

Sept. 30, 1941.

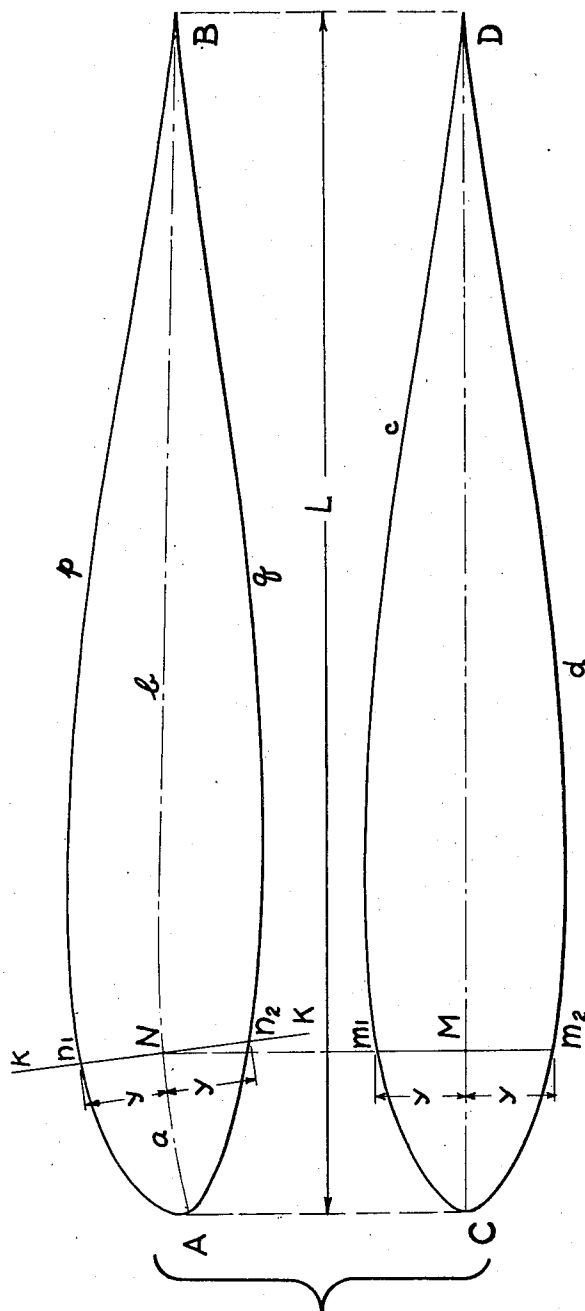
2,257,260

A. KARTVELICHVILI, NOW BY JUDICIAL
CHANGE OF NAME A. KARTVELI

AIRFOIL

Filed Aug. 27, 1938

2 Sheets-Sheet 1.



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2 Sheets-Sheet 2

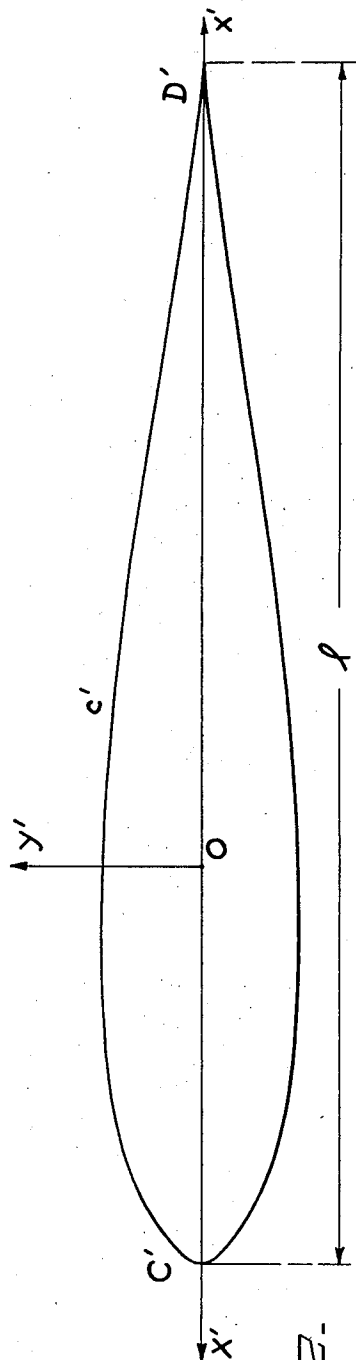


Fig. 2-

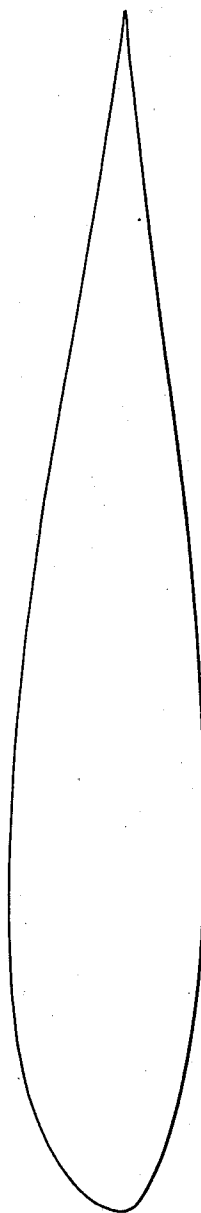


Fig. 3-

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UNITED STATES PATENT OFFICE

2,257,260

AIRFOIL

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Application August 27, 1938, Serial No. 227,099

4 Claims. (Cl. 244—35)

This invention relates to airfoils, and its object is to provide an airfoil having an improved profile or section.

More particularly, its object is to provide such a shape for an airfoil-section that the aerodynamic qualities and properties of the airfoil will all be superior to those of subsistent airfoils and specifically, such that its minimum profile-drag will be smaller, its maximum lift coefficient will be greater, and the "lift-curve" in the neighborhood of the burble-point will be smoother, than that of the ordinary airfoil.

A further particular object of the invention is to provide an airfoil which will have a greater operative range of angles of attack from zero lift to maximum lift than the ordinary airfoil, yet which will nonetheless have very little travel of the center of pressure.

The other objects and advantages of the invention will become apparent as this disclosure progresses.

The presently-preferred embodiment of these and other inventive concepts is illustrated in the accompanying drawings and expounded herein-after, but it is to be understood that the invention is limited in its embodiments only by the scope of the sub-joined claims. In the said drawings,

Figure 1 is a composite diagram showing a typical subsistent airfoil-section and the mode of laying it out;

Figure 2 is a diagram for use in showing how the present airfoil-section is derived, and

Figure 3 is a scale drawing of the profile of the airfoil derived by the present invention.

To clearly differentiate the present concept from all prior concepts in its category, it is necessary to set forth the prevalent method by which ordinary airfoils are laid out. Referring to Figure 1, a median line, $AabB$, is arbitrarily or empirically chosen. This line has its chord, L , equal to that desired of the final airfoil. A symmetrical section, $CcDdC$, called the thickness-distribution curve, is then arbitrarily or empirically selected, and it is hence by no means an ideally streamlined section. The chord, CD , of this curved figure is also equal to that of the airfoil sought. The airfoil sought is then constructed by points, using the following procedure: let M be a point on the chord line CD and m_1 and m_2 be the corresponding ordinates of the thickness-distribution curve; $Mm_1 = Mm_2 = y$. N is the projection of M over the line $AabB$. Through N draw the normal KK to the line $AabB$. On KK lay out $Nn_1 = Nn_2 = y$. Point n_1 and n_2 will belong to the airfoil sought and the locus of points such as

n_1 and n_2 will completely define the airfoil; these points are located by moving point M along the straight line CD and repeating the previous construction-procedure, giving the curve $ApBqA$.

For an airfoil thus generated, the aerodynamic characteristics will depend upon the shape of the median line and the shape of the thickness-distribution curve. With a given median line, these characteristics will depend solely upon the configuration of the thickness-distribution curve. For an ordinary airfoil, this thickness-distribution curve is arbitrarily chosen.

In the present invention, the thickness-distribution curve used is an ideal mathematical streamline for which an analytical expression can be given. According to this invention, the thickness-distribution curve is a plane closed contour the rectangular coordinates, X and Y , of which, have the following analytical relations in terms of a parameter, θ :

$$\left. \begin{aligned} X &= 2a(1 + \cos \theta) \frac{1 + S \cos \theta}{1 + S^2 + 2S \cos \theta} - 2\lambda \\ Y &= 2a(1 + \cos \theta) \frac{S \sin \theta}{1 + S^2 + 2S \cos \theta} \end{aligned} \right\} \quad (1)$$

Where a , S and λ are constant quantities for a given airfoil.

Referring to Figure 2, the contour $CcDdC$ is the line determined by Equations 1. It can be seen that the X axis is directed along the line of symmetry CD , the Y axis is perpendicular to it and the origin O is inside the segment CD . When θ is varied from zero to π , the point describes the upper part CcD of the contour; similarly, when θ is varied from zero to $-\pi$, the point describes the lower part CdD of the contour. The quantities a , S and λ , are constant and bear the following relationships to the chord-length, L , and to the thickness-ratio, k (which is to say, the ratio of the maximum thickness t of the thickness-distribution curve to its chord, L):

$$\left(\begin{aligned} a &= L/4(1 + .77k) \\ S &= \frac{.77k}{L/4(1 + .77k)} \\ \lambda &= L/4(1 - .592k^2) \end{aligned} \right) \quad (2)$$

The quantities k and L are chosen differently for every usage to which the airfoil is to be adapted, and when thus known, the relationships 1 and 2 permit the accurate construction of the present thickness-distribution curve, Equations 2 giving immediately arithmetical values for a , S

and λ ; then, replacing the values a , S and λ in system 1, we obtain

$$\begin{aligned}x &= f(\theta) \\ y &= \psi(\theta)\end{aligned}$$

or, in other words, we obtain the two coordinates of a point on the thickness-distribution curve in terms of a parameter θ .

The thickness-distribution curve thus obtained, from which the present novel airfoil is derived, differs radically from the ordinary in that its entering edge section is substantially sharp, and in that its trailing edge section is of a novel "feathering" shape; that is to say, at the rear, the upper and lower branches of it come tangent to the axis of symmetry, thereat, thus forming an angle of zero therewith, whereas in the ordinary thickness-distribution curve, its upper and lower branches form an angle differing greatly from zero degrees.

The outstanding advantage of the present thickness-distribution curve is that an infinite cylinder having a cross-section of this shape, if placed in a stream of incompressible and frictionless fluid, will produce a mathematically perfect streamline flow in which the drag will be zero. Experiments have shown that even in the case of a compressible and viscous fluid the flow around the cylinder of the present cross-section will approach a mathematically perfect streamline flow far more closely than in the case of the arbitrarily or empirically chosen distribution-curves universally employed heretofore, in determining ordinary airfoil-sections.

After this novel shape of the present thickness-distribution-curve has been thus determined, a median line $H-H$ of the desired final airfoil section, and which may be determined arbitrarily, empirically, or analytically, is laid down, and the final shape of the airfoil-section is obtained from the novel thickness-distribution-curve and enfolded around this line in the manner previously described, thus adapting the novel method of the present invention to median lines of any desired kind. When the thickness-distribution curve is transferred onto the skeleton curve, such as $H-H$, all the essential and beneficial geometrical and aerodynamic characteristics of the present novel thickness-distribution curve will reappear in the final airfoil; the leading edge will retain the novel shape, with a downward reflex, and the trailing edge surfaces will be curved, downwardly and upwardly, respectively, bitangent to the rear edge of the skeleton curve.

It is to be understood that by variously changing the shape of the skeleton curve $H-H$ and the thickness ratio k , an infinite number of sections can be developed from the same shape of distribution curve, and each member of this family of airfoils will lie within the scope of this invention.

Figure 3 gives the contour of an airfoil obtained by employing the concepts of this invention and by using the thickness-distribution curve of this invention combined with an ordinary skeleton curve.

It is to be observed that the airfoil, in profile outline, includes a sharp, downwardly flexed entering edge. It has been found that the radius of the leading edge of any airfoil constructed by

the method conforming to this invention can be expressed by the formula:

$$r = .694 \frac{t^2}{L}$$

where t is the maximum thickness of the airfoil and L is the chord. The entering edge is continued by a central and aft-central portion having, on the top and on the bottom, a shape approaching that of a parabola. The contour of the airfoil is completed by a doubly re-curved feathering trailing edge portion osculatory to the central portion and tangent to the median line at the trailing edge at zero degrees.

Wind tunnel tests run on airfoils conforming to the invention have conclusively demonstrated their superiority to an ordinary airfoil in regard to maximum lift, minimum drag and the smoothness of the lift curve. By simply varying the various pertinent factors in the equations above, the airfoil may be adapted over a wide range of uses, from high speed airplanes with the minimum compatible lift, to low speed, high lift airplanes.

In employing the method of the present invention in constructing an airfoil, there can be first built a basal symmetric thickness-distribution section, made—without bracing, etc.—of a re-curved, bent strip of material and having abscissae and ordinates of lengths expressed by the mathematical equations given hereinabove, and having its chordwise length equal to the chord of the desired ultimate airfoil; and having any desired spanwise length; then a structural member, such as a bent strip of material, can be built and laid down which will act as the median member of the ultimate airfoil; on this member can be arranged and attached, successive members, such as strips of metal, perpendicular thereto, the respective lengths of said members respectively corresponding to the respective ordinates of the thickness-member; then by laying or wrapping sheet-material continuously about the previously-formed "skeleton" in such manner as to connect the ends of the "perpendicular-members," the airfoil can be completed.

Having now made certain the nature and purposes of my invention, and at least one manner of executing same, according to the statutes, what I claim as my property and desire to secure by Letters Patent of the United States, is:

1. An airfoil-section having an essentially sharp entering edge; bi-convex forward, central and aft-central portions, and a bi-concave trailing edge portion.
2. An airfoil-section having an essentially sharp entering edge; bi-convex forward, central and aft-central portions, and a bi-concave trailing-edge portion, the upper and lower branches of which each come tangent to the axis of symmetry at an angle equal to zero degrees.
3. An airfoil-section, asymmetrical about its chord, and having a sharp, downwardly flexed entering edge, substantially modified, parabolic forward, central and aft-central portions, and a bi-concave trailing-edge portion.
4. In an airfoil-section, an asymmetrical bi-convex central portion, and a trailing-edge portion embraced between two re-curved lines osculatory to such a central portion.

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