PERFORMANCE IMPROVEMENT ON TAILPLANES BY TURBULATORS

By D. Althaus

Airfoils on tailplanes operating at lower Reynolds numbers than the wing may produce large laminar separation bubbles, with excessive additional drag when the flap is deflected.

In order to demonstrate the effectiveness of turbulators, tests were made in the Laminar wind tunnel of the University of Stuttgart on a model of the FX 71-L-150/30 airfoil with a chord of 0.5 m, at Reynolds numbers of 0.7 and 1.5 millions.

In Figure 1 the lift-drag polar for the model with clean surface shows a detrimental increase in drag when the flap is deflected down + 15°. This is due to a laminar separation bubble forming over the flap hinge on the side opposite to the flap deflection. Moving up from small lift coefficients, the drag coefficient reaches a maximum followed by a sharp minimum. This corresponds to the point where transition at the suction side has moved up to the laminar separation point, the separation bubbles has been removed. At higher lift—coefficients transition moves rapidly towards the leading edge of the airfoil producing the strong increase in drag.

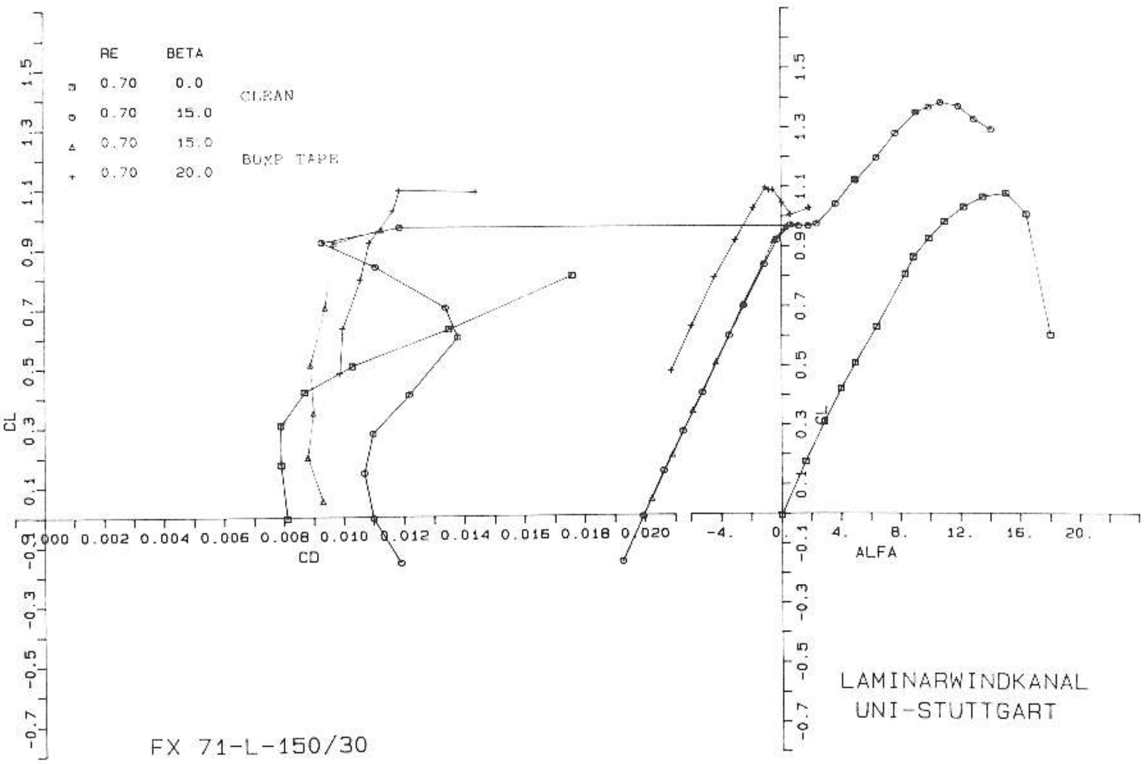

FIGURE 1.

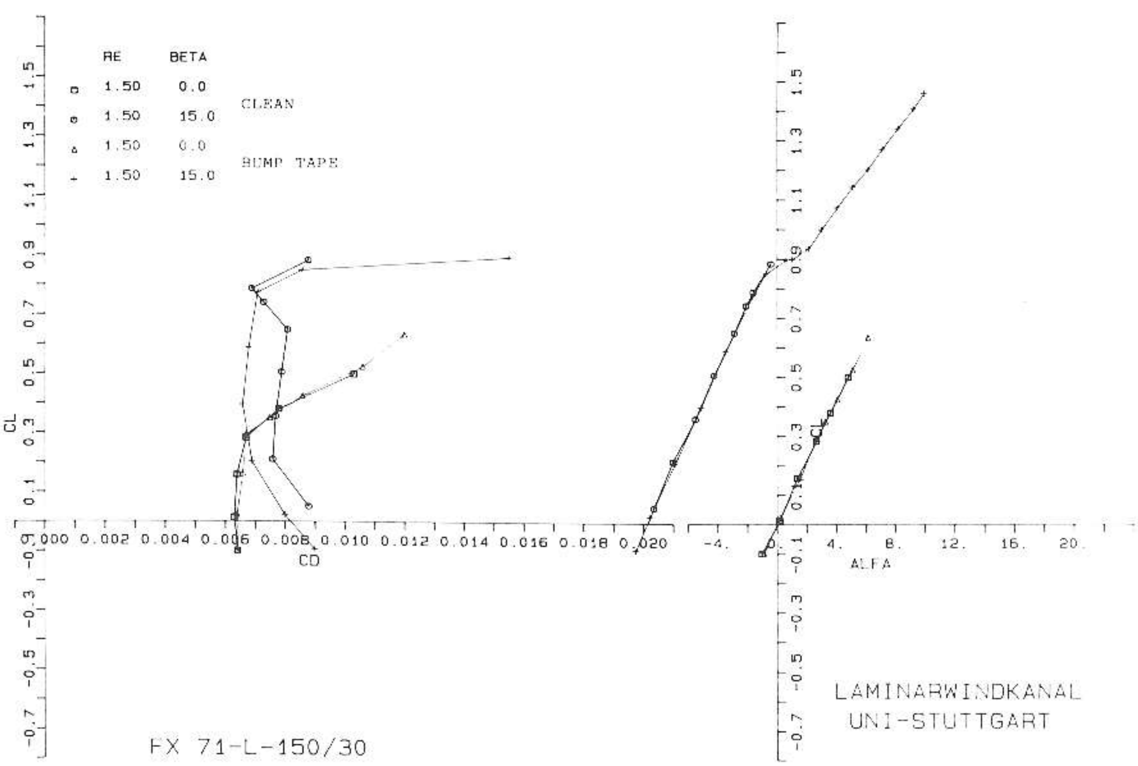

FIGURE 2.

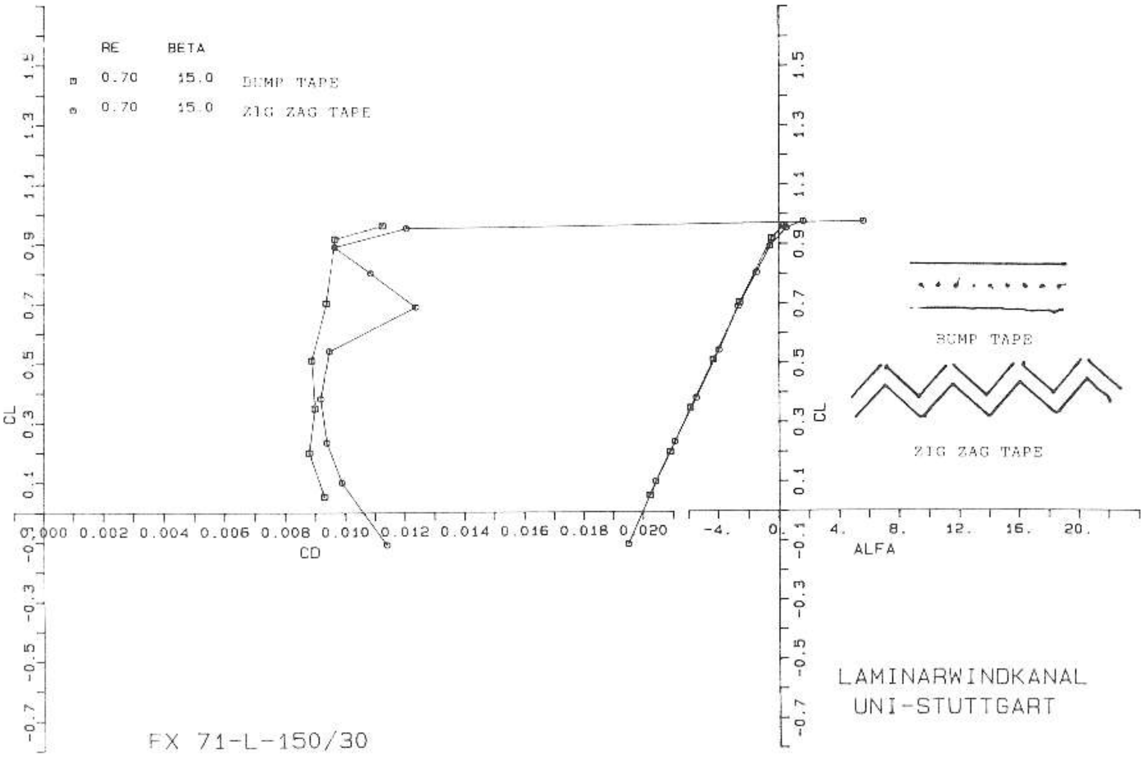

FIGURE 3.

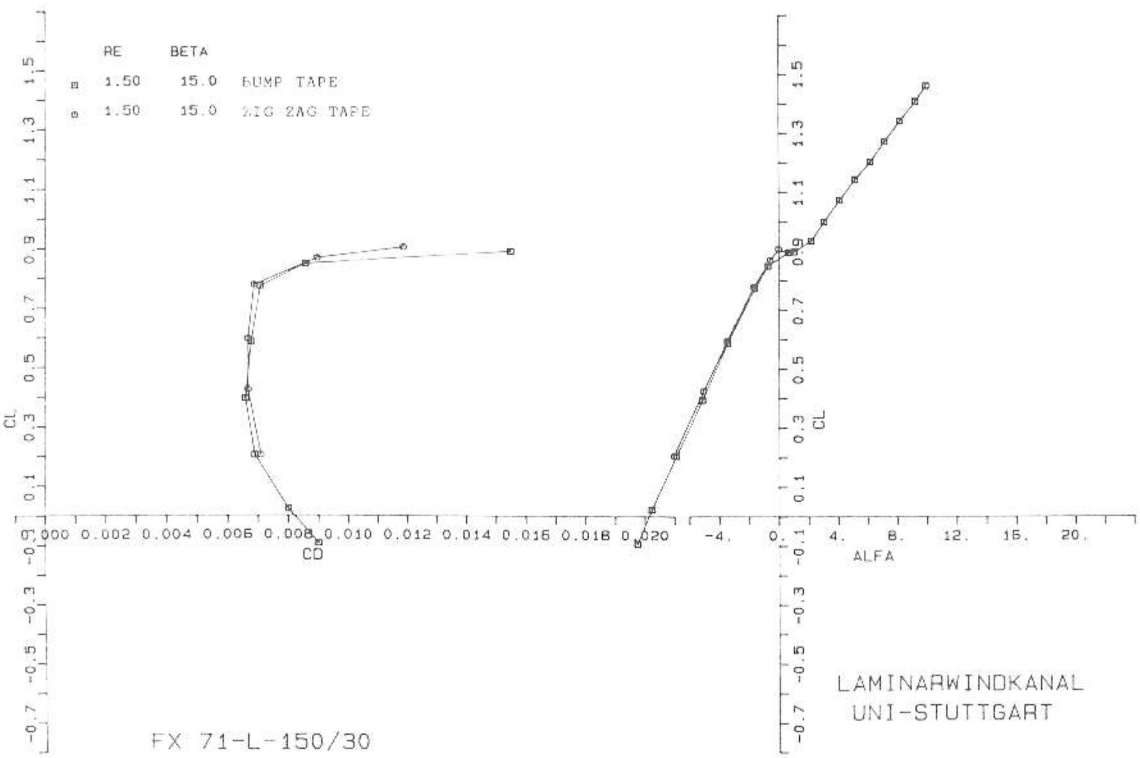

FIGURE 4.

When early transition of the boundary layer is forced by a turbulator the loss of performance by the large separation bubble is avoided. The turbulator is a self sticking tape 10 mm wide, 0.25 mm high with digged in bumps fixed with its leading edge at x/c = 0.67 shortly before the flap hinge (x/c = 0.7). The bumps are 0.65 mm high with a distance of 5 mm (Figure 3). In Figure 1, the performance with the bump tape is demonstrated for ß = + 15° flap deflection showing a nearly constant drag coefficient over a large range of lift. At 20° flap angle there is still a usable drag polar whereas early separation was observed with the clean model, where additional drag by laminar separation is, of course, produced even at small flap deflections.

Figure 2 shows tests for Re = 1.5 millions. At a flap angle of 15° the difference in drag between the clear surface and that with the bump tape is smaller, owing to the fact that the dimensions of the separation bubble have been decreased by the higher Reynolds number. At zero flap deflection, there is no difference between both conditions. This means the turbulator has no negative influence on the boundary layer.

Figures 3 and 4 show the effectiveness of two different turbulators: the bump tape and a zig-zag tape with a thickness of 0.4 mm, both at the same position. At Re = 0.7 million, the zig-zag tape is not yet full in effect. It should be placed a small distance ahead but this might be detrimental at Re = 1.5 million (Figure 4), where both turbulators have nearly the same effect.

The airfoils FX 71-L-150/25 and FX 71-L-150/20 (/20 = 20% flap chord) /1/ shows the same effect. The same holds for the other symmetrical airfoils NACA 641 012 K 25 (25% flap chord), FX L III 142 K 25 and FX L V 152 K 25, all published in /1/. Bump tapes at 3% of airfoil chord before the flap hinge should improve performance with deflected flaps.

Of course, turbulators must be used on both sides of an airfoil at a tailplane.

/1/ D. Althaus, F.X. Wortmann, Stuttgarter Profilkatalog I, Vieweg & Sohn, Braunschweig/Wiesbaden