

LEADING EDGE HIGH LIFT DEVICES WITH LAMINAR FLOW CONTROL

This invention relates to an aircraft wing assembly including a leading edge high lift device and in particular to such assemblies incorporating means for reducing the chordwise extent of the turbulent boundary layer over at least one of the upper and lower wing surfaces. The invention also extends to aircraft including such wing assemblies, to high lift devices for use in such assemblies, and to methods of reducing the drag associated with a wing having a leading edge high lift device.

In this Specification, the terms forward, rearward, upper, lower, chordwise, spanwise, etc., refer to the orientation of an aircraft when in straight and level flight.

Great effort and expense has been expended by aircraft designers and aerodynamicists to reduce as much as possible the drag of the aircraft and particularly the drag experienced by the flow of air over the surface or skin of the aircraft. Typical measures have included making the surface very smooth providing the surface with a special texture or microscopic structure to enhance the characteristics of flow over the surface. Another technique is to apply a method of boundary layer control referred to as forced hybrid laminar flow. In this process, a laminar boundary layer is maintained over the wetted surface for as long as possible so as to delay the

onset of a turbulent boundary layer. It is not normally feasible to prevent entirely the transmission from a laminar to a turbulent boundary layer, although by delaying its onset the boundary layer can be kept in the laminar regime for longer, thereby leading to a reduction in drag. The process is known as forced hybrid laminar flow as the principle aim is to delay the onset of turbulence rather than to maintain a completely laminar flow over the wetted surface (although we do not intend to exclude this possibility).

In order to achieve this form of boundary layer control, the boundary layer is caused to adhere to the surface by providing a negative pressure over the surface by means of a multiplicity of perforations - of the order of microns in diameter - in the surface. This reduces the growth rate of the boundary layer and thereby delays the onset of the laminar/turbulent transition.

One of the main problems encountered in the design of forced hybrid laminar flow aircraft wings is the need to provide voluminous ducting in the fixed leading edge of the wing to provide the suction required to draw air through the perforations in the wing surface. The ducting area required encroaches on the space normally occupied by the forward spar of the wing. Shifting the forward spar rearwardly to accommodate such ducting has tremendous implications in terms of the increased weight of the wing. Furthermore, for a wing with a leading edge slat, the area

conventionally occupied by the extension/retraction and guide mechanisms for the slats would now be occupied by the voluminous ducting. Accordingly proposals to date for a leading edge slat design for a wing with forced hybrid flow
5 over its upper surface have reverted to the Kruger flap which involves providing a hinge at the lower forward extremity of the fixed leading edge or "D nose" of the main wing and making a portion of the underside of the "D nose" hingeable downwards and forwards. However Kruger flaps are
10 not as aerodynamically efficient as slats.

A need therefore exists for a wing assembly which incorporates a high lift device and a provision for forced hybrid laminar flow, but which does not compromise the structural design of the main wing portion and which does
15 not have the weight penalties referred to above.

Accordingly, in one aspect of this invention, there is provided an aircraft wing assembly including a main wing portion and a leading edge high lift portion movable between a retracted position in which it generally merges
20 with the main wing portion and a deployed position forwardly thereof, wherein at least a substantial part of an exposed upper surface of said high lift portion is air permeable or perforated and in flow communication with a suction passage associated with said leading edge portion,
25 whereby in flight, suction may be applied to said suction passage to at least reduce the chordwise extent of the

turbulent boundary layer over at least one of the upper and a lower wing surface.

In another aspect, this invention provides an aircraft incorporating a wing assembly as defined above.

5 In a further aspect, this invention provides a leading edge high lift device for use with a main wing portion for being moved between a retracted and a deployed position, wherein at least a substantial part of an upper surface of the high lift device is air permeable or perforated and in
10 flow communication with a suction passage of said high lift device, whereby in flight, suction may be applied to cause a negative pressure difference to at least reduce the chordwise extent of the turbulent boundary layer over at least one of the upper and a lower wing surface.

15 In yet another aspect, this invention provides a method of reducing the drag associated with an aircraft wing having a leading edge high lift device, which method comprises providing a substantial part of an exposed upper surface of the high lift device with an air permeable or
20 perforated surface and applying suction through said surface to at least reduce the chordwise extent of the turbulent boundary layer on at least one of the upper and a lower wing surface.

Whilst the invention has been defined above, it
25 extends to any inventive combination of the features set out above or in the following description.

The invention may be performed in various ways and, by way of example only, an embodiment thereof and various modifications will now be described in detail, reference being made to the accompanying drawings, in which:-

5 Figure 1 is a section view through the forward part of a wing assembly in accordance with this invention, with the leading edge slat retracted, taken at a section part way along the wing;

Figure 2 is a view similar to Figure 1 but showing the
10 suction telescope at the wing root region;

Figure 3 is a top plan view on the in-board leading portion of the port wing of an aircraft incorporating the assembly of Figures 1 and 2;

Figure 4 is a detailed view showing the interface
15 between the trailing edge of the leading edge slat and the main body portion;

Figure 5 is an enlarged view of the trailing edge portion, and

Figure 6 is a view looking forwardly on the trailing
20 edge portion on lines VI - VI of Figure 5.

Referring to the Figures, the wing assembly comprises a relatively fixed main wing portion 10 and a relatively moveable leading edge slat 12 mounted on the main wing portion 10 by means of curved track extension/retraction
25 mechanisms shown generally at 14, for movement between the position shown in Figure 1 in which the leading edge slat 12 merges generally smoothly with the main wing portion 10

and a high lift, deployed, configuration in which it is extended forwardly and downwardly to increase the camber and effective surface area of the wing and thus the lift produced. It will be seen from Figure 1 that the D nose
5 portion 16 of the main wing is of relatively small transverse section and that some of this area is occupied by the extension/retraction mechanism.

In this arrangement, boundary layer control is effected by applying suction through the leading edge slat
10 12 rather than to the main wing portion 10. Thus the ducting and services required for the boundary layer control (with the exception of the suction telescope or telescopes to be described below), can be located primarily in the leading edge slat 12, although in other arrangements
15 this may be supplemented by providing perforations and suction in the fixed leading edge.

The leading edge slat 12 comprises a double-walled forward section 18 of generally convex form and a rearward surface 20 of generally concave form. The double-walled
20 construction comprises an outer surface 22 and an inner surface 24 interconnected by elongate generally spanwise webs 26 to define a series of air suction chambers 28 internally of the outer skin. The inner surface 22 together with the rearward surface 20 together define an
25 air suction duct 30. As seen more particularly in Figure 4, the outer skin has perforations 32 over a substantial portion of its surface, apart from the lower portion 34

(see Figure 1) - (although this could be perforated if required). Each of the chambers 28 communicates with the air suction duct through a series of orifices or air transfer ports 36. The sizes of the air transfer ports 36
5 can be selected to provide a required pressure differential profile in the chordwise direction of the wing. It would also be possible to adjust the pressure in the spanwise direction by providing suitable webs to sub-divide the chambers 28.

10 Referring again specifically to Figure 4, the trailing edge 40 of the leading edge slat 12 is specially machined adjacent its interface with the main wing portion to provide a series of channels or grooves 42 which communicate with the space defined between the rearward
15 surface 20 of the slat and the forward portion of the main wing surface, and which define with the surface of the main wing portion a series of suction ports, as can be seen in Figures 5 and 6. The slat includes a seal strip 44 to seal the gap between the slat 12 and the main wing portion 10;
20 and the rearward surface 20 of the slat includes air transfer ports 36 to create suction in the space between the slat 12 and the main wing portion 10 above the seal strip 44. This arrangement allows suction to be provided at the line of contact 41 between the trailing edge of the
25 slat and the main wing portion, thus reducing the possibility of turbulence being initiated at the interface.

Thus, in normal cruise flight, with the slat 12 retracted, suction is applied to the air suction duct 30 to provide the required pressure profile over the surface exposed leading edge and upper surfaces of the slat 12, and
5 adjacent the interface 41 between the trailing edge 40 of the slat 12 and the main wing portion 10 to defer the onset of the transition from laminar to turbulent flow.

The suction may be applied in various ways, one example being shown in Figures 2 and 3. Here, the air
10 suction duct 30 on the innermost slat 12 includes a suction telescope 46 curved to be concentric with the arc of movement of the slat 12 and carrying a relatively fixed portion 48 located within the wing root portion of the aircraft and connected to a suction pump 50, and a rela-
15 tively moveable portion 52 slidably located in the distal end of the suction telescope 46 and connected in flow communication with the air suction duct 30. The suction may be applied to the outer neighbouring slats 12 by means of hose connections and suitable seals, or a common suction
20 duct may extend spanwise along the D-nose 16 of the wing, which feeds spaced suction telescopes servicing one or more slats 12. In this instance, a suction telescope may be located at the wing pylon point 54. Alternatively the telescope may not be required as suction will typically
25 only be required in cruise flight, when the slat will be retracted. In this case the telescope may be replaced by a docking arrangement which provides sealed communication

with the suction source in the retracted condition, and which separates when the slat is deployed, thus providing an arrangement which has a lower weight and complexity than the telescoping arrangement.

5 We have found that, with the illustrated slat design, it may not be necessary for the perforations to be provided as far back chordwise as in existing proposals. Thus it may be sufficient to provide perforations in the slat possibly with some or no further perforations in the fixed
10 leading edge of the main wing portion 10.

 The illustrated embodiments have several further advantages. Due to the geometry of the slat 12 it is possible to provide perforations on the slat which are to the rear of the D-nose 16 of the fixed main wing portion,
15 without requiring significant structural modification of the main wing portion. The slat 12 protects the fixed leading edge of the main wing portion and any damage to the leading edge (e.g. bird strike) will tend to be sustained by the slat rather than the fixed leading edge, which is
20 more difficult to repair. The perforated surface is usually made of stainless steel or titanium and in previous proposals for forced hybrid laminar flow in a fixed leading edge, the incorporation of such material with composites and other materials has proved problematic due to the
25 different structural characteristics of the materials, whereas the slat of this invention may be made of the same

material as the perforated surface or of compatible materials.



Claims

1. An aircraft wing assembly including a main wing portion (10) and a leading edge high lift portion (12) movable between a retracted position in which it generally merges with the main wing portion and a deployed position forwardly thereof, characterised in that at least a substantial part of an upper surface (22) of said high lift portion is air permeable or perforated and in flow communication with a suction passage (30) associated with said high lift portion, whereby in flight, suction may be applied to said suction passage to at least reduce the chordwise extent of the turbulent boundary layer over at least one of the upper and a lower wing surface.

2. An aircraft wing assembly according to Claim 1, including means for controlling the degree of suction at selected points or regions over the exposed surface (22).

3. An aircraft wing assembly according to Claim 2, wherein said means for controlling includes a plurality of chambers (28) extending within said high lift portion (12) and in flow communication with the air permeable or perforated part of the exposed surface (22), and said suction passage (30).

4. An aircraft wing assembly according to Claim 3, wherein said means for controlling includes one or more orifice means (36) or restricted passage means associated



with one or more of said chambers (28), for controlling the flow to or from said chambers.

5. An aircraft wing assembly according to Claim 3 or Claim 4, wherein each of said chambers (28) is elongate and
5 extends generally spanwise.

6. An aircraft wing assembly according to any preceding Claim, wherein said leading edge high lift portion comprises a slat (12) which includes a trailing edge region (40) which lies in contact with or closely
10 adjacent the main wing portion (10) when said slat is in its retracted position, said assembly further including passage or perforation means (42) for drawing in air or applying suction in the region of an interface (41) between the trailing edge region of said slat and the main wing
15 portion (10).

7. An aircraft wing assembly according to Claim 6, wherein said passage or perforation means includes orifice means (36) in a surface (20) of the slat (12) which faces the main wing portion (10), said orifice means being in
20 flow communication with said suction passage (30).

8. An aircraft wing assembly according to Claim 7, wherein said passage or perforation means includes a plurality of generally spanwise spaced channels (42) in the trailing edge region (40) of said slat which co-operate
25 with the adjacent surface of the main wing portion (10), when the slat (12) is in the retracted position, to define a plurality of suction ports at said interface (41).



9. An aircraft wing assembly according to Claim 6,7 or 8, including seal means (44) extending generally spanwise between a rearward facing surface (20) of the slat and the main wing portion (10) to provide a seal
5 therebetween when the slat (12) is in the retracted position.

10. An aircraft wing assembly according to any preceding Claim, including one or more suction pump means (50) for applying suction to said suction passage (30).

10 11. An aircraft wing assembly according to Claim 10, wherein a said suction pump means (50) is located in said main wing portion (10) and is in flow communication with said high lift portion (12) via extendable suction duct means (46) extending between the main wing portion and the
15 high lift portion.

12. An aircraft wing assembly according to any preceding Claim, including one or more further said high lift portions (12), the said high lift portions being arranged spanwise with respect to each other, and each high
20 lift portion including a said suction passage (30) in flow communication with a suction passage (30) of at least one other said high lift portion.

13. An aircraft wing assembly as in Claim 12 in which said flow communication with a suction passage (30) of at
25 least one other said high lift portion takes place via a further seal acting between adjacent high lift portions.



14. An aircraft characterised by incorporating a wing assembly according to any preceding Claim.

15. A leading edge high lift device (12) for use with a main wing portion (10) for being moved between a retracted and a deployed position, characterised in that at least a substantial part of an upper surface (22) of the high lift device is air permeable or perforated and in flow communication with a suction passage (30) of said high lift device whereby, in flight, suction may be applied to cause a negative pressure difference to at least reduce the chordwise extent of the turbulent boundary layer over at least one of the upper and a lower wing surface.

16. A leading edge high lift device according to Claim 15 including a series of generally spanwise spaced channels (42) in a trailing edge region (40) thereof.

17. A method of reducing the drag associated with an aircraft wing having a leading edge high lift device (12), which method is characterised by providing a substantial part of an exposed upper surface (22) of the high lift device with an air permeable or perforated surface and applying suction through said surface to at least reduce the chordwise extent of the turbulent boundary layer on at least one of the upper and a lower wing surface.