PUBLISHED	H. K. D. VAN DEN BUSSCHE	Serial No.
MAY 25, 1943.	BOUNDARY LAYER CONTROL IN AEROFOILS	235,640
BY A. P. C.	Filed Oct. 18, 1938	

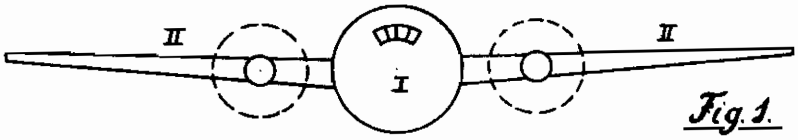

Fig. 1.

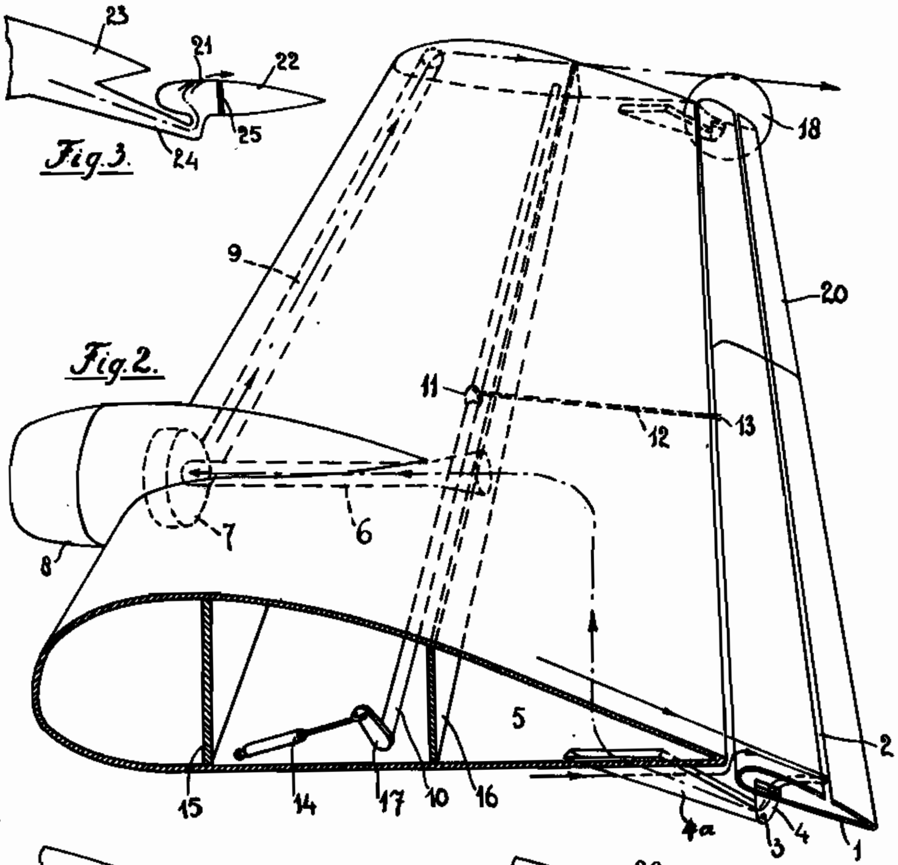

Fig. 3.

Fig. 2.

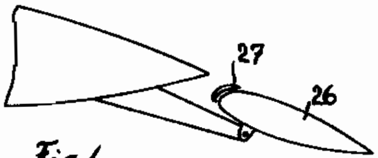

Fig. 4.

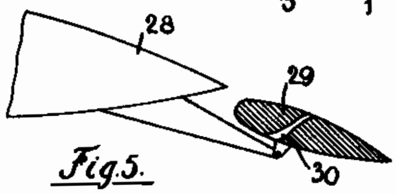

Fig. 5.

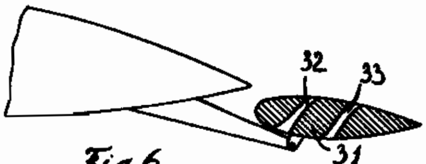

Fig. 6.

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Published May 25, 1943 Serial No. 235,640

ALIEN PROPERTY CUSTODIAN

BOUNDARY LAYER CONTROL IN AEROFOILS

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Application filed October 18, 1938

My invention relates to aircraft and more particularly to aerofoils and it is one of the objects of my invention to provide novel means for compensating the losses of energy in the boundary layer of aerofoils. It is known to those skilled in the art that the lift-coefficient of an aerofoil increases in proportion to the angle of attack of the relative wind up to a certain critical angle which has been found by tests to lie between 10 and 20 degrees. The lift-coefficient developed at the critical angle of attack is called the maximum lift-coefficient. Beyond this critical angle the lift-coefficient drops again owing to discontinuity of the airflow over the upper surface of the wing. This discontinuity is known as burbling and the aerofoil is said to be in stalling position. Stalling is due to energy losses in the boundary layer of the upper surface of the wing which results in a decrease of velocity of the airflow over the wing in the direction towards the trailing edge thereof. An increase of the angle of attack results in increasing energy losses in the boundary until the velocity of the airflow at the trailing edge of the wing becomes zero and there begins backflow from the trailing to the leading edge, causing separation of the airstream from the upper surface of the aerofoil. Now stalling begins and an increase of the angle of attack will cause the separation to become more and more accentuated until the critical angle of attack is reached and separation takes place almost throughout the aerofoil from the trailing to the leading edge.

It is also known to increase the maximum lift-coefficient of an aerofoil by arranging a narrow-chord aerofoil in close relation to the trailing edge of the main aerofoil, only a narrow gap being left between the two aerofoils. This narrow-chord aerofoil is called external aerofoil section flap.

The maximum lift-coefficient can be increased by deflecting the trailing edge of the flap with a point well forward of and below the chord thereof as hinge-point. The suction which arises at the upper surface and in particular at the leading edge of the flap when deflected, sucks away the boundary layer of the main wing, thereby accelerating the boundary layer and compensating energy losses in this boundary layer. The suction effect is increased in proportion as the flap is deflected, while a linear increase of the lift occurs in proportion as the deflection angle grows until the critical angle of the flap relative to the direction of the airflow behind the main wing is reached, which according to tests lies between 30 and 35 degress relative to the chord of the main wing. Deflecting the flap to a greater angle does not increase the lift-coefficient, which then drops rapidly. This is due to stalling of the aerofoil section flap which takes place in the same way as described with reference to the plain wing. When stalled the flap is no longer effective and does not exert its beneficial action on the flow over the main wing.

Several means are known for compensating the energy losses in the boundary layer of a simple aerofoil and for thereby delaying stalling to a much higher angle of attack. They are known as means for boundary layer control, the most effective of which are the following:

1. Removal of the boundary layer of the aerofoil at the rear half of the upper surface through a spanwise extending slit or series of openings by means of suction maintained at the inside of the wing, for instance with the aid of a blower or other pump provided in the interior of the wing. It has been found by tests that the maximum lift-coefficient of a certain aerofoil, which without boundary layer control amounted to 1.5, can be increased in this manner to 5.5. By the same means the profile drag coefficient of the wing is substantially reduced. Thus the ratio of lift to drag of the aerofoil which is a measure of its efficiency, is increased considerably.

This mode of boundary layer control however involves several disadvantages which render it practically inapplicable: a great quantity of air must be sucked off and handled which requires a large and heavy pumping installation, air ducts etc. The operation of the pump requires considerable power and the difference between the angle of attack for cruising and the maximum lift-coefficient is very great (about 40 degrees) which requires a long-legged and heavy undercarriage, to say nothing of the discomfort for the passengers and crew of an airplane equipped with this kind of boundary layer control.

2. Boundary layer control by blowing air tangentially to the upper surface of the aerofoil through a slot opening towards the rear. This method is not as satisfactory as the one first mentioned and with a very high power absorption the maximum lift-coefficient still remains below 3. Thus this method offers the same advantages but also involves the same drawbacks as the method first mentioned.

3. The energy losses in the boundary layer of an aerofoil can also be compensated by subdi-

viding it by spanwise extending slots into two or more parts, each of well rounded form, forming a so called Lachmann or Handley-Page. With any such combination of parts a lift-coefficient of about 2,3 can be obtained.

These slotted wings involve the drawback that the maximum lift-coefficient, which is only a moderate one, is only reached at a very high angle of attack, the cruising and maximum lift angle being spaced about 30 degrees; and moreover the profile drag is considerably increased.

According to the present invention, now, boundary layer control is applied not to the main wing, but to the external aerofoil section flap of an aerofoil provided with such flap.

By applying the boundary layer control to the flap, stalling of the flap does not take place at the low deflection angle of about 35 degrees, but is delayed to a much higher deflection angle and the lift-coefficient of the flap-wing combination can thus be increased to about 4.

Windtunnel tests have shown that the volume of air to be sucked off and the power required for this purpose are proportional to the surface of the wing to which boundary layer control by suction or pressure is applied. In the case of the combination of a main wing and an external aerofoil flap of equal span they are proportional to the chord.

As in most cases the chord of the external aerofoil flap is only one sixth of the total chord of the combination, the power required to obtain very high lift-coefficients of the combination and the volume of air to be sucked off are also about one sixth of those required to obtain the same results on a plain wing by means of boundary layer control by suction or pressure.

Another important advantage offered by the invention consists therein that the high lift-coefficients are reached at normal angles of attack, viz. 10 to 15 degrees.

The application of boundary layer control to a wing subdivided by spanwise extending slots can also be applied to the external aerofoil flap. In that case the following advantages are obtained:

1. In the case of its application to the external aerofoil flap the increase of the profile drag coefficient connected with the subdivision of the aerofoil covers only a minor part of the total wing area and consequently also the total increase of profile drag is only a fraction of that obtained by subdividing a plain wing by slots.

2. The highest lift-coefficient is reached at a normal angle of attack of from 10 to 15 degrees.

In the drawings affixed to this specification and forming part thereof several embodiments of my invention are illustrated diagrammatically by way of example.

In the drawings

Fig. 1 is a front elevation of a twin-engined mid-wing monoplane having tapered wings, while

Fig. 2 is a diagrammatic view, drawn to a larger scale and showing the wing structure and its relation to the fuselage.

Figs. 3 to 6 are cross-sections of combinations of a wing with an external aerofoil section flap, in which various boundary layer control systems are applied to the flap.

In Figs. 1 and 2 the invention is shown as embodied in a mid-tapered-wing monoplane in which I is the fuselage and II are the opposed wings, the method of boundary layer control being removal of the boundary layer by suction. Fig. 2 shows the external aerofoil section flap 1 as being hollow and hinged to the points 3 and being formed with a spanwise extending slit 2. Hollow streamlined supporting members 4, 4a distributed along the span allow the air entering through the slit 2 into the flap to pass into the hollow rear portion 5 of the main wing II and through a tube 6 to the pump or fan 7 which provides for the required suction and is driven by the engine 8 or an auxiliary unit over a suitable clutch operated automatically or by the pilot or both. A spanwise extending channel 9 leads the air from the pump 7 to the outside. End-plates 16 reduce pressure losses at the outer ends of the external aerofoil flap.

The operation of this boundary layer control is as follows: the air forming the boundary layer of the flap is sucked off through the slit 2, the hollow flap 1, the supporting members 4, 4a, the rear part 5 of the wing II and the tube 6 into the pump 7 which ejects it through the tube 9.

Deflection of the flap is carried out as follows: a jack 14 acts on a lever 17 which rotates the torsion tube 10 in clockwise direction, its motion being transmitted through a lever 11 to a rod 12 hinged to the leading edge of the flap at a point 13 so arranged above the hinge points 3 of a flap as to make the operating force a minimum. The flap is thus rocked in clockwise direction and its angle relative to the chord of the main wing is increased. At the same time the aileron 20 is deflected to the same or a somewhat smaller angle than the maximum deflection angle of the flap, which is governed by a suitable device linked between the torque tube 10, the lever 17 and the ailerons 20 which also enables the ailerons to be raised and lowered as required for the rolling motion of the airplane.

While in the embodiment shown in Figs. 1 and 2 the boundary layer is sucked off from the main aerofoil through a slit extending spanwise of the external section flap, Fig. 3 illustrates the ejection of an air jet through a similar slit 21 extending spanwise over the front half of the hollow flap 22, the air being forced by a fan or the like (not shown) mounted in the hollow main wing 23 through the hollow supporting members 24. The interior of the flap is shown to be subdivided by a spanwise extending partition 25.

In the modification illustrated in Fig. 4 the external section flap 26 is provided with an auxiliary wing 27 arranged in front of its leading edge which may be utilized for the sucking or blowing off of the boundary layer on the flap in the manner indicated in Fig. 1 or 3.

Fig. 5 illustrates a combination of an aerofoil 28 with an external section flap 29 divided in two halves by a slot 30, and Fig. 6 shows a flap 31 divided into three parts by two slots 32, 33 adapted to serve as air passages for the boundary layer sucked or blown off the flap surface and carrying along the boundary layer on the main wing.

Various changes may be made in the details disclosed in the foregoing specification without departing from the invention or sacrificing the advantages thereof.

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