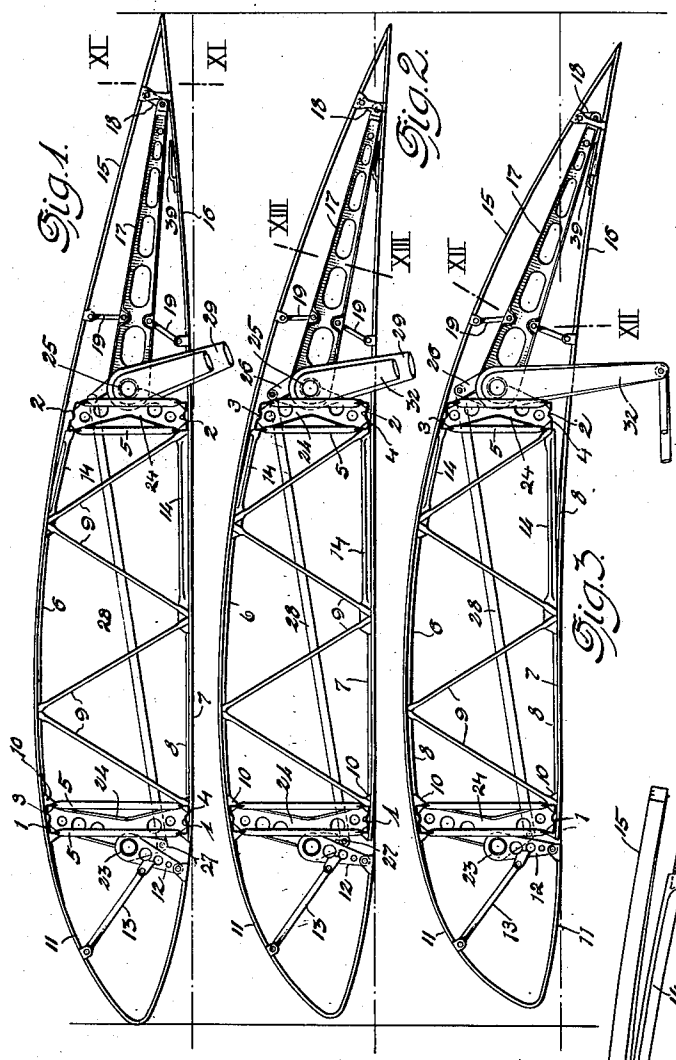
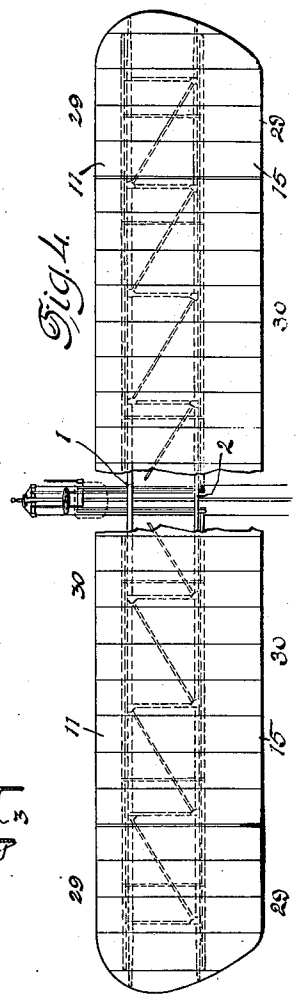
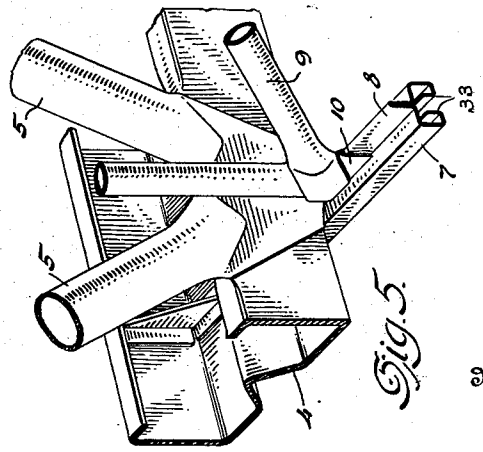
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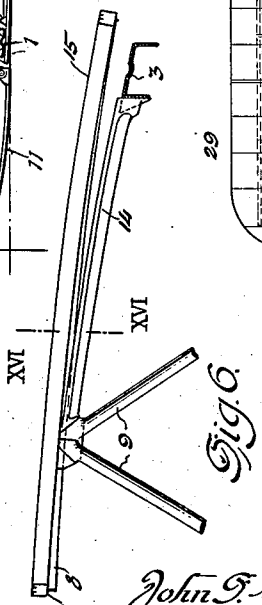
AEROFOIL

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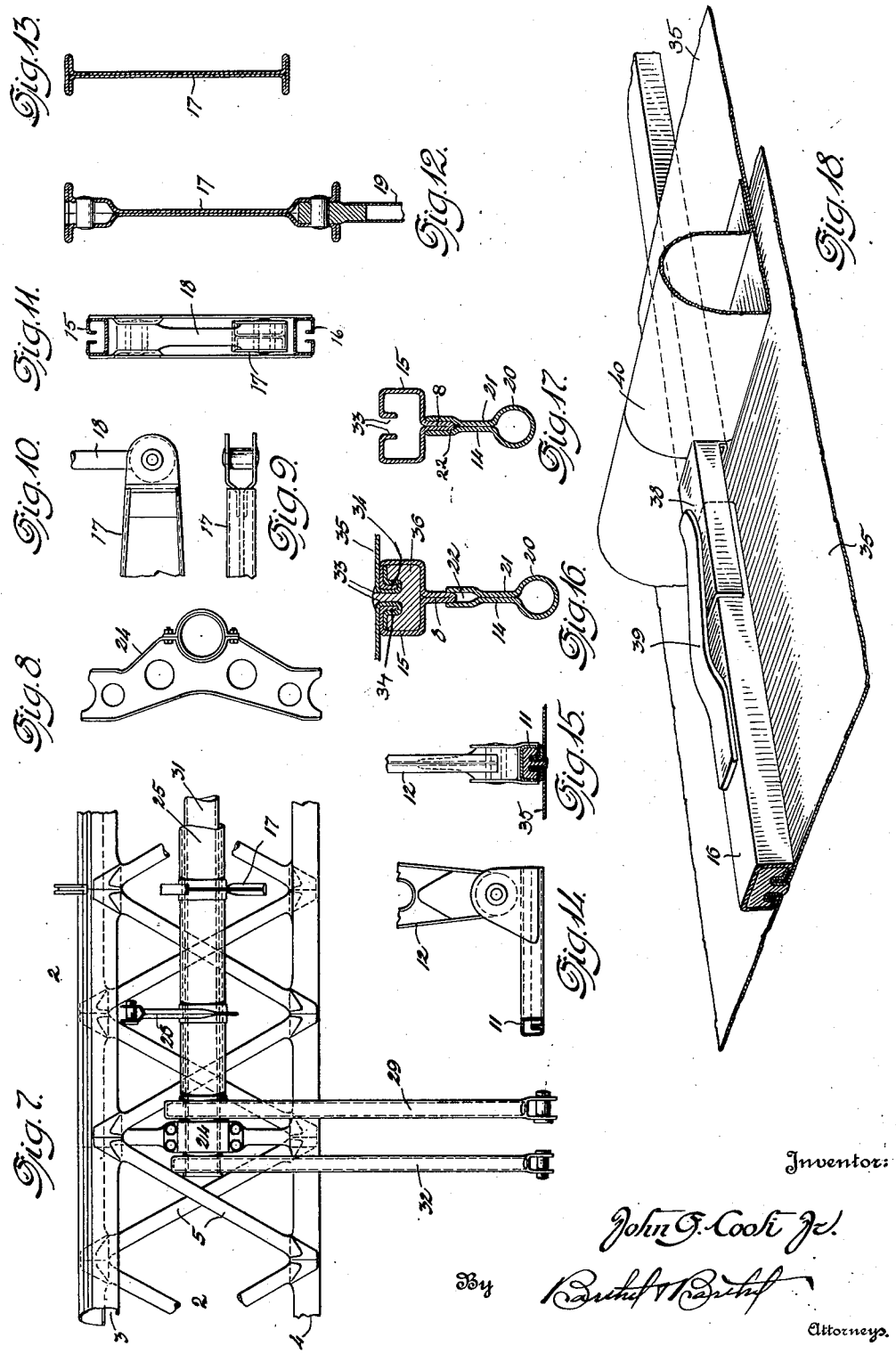


Inventor:
John F. Cook Jr.
By Brittain & Brittain
Attorneys

June 24, 1930. J. F. COOK, JR 1,766,107

AEROFOIL

Filed Sept. 5, 1924 2 Sheets-Sheet 2



Inventor:

John F. Cook Jr.

By Bristol & Bristol

Attorneys.

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UNITED STATES PATENT OFFICE

JOHN F. COOK, JR., OF DETROIT, MICHIGAN

AEROFOIL

Application filed September 5, 1924. Serial No. 735,986.

This invention relates to an improved aerofoil and more particularly to an internally trussed wing or aerofoil of metallic construction.

An object of the present invention is to secure in an aerofoil relatively high speed efficiency, together with high lift and low landing speed, to insure safety in landing and take-off. A further object is to permit increase in unit loading, to secure in a variable camber aerofoil a substantially stable center of pressure, and to maintain during change of camber and incidence, the relation of the main portion of the aerofoil relative to the fuselage and line of flight. It is also an object to provide an aerofoil construction wherein its camber may be changed at will, and wherein throughout the entire range of such adjustment, its upper and lower surfaces will have a minimum discontinuity of curvature. A further object is to secure change in camber and incidence by a simultaneous movement of nose and trailing edge portions, whereby the rearward movement of the maximum ordinate and consequent rearward movement of center of pressure is counteracted by a simultaneous increase in angle of incidence which will normally cause a forward movement of the center of pressure. It is also an object to provide certain new and useful structural features whereby cheapness, strength and durability of construction are secured, the necessity for riveting of wing covering is obviated, thereby making such covering removable for the purpose of repair, and whereby certain other advantages are secured, all as will hereinafter more fully appear.

With the above and other ends in view, the invention consists in the matters hereinafter set forth and more particularly pointed out in the appended claims, reference being had to the accompanying drawings, in which

Figure 1 is a vertical cross section of an aerofoil illustrative of the present invention and showing the same at its position of adjustment giving greatest efficiency for high speed;

Fig. 2 is a similar section showing the aerofoil in mid position of its adjustment;

Fig. 3 is a section similar to Figs. 1 and 2, and showing the aerofoil adjusted to produce a cross section of high efficiency for low speed;

Fig. 4 is a diagrammatic plan view of a portion of an aerofoil illustrating the application of aerofoils embodying the invention to the wing construction thereof;

Fig. 5 is a perspective detail of a portion of a wing spar showing the manner of attaching a rib thereto;

Fig. 6 is a sectional detail illustrative of the manner of attaching a flexible rib to a trussed rib connecting front and rear spars;

Fig. 7 is an enlarged detail showing in elevation a portion of a rear spar and means mounted thereon for operating portions of an aerofoil of which said spar is a part;

Fig. 8 is a side elevation of a bearing member for shafts forming part of the means for operating the aerofoil;

Fig. 9 is a detail showing in plan view the construction of the rear end of a lever for operating the trailing edge portion of the aerofoil;

Fig. 10 is a detail showing in side elevation, the part shown in Fig. 9;

Fig. 11 is an enlarged cross section substantially upon the line XI—XI of Fig. 1, showing the manner of connecting the rear end of said operating lever to upper and lower flexible ribs adjacent the trailing edge of the aerofoil;

Fig. 12 is a sectional detail of said operating lever substantially upon the line XII—XII of Fig. 3;

Fig. 13 is a cross sectional detail of said lever substantially upon the line XIII—XIII of Fig. 2;

Fig. 14 is a detail showing in side elevation the manner of connecting a front operating lever to the end of a flexible rib;

Fig. 15 is a similar detail showing in end elevation the parts shown in Fig. 14;

Fig. 16 is a sectional detail substantially upon the line XIV—XIV of Fig. 6, showing a flexible rib in cross section and in the

position relative to its trussed rib, illustrated in Fig. 1;

Fig. 17 is a similar sectional detail, showing the flexible rib in the position illustrated in Fig. 3, and

Fig. 18 is a perspective detail of a portion of the lower flexible rib adjacent the trailing edge of the aerofoil and showing an overlapped joint for the aerofoil skin or sheet metal covering.

It is well known that wing curvature is a determining factor in the efficiency of an aerofoil. An aerofoil of low camber having a relatively low lift has been found to have high efficiency at small angles of incidence and at high speeds. Generally speaking, a high speed type of airplane requires a totally different wing section and incidence from that of a low or moderate speed type. It is essential that the speed at the time of landing be not so great as to endanger the safety of the pilot or of the airplane, and as the most efficient wing section for low speed is not the most efficient section for high speed, airplanes have hitherto usually been a compromise between fast and low speed sections in order to insure safe landing and take-off, that is to say, to obtain slow landing speed with a fixed wing airplane, it is necessary to sacrifice maximum speed.

Where maximum speed is of first consideration, an approximation to a stream line wing section at a small angle of incidence is necessary. For slow flying, a wing section characterized by good upper and lower surface cambers and comparatively large angles of incidence is necessary. At the small angles of incidence used in high speed types, the drift co-efficient should be a minimum, and for the minimum expenditure of power at maximum speed the lift co-efficient at the minimum value of the drift co-efficient should be sufficient for the wing area chosen, to support the load at that speed. The lift may be increased by an increase in the angle of incidence and by an alteration in section.

The lift co-efficient should increase continuously from a negative or zero angle to about sixteen degrees, and it should then remain constant and decrease at a low rate without having a sharp critical angle.

For good speed range the center of pressure for the range of flying angles used, should have a stable position and a minimum range of movement along the chord.

The position of the maximum ordinate of an aerofoil is an important factor in determining the location of the center of pressure, and movement of the maximum ordinate to the rear will normally cause rearward movement of the center of pressure. Conversely, increase in the angle of incidence will normally cause forward movement of the center of pressure. Variation in wing section or change in camber with a simultaneous increase in the angle of incidence of the aerofoil, will therefore secure a substantially stable or fixed center of pressure as change in camber tends toward rearward movement of the center of pressure and change in incidence tends toward forward movement of the center of pressure, the two changes when simultaneously effected, thus counterbalancing each other in their effect upon the movement of the center of pressure, and by a proper proportioning, the center of pressure will therefore remain substantially constant.

In the present construction the nose and trailing edge portions of the aerofoil are arranged for simultaneous adjustment, and therefore the lift is increased and the unit loading of the wing or aerofoil may also be greatly increased due to change in cross-section of the wing, while in flight, from a configuration suitable for high speed, to a configuration of deep camber suitable for high lift at slow speed, thus giving a reasonably low landing speed and a maximum speed not permissible in a wing construction as ordinarily designed for load carrying.

The aerofoil as illustrated in the accompanying drawings is constructed entirely of metal, the spars and ribs being preferably made of alloy steel members secured together by electric spot welding, while the sheet plates forming the skin or covering are preferably of aluminum or other metallic alloys, light in weight and of great strength and flexibility, which permits of flexing to change the camber and provides for continuity of curvature upon such flexure.

An aerofoil illustrative of the present invention is shown in Figs. 1, 2 and 3, having for its main supporting members a front spar 1 and a rear spar 2, both of the double warren truss type, and as shown in Fig. 7, each comprising an upper chord member 3 and a lower chord member 4 of open channel section, connected by tubular lattice web members 5.

The wing or aerofoil ribs each comprise an upper chord member 6 and a lower chord member 7 which chord members are of open channel formation with a central longitudinal rib 8 formed integral with the closed side of the channel, and tubular trussing members 9 extending between and preferably spot welded to the chord members. These trussed ribs extend between and connect the spars, each trussed rib being connected at its front end to the front spar by corner brackets 10 on said spar which are welded to the ribs 8 of the chord members of the trussed rib, said ribs 8 being cut away where the chord members cross the spar, to lie flat thereon and to be welded thereto. The upper chord member 6 is continued around the nose or entering edge of the wing and prop-

erly curved to give the desired cross-sectional contour to said nose. From the front spar forwardly, the rib 8 of this forward continuation 11 of the chord member 6, is gradually tapered out or diminished until it merges into the channel bottom or closed side of the member midway between the entering edge of the aerofoil and said spar so that said forward portion 11 will be flexible, but more nearly rigid adjacent the spar. The trussed or rigid portions of the chords 6 and 7 are curved to give the desired curvature to the upper and lower wing surfaces between the spars, and the flexible forward portion 11 of the member 6 after curving downwardly toward the entering edge of the aerofoil to form a continuation of the curvature of the rigid portion, is given an abrupt turn backwardly, the abrupt turn forming the entering edge and the backward continuation forming the lower side of the nose portion and following the desired curvature of said side backwardly to a point adjacent the forward side of the front spar where the free end of this flexible part 11 is pivotally secured to the lower end of an operating arm 12 as shown in detail in Figs. 14 and 15. There is a space between this free end of said flexible rib and the forward end of the lower fixed chord 7 of the trussed chord, which forward end is welded to and extends across the lower side of the front spar. The sectional contour or curvature of the nose portion of the aerofoil forwardly of the front spar may therefore be modified or adjusted at will by a swinging movement of the arms 12, one of which is preferably provided for each rib, and to assist in giving the proper curvature to the upper side of the nose portion in all positions of its adjustment, a link 13 is pivotally attached at one end to each of said flexible ribs 11 intermediate the entering edge and spar of the aerofoil and at their opposite ends, these links are pivotally attached to the arms 12 intermediate the ends thereof. The several flexible ribs 11 are thus moved endwise by the operating arms to change the cross-sectional contour of the nose portion of the aerofoil and the curvature of the upper side of said nose portion is simultaneously changed by the links 13, proper cross-sectional contour of the nose portion of the aerofoil and continuity of the curvature of the upper surface of the aerofoil, being thus maintained throughout the range of adjustment of said nose portion.

Each of the several trussed or rigid ribs is connected at its rear end to the rear spar 2 by short supplemental chord members 14 which are secured in any suitable manner at their rear ends to the channel chords 3 and 4 of the rear spar and at their forward ends, to the chord members 6 and 7 at the points of intersection of lattice members 9 with these chords, and thus the rearwardly extending portions 15 and 16 of said chords 6 and 7 are free to flex from a point forwardly of the rear spar or place of attachment of the supplemental chord members 14 to said members 6 and 7, to the trailing edge of the airplane, and are unattached to the spar but pass across it without contacting therewith. These rear end portions are therefore free to flex, the rib 8 of each of the members 6 and 7 being tapered or reduced from the point of attachment of the supplemental member 14 thereto, rearwardly until it merges into the bottom of the channel of the member at a point near or slightly in the rear of the rear spar as shown in Fig. 6. The rear end portions or flexible ribs 15 and 16 are continued rearwardly in curved and converging relation and meet at an acute angle where they are secured together and from the trailing edge of the aerofoil. An adjustable trailing portion is thus provided which may be bent or deflected as desired by means of one or more long levers 17 which extend into this rear edge portion of the aerofoil and are pivotally connected at their rear ends to the flexible ribs 15 and 16 near the trailing edge of the areofoil by means of links 18 as shown in Figs. 9, 10 and 11. These flexible rib members are also attached intermediate the trailing edge of the areofoil and their point of rigid support and connection to their trussed ribs, by means of links 19 which are pivotally attached at one end to the flexible rib members and at their inner ends to the lever 17, as shown in Fig. 12. Each of these levers 17 is preferably formed from sheet metal by folding the sheet into an I-cross-section as shown in Fig. 13, to give maximum strength and minimum weight.

The supplemental chord members 14 are also preferably formed of sheet metal by folding a sheet strip upon itself to provide a tubular inner part 20 and a laterally outstanding rib 21 formed to provide a channel 22 to receive the rib 8 on the adjacent flexible chord member 15, thus permitting the rib upon flexure of the chord member, to move into and out of said channel which forms a guide therefor as shown in detail in Figs. 16 and 17.

The flexible or bendable nose and trailing edge portions of the areofoil are operated, as before stated, by the lever arms 12 and 17 respectively and the arms 12 are secured upon a tubular shaft 23 mounted in bearing members 24 which are secured in any suitable manner within the front spar 1, preferably one at each intersection of a rib structure with the spar, and the levers 17 are secured upon a tubular shaft 25 mounted in bearings on bearing members similar to the members 24, and which bearing members are secured within the rear

spar 2. An arm 26 secured to the shaft 25 is connected to an arm 27 on the shaft 23 by means of a connecting rod or rods 28 so that said shafts are caused to turn simultaneously and when the shaft 25 is turned by means of an operating lever 29, both nose and trailing edge portions of the aerofoil will be adjusted.

As shown diagrammatically in Fig. 4, the wing or wings of the airplane are preferably made in separate sections, preferably, there being a section 29 at each end of the wing which is operable separately from the intermediate or main portion 30 of the wing, these end portions being operable independently and independent of the main part 30 for the purpose of lateral control, and to operate the end sections 29, a tubular shaft 31 as shown in Fig. 7 passes through the shaft 25 and on the outer ends of this shaft 31 are secured the levers 17 which operate the end or lateral control sections 29, said shaft 31 being operated by an operating lever 32, all as illustrated in Fig. 7. With this arrangement, the end sections 29 may be operated to vary the camber and incidence for the purpose of lateral control, and both the end and main portions may be operated to change camber and incidence for the purpose of increasing lift in getting off and give a high speed sectional contour during flight.

As previously described, each of the several aerofoil ribs comprises a rigid or trussed section extending between the front and rear spars, and the upper chord member 6 of this trussing is extended forwardly to outline the upper and lower sides of the nose portion, this forwardly extending flexible portion 11 being devoid of trussing so that it may be readily flexed to change its position and contour. This upper chord member 6 is also extended rearwardly from its point of connection with the trussing forwardly of the rear spar, and is made flexible so that it may be readily bent or deflected downwardly for the purpose of changing the curvature of the upper side of the trailing edge portion of the aerofoil. The lower chord member 7 of the fixed portion of each rib extends from the lower side of the front spar adjacent the free end of the flexible portion 11 of the upper chord, rearwardly from its rigid connection with its trussing forwardly of the rear spar, to the trailing edge of the aerofoil where it is secured to the end of the flexible end portion 15 of the upper chord. The two rearwardly extending portions 15 and 16 of the upper and lower chords thus outline the trailing edge portion of the aerofoil and may be flexed as clearly shown in Figs. 1 to 3 inclusive to modify the camber of the aerofoil. These chord members of the ribs thus form an outline for the entire cross-section of the aerofoil and are substantially continuous. They are therefore adapted for the securing directly thereto of the outer skin or covering of the aerofoil. This outer skin is preferably formed of thin flexible sheet metal strips or plates, which as shown in Fig. 4 are preferably of a width to extend from rib to rib and to secure the edges of these plates to the ribs, each chord member of each rib is preferably of channel shape in cross-section with the open side of the channel facing outwardly. The free edge portions of the metal forming each channel is preferably bent laterally to partially close the channel, and then bent inwardly as indicated at 33 in Figs. 16 and 17. The edge portions 34 of the sheet metal 35 forming the skin of the aerofoil, are bent inwardly through the open side of the channel, and thence upwardly and against the inturned edge portions 33 and top of the channel.

A filler strip 36 of suitable material is then forced into the channel endwise thereof to completely fill the channel and securely lock the inturned edge portions 34 of the sheets 35 within the channel. The several plates forming the skin or covering 35 of the aerofoil is therefore securely interlocked along their edges with the several rib members, and in such a manner that these sheet metal plates may be removed without destroying the rib members or plates, for the purpose of repair or replacement, and the plates are securely held in place evenly and smoothly upon the ribs without the necessity for riveting them in place. A very smooth even exterior surface is thus provided for the aerofoil, and this skin or covering being of flexible sheet metal, may be readily flexed to change the camber and incidence of the aerofoil without destroying the continuity of curvature of its exterior surface. Further, this exterior curvature is maintained between the several ribs as the sheet metal covering is securely held to the ribs along its edges under a certain amount of strain so that these metal plates will conform perfectly to the curvature of the ribs in all positions of their adjustment, and will not sag or curve inwardly between the ribs. Further, a covering is provided which will readily flex with the adjustment of the trailing edge portion of the aerofoil, so that this portion may be flexed without leaving a gap in the covering or interrupt the continuity of its curvature in all positions of adjustment.

The metal of this sheet metal covering also causes it to conform perfectly with the change in contour of the nose portion of the aerofoil, and by overlapping this sheet metal covering with the forward edge of the covering forming the lower surface of the aerofoil and which is secured to the fixed chord members 7 of the ribs, the necessary rela-

tive movement of the nose covering and covering which is secured to the fixed portion of the ribs is provided for, and the gap between the free ends of the flexible rib portion 11 and the forward ends of the fixed chord 7 of the ribs is closed and the break in the continuity of the surface will only be that of the thickness of the sheet metal covering for the nose portion which overlaps the fixed covering forming the lower side of the aerofoil.

If found necessary or desirable due to the flexure of the trailing edge portion of the aerofoil, the several flexible portions 16 of the lower chord members 7 of the ribs, may be provided with a slip joint adjacent to and forwardly of the trailing edge of the aerofoil. This slip joint is shown in detail in Fig. 18, and comprises the dividing of the member 16, expanding and cutting away the inturned edge portions of its channel so that this expanded end portion 38 may be slipped over the adjacent end portion of the other part of the member and slide freely thereon. A flat spring 39 is secured to the inner end portion with its free yielding end riding upon the expanded end portion to firmly hold the ends in contact and permit a free relative longitudinal movement between the divided ends of the members 16. To close the gap in the covering 35 between the relatively movable ends of the members 16, the covering or skin forming the lower surface of the aerofoil and secured to the portion of the members 16 which are fixed against longitudinal movement, is extended rearwardly to overlap the covering which is secured to the movable parts of the rib members, and in order to stiffen the edge portion of the inner layer along the line of this overlap, said edge portion is rolled or formed into an upstanding bead or rib 40. This rib 40 not only strengthens the edge portion of the covering, but also forms a support for the free edge of the outer overlapped edge portion of the covering, thus preventing any deflection of the covering inwardly between the ribs due to the pressure of air against the outer surface thereof. A tight joint is thus secured in the skin or covering as the air pressure will always hold the outer overlapped edge portion of the covering in contact with the inner edge portion, and at the same time a slip joint is secured for permitting free relative movement between the overlapping portions of the covering.

If found desirable a similar slip joint may be provided between the forward ends of the fixed chord members 7 of the ribs and the free ends of the several flexible rib portions 11, and the overlapping edge portions of the covering at this point may also be formed as illustrated in Fig. 18 to stiffen the sheet metal covering and provide a tight joint.

Obviously, changes in the construction and arrangement of parts as illustrated in the accompanying drawings, may be varied to suit the conditions of manufacture and to conform to the particular type of aerofoil constructed. Other changes falling within the scope of the appended claims and within the spirit of the invention may also be made without departing from the broad principles of operation embodied in the invention, and I do not therefore limit myself to the particular construction of arrangement shown.

Having thus fully described my invention, what I claim is:—

1. An aerofoil comprising spars, rigid trussed ribs connecting said spars and having upper and lower flexible chord members extended beyond one of the spars forming a flexible nose framing and formed to conform to the desired cross-sectional outline of said nose portion of the aerofoil, means within said nose portion connected to said flexible chord members for flexing the same, to modify the cross-sectional curvature of said nose portion, and a flexible covering secured to said chord members.

2. An aerofoil as specified in claim 1, and wherein said covering is formed of sheet metal.

3. An aerofoil as set forth in claim 1 and wherein said covering is of sheet metal with edge portions of the metal overlapped and free to move, one relative to the other to provide for lateral flexure of said flexible edge portion of the aerofoil.

4. An aerofoil including trussed front and rear spars, trussed ribs connecting said spars and having upper and lower chord members with end portions of said chord members extended beyond the spars and formed to conform to the desired cross-sectional contour of the nose and trailing edge of the aerofoil, said extended portions of said chord members being flexible, a flexible covering secured to said chord members of said ribs throughout the length of the upper sides thereof, and means connected to said chord members intermediate its ends to the flexible portions thereof for simultaneously flexing said flexible portions to change the camber of the aerofoil and the angle of incidence thereof during flight.

5. An aerofoil as set forth in claim 4 and wherein the forwardly extending flexible end portions of the rib chord members are bent to form the entering edge of the aerofoil and extended rearwardly to a point adjacent the forward ends of the lower chord members to provide a gap therebetween and said means for flexing said nose portion of the aerofoil includes levers pivotally attached to the free ends of said flexible end portions of said chord members.

6. An aerofoil as set forth in claim 4, and wherein the forward flexible end por-

tions of the rib chord members are bent to form the entering edge of the aerofoil, with their ends spaced from the forward ends of the lower chord members, and means for flexing said nose portion including levers within the aerofoil supported by said spars and connected to the adjacent ends of said upper and lower chord members, and links connected to said upper members forwardly of said forward spar to change the contour of said flexible nose portion of the aerofoil.

7. An aerofoil including trussed front and rear spars, trussed ribs connecting said spars and having upper and lower chord members with flexible portions of said chord members extending beyond one of said spars and formed to outline the desired cross-sectional contour of an edge portion of the aerofoil, a flexible covering secured to said chord members, and means mounted upon one of said spars and extending into said edge portion of said aerofoil and connected thereto adjacent the edge thereof and intermediate said edge and said spar, to flex said flexible portions and modify the cross-sectional curvature of said edge portion.

In testimony whereof I affix my signature.

JOHN F. COOK, JR.