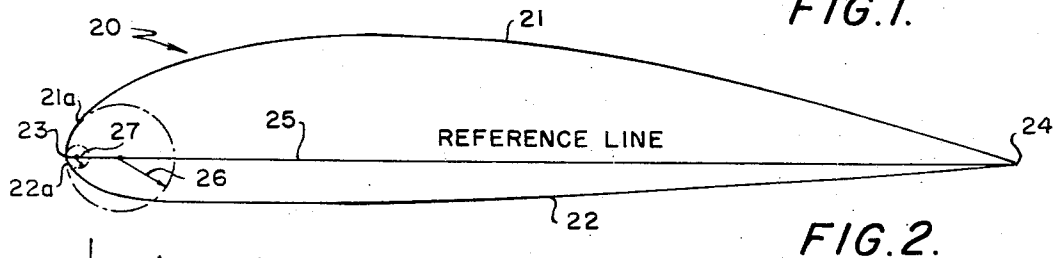
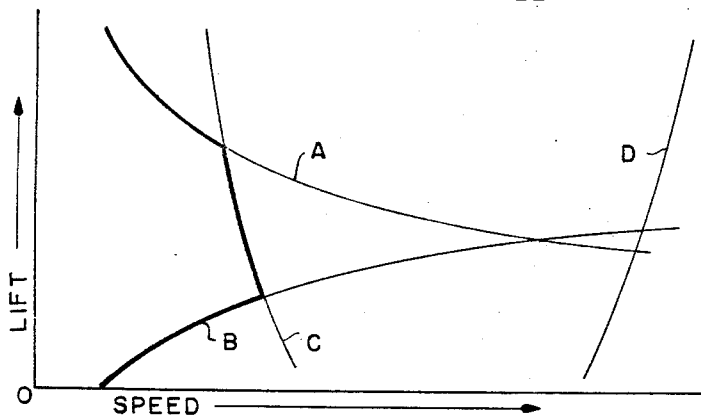
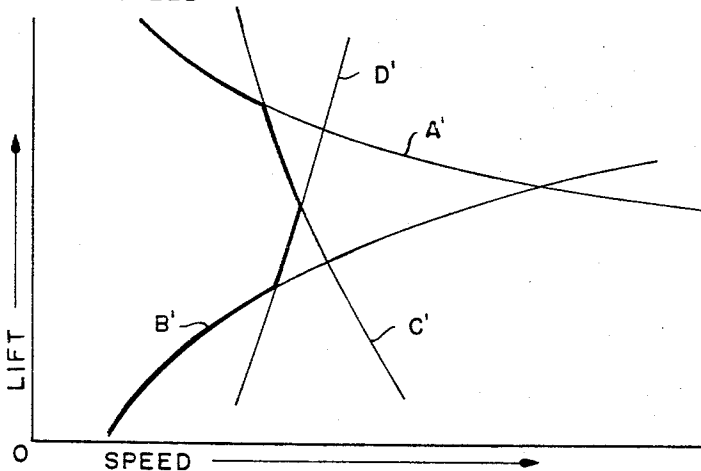
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HYDROFOIL WITH UNSYMMETRICAL NOSE PROFILE

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3,343,512 HYDROFOIL WITH UNSYMMETRICAL NOSE PROFILE

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This invention relates to improvements in hydrodynamic shapes and more particularly to improved hydrodynamic shapes particularly suited for use in hydrofoils and the like.

Heretofore, hydrodynamic shapes used on hydrofoils and the like have often been derived from aerodynamic practice which has not had to deal with problems of cavitation which, of course, are peculiar to foils operating in liquid rather than air. Typically, the hydrofoils so derived have been symmetrical in section, or at least have had a nose or leading edge profile which is characterized by a curved surface having substantially the same radius of curvature both above and below the major reference line. Hydrofoils so characterized induce cavitation at unduly low speeds, thereby limiting the effectiveness of the foil as a hydrodynamic element and often subjecting it to severe erosion. Moreover, changes in lift of conventional symmetrical hydrofoils have generally been accomplished by changing the camber or the angle of attack with a reduction of cavitation limits.

It is a principal object of this invention to provide improved hydrodynamic foil sections or configurations which may be operated at greater speeds without cavitation and with more effective lift than has been possible with hydrofoils of conventional configuration.

Another object of this invention is the provision of hydrodynamic foil sections having wider ranges of operating limits and having more desirable lift to drag ratios as well as presenting more effective water surface penetrating shapes.

As another object of this invention aims to provide hydrofoils having improved cavitation limits, lift to drag ratios and penetrability characteristics through the provision of a nose or leading edge characterized by a curved surface of which the portion above the nose-to-tail reference line has a radius of curvature substantially greater than the radius of curvature of the portion of the curved surface which is below the line of reference.

Yet another object is the provision of an improved hydrodynamic foil shape of the just mentioned character in which the larger radius of curvature is on the order of five times the smaller radius of curvature.

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 schematic view illustrating a typical hydrofoil section according to the prior art;

FIG. 2 is a schematic view of a hydrofoil section embodying the present invention;

FIG. 3 is a set of curves graphically representing cavitation limits of the prior art hydrofoil of FIG. 1; and

FIG. 4 is a set of curves graphically representing cavitation limits of the hydrofoil of FIG. 2 embodying the invention.

Referring to FIG. 1, a typical prior art hydrofoil 10 comprises a body having curved upper and lower surfaces 11 and 12 extending between leading and trailing edges 13 and 14. The body may be further characterized as having curved nose surface portions 11a and 12a of the upper and lower surfaces, which portions lie adjacent the leading edge 13 and respectively lie above and below

a reference line 15 extending between the leading and trailing edges. In this typical prior art configuration the radius of curvature of the upper curved nose surface portion 11a is the same as the radius of curvature of the lower curved nose surface portion 12a, the radius of each being indicated by the single arrow 16.

A camber line is indicated at 18 and represents the mean thickness of the hydrofoil 10. Deviation of the camber line 18 from the reference line results from increased curvature of the upper surface 11 which is one measure resorted to to increase lift.

It will be understood that the terms "upper" and "lower" are chosen for convenience of description, with the upper surface being that which lies in the direction of lift, and that the invention is not limited to any particular orientation with respect to earth. Thus, the invention contemplates embodiments in hydrodynamic shapes other than hydrofoils, for example screw propellers, propeller shrouds, and the like.

In addition to cambering the hydrofoil to gain increased lift as shown by camber line 18, it is conventional practice to operate at a significant angle of attack. However, cavitation will occur if the angle of attack and lift are too great.

FIG. 3 graphically illustrates, by a set of curves, the cavitation limits of a typical hydrofoil such as hydrofoil 10 of FIG. 1. Thus, curve A, the vertical ordinates of which are lift and the horizontal ordinates of which are speed, is representative of the lift versus speed characteristics attributable to the upper nose surface 11a of the hydrofoil 10. Curve B is representative of the lift versus speed characteristics attributable to the lower nose surface 12a of the hydrofoil 10. Curve C is representative of the lift versus speed characteristics attributable to the upper surface 11 in the region of maximum thickness of the hydrofoil 10, and curve D represents the lift versus speed characteristics attributable to the lower surface 12 in the region of the maximum thickness of the hydrofoil 10.

The normal effective operating range of the hydrofoil 10 is indicated by the shaded segments of curves A, B and C. It will be noted that with this conventional hydrofoil configuration curve D is so displaced in the direction of higher speed requirements that when operating in the normal effective range, the lower surface is not making any desirable lift contribution to the operation of the hydrofoil.

Referring now to FIG. 2, a hydrofoil 20 embodying the present invention comprises a body having curved upper and lower surfaces 21 and 22 extending between leading and trailing edges 23 and 24. The body may be further characterized as having curved nose surface portions 21a and 22a of the upper and lower surfaces, which portions lie adjacent the leading edge 23 and respectively lie above and below a reference line 25 extending between the leading and trailing edges. In this embodiment of the invention, the radius of curvature of the upper nose surface portion 21a is on the order of five times the radius of curvature of the lower curved nose surface portion 22a, the radius of the former being indicated by an arrow 26 and the radius of the latter being indicated by an arrow 27.

It has been determined that the just described configuration of the hydrofoil 20, wherein the radius 26 of the upper nose section is on the order of five times greater than the radius 27 of the lower portion, substantially increases the upper surface pressure near the nose or leading edge more effectively than by any other means attempted, and shifts the stagnation pressure location to the upper surface.

This increased pressure retards cavitation development with increased angle of attack so that greater lift can be produced within the effective cavitation limits of the hy-

drofoil. Also, with unsymmetrical surfaces 21, 22, it is possible to design for cavitation speeds of the upper and lower surfaces 21, 22 to be nearly equal, which situation, as exemplified by FIG. 2, is not obtained with conventional practice. Accordingly, thinner foils can be used to reduce profile drag, larger aspect ratios can be used to reduce induced drag, and more efficient hydrofoils result which can be used for greater operating speeds. Additionally, the thinner foil configuration is better for surface piercing foils and foils that operate near the surface where depth influences the angle of attack.

FIG. 4 graphically illustrates, by a set of curves, the cavitation limits of the hydrofoil 20 embodying the invention, the vertical ordinates of the curves representing lift and the horizontal ordinates being speed. Thus, curve A' is representative of the lift versus speed characteristics attributable to the upper nose surface 21a of the hydrofoil 20. Curve B' is representative of the lift versus speed characteristics attributable to the lower nose surface 22a of the hydrofoil 20. Curve C' is representative of the lift versus speed characteristics attributable to the upper surface 21 in the region of maximum foil thickness, and curve D' represents the lift versus speed characteristics attributable to the lower surface 22 in the region of maximum thickness.

The normal operating range of the hydrofoil 20 is indicated by the shaded segments of the curves A', B', C' and D'. It will be noted that the configuration of the hydrofoil 20 embodying this invention, the curve D' falls in the normal operating area of the hydrofoil as indicated by the shaded curve segments.

From the foregoing detailed description of one embodiment of the invention, it will be appreciated that the invention satisfies the previously stated objects and advantages as well as others apparent from the description.

Obviously many modifications and variations of the present invention 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 hydrodynamic body having upper and lower surface portions which lie above and below a reference line and which extend from a nose portion at the leading edge of said body and terminate at the trailing edge of said body, wherein the improvement comprises:
 - a curved nose for said body wherein the portion of said nose above said reference line has a radius of curvature substantially larger than the radius of curvature for the portion below said reference line, said improvement affording a hydrodynamic body which may be operated at greater speeds without cavitation and with more effective lift and one having wider ranges of operating limits and improved lift to drag ratios and penetrability characteristics.
2. A hydrodynamic body as in claim 1 wherein said hydrodynamic body comprises a hydrofoil.
3. A hydrodynamic body as in claim 2 wherein said hydrofoil is a lift producing member.
4. The hydrodynamic body of claim 1 wherein the centers of the radius of curvatures for said upper and lower nose portions lie on said reference line.
5. The hydrodynamic body of claim 4 wherein said radius of curvature of said upper nose portion is substantially five times greater than the radius of curvature for said lower nose portion.

References Cited

UNITED STATES PATENTS

1,976,046	10/1934	Tietjens	114—66.5
3,109,495	11/1963	Lang	114—66.5

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