FLOW CONTROL OF BOUNDARY LAYER TRANSITION AND SEPARATION ON AIRFOILS AND BODIES IN FREE ATMOSPHERE CONDITIONS

Lukáš Popelka, Lubor Zelený
Institute of Thermomechanics AS CR, Prague, Aeroclub Přibyslav

The paper deals with visualisation of uncontrolled and controlled cases of boundary layer transition and separation carried out during in-flight measurements. Oil flow and tuft techniques have been applied. Influence of passive flow control devices to the performance of the entire aircraft has been established and importance of active and adaptive approach shown.

1. Measurement methodology

Self-launching TST10a sailplane OK-A631 /LZ/, Fig. 1, was used as test aircraft. Main dimensions of wing are presented on drawing Fig. 2. Standard altimeter and airspeed indicator were connected to factory designed static ports located 1780 mm aft of the fuselage nose and 250 mm above its lower surface contour. Thermocouple was installed outside the canopy frame to measure flow temperature. GNSS Flight Recorder LX20 was used to acquire GPS signal. Recorded flight track was post-processed and evaluated flight speed and sink rate reduced to International Standard Atmosphere. Calibration of sailplane pitot-static system was obtained.

Fig. 1 Test aircraft TST10a OK-A631 /LZ/

Oil flow visualisation on two positions along wingspan was prepared. Oil was applied on surface prior to the take-off, and flight of 10 minutes duration was carried out. Airspeed V = 100 km/h IAS was held constant during whole flight, even during climb and approach to landing.
Array of tufts was applied to the wing root area, Fig. 3 and video recording acquired for airspeed V = 85, 100, 130 and 160 km/h IAS. Extent of separation was studied in these conditions in straight flight.
Detailed measurement of TST10a saiplane speed polar was based on GPS methodology, *Popelka (2006)*, which was further refined. Every measurement programme was started at altitude of 2000m MSL or higher, for each airspeed 4 individual straight flight sequences were used. Flight track of 300m altitude loss in each sequence was recorded.
Expenses for numerous required test flights were covered by Mr. Zelený, the owner of TST10a OK-A631 /LZ/.

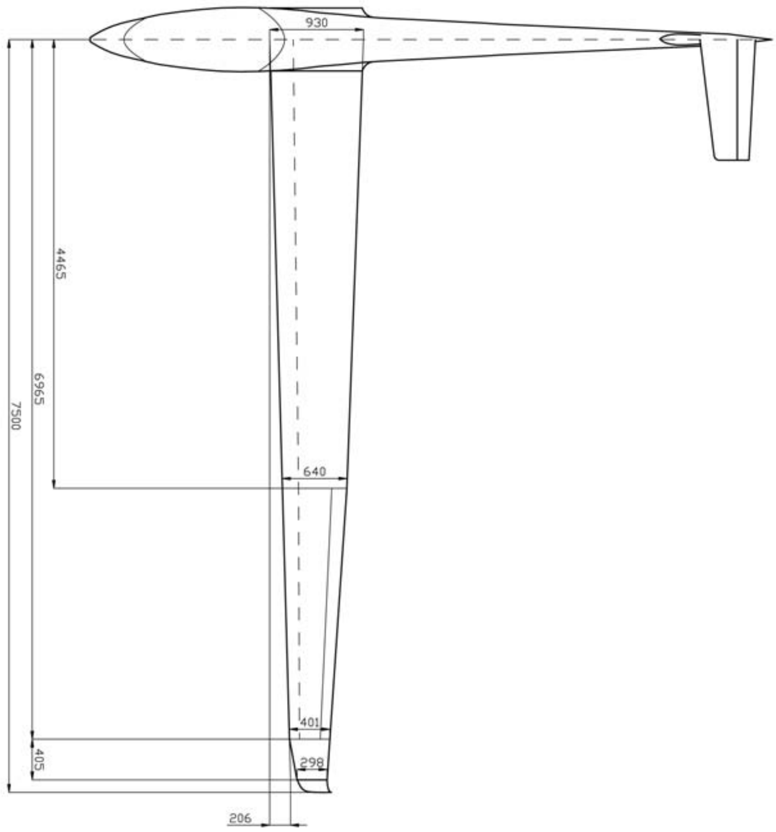

Fig. 2 Main dimensions of TST10a wing

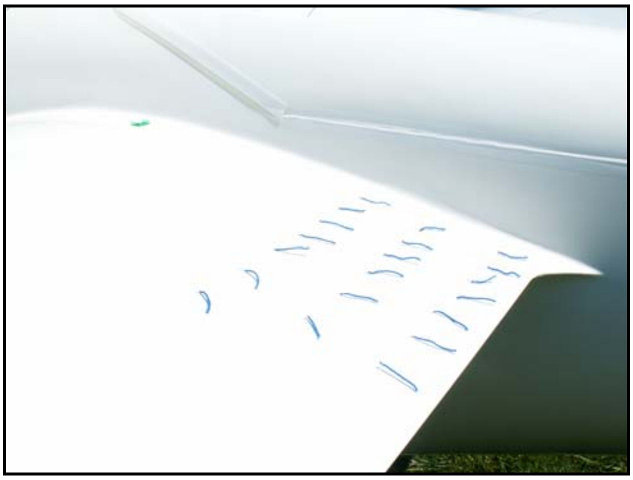

Fig. 3 Array of tufts and vortex generator installed on the left wing root of TST10a prior to the test flight

2. Results

Region of separation bubble was determined, Fig. 4. Based on previous findings on Standard Cirrus sailplane, leading to 10.7% glide ratio L/D improvement of OK-7077 /CX/ at 115 km/h IAS, Zig-zag type turbulators were applied along the wingspan.

Visualization in the transition wing-fuselage geometry have been done by tufts, Fig 5, on four airspeeds covering the common competition range. Region of separated flow has been determined, counter-rotating vortex generator of height h = 3mm (denoted as VG1) applied on chordwise location x/c = 0.48 and separation suppression observed.

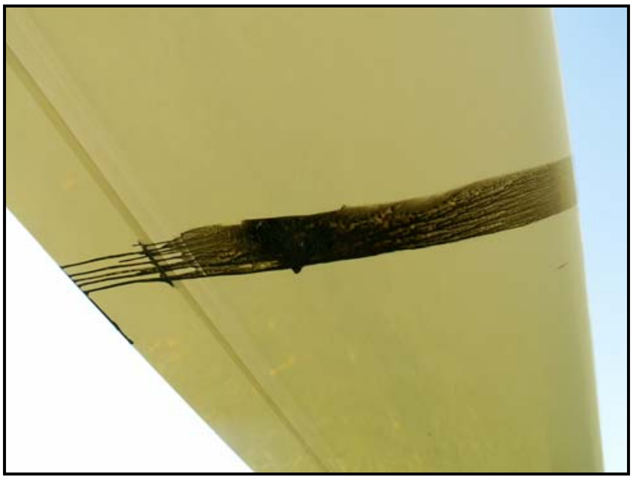

Fig. 4 Oil-flow visualization on lower surface of outer wing segment of TST10a sailplane, in the aileron region. V = 100 km/h IAS. Right to left: laminar boundary layer, separation bubble, turbulent boundary layer

Fig. 5 Tuft visualization on left wing root of TST10a, V = 85km/h IAS. Left figure – uncontrolled case, note large region of separated flow. Right figure – VG1 applied, attached flow till the proximity of wing trailing edge

Effect on performance of sailplane have been consequently established by measuring both uncontrolled and controlled speed polar of the test sailplane, as presented on Fig. 6. Measured glide ratio curves are plotted along with theoretical curve, *Popelka (2006)*. Installation of wing-root VG1 resulted to L/D improvement in low-speed range. Compared to the theoretical curve, it can be stated that notable shift towards TST10 performance potential utilization has been reached. The remaining difference can be accounted to the drag of fixed main undercarriage.

On the other hand, substantial decrease of L/D has been observed for typical interthermal glide airspeed. Unacceptable deterioration of high-speed sailplane performance has lead to the new layout of vortex generator VG2 currently installed on test aircraft.

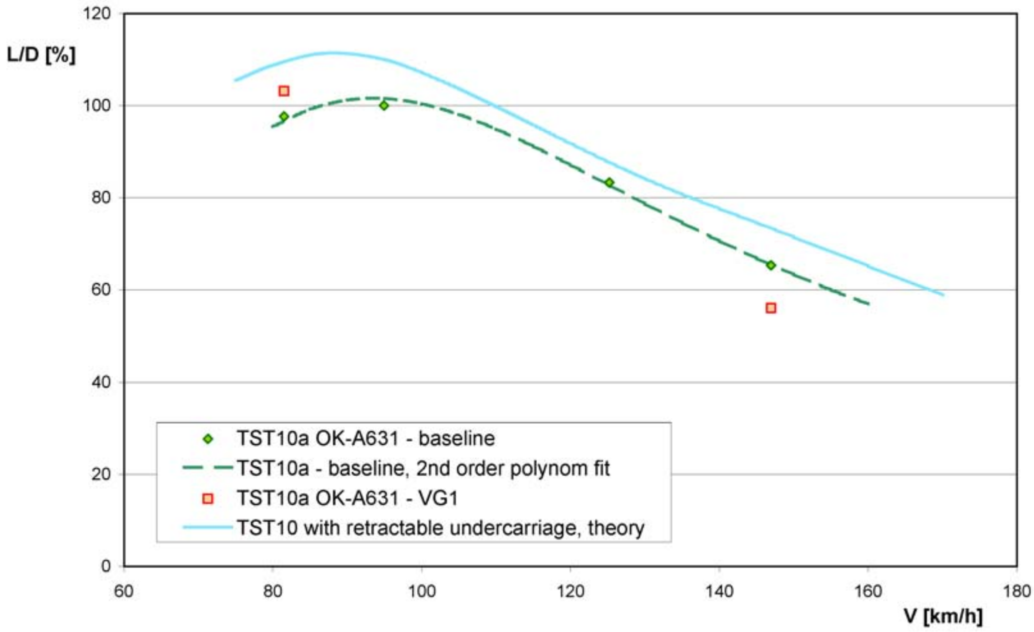

Fig. 6 Measured L/D performance of TST10a saiplane – baseline, VG installed and theoretical prediction. Wing loading, m/S = 31.4 kg/m²

3. Conclusions

Methodology of flow visualisation feasible for in-flight investigation on airfoils and bodies was developed. Sailplane speed-polar measurement with use of GNSS FR was further improved.

Two types of passive flow control devices were used. For boundary layer transition control the optimum turbulator location was established. The case of separation control have shown potential of performance improvement. The need of off-design detrimental effect minimization has been demonstrated. In given wing-fuselage geometry, application of acoustic-driven synthetic jet is feasible. Such active device could be optimized to supress separation on V = 85 km/h IAS. For higher airspeeds the jet intensity should be lowered, with dynamic pressure as trigger and hence adaptive control can be reached.

4. Acknowledgment

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5. Literature

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