April 11, 1961 R. S. ROSS 2,979,287

INFLATABLE WING WITH VARIABLE CAMBER

Filed Sept. 2, 1959 2 Sheets-Sheet 1

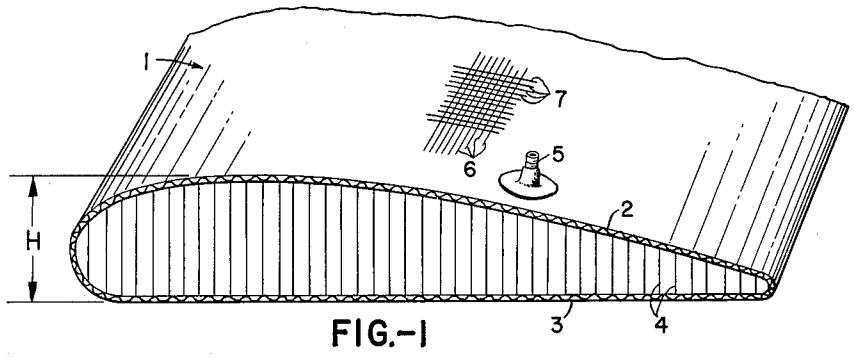


FIG.-1

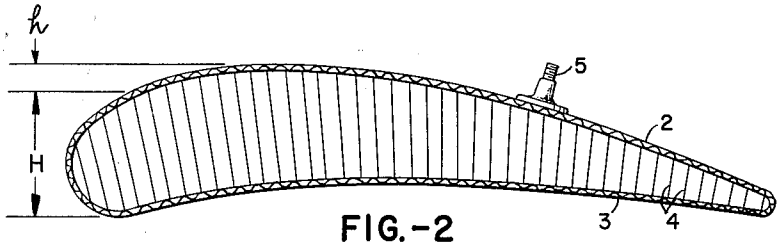


FIG.-2

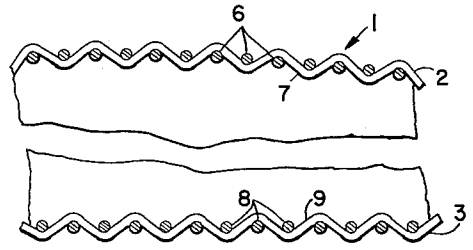


FIG.-3

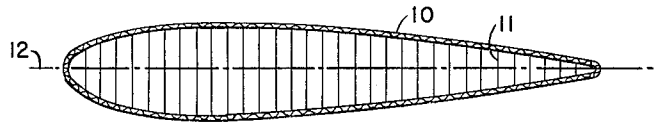


FIG.-4

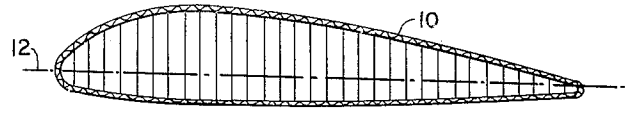


FIG.-5

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INFLATABLE WING WITH VARIABLE CAMBER

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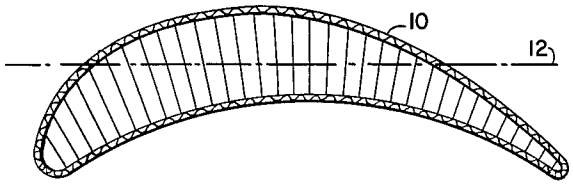


FIG.-6

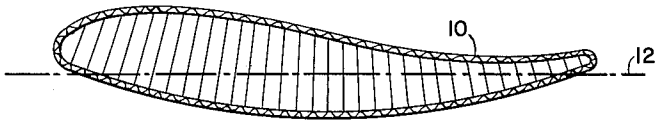


FIG.-7

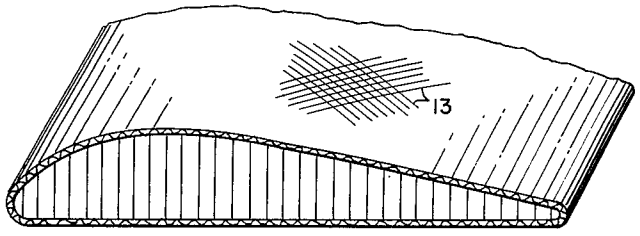


FIG.-8

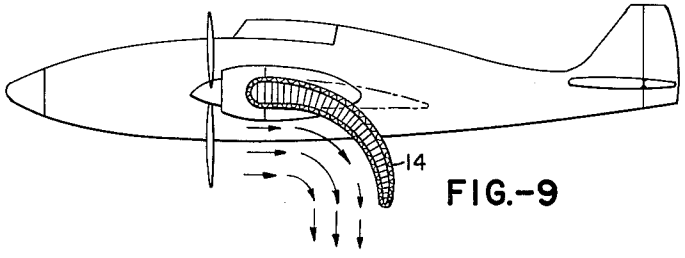


FIG.-9

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INFLATABLE WING WITH VARIABLE CAMBER

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Filed Sept. 2, 1959, Ser. No. 837,725

5 Claims. (Cl. 244—44)

This invention relates to air-impervious flexible fabric airfoils for aircraft, and, more particularly, is concerned with wings of this type in which the variation of the air pressure inflating the wing is used to alter the camber of the wing and its lift-drag ratio.

It is the general object of the invention to provide an air-impervious inflatable fabric airfoil having upper and lower surfaces tied together with a plurality of threads and characterized by simplicity of construction, low weight, and excellent durability and efficiency and wherein the camber of the airfoil and its lift-drag ratio can be quickly changed by merely changing the inflation pressure of the airfoil.

Another object of the invention is the provision of a wing of the type described in which the warp cords of the fabric extends substantially longitudinally of the wing, the weft cords extend substantially transversely of the wing, and with the weft cords of the one surface of the wing, usually the upper, being more elastic than the weft cords of the other surface of the wing, usually the lower, so that increase of inflation pressure in the wing causes the weft cords in the upper surface of the wing to elongate and increase the camber of the wing.

For a better understanding of the invention, reference should be had to the accompanying drawings wherein—

Figure 1 is a fragmentary cross sectional view of a wing incorporating the features of the invention, and shown partly in perspective;

Figure 2 is a view similar to Figure 1, but with the wing shown only in cross section, and with a higher inflation pressure illustrating the manner of increasing the camber and lift of the wing;

Figure 3 is a fragmentary view, on enlarged scale, of the wing of Figure 2, but with the tie threads omitted;

Figure 4 shows in diagrammatic cross section a streamlined airfoil constructed in accord with the invention and at a given low inflation pressure;

Figures 5, 6, and 7 are views of the airfoil of Figure 4 but at different inflation pressures;

Fig. 8 is a fragmentary cross sectional view of a wing showing another embodiment of the invention; and

Figure 9 shows a VTOL aircraft utilizing the invention as a propeller slip-stream device.

In the drawings, the numeral **1** indicates generally an inflatable airfoil having a body formed to wing shape of flexible air-impervious material, for example rubberized fabric, and including an upper surface **2** and a lower surface **3** joined together by a plurality of tie threads **4**, substantially in the manner illustrated and described in the aforesaid patent application of William C. Johnson. A typical material which can be utilized is that manufactured and sold by Goodyear Tires & Rubber Company of Akron, Ohio, under the trademark "Airmat," but with the length with the tie threads **4** connecting the upper and lower surfaces of the wing being progressively changed to hold the surfaces **2** and **3** in the airfoil shape illustrated. More particularly, the airfoil **1** provided has a maximum thickness, usually about one-third of the way back from the leading edge, with the thickness of the airfoil tapering from this point towards the trailing edge of the airfoil where the airfoil is relatively thin, and

with the forward edge of the airfoil being of progressively lesser thickness from about one-third of the way back from the leading edge to the leading edge, the leading edge having a smoothly curved thicker section than the trailing edge. A valve stem **5** is provided for inflating the airfoil to the desired degree of pressure, as hereinafter more fully discussed.

The important feature of the invention is that the flexible fabric forming the body of the wing is made so that the warp cords or threads **6** of the fabric, and diagrammatically shown in Figure 1, extend lengthwise or longitudinally of the wing, with the weft cords or threads **7** extending transversely of the wing, or from front to rear, again in the manner diagrammatically shown in Figure 1. The weft threads or cords **7** of the fabric of the top only of the wing are made more elastic or resilient than are the warp threads **6** so that by varying the inflation pressure inside of the wing the camber of the wing can be changed together with its effective lift-drag ratio.

More particularly, Figure 1 illustrates the wing of the invention inflated to a lower pressure, for example 10 pounds, to produce a height H for the wing. However, when the same wing is inflated to a greater pressure, for example, 20 pounds per square inch, then the weft threads or cords **7** in the upper surface **2** of the wings stretch under the heavier inflation pressure to change the shape of the wing from that shown in Figure 1 to that illustrated in Figure 2. In other words, the camber of the wing has been increased, with an increase in height by an amount *h* to thereby increase the lift characteristics of the wing by changing its lift-drag ratio.

Accordingly, with the improved airfoil or wing of the present invention, and when used on a heavier-than-air aircraft, it is the usual practice to inflate the wing with a higher pressure when taking off or landing, i.e. to provide a wing contour, for example as shown in Figure 2, to assist the airplane in taking off or landing. However, once the aircraft is in the air, the pressure in the wings can be reduced to return the contour thereof, for example to that shown in Figure 1, whereby the lift-drag ratio is improved to increase the speed of the aircraft for purposes of continued or extended flight.

Figure 3 illustrates in larger scale the upper surface **2** of the airfoil **1** and the lower surface **3** of the airfoil of Figures 1 and 2, but with the tie threads and air-impervious coating omitted for purposes of simplification. The warp threads or cords **6** of the flexible fabric forming the wing body are more clearly shown in Figure 3, as are the weft threads or cord **7**. The feature endeavored to be shown in Figure 3 is that the warp cords **6** are not as elastic as the weft cords **7** of the upper wing surface so that different inflation pressures are able to stretch the weft cords **7** of the upper surface **2** to a greater or less amount, all as stated above. Insofar as the lower airfoil surface **3** is concerned the warp threads or cords **8** and the weft cords or threads **9** are of the same type as the warp threads or cords **6**.

Looking at Figures 4 to 6, will be seen that in Figure 4 is illustrated a body **10** made of air-impervious flexible material secured together with suitable tie threads **11**, as before, but with the body **10** being of streamlined airfoil shape with each portion thereof lying to one side of a center line **12** being equal but of opposite hand. A body of this shape is easier to form than one of a lifting airfoil shape, such as shown in Figure 1. If, however, the weft threads of the fabric forming the body **10** are made more elastic in the upper surface only of the body, with these weft threads running from front to back of the body, i.e. transversely, than inflation of the body to a comparatively low initial pressure produces the shape of Figure 4. But if the pressure is increased the body

changes to that shown in Figure 5, and a still further increase in pressure in the body results in the shape shown in Figure 6. In other words, a streamlined airfoil-shaped body of the type of Figure 4 can be provided by the present invention which does not possess lift characteristics when moved on the axis of its center line, but which can be changed in contour to provide a shape in cross section upon being inflated to a higher pressure to produce definite lift characteristics of greater or less degree. Of course, even the body of Figure 4 when inclined to the center line 12 and moved forwardly achieves lift action.

Fig. 7 illustrates the body of Fig. 4 inflated to a still lower pressure than the body of Fig. 4 with the body cambering in the opposite direction.

Although the invention has been specifically described heretofore as making the upper surface elastically extensible, and this is normally preferred, it is also possible to make the lower surface extensible elastically and make the upper airfoil surface inextensible.

The invention likewise contemplates placing cords in the airfoil at a bias angle with respect to the front to rear dimension of an airfoil. For example, Fig. 8 illustrates diagrammatically an arrangement of this type wherein warp and weft cords 13 of a fabric on the top of the airfoil are both laid at a bias angle, usually of about 45 to 60° with the longitudinal axis of the wing.

Usually the bias laid cords 13 are in a fabric which overlies and reinforces the fabric forming the "Airmat," and by placing the bias laid fabric on both the upper and lower surfaces of the airfoil the airfoil is reinforced against torsion bending. In the preferred practice two layers of bias laid fabric may be applied top and bottom of the airfoil with the warp cords of the several layers extending at opposite bias angles to each other inasmuch as the warp cords are normally straight whereas the weft cords are woven over and under the warp cords and do not provide as strong a reinforcement.

Of course, when the regular "Airmat" fabric is reinforced as described, and a portion of the airfoil is still to be made extensible in accord with the present invention it is necessary to make at least the warp cords, and preferably both the warp and weft cords extensible in those areas of the airfoil which are going to be allowed to extend or contract under changes in internal air pressure.

One of the features of the invention is that the airfoils herein illustrated and described can be employed in conjunction with standard airfoils, such as shown in the Johnson application above mentioned, and as control surfaces therefore being made to bend up or down from change in internal air pressure. Figs. 4, 5, 6 and 7 illustrate the manner in which the airfoil of Fig. 4 can be made to bend in one or another direction from increased or decreased air pressure.

By employing the principles of the invention airfoils of various shapes can be made including supersonic airfoils of a decided wedge-shape.

The operation of the invention in the manner described is achieved, as will be understood, without the tie threads 4 changing in length as the airfoil contour is changed by varying the internal air pressure.

The airfoils of the present invention adapt themselves to a variety of uses either as conventional lifting wings for an airplane, as empennage elements, as control surfaces, helicopter blades, and the like. They may also be used as a propeller slip stream deflection device of variable contour for use in a vertical take-off aircraft as diagrammatically shown in Fig. 9 wherein the airfoil is indicated by the numeral 14. Once the aircraft is in the air the contour of the airfoil is changed or flattened as herein described to allow more effective forward flight.

In accord with the patent statutes, certain best known embodiments of the invention have been illustrated and described in detail, however, it is to be particularly understood that the invention is not to be limited thereto or thereby, but that its scope is defined in the appended claims.

What is claimed is:

1. An inflatable wing for an aircraft including flexible fabric formed to the shape of a wing, an air-impervious coating on the fabric, a plurality of tie threads extending substantially vertically of the wing and connecting the upper and lower wing surfaces together, and of proper length to contour the wing in cross section to airfoil shape, the flexible fabric having warp threads extending substantially longitudinally of the wing and weft threads extending substantially transversely, the weft threads on the upper surface of the wing being more readily extensible than the warp threads throughout the wing and more readily extensible than the weft threads on the lower surface of the wing, and means for inflating the wing to different internal pressures to change the camber of the wing and the lift-drag ratio thereof.

2. An inflatable wing for an aircraft including flexible fabric formed to the shape of a wing, an air-impervious coating on the fabric, a plurality of tie threads extending substantially vertically of the wing and connecting the upper and lower wing surfaces together, and of proper length to contour the wing in cross section to airfoil shape, the flexible fabric having warp threads extending substantially longitudinally of the wing and weft threads extending substantially transversely, the weft threads on the upper surface only of the wing being elastic, and means for inflating the wing to different internal pressures to change the camber of the wing and the lift-drag ratio thereof.

3. A wing for an aircraft comprising an air-tight, wing-shaped body of flexible rubberized fabric having upper and lower surfaces, a plurality of inextensible but flexible tie means extending substantially vertically between the upper and lower surfaces to contour the wing to airfoil shape in cross section, the fabric being formed of warp cords extending substantially lengthwise of the wing body and of weft cords extending substantially transversely of the wing body, the weft cords on the upper surface only of the wing body being relatively stretchable, and means for inflating the wing body.

4. An airfoil for an aircraft or the like comprising an air-tight, airfoil-shaped body of flexible impregnated fabric having upper and lower surfaces equidistant at opposite areas from a center line bisecting the airfoil from front to rear, a plurality of inextensible but flexible tie threads extending substantially vertically between said surfaces to normally hold the airfoil to the shape specified, the fabric being formed or warp cords extending substantially lengthwise of the airfoil and of weft cords extending from front to rear of the airfoil, the weft cords on the upper surface of the airfoil being more stretchable than the warp cords throughout the airfoil and more stretchable than the weft cords in the lower surface of the airfoil, and means for inflating the airfoil.

5. An airfoil for an aircraft comprising a flexible, air-tight, airfoil-shaped body having upper and lower surfaces, a plurality of inextensible but flexible tie means connecting the upper and lower surfaces, one surface of the airfoil being substantially inextensible, and the other surface of the airfoil being elastically extensible in a front to rear direction, and means for inflating the airfoil to a degree to provide a desired extension of the extensible surface of the airfoil and a desired camber of the airfoil.

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