Feb. 21, 1950 M. A. GARBELL 2,498,262

FLUID FOIL LIFTING SURFACE

Filed Sept. 16, 1946 3 Sheets-Sheet 1

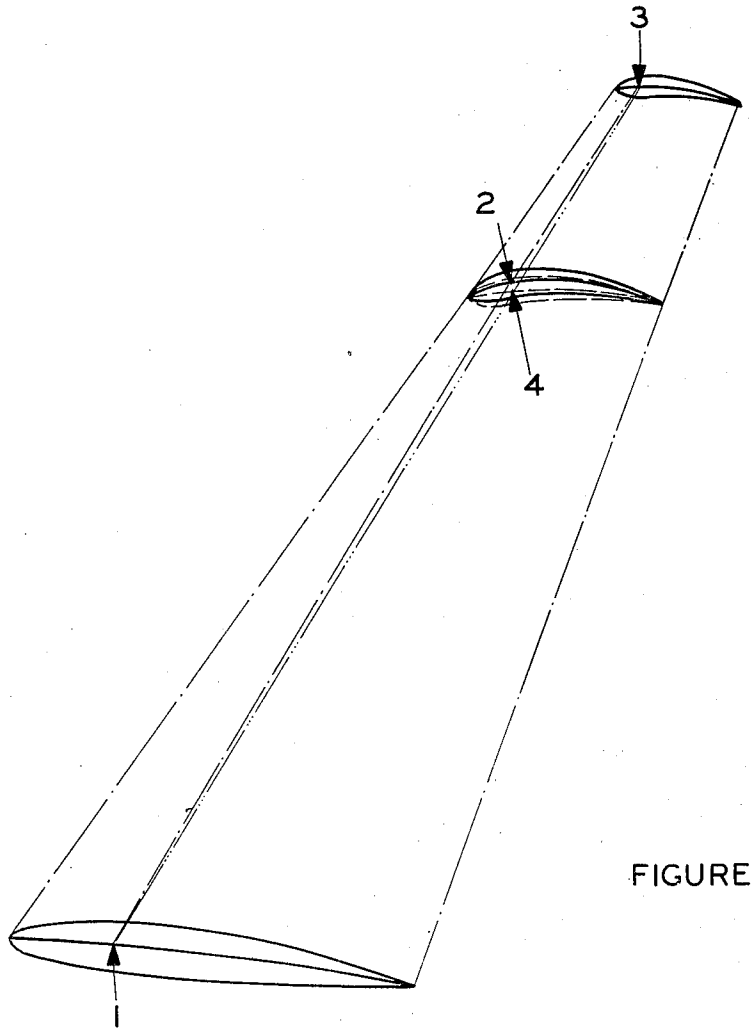


FIGURE 1

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FLUID FOIL LIFTING SURFACE

Filed Sept. 16, 1946

3 Sheets-Sheet 2

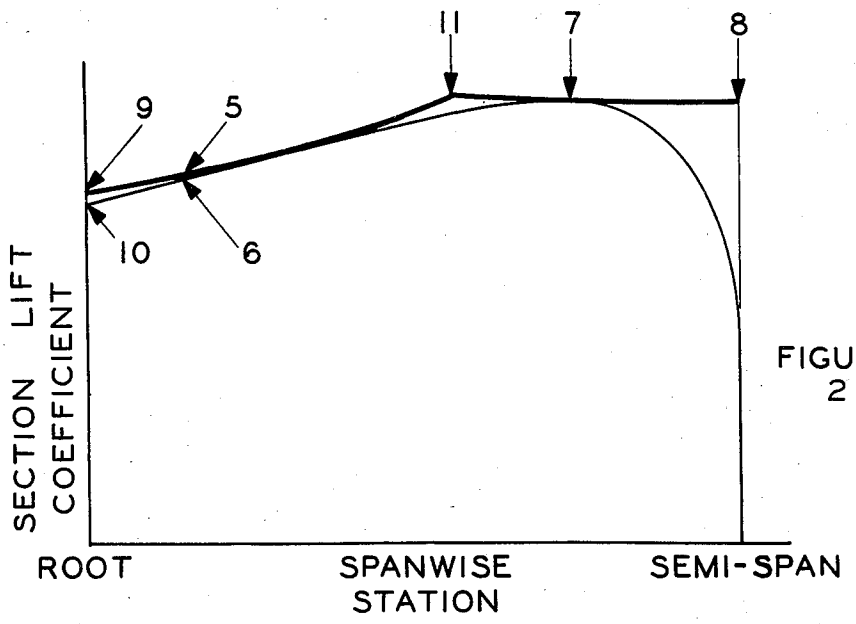


FIGURE 2

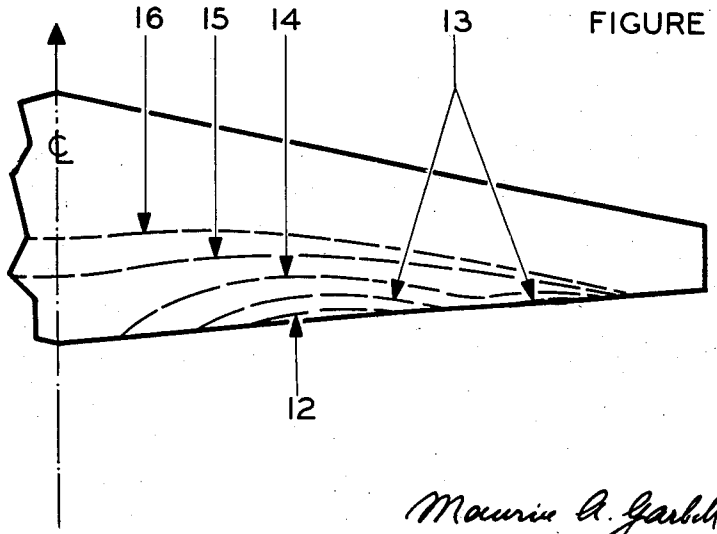


FIGURE 3

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FLUID FOIL LIFTING SURFACE

Filed Sept. 16, 1946 3 Sheets-Sheet 3

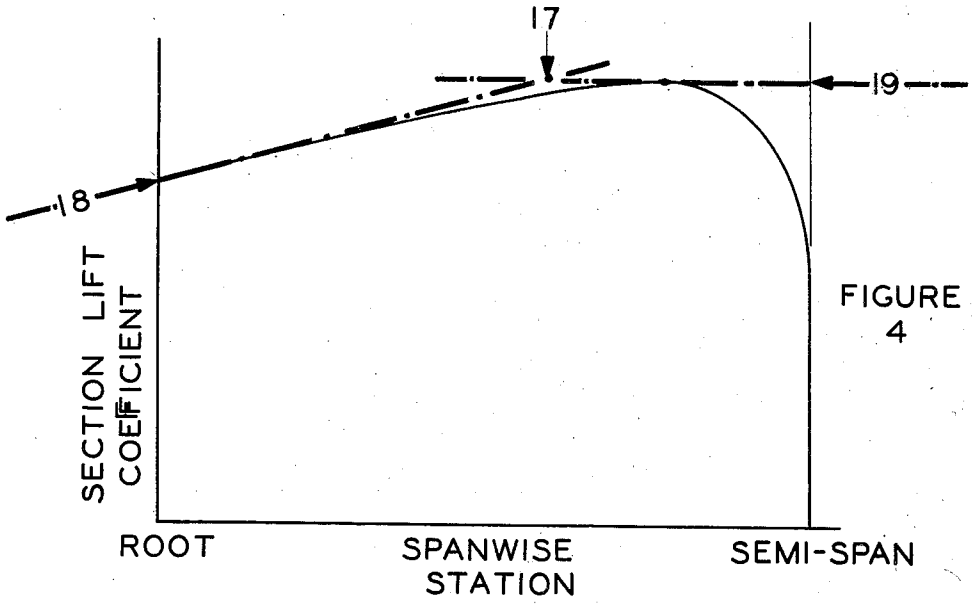


FIGURE 4

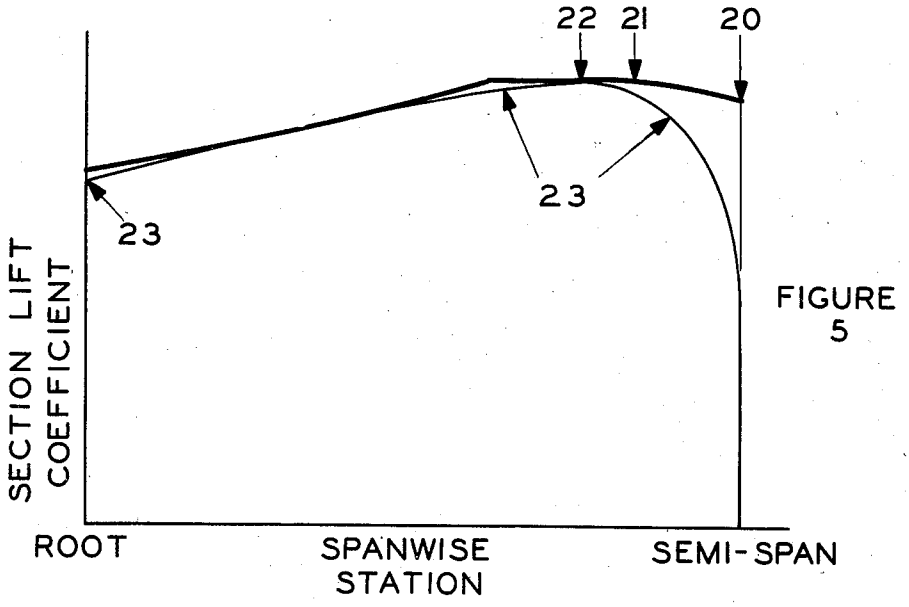


FIGURE 5

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Patented Feb. 21, 1950 2,498,262

UNITED STATES PATENT OFFICE

2,498,262

FLUID FOIL LIFTING SURFACE

Maurice A. Garbell, San Francisco, Calif., assignor, by direct and mesne assignments, of one-fourth to Maurice A. Garbell, Inc., San Francisco, Calif., a corporation of California, and three-fourths to Garbell Research Foundation, San Francisco, Calif., a corporation of California

Application September 16, 1946, Serial No. 697,281

12 Claims. (Cl. 244—35)

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This invention relates to the design and construction of surfaces to be driven through a fluid, and in particular through the air, intended to produce a useful force component perpendicular to the relative velocity of the fluid with respect to the surface; the said useful force component will be referred to hereinafter as "lift," and the said surfaces will be referred to hereinafter as "lifting surfaces."

The present application is a continuation in part of my co-pending application entitled Fluid foil lifting surface, Serial Number 683,815, filed on July 16, 1946, now Patent No. 2,441,758 of May 18, 1948, the general object of which is the attainment of good stalling characteristics on lifting surfaces by means of a novel method of fluid-foil selection, wherein the mean-line camber and if necessary the thickness ratio of one or more fluid-foil sections interjacent between the root and the tip of the lifting surface are varied from the respective values obtainable by straight-line fairing between the root and tip sections by following the subject method of the said co-pending application.

The general objects of the invention specified in the instant application are the attainment of good stalling characteristics, the elimination of violent rolling moments, the creation of stable nose-down pitching moments at the stall, the maintenance of adequate lateral-control effectiveness, the reduction of the fluid-dynamic drag, and a reduction of the resulting drag moment with respect to the root of the lifting surface.

Another object of the invention specified in the instant application is the attainment of especially high lifting-surface lift coefficients in those designs in which engineering considerations other than those pertaining solely to the control of stalling characteristics permit the fluid-dynamical design engineer to utilize interjacent fluid-foil sections having a mean-line camber greater than the mean-line camber of the section at the root or the section at the tip of the lifting surface, wherein the spanwise location, mean-line camber, and thickness ratio of the said interjacent fluid-foil sections are defined and explained in the subject specification of this invention.

Other objects and advantages will be apparent from an examination of the drawings accompanying the instant application taken in conjunction with the following, and in which:

Figure 1 shows a schematic perspective view of a lifting surface designed and constructed according to the method outlined in the subject specification.

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Figure 2 illustrates the spanwise distribution of actually prevailing section lift coefficients and the spanwise distribution of maximum attainable section lift coefficients on a typical lifting surface designed and constructed according to the subject method of this invention.

Figure 3 illustrates the typical inception and growth of the stall of a lifting surface designed and constructed according to the subject method of this invention.

Figure 4 illustrates the procedure employed in the finding of the optimum spanwise location of the third controlled fluid-foil section in a lifting surface designed and constructed according to the subject method of this invention.

Figure 5 illustrates the spanwise distribution of actually prevailing section lift coefficients and the spanwise distribution of maximum attainable section lift coefficients on a typical lifting surface designed and constructed according to the subject method of this invention, the tip section of said lifting surface having a thickness ratio smaller than the optimum thickness ratio for absolutely maximum attainable section lift coefficient for the series of fluid-foil sections employed in the lifting surface.

A preferred embodiment of this invention is described in the following specification; the broad scope of the invention is expressed in the claims concluding the instant application.

The invention consists of novel methods and combinations of methods described hereinafter, all of which contribute to produce a safe and efficient lifting surface.

Referring to the drawings for more specific details of the invention, Figure 1 serves to illustrate the preferred embodiment of this invention, comprising a lifting surface with three or more "controlled" fluid-foil sections, in which a section with a small mean-line camber 1 is located at the root of the lifting surface, a section with a greater mean-line camber 3 is located at the fluid-dynamically effective tip of the lifting surface (the actual tip fairing of the lifting surface may comprise a faired three-dimensional body without identifiable mean-line camber, which is not of any consequence in the application of the subject invention), and one or more interjacent sections 2 are selected following the method outlined below, said interjacent fluid-foil sections having values of the mean-line camber at variance with the values 4 obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root and the fluid-foil section located at the

tip of the lifting surface, wherein the respective values of the mean-line camber of one or more of the interjacent fluid-foil sections exceed the mean-line camber of the more highly cambered tip section. It shall be understood that the preceding considerations apply to all types of lifting surfaces regardless of the respective thickness ratios of the root and tip sections. It shall also be understood that additional considerations relative to the respective thickness ratios of the various controlled fluid-foil sections are presented herein for lifting surfaces wherein the thickness ratio of the root section is the greatest, and the thickness ratio of the tip section is the smallest, respectively, of any fluid-foil section employed in the lifting surface.

Figure 2 illustrates the preferred manner in which this invention, through the employment of the aforementioned method of fluid-foil selection, achieves the establishment of a curvilinear polygon 5 describing the spanwise distribution of maximum attainable section lift coefficients, said curvilinear polygon being so shaped that it envelops closely the curve 6 describing the spanwise distribution of the actually prevailing section lift coefficients, except that beyond the spanwise point 7 at which the highest actually prevailing section lift coefficient occurs the maximum attainable section lift coefficient exceeds substantially the actually prevailing section lift coefficient, so that the stall inception occurs near mid-semispan, spreads more prevalently inboardward and to a smaller extent outboardward as shown in orderly progression by curves 12, 13, 14, 15, and 16 in Figure 3, and does not involve the extreme tip of the lifting surface prior to the breakdown of the fluid flow over the entire remaining lifting surface. As used herein the curvilinear polygon 5 describing the spanwise distribution of maximum attainable section lift coefficients is established by the respective values of the maximum attainable lift coefficients of the root section 9, the tip section 8, and the third or additional control section 11, and by the respective maximum attainable lift coefficients 5 of the sections obtained by conventional fairing between each pair of controlled sections 9—11, 11—8, etc.

The curve 6 describing the spanwise distribution of the actually prevailing section lift coefficients at the maximum lift coefficient of the lifting surface is obtained by conventional methods of experimentally verified calculation for the desired lifting surface, taking into consideration the planform, effective aerodynamic washout, section lift-curve-slope characteristics, etc.

The term "envelopment" as used herein signifies the establishment of curvilinear polygon 5 on the convex side of the curve 6, wherein each individual branch 9—11, 11—8, and so forth of the curvilinear polygon 5 is tangent or nearly tangent to curve 6.

The following specification outlines the method employed in the design of the subject lifting surface of this invention, whereby to select the most opportune values of fluid-foil section mean-line camber and fluid-foil section thickness ratio required to achieve the objects of the instant invention:

To apply the subject method of this invention it is actually necessary to know only the planform of the lifting surface and the desired stall pattern. Inasmuch as practical considerations other than those pertaining solely to the control of the stalling characteristics ordinarily predetermine certain design parameters of the lifting surface,

preferred embodiments of the subject method of this invention are hereinafter explained for two typical combinations of predetermined design parameters:

In the first typical configuration the following design parameters, for example, are assumed to be given a priori: (*a*) the planform of the lifting surface, based on structural and practical design considerations; (*b*) the series of fluid-foil sections to be employed, based on high-speed and other performance requirements; (*c*) the maximum permissible effective aerodynamic washout, based on drag considerations and structural bending-moment limitations; (*d*) the thickness ratio of the fluid-foil section at the root, based on the critical-Mach-Number requirements and structural weight considerations; (*e*) the thickness ratio of the fluid-foil section at the tip, based on practical space requirements for control-surface balances, etc.; (*f*) the maximum mean-line camber of any fluid-foil section on the lifting surface, based on drag and pitching-moment limitations.

The subject method of this invention is employed firstly to design the lifting surface without any effective aerodynamic washout, that is, with the three or more controlled fluid-foil sections placed at such an angle of incidence with respect to the reference chord plane of the lifting surface that the said fluid-foil sections operate at their respective zero-lift angles of attack when the entire lifting surface operates at its angle of attack for zero overall lift.

Based on fundamental experimental wind-tunnel data available for the preselected series of fluid-foil sections, graphs are plotted showing the variation in the maximum attainable section lift coefficient versus the mean-line camber, thickness ratio, and Reynolds number, respectively; similar graphs are plotted showing the variation in the section zero-lift angle of attack versus the mean-line camber, thickness ratio, and Reynolds number, respectively.

For the spanwise location of the third and additional controlled sections 2 and 11, the subject method of this invention utilizes preferably locations between the spanwise point of the highest actually prevailing section lift coefficient 7 and the spanwise point located twice as distantly from the tip 8 as point 7, with a preferable optimum at the point 17, where the tangent to the inboard portion of the curve of spanwise distribution of the actually prevailing section lift coefficients 18 intersects the horizontal tangent 19 to the same curve, as shown in Figure 4.

It will be understood, however, that inescapable practical design considerations may require that the additional controlled sections 2 and 11 be placed at spanwise stations located inside power plant nacelles or at those spanwise stations where the lifting surface is mechanically jointed for sudden changes in planform taper, or sweep-back, as is the case in craft with removable or foldable outboard panels.

The thickness ratio obtainable at the third section 11 is calculated by straight-line interpolation between the root section and the tip section or is determined by such structural or other criteria of different nature as may be considered to prevail. However, the subject method of this invention teaches that best results are achieved if the thickness ratio of the tip section 3 is smaller than the optimum section thickness ratio for absolutely maximum attainable section lift coefficient of the fluid-foil series chosen, and if the thickness ratio of the

third section 2 and 11 is chosen equal to or slightly greater than the said optimum thickness ratio, so that the optimum thickness ratio occurs either at the third section 2 and 11 or at a spanwise location 21 near the point 22 of highest actually prevailing section lift coefficient.

The approximate maximum attainable lift coefficient of the entire lifting surface for appropriate values of the Reynolds number is estimated for example by dividing the maximum attainable section lift coefficient of the third fluid-foil section (obtained from the aforementioned wind-tunnel data for the selected values of the section thickness ratio and the maximum permissible mean-line camber) by the highest spanwise value of the "additional section lift coefficient

$$C_{l_{a_1}}$$

(as defined in Army-Navy-Commerce Manual ANC–1(1) entitled "Spanwise Air-Load Distribution"), as follows:

$$C_{L_{max}} = \frac{C_{l_{max}} \text{ of interjacent section}}{C_{l_{a_1}} \text{ highest}}$$

and by repeating this operation with checks of the Reynolds number of the said most highly cambered interjacent section as specified in the co-pending application, until the maximum attainable lift coefficient of the lifting surface is accurately determined.

The spanwise distribution 6 of the actually prevailing section lift coefficients is then calculated for the maximum lift coefficient $C_{L_{max}}$ of the entire lifting surface, following one of the conventional calculation methods.

For the Reynolds number and the pre-selected thickness ratio of the tip section, the required value of the mean-line camber is determined from the graph showing the experimentally measured variation of the maximum attainable section lift coefficient with varying mean-line camber, selecting that value of the mean-line camber that produces a maximum attainable section lift coefficient 8 substantially equal to the highest actually prevailing section lift coefficient 7.

For the Reynolds number and the pre-selected thickness ratio of the root section, the required value of the mean-line camber is determined from the graph showing the experimentally measured variation of the maximum attainable section lift coefficient with varying mean-line camber, selecting that value of the mean-line camber that produces a maximum attainable section lift coefficient 9 equal to or slightly superior to the section lift coefficient 10 actually prevailing over the root section.

From the foregoing, it will be readily seen that the lifting surface obtained by the invention, and defined by the curvilinear polygon 5, embodies the combination of a fluid-foil section 1 or 9 having the smallest mean-line camber at the root, a fluid-foil section 3 or 8 having a greater mean-line camber at the tip, and one or more interjacent controlled sections 2 or 11 having values of the mean-line camber at variance with the values 4 obtainable at the respective spanwise stations by means of straight line fairing between the root section and the tip section, wherein the mean-line camber of the third or an additional interjacent controlled section exceeds the mean-line camber of the more highly cambered tip section, while avoiding the undesirable effects of any material amount of aerodynamic washin.

If, for reasons other than those pertaining solely to the control of stalling characteristics, washout is desired, a small amount of effective aerodynamic washout is introduced, ½° to 1° in each step of the application of the method, wherein the total effective aerodynamic washout is distributed in appropriate fashion between the controlled sections and where the total washout is less than the maximum permissible washout as defined in the aforesaid initial design assumptions. The entire heretofore specified procedure including the establishment of a curve 6 conforming to the washout chosen is then repeated for the selected amount of effective aerodynamic washout, until the desired results as illustrated in Figures 2 and 3 are attained while satisfying the aforesaid requirements of different nature.

A typical example of the application of the principles of this invention to one well-known type of lifting surface is as follows: Here we assume a planform taper ratio of three to one, an aspect ratio of ten, a total effective aerodynamic washout of zero degree, a section thickness ratio tapering linearly from 22 per cent at the root to 15 per cent at the tip, the utilization of "63–" series NACA "low-drag" fluid-foil sections, a mean-line camber of the most highly cambered controlled section 2 characterized by an "ideal lift coefficient" C_{l_i} equal to 0.4. The term "ideal lift coefficient" is to be interpreted as defined by the National Advisory Committee for Aeronautics nomenclature and is herein used as a parameter characteristic of the mean-line camber of a fluid-foil section. Calculations based on conventional methods will indicate that a lifting surface having the above general design parameters will experience, at its maximum resultant lift coefficient, a distribution of section lift coefficients as illustrated in curve 6.

Following the procedures hereinbefore described, we achieve in the above-outlined construction the desirable stalling characteristics taught by this invention by placing the most highly cambered controlled section at a station approximately 70 per cent of the semi-span from the root and with an effective aerodynamic washout of zero degree with respect to the root section and through the use of mean-line camber of the root section 1 characterized by an "ideal lift coefficient" C_{l_i} equal to 0.1, and a mean-line camber of the tip section 3 characterized by an "ideal lift coefficient" C_{l_i} equal to 0.35.

In this structural example the mean-line camber of the interjacent controlled section 2 is greater than that of the root section 1 and of the tip section 3, and hence greater than that of the interpolated section 4 obtainable at the 70 per cent semi-span station by means of straight-line fairing between sections 1 and 3, and which accomplishes the envelopment of curve 6 by the curvilinear polygon 5.

It will be fully appreciated by those skilled in this art that the invention may be readily embodied in various devices wherein the thickness ratio of the interjacent section 2 is varied from that obtainable through straight-line fairing between root section 1 and tip section 3 in order to facilitate the attainment of the objectives of this invention with the smallest possible range of values of section mean-line camber.

The second typical configuration differs from the first in that two interjacent sections 2 may be utilized. Hence, the following design pa-

rameters are assumed to be given a priori: (*a*) The plan form of the lifting surface; (*b*) the series of fluid-foil sections to be employed and their fluid-dynamic characteristics; (*c*) the maximum permissible effective aerodynamic washout; (*d*) the thickness ratios of the fluid-foil section at the root and of the fluid-foil section at the tip, respectively; (*e*) the maximum mean-line camber to be assigned to any fluid-foil section on the lifting surface.

The number of interjacent "controlled" fluid-foil sections, in this case, is not limited. The following representative specification applies to the case of two interjacent controlled fluid-foil sections; however, the reasonings specified therein are obviously usable in the design of lifting surfaces with a different number of interjacent controlled sections. Here it will be understood that the values of the mean-line camber of one or more of the interjacent controlled sections **2** are greater than that of the more highly cambered tip section **3**, while one or more of the remaining interjacent controlled sections **2** may be either greater or smaller than that of the aforementioned tip section **3**, depending on the range of section thickness ratios encountered between the root and the tip of the lifting surface.

In this case the instant method teaches that the optimum spanwise location for the interjacent fluid-foil section having the greatest mean-line camber is in the vicinity of the spanwise station carrying the highest actually prevailing section lift coefficient **7**, and that the optimum spanwise location for the second interjacent fluid-foil section is point **17**, where the tangent at the root to the curve of spanwise distribution of the actually prevailing section lift coefficients **18** intersects the horizontal tangent **19** to the same curve, as shown in Figure 4. The instant method also teaches that best stalling characteristics are obtained by assigning to the two or more interjacent fluid-foil sections values of the section thickness ratio that, for the series of fluid-foil sections selected, yield the absolutely maximum attainable section lift coefficients.

The approximate maximum attainable lift coefficient of the entire lifting surface is estimated by dividing the maximum attainable section lift coefficient of the most highly cambered fluid-foil section by the highest spanwise value of the "additional section lift coefficient

$$C_{l_{a_1}}"$$

in a manner substantially similar to that previously outlined.

The spanwise distribution of the actually prevailing section lift coefficients **23** is then calculated for the maximum lift coefficient of the entire lifting surface as previously outlined.

For the Reynolds number of the additional interjacent fluid-foil section, preferably located at the spanwise station **17** abovedefined, the required value of the mean-line camber and if necessary the thickness ratio is determined substantially as outlined for the fluid-foil section **11** in the co-pending application.

The value of the mean-line camber of the fluid-foil section located at the tip of the lifting surface is not of consequence in the application of the subject method of this invention, provided that the maximum attainable section lift coefficients represented by the curved segment connecting points **22** and **20** Figure 5 remains

substantially above the curve of actually prevailing section lift coefficients **23**.

If the designer intends to achieve positive stall inception in a certain spanwise panel of the lifting surface, the subject method of this invention specifies that in either of the aforedescribed design procedures the mean-line camber and thickness ratios, as well as the spanwise location, of the sections comprised within or adjacent to the panel for which stall inception is desired be so selected that within the "stall inception panel" the curve of maximum attainable section lift coefficients lies slightly below the curve of actually prevailing section lift coefficients, without modifying the aforedescribed relationship of the maximum attainable section lift coefficients and the actually prevailing section lift coefficients on the remainder of the semispan of the lifting surface outside of the "stall-inception panel" proper.

If, in any of the aforedescribed cases, the lifting surface under consideration is modified by excrescences such as, for example, power-plant nacelles, or flaps that modify the local zero-lift angle and the local maximum attainable section lift coefficient, the calculation of the maximum attainable section lift coefficients and of the effective washout at the various spanwise stations takes due account of the effects of these modifications by introducing "equivalent values" of the effective washout and section mean-line camber into the subject method of this invention.

Upon completion of the procedure outlined for the subject method of this invention, the zero-lift angles of the fluid-foil sections selected thusly are determined for their respective mean-line cambers, thickness ratios, and Reynolds numbers, and each fluid-foil section is set properly with respect to the reference chord plane of the lifting surface, so that the desired effective washout is achieved.

By practicing my invention a lifting surface can be designed and constructed to achieve the objects hereinbefore stated.

Theoretical calculations, as well as numerous tests performed in flight and in the laboratory, have demonstrated convincingly that each of the objects of this invention has been fully achieved.

The inventor wishes it to be clearly understood that the generally judged excellently satisfactory stalling characteristics of lifting surfaces designed and constructed according to the subject method of this invention are directly attributable to the use of three (or more) controlled fluid-foil sections selected according to the hereinbefore specified method of this invention, and to the aforedescribed method employed in the design of such lifting surfaces.

This invention accomplishes an important improvement in the art, and the discoveries herein disclosed are of great value to all types of aircraft (as well as to craft operating in other fluids), throughout their entire operating range, and especially in the critical low-speed operation where steadiness of lift and lift variation, stability of the craft, control effectiveness, and smoothness and stability of control forces are of vital importance for the safety and efficiency of the craft; also in violent maneuvers at high speeds when high lifting-surface lift coefficients comparable with those occurring at the low-speed stall are encountered and even temporarily surpassed.

I claim:

1. A lifting surface with three or more controlled fluid-foil sections, in which the first sec-

tion with a small mean-line camber is located at the root, the second section with greater mean-line camber is located at the fluid-dynamically effective tip, and the third or additional fluid-foil sections are located at stations interjacent between the root and the tip, wherein the values of the mean-line camber of the interjacent fluid-foil sections are at variance with the values of the mean-line camber obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section, said three or more controlled fluid-foil sections having values of the mean-line camber selected in such manner that the resulting spanwise distribution of maximum attainable section lift coefficients of the three or more controlled sections forms a curvilinear polygon enveloping a curve representing the spanwise distribution of section lift coefficients prevailing at the maximum attainable lift coefficient of the lifting surface, for a given planform and discarding the effect of any material amount of aerodynamic washin.

2. A lifting surface with three or more controlled fluid-foil sections adapted to provide stall inception within a predetermined interval of spanwise stations, in which the first section with a small mean-line camber is located at the root, the second section with greater mean-line camber is located at the fluid-dynamically effective tip, and the third or additional fluid-foil sections are located at stations interjacent between the root and the tip, wherein the values of the mean-line camber of the interjacent fluid-foil sections are at variance with the values of the mean-line camber obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section, said three or more controlled fluid-foil sections having values of the mean-ilne camber selected in such manner that the resulting spanwise distribution of maximum attainable section lift coefficients of the three or more controlled sections forms a curvilinear polygon enveloping a curve representing the spanwise distribution of section lift coefficients prevailing at the maximum attainable lift coefficient of the lifting surface, for a given planform and discarding the effect of any material amount of aerodynamic washin, and that the said polygon representing the resulting spanwise distribution of maximum attainable section lift coefficients be so shaped that the first intersection with the curve representing the spanwise distribution of prevailing section lift coefficients occurs in that interval of spanwise stations for which stall inception is to be obtained.

3. A lifting surface with three or more controlled fluid-foil sections, in which the first section with a small mean-line camber and greatest thickness ratio is located at the root, the second section with greater mean-line camber and smallest thickness ratio is located at the fluid-dynamically effective tip, and the third or additional fluid-foil sections are located at stations interjacent between the root and the tip, wherein the values of the thickness ratio of the interjacent fluid-foil sections are greater than the values of the thickness ratio obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section.

4. A lifting surface with three or more controlled fluid-foil sections, in which the first section with a small mean-line camber is located at the root, the second section with greater mean-line camber is located at the fluid-dynamically effective tip, and the third or additional fluid-foil sections are located at stations interjacent between the root and the tip, wherein the values of the thickness ratio of the interjacent fluid-foil sections are at variance with the values of the thickness ratio obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section, said three or more controlled fluid-foil sections having values of the mean-line camber and the thickness ratio selected in such manner that the resulting spanwise distribution of maximum attainable section lift coefficients of the three or more controlled sections forms a curvilinear polygon enveloping a curve representing the spanwise distribution of section lift coefficients prevailing at the maximum attainable lift coefficient of the lifting surface, for a given planform and discarding the effect of any material amount of aerodynamic washin.

5. A lifting surface with three or more controlled fluid-foil sections adapted to provide stall inception within a predetermined interval of spanwise stations, in which the first section with a small mean-line camber is located at the root, the second section with greater mean-line camber is located at the fluid-dynamically effective tip, and the third or additional fluid-foil sections are located at stations interjacent between the root and the tip, wherein the values of the thickness ratio of the interjacent fluid-foil sections are at variance with the values of the thickness ratio obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section, said three or more controlled fluid-foil sections having values of the mean-line camber and the thickness ratio selected in such manner that the resulting spanwise distribution of maximum attainable section lift coefficients of the three or more controlled sections forms a curvilinear polygon enveloping a curve representing the spanwise distribution of section lift coefficients prevailing at the maximum attainable lift coefficient of the lifting surface, for a given planform and discarding the effect of any material amount of aerodynamic washin, and that the said resulting spanwise distribution of maximum attainable section lift coefficients be so shaped that the first

intersection with the spanwise distribution of prevailing section lift coefficients occurs in that interval of spanwise stations for which stall inception is to be obtained.

6. A lifting surface with three or more controlled fluid-foil sections, and having a highest actually prevailing section lift coefficient at a predetermined spanwise station, in which the first section with a small mean-line camber is located at the root, the second section with greater mean-line camber is located at the fluid-dynamically effective tip, and one of the interjacent fluid-foil sections is located near a spanwise point where a tangent to the inboard portion of the curve representing the spanwise distribution of actually prevailing section lift coefficients, for a given planform and discarding the effect of any material amount of aerodynamic washin, intersects a substantially horizontal tangent to the highest point of the same curve, wherein the values of the mean-line camber of the interjacent fluid-foil sections are greater than the values of the mean-line camber obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section.

7. A lifting surface with three or more controlled fluid-foil sections, and having a highest actually prevailing section lift coefficient at a predetermined spanwise station, in which the first section with a small mean-line camber and greatest thickness ratio is located at the root, the second section with greater mean-line camber and smallest thickness ratio is located at the fluid-dynamically effective tip, and one of the interjacent fluid-foil sections is located near a spanwise point where a tangent to the inboard portion of a curve representing the spanwise distribution of actually prevailing section life coefficients, for a given planform, and discarding the effect of any material amount of aerodynamic washin, intersects a substantially horizontal tangent to the highest point of the same curve, wherein the values of the thickness ratio of the interjacent fluid-foil sections are greater than the values of the thickness ratio obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section.

8. A lifting surface with three or more controlled fluid-foil sections, and having a highest actually prevailing section lift coefficient at a predetermined spanwise station, in which the first section with a small mean-line camber is located at the root, the second section with greater mean-line camber is located at the fluid-dynamically effective tip, and two of the interjacent fluid-foil sections are located respectively near the spanwise station of highest actually prevailing section lift coefficient and near a spanwise point where a tangent to the inboard portion of a curve representing the spanwise distribution of actually prevailing section lift coefficients, for a given planform and discarding the effect of any material amount of aerodynamic washin, intersects the horizontal tangent to the highest point of a substantially same curve, wherein the values of the mean-line camber of the interjacent fluid-foil sections are greater than the values of the mean-line camber obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section.

9. A lifting surface with three or more controlled fluid-foil sections, and having a highest actually prevailing section lift coefficient at a predetermined spanwise station, in which the first section with a small mean-line camber and greatest thickness ratio is located at the root, the second section with greater mean-line camber is located at the fluid-dynamically effective tip, and two of the interjacent fluid-foil sections are located respectively near the spanwise station of highest actually prevailing section lift coefficient and near a spanwise point where a tangent to the inboard portion of a curve representing the spanwise distribution of actually prevailing section lift coefficients, for a given planform and discarding the effect of any material amount of aerodynamic washin, intersects a substantially horizontal tangent to the highest point of the same curve, wherein the values of the thickness ratio of the interjacent fluid-foil sections are greater than the values of the thickness ratio obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section.

10. A lifting surface with three or more controlled fluid-foil sections, in which the first section with a small mean-line camber and greatest thickness ratio is located at the root, the second section with greater mean-line camber and smallest thickness ratio is located at the fluid-dynamically effective tip, and the third or additional fluid-foil sections are located at stations interjacent between the root and the tip, wherein the values of the thickness ratio of the interjacent fluid-foil sections are smaller than the values of the thickness ratio obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section.

11. A lifting surface with three or more controlled fluid-foil sections, and having a highest actually prevailing section lift coefficient at a predetermined spanwise station, in which the first section with a small mean-line camber and greatest thickness ratio is located at the root, the second section with greater mean-line camber and smallest thickness ratio is located at the fluid-dynamically effective tip, and one of the interjacent fluid-foil sections is located near a spanwise point where a tangent to the inboard portion of a curve representing the spanwise distribution of actually prevailing section lift co-

efficients, for a given planform and discarding the effect of any material amount of aerodynamic washin, intersects a substantially horizontal tangent to the highest point of the same curve, wherein the values of the thickness ratio of the interjacent fluid-foil sections are smaller than the values of the thickness ratio obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section.

12. A lifting surface with three or more controlled fluid-foil sections, and having a highest actually prevailing section lift coefficient at a predetermined spanwise station, in which the first section with a small mean-line camber and greatest thickness ratio is located at the root, the second section with greater mean-line camber and smallest thickness ratio is located at the fluid-dynamically effective tip, and two of the interjacent fluid-foil sections are located respectively near the spanwise station of highest actually prevailing section lift coefficient and near a spanwise point where a tangent to the inboard portion of a curve representing the spanwise distribution of actually prevailing section lift coefficients, for a given planform and discarding the effect of any material amount of aerodynamic washin, intersects a substantially horizontal tangent to the highest point of the same curve, wherein the values of the thickness ratio of the interjacent fluid-foil sections are smaller than the values of the thickness ratio obtainable at the respective spanwise stations by means of straight-line fairing between the fluid-foil section located at the root of the lifting surface and the fluid-foil section located at the tip of the lifting surface, and wherein the mean-line camber of one or more of the interjacent fluid-foil sections exceeds the mean-line camber of the more highly cambered tip section.

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