Sept. 13, 1932. J. K. NORTHROP 1,877,022

AIRFOIL

Filed July 19, 1930 2 Sheets-Sheet 1

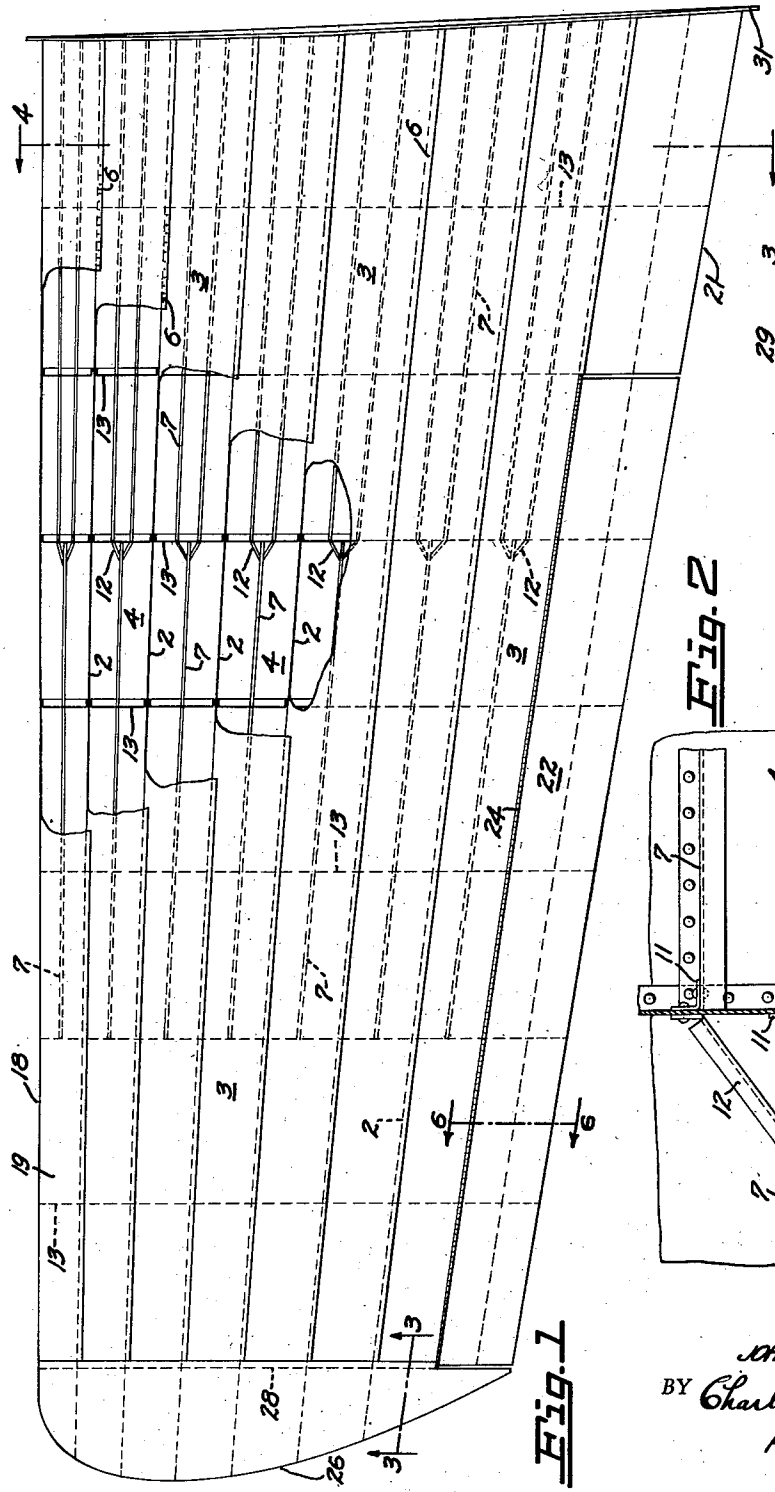


Fig. 1

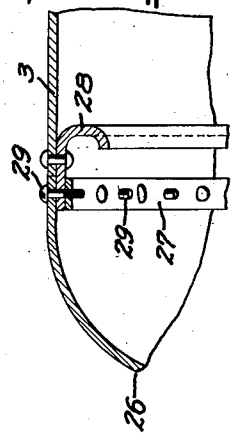


Fig. 3

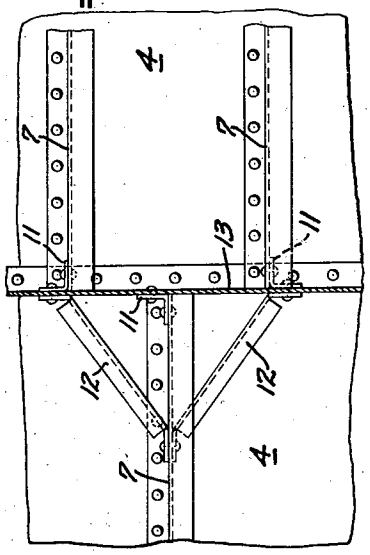


Fig. 2

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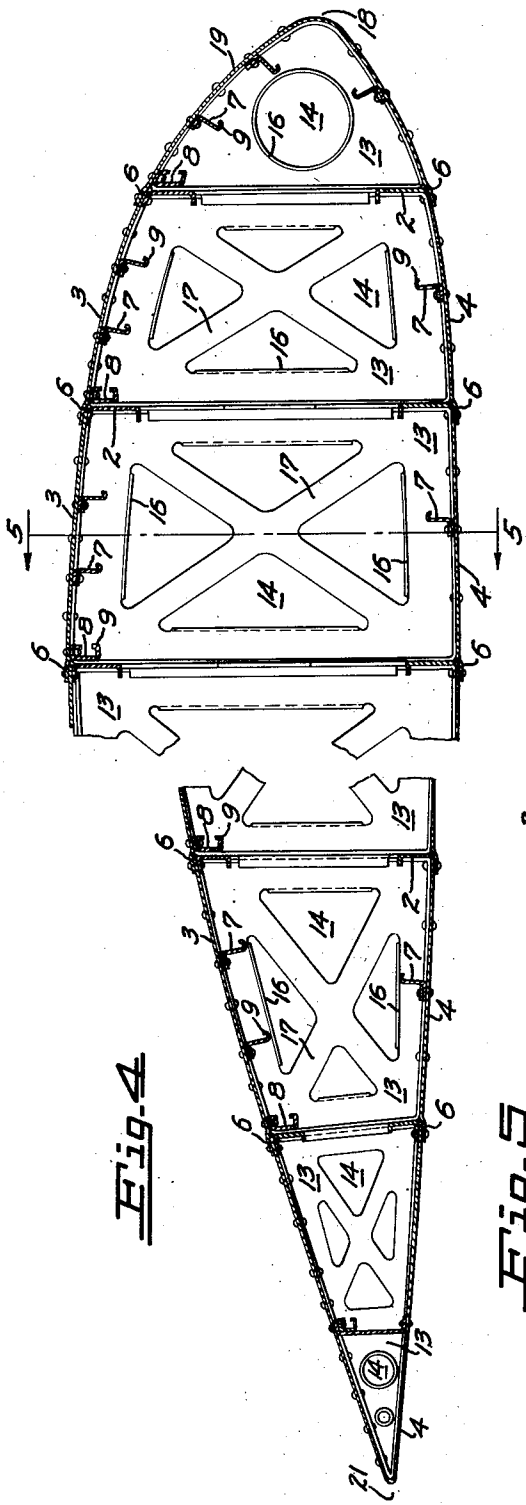


Fig. 4

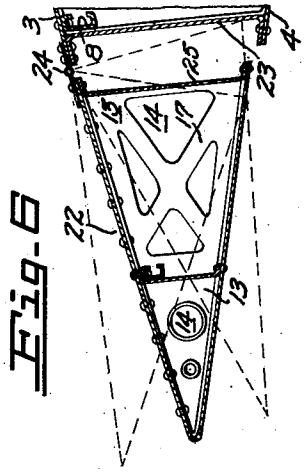


Fig. 6

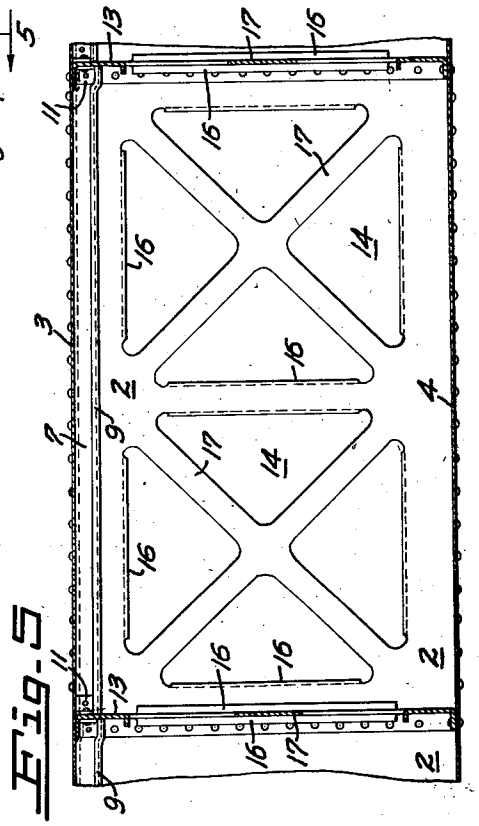


Fig. 5

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UNITED STATES PATENT OFFICE

JOHN K. NORTHROP, OF GLENDALE, CALIFORNIA, ASSIGNOR TO NORTHROP AIRCRAFT CORPORATION, OF LOS ANGELES, CALIFORNIA, A CORPORATION OF DELAWARE

AIRFOIL

Application filed July 19, 1930. Serial No. 469,012.

My invention relates to aircraft, and particularly to the construction of airfoils.

It is among the objects of my invention to provide an airfoil having relatively great strength in proportion to its weight.

Another object is the provision of an airfoil having a rugged covering which will not require frequent servicing.

A further object of my invention includes the provision of an airfoil having nearly ideal reinforcement.

The invention possesses numerous other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of my invention. It is to be understood that I do not limit myself to this disclosure of species of my invention, as I may adopt variant embodiments thereof within the scope of the claims.

Referring to the drawings:

Figure 1 is a schematic plan view of the airfoil of my invention showing particularly the manner in which the longitudinal stiffening bars are arranged.

Figure 2 is a fragmentary detail view of one of the stiffening bar joints, which are shown schematically in Figure 1.

Figure 3 is a fragmentary vertical sectional view showing the wing tip assembly; the plane of section being indicated by the line 3—3 of Figure 1.

Figure 4 is a broken transverse sectional view through the airfoil. The plane of section is indicated by the line 4—4 of Figure 1.

Figure 5 is a fragmentary longitudinal sectional view of the airfoil taken in a plane indicated by the line 5—5 of Figure 4.

Figure 6 is a vertical sectional view showing the aileron mounting; the plane of section being indicated by the line 6—6 of Figure 1.

Broadly stated, the airfoil embodying my invention comprises a plurality of nested longitudinal channels, the flanges of which form the exterior surface of the airfoil. Transverse bulkheads are installed to reinforce the channel webs and flanges against buckling, and longitudinal stiffening bars are fixed to the top and bottom flanges to reinforce those members against compressional and tensional stresses, and against local deflections. The stiffening bars are preferably decreased in number and in weight toward the airfoil tip, and the top and bottom flanges may be similarly lightened by a decrease in thickness, to maintain an approximately uniform factor of safety along the airfoil.

It is to be noted that this construction may be used in any type of wing. And, although I have selected full cantilever wing for illustration herein, I do not limit my invention to such structures. It is believed, that the minor modifications, which would have to be made to adapt the construction shown herein to suit other types of wings, will immediately suggest themselves to those skilled in the art. For instance; if the structure were modified to produce a rectangular, externally reinforced wing; it would be necessary to provide additional reinforcement to resist the stresses imposed on the structure at the points where the external members join the wing. Since the tapered cantilever wing shown herein embodies practically all of the structural difficulties encountered in the construction of the wings themselves; it is believed that the following detailed description will suffice to set forth principles of construction that can be applied to any wing structure.

In greater detail the airfoil embodying my invention comprises a plurality of longitudinal intermediate channels having a web 2, a top flange 3, and a bottom flange 4; the web 2 and bottom flange 4 are preferably integrally formed from a single sheet, and the top flange 3 preferably comprises a separate sheet. Although this construction of the channels is shown as being preferably used,

it is to be noted that they may also be built up by making the web 2 and the flanges 3 and 4 from separate sheets, or by forming the channels each from a single sheet. It is also to be noted that, although the channels are shown as being continuous from the root to the tip of the airfoil, these channels may be be built up of riveted or welded sections. This construction is particularly advantageous when it is desirable to decrease the thickness of the channel flanges from root to tip.

A number of such channels are nested together, as can best be seen in Figure 4, so that the top and bottom flanges form the external shell, and the webs form longitudinal stiffening members of an airfoil. The joints 6, between successive channels, may be held in the manner best suited to the materials employed, but at present I prefer to rivet all such joints. The channels may be made from any suitable material; however, metallic sheets, such as duralumin or alclad, have been found to give very good results, and are preferably used.

In order to reinforce the top and bottom flanges against the compressional and tensional stresses imposed on the airfoil, the Z-shaped longitudinal stiffening bars 7, and the C-shaped bars 8, each having a curled flange 9, are riveted in spaced position on the flanges 3 and 4 as shown in Figure 4. By giving depth to the flanges, these bars strengthen the airfoil far more than would an equal weight of material incorporated in the flanges themselves. The stiffening bars are preferably interposed between the bulkheads and fixed thereto by means of a bracket 11 as shown in Figure 2.

Considerations of structural economy and dynamic stability lead to the design of an airfoil tapering in section from root to tip. This means that the wing exerts less lift toward the tip, and the resulting stresses are less. The stresses are further lessened toward the tip, because of the well-known stress distribution in a cantilever beam. Therefore the sectional moment of inertia of the airfoil, as a beam, may be materially lessened toward the tip of the wing and still preserve the same factor of safety; and at the same time decrease the weight. The factor of safety may be defined in the usual manner, as the ratio between the unit stress that the given material can withstand without permanent deformation and the unit stress imposed by the loading.

This result may be accomplished in several ways. If the channels are built-up sections, the plates toward the tip may be made thinner, and fewer stiffening bars 7 and 8 may be employed. If the channels are formed by plates of uniform thickness, the desired effect may be obtained by the number and arrangement of the stiffening bars. The method of placing the stiffening bars is indicated schematically in Figure 1, which shows twice as many stiffening bars in the root section as in the central section, and none in the tip section. A variant construction is to have three bars in each channel adjacent the root of the wing, two in each channel in the central section, and one in each channel in the tip section. Figure 2 shows the joint connecting two stiffening bars into one by means of the angle braces 12. The bars on the bottom flange, which are omitted from Figure 1 to avoid complicating the drawings, are similarly disposed according to the number employed.

The bottom shell may be made proportionately lighter than the top shell, because it is subjected to heavy stresses in tension only; and thin plates will develop their full strength in tension without danger of buckling. Accordingly, the bottom shell is preferably made lighter than the top shell by suitable modifications, such as using a lesser number of stiffening bars, or using thinner plates.

A plurality of spaced transverse bulkheads 13 are riveted into the channels to reinforce the webs and flanges against buckling; the position of these bulkheads being indicated schematically in Figure 1. Suitable holes 14 are punched in the bulkheads 13 and the channel webs 2 to lighten the weight of these members; and the flanges 16 are formed on the edges of the lightening holes to reinforce the respective members in compression. Since they are designed for tension only, the diagonal ties 17 need not be further reinforced; this construction is clearly shown in Figures 4 and 5.

In assembling the airfoil, the following procedure may conveniently be followed: A curved channel, forming the leading edge 18 of the airfoil, is first assembled; and comprises a single piece shell plate 19 having the transverse bulkheads 13 and the longitudinal stiffening bars 7 and 8 arranged and riveted in place as shown in Figure 4. An adjacent intermediate channel, in assembled condition with its transverse bulkheads 13 and stiffening bars 7 and 8 riveted in position, is then nested into the first channel and riveted in place. Since the upper flange of the intermediate channel is shown as being formed from a separate sheet, the upper row of rivets will engage three thicknesses of metal, while the lower row will only engage two.

The succeeding intermediate channels are similarly assembled and secured in place until the last channel, forming the trailing edge 21, is reached. This channel is preferably formed by bending a single sheet into a V shape, as shown in Figure 4, and riveting the reinforcing members in place. It will be noted that the rivets in all of the channels

but the last can be reached during assembly through the open side opposite the web. The last channel has no open side when nested in position, but its two ends are open, the aileron 22 not yet being placed, and the rivets can be reached through these open ends.

The rear portion of the intermediate channel, adjacent the aileron 22, is closed with a flanged plate 23 riveted in place as shown in Figure 6. The aileron 22 is pivotally mounted by the hinge 24 on the upper flange 3 of the adjacent intermediate channel as shown; the aileron being formed from a channel similar to that making up the trailing edge 21, except that the channel 25 is inserted with its flanges pointing outward in order that the rivets may be set. It is to be noted that the depth of the leading edge of the aileron is slightly less than the adjacent edge of the intermediate section; which permits the aileron to pivot about its hinge 24, so that it may be depressed or elevated as shown by the dotted lines in Figure 6.

The channel for the wing tip 26 is built up in a manner similar to that described for the leading edge 18, and is secured in place as shown in Figure 3. A strap 27 is riveted to a bulkhead 28 secured adjacent the tip end of the channels, and suitable screws 29 are inserted through the edges of the wing tip channel and threaded into the strap. To complete the airfoil, a flange 31 is riveted to the channel ends at the root of the wing to provide a connection to the fuselage.

The edges of the channels at the joints 6, as shown in Figure 4, are bulged out to receive the adjacent nested channels. This, however, is exaggerated in the drawings to show the construction more clearly. Actually, due to the comparative thinness of the flanges, this effect is very slight, and the shell formed by the channel flanges is substantially a smooth surface.

I claim:

1. In an airfoil, a channel, the flanges of which diminish in thickness toward the tip of the airfoil approximately in ratio to the decrease in stress, the top flange being thicker than the bottom flange at any transverse section.

2. In an airfoil, a channel, stiffening bars fixed to the channel flanges, and transverse bulkheads in the channel.

3. In an airfoil, a longitudinal channel, longitudinal stiffening bars fixed to the channel flanges, and transverse bulkheads in the channel.

4. An airfoil comprising a plurality of channels, the sectional moment of inertia of the airfoil decreasing toward the tip approximately in ratio to the decrease in stress, and transverse bulkheads in the channels.

5. An airfoil comprising a plurality of reinforced channels, the sectional moment of inertia of the airfoil decreasing toward the tip approximately in ratio to the decrease in stress, and transverse bulkheads in the channels.

6. An airfoil tapering from root to tip comprising a plurality of reinforced channels, the sectional moment of inertia of the airfoil decreasing toward the tip approximately in ratio to the decrease in stress, and transverse bulkheads in the channels.

In testimony whereof, I have hereunto set my hand.

JOHN K. NORTHROP.