AN INVESTIGATION INTO PERFORMANCE ENHANCEMENT OF A SPORTS-CLASS SAILPLANE BY USE OF TURBULATOR TAPES

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Can turbulator tapes enhance the performance of sports-class sailplanes? There have been figures quoted for the positioning of turbulator tapes on the wings of several sports-class sailplanes. Proving them is not usually reported in detail (exception being the Althaus/ Astir report in Soaring and that was not confirmed by inflight testing).

In order to see if the fitting of turbulator tapes would enhance the performance of my Glasflugel Club Libelle, I chose the method originated by Richard H. Johnson of measuring wing drag and German zig-zag turbulator tape. I drew up a program of testing and with three other pilots successfully carried out a considerable number of flights. The results, within the confines of the program, indicated a decrease in wing drag with the turbulator tape at 55% AFT of the wing leading edge.

All flights had to be from winch launches and the testing carried out interthermal. In order to avoid the influences of both sink and lift a netto variometer was used to locate reasonably stable air-masses. The majority of the testing was carried out during the Southern winter months. Even during the limited soaring to between 3000 ft and 5000 ft it was quite easy to locate the required stable air-masses.

The test program called for sufficient flights at each stage to establish adequate results. The first flights were carried out without fitting turbulator tape i.e. a clean wing. Some five flights were made, two of these produced essentially identical results, two produced minor variations, and one produced unacceptable results. The four acceptable flights were analyzed and averaged out to produce the clean-wing line in the diagram.

The next series of flights was made with a sample one meter length of .5 mm thick zigzag turbulator tape placed at 50% chord AFT of the leading edge. The results were disappointing and showed marginally decreasing drag starting at 70 kts, but by 80 kts it was quite noticeable. Several extra flights were made to confirm this. The tape was removed and replaced at 55% chord AFT of the leading edge. From the first flight results it was realized that a substantial reduction in drag was being recorded. On subsequent flights, though an anomaly showed up in the 55 kts results; there was a kink in the line that I could not understand, (the infamous laminar bucket?). Next the tape was removed and replaced at 60% chord AFT of the leading edge. The results were difficult to analyze and I suspect the tape was either right on the laminar bubble or too close for the airflow to re-attach in

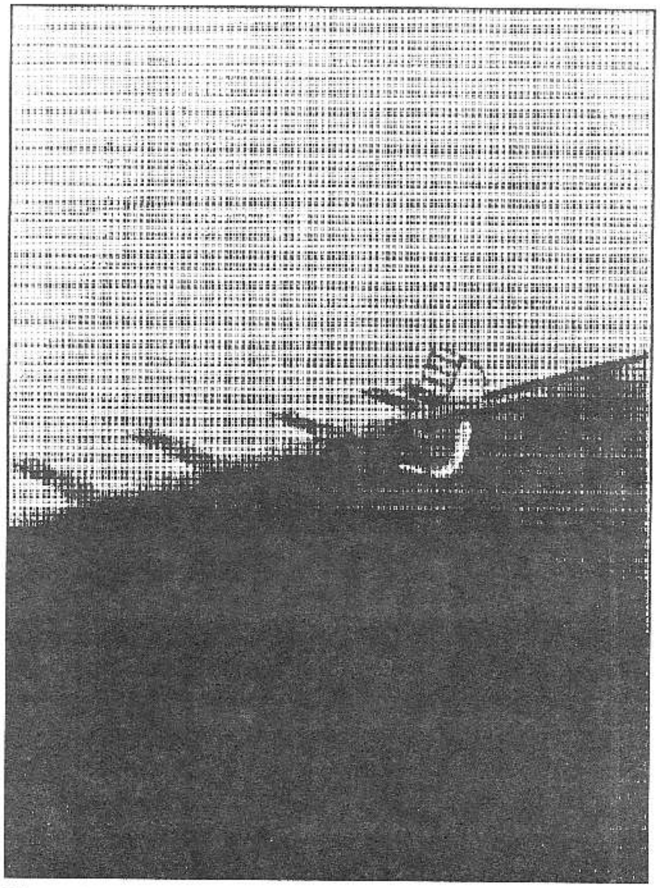

Photo 1

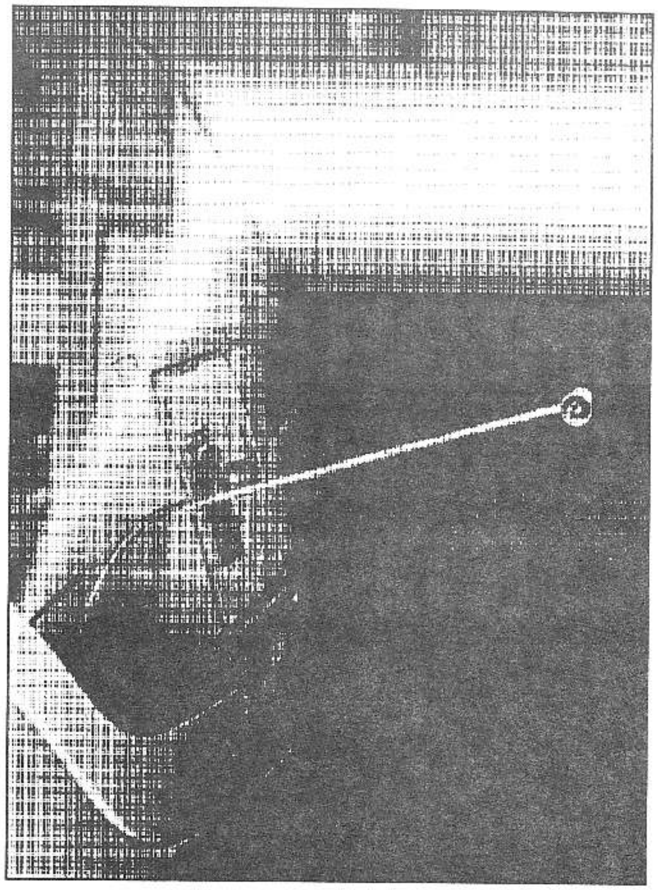

Photo 2

Influence of Zig–Zag Turbulators

Glasflügel H205 Club Libelle
Wortmann FX66–17AII–182
Clean wing and with Zig–Zag Turbulator at 55% aft of wing L.E.

indicated air speed		indicated drag clean	indicated drag turb.	speed diff.	clean speed diff %	L/D clean	L/D turb.
kts	40	27·67	25·68	1·99	7·2%	31·25	33·5
fps	67·56	46·73	43·37	3·36			
kts	50	29·58	28·08	1·50	5·07%	34·9	36·66
fps	84·45	49·96	47·43	2·53			
kts	55	30·64	29·08	1·56	5·09%	33·0	34·67
fps	92·90	51·75	49·12	2·63			
kts	60	31·80	29·85	1·95	6·12%	31·75	33·69
fps	101·35	53·71	50·42	3·29			
kts	70	34·65	32·64	2·01	5·8%	27·39	28·97
fps	118·24	58·53	55·13	3·39			
kts	80	38·01	36·28	1·73	4·56%	22·53	23·55
fps	135·13	64·20	61·28	2·92			

Figure 1.

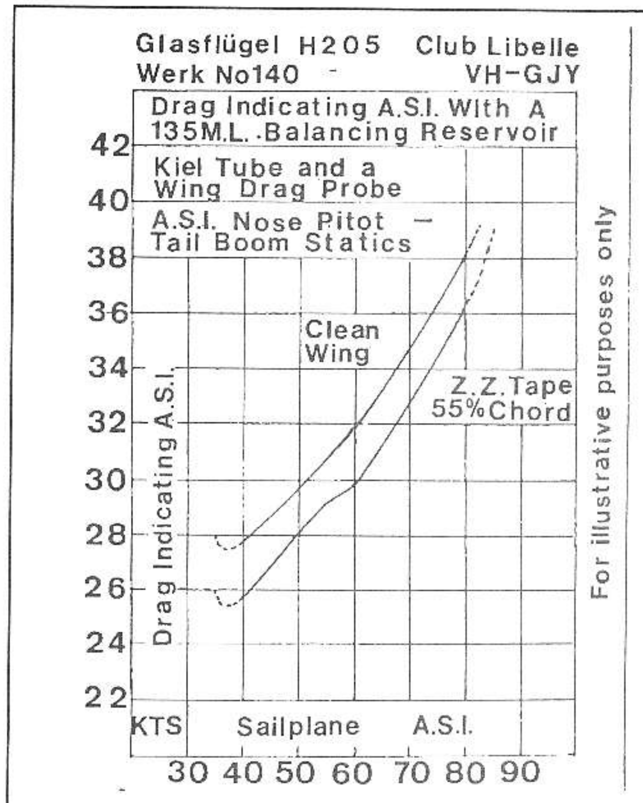

Figure 2.

ANNEXURE 'A'

Johnson Theorem for calculating drag values as L/D

Force	Mass	Accel
F =	M	A

equation to estimate the air momentum loss at the probe chord location, and that is equal to the wing profile drag at all the other chord locations and can be estimated without actually testing there. The mass of the wing boundary layer can be assumed to be the exposed wing span X total exposed probe height x B.L. ave. velocity x Air Density (assume .002377 slugs/FT3 if using C.A.S. in Ft/Sec.)

The A acceleration term is simply the saiplane C.A.S. minus the average B.L. velocity indicated by the drag probe measurements.

This last calculation may be somewhat indirect because it involves more thought than simply using the charts drag I.A.S. values. Instead the B.L. velocity must be estimated as follows:

Dynamic pressure at Keil tube = $\frac{1}{2}PV^2k$ in P.S.F.

Dynamic pressure at Drag probe = $\frac{1}{2}PpV^2$ ave P.S.F.

Since it is reasonable to assume P = Pp and drag probe

Δ P = P keil - P Probe in P.S.F.

$$\frac{1}{2} P\, V^2_{D\ \mathrm{INDICATED}} = \frac{1}{2} P\, V_K^2 - \frac{1}{2} P\, V_P^2\ \mathrm{AVE}$$

$V^2 Di = V^2k - V^2p$ ave

V^2p ave $= V^2k - V^2 Di$ Vp ave = $\boxed{\sqrt{V^2k - V^2 Di}}$ ~F.P.S.

The acceleration term A = Vk - Vp ave

The mass term P (= .002377^3) x Volume/Sec

All units = Ft, Ft/sec, Ft^3 air density .002377 slugs/Ft^3

Volume of Boundary layer air decellerated/sec = Vk x exposed Wingspan x Top and Bottom Surface Probe height

an orderly manner. There was only a marginal decrease in drag above 75 kts.

The results given in Diagrams 1 and 2 prove that wing profile drag can be reduced by using turbulator tape on a sports-class sailplane.

The photographs show the keil tube and drag probe used. The keil tube is exactly according to Dick Johnson's drawings. The drag probe is the improved version with the pitot holes at 4 mm spacing (.005 C) for a 800 mm wing chord station.

Having reached this stage, the question became what is the actual improvement in L/D? A request was made for funding for a series of very high aerotows in order to re-plot the polar curve. This was not forthcoming, so attempts were made to convert the drag probe data mathematically by a method due to R.H. Johnson. This is reproduced in "Annexure A".

My first thoughts were that for any given airspeed only a reduction in profile drag can influence the L/D of any sailplane as all other drag figures will remain constant.

Taking only the round figures 40-50-60-70-80 kts IAS the reduction in profile drag appears to average 5.75 percent. Now this when added to the known clean L/D gives a figure for turbulated L/D. This is a very simplistic view.

Unfortunately this theorem could not be made to work. There is either an error in Dick's reasoning or the theorem has been wrongly interpreted. It has been included, as with some reworking it may be possible to convert a Johnson type drag diagram directly into L/D via this theorem. One problem with using Dick's drag testing method is that it can only really be applied to a wing that has the same profile from root to tip and no aerodynamic twist (washout). Reynolds numbers also have an influence, e.g. very narrow tip chords may not respond to turbulators in a similar manner to the larger chord of the main area of the wing.

F.G. Irving kindly supplied a copy of a N.A.C.A. paper by A. Silverstein and S. Katzoff which was a simplified method for determining wing profile drag in flight, dated 1940.

This paper was of considerable interest in that it described in detail a drag probe (integrating rake) not unlike Dick Johnson's but mounted between .15 c and .3 c behind the trailing edge. The paper continues in finite detail to cover every possible calculation. The end result however is a reading on a A.S.I. in the cockpit as per Dick Johnson's method.

My own feeling is that Dick Johnson's drag probe mounted directly on the trailing edge puts the probe right where the laminar flow is and that is what we are measuring (in terms of drag reduction). Incidentally, the reason why both the upper and lower surface laminar flows have to be integrated into one measurement is that any reduction in drag of either upper or lower surfaces has to be measured as to reflect an overall reduction in profile drag, and hence an increase in L/D.

To take pure research further takes this project away from the (older) sports class sailplanes, the average pilot and my own attempts to enhance the performance of my Club Libelle.

There is no doubt that the use of turbulators can influence the profile drag of earlier laminar flow profiles, used on sports class sailplanes, and that the average pilot can prove this using the Johnson method of drag testing. The high cost of very high aerotows will however prevent most pilots from producing new polar curves that would substantiate the drag reduction.

Therefore there is a very real need for a mathematical solution to Johnson type profle drag measuring that will convert the results into L/D figures. If that solution can also be applied to wings with aerodynamic twist and/or changes to the profile, then it will be of great benefit.

The following sources formed the basis of this paper: R.H. Johnson, At Last an Instrument That Reads Drag; R.H. Johnson, DG 100 Flight Test; W. Dirks, Boundary Layer Control; D. Althus, Astir Wings; L. Boermans, Design of AS-W 24 Tailplane.

Additional sources consulted: Millicer - Aerodynamics for Sailplane Pilots; P. Masak - Performance Enhancement; D. Althus - Performance Improvement of Tailplanes by Turbulators; Stuttgater Profile Katalog I - Wortman FX66-17AII-182 Analysis; L. Clancy - Aerodynamics 1986; S. Hoener - Aerodynamic Drag 1951; N.A.C.A. - Report No.660 1938; A. Silverstein/S. Katzoff - Simplified Profile Drag 1940

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