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MULTICRITERIA DESIGN OF SAILPLANE AIRFOILS

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Summary: *The article presents results of multicriteria design of airfoils suited for sailplanes. Airfoils for root and tip wing section as well as for empennage has been designed. The use of turbulators has been proposed on two older airfoils and the possibilities of drag reduction has been discussed.*

1. Introduction

Cross-country flight of a sailplane together with take-off and landing regimes create conflicting demands on performance. To enhance airfoil aerodynamic properties, an optimization task based on target criteria and Xfoil solver has been created. Since the constraint of trailing edge shape for easy manufacture has been applied, the resulting airfoils are not general solutions of the task, but an overall improvement has been gained over the best published airfoils in selected category.

2. Airfoil tailoring

Wing airfoils have been designed for a conceptual study of a club class sailplane, Fig. 1. New airfoils are labeled as PW212-163 (root) and PW311-161 (tip). 33 target criteria in three flight regimes have been used, as established in previous work *Popelka et al (2004)*. The airfoils for the empennage - PW401-137 K25 for horizontal stabilizer and PW402-136 for vertical stabilizer have been tailored as well. Modifications arose from successful design DU86-137/25, *Boermanns & Bennis (1992)*. Contours and calculated aerodynamic coefficients of PW series airfoils, Figs. 2 to 7.

3. Modifications of older airfoils

Turbulators can affect significantly the properties of older airfoils. Xfoil solutions create a quick

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and verified tool for such analysis. Ongoing survey on sailplanes used in Czech Republic has shown, that a room for improvement could be found on VSB-62 wing and VSO-10 empennage. Forced transition on both sides of Eppler STF863-615 airfoil used on entire VSB-62 wing yields reduction of detrimental laminar separation bubbles, Fig. 8 sq. Similar promising results are predicted on NACA 64-009, NACA 64-0012 which create the empennage of VSO-10 sailplane, Fig. 16 sq. Trends of polar shape are in general agreement with findings of wind-tunnel testing performed by *Althaus (1991)* on Wortmann FX 71-L-150 airfoil. Calculations show a slight increase of drag under the conditions without flap deflection. This fact is an inspiration for further experimental work and visualisation could prove, if laminar boundary layer can overcome unsealed gap and continue on the flap itself.

4. Conclusions

Conceptual design of specific sailplane category with new airfoils is a logical consequence of complex project, aiming at synthesis of numerical modelling, wind-tunnel and in-flight testing. Created methodology, which was herein used for club class can be employed for arbitrary sailplane. Parallel programme for training class has been established in extent of airfoil selection from published data (according to optimization critera indeed) and conceptual study of entire sailplane. Another more general aim is to study the possibilities of active control of boundary layer transition to replace fixed turbulator strips used nowadays, as initiated by *Sartorius (2002)*.

5. Acknowledgment

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6. Literature

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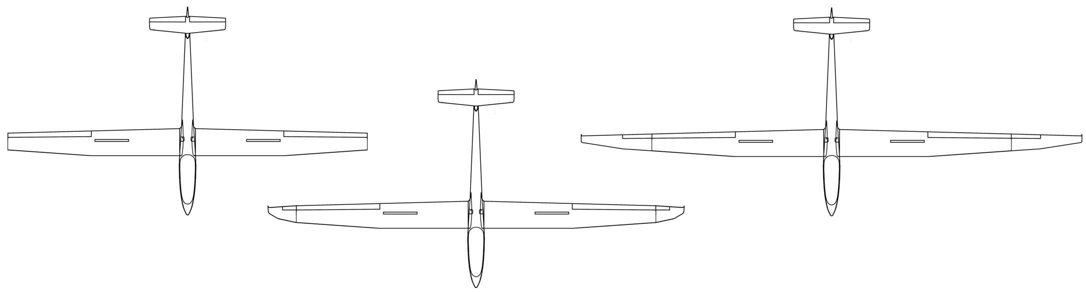

Figure 1: Conceptual design of club class sailplane, B project versions: B/Acro, B/Club, B/18m

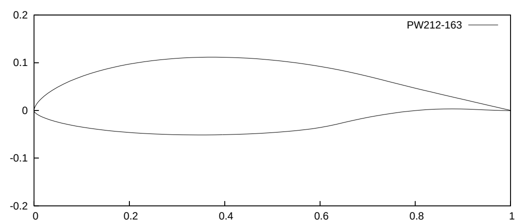

Figure 2: Geometry of PW212-163 airfoil

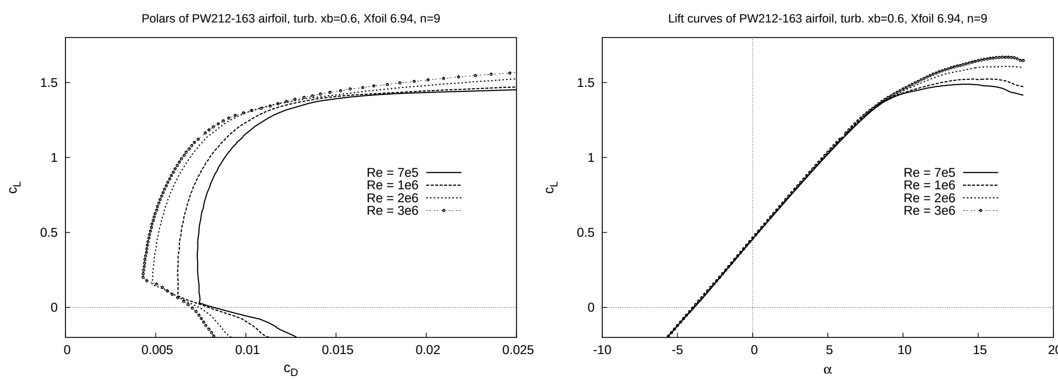

Figure 3: Polars and lift curves of PW212-163

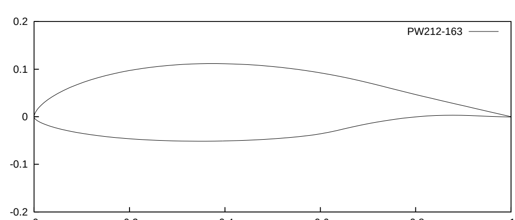

Figure 4: Geometry of PW311-161 airfoil

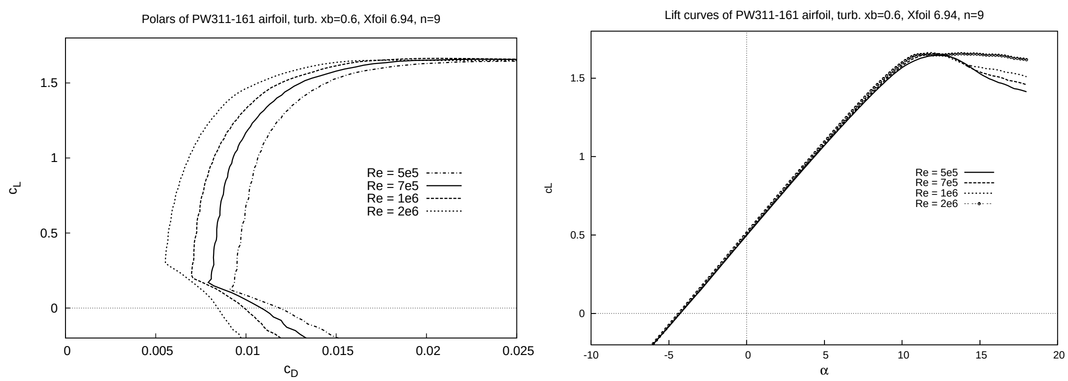

Figure 5: Polars and lift curves of PW311-161

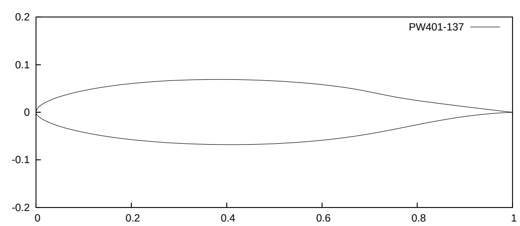

Figure 6: Geometry of PW401-137 airfoil

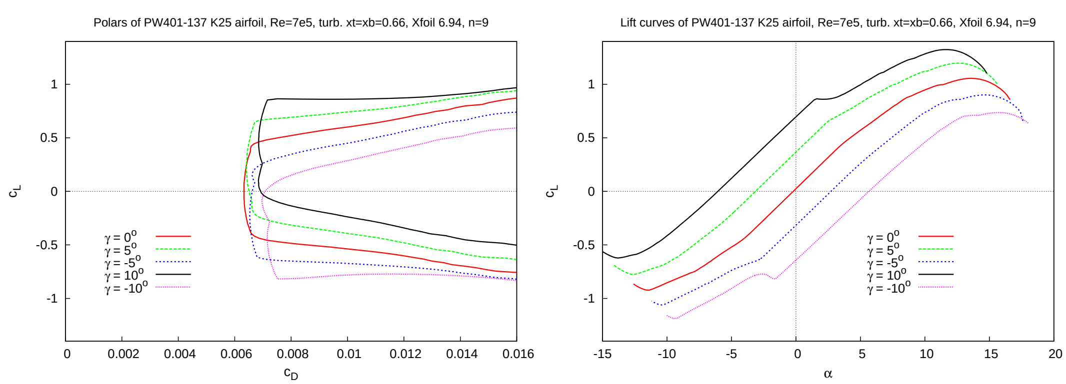

Figure 7: Polars and lift curves of PW401-137 K25, $Re = 7 \cdot 10^5$

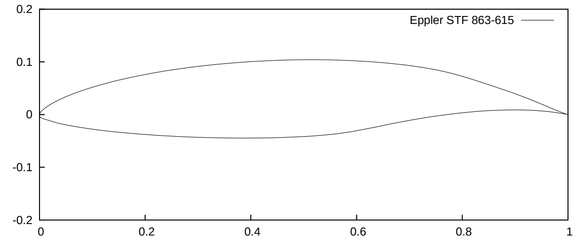

Figure 8: Geometry of Eppler STF 863-615 airfoil

Figure 9: VSB-62 and VT-16 sailplanes, wing root of VSB-62 (Eppler STF 863-615), photo ©Jan Rensa jr.

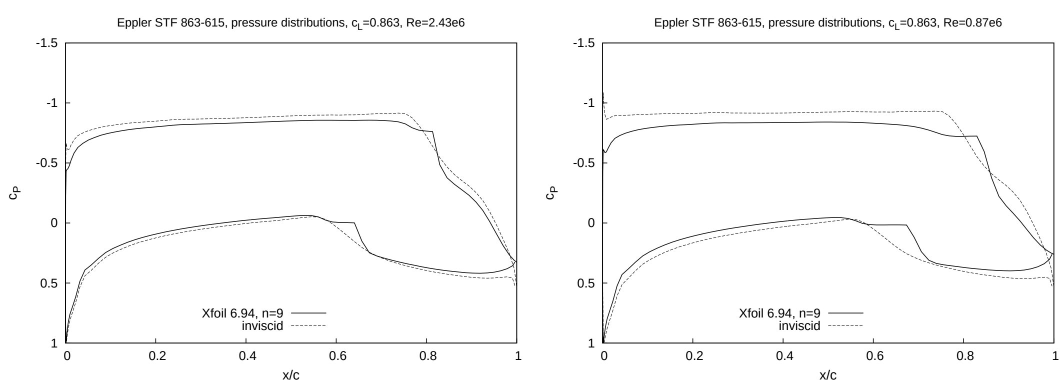

Figure 10: Calculated pressure distributions on wing root and tip airfoils, Re and c_L correspond to airspeed of V=85 km/h

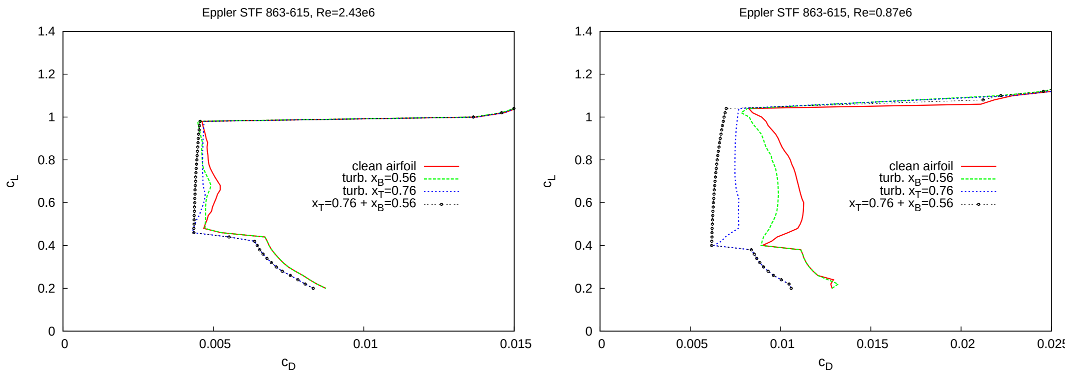

Figure 11: Calculated polars of wing root and tip airfoils at V=85 km/h, usage of turbulators

Figure 12: Horizontal stabilizer of VSO-10C OK-0530 sailplane, elevator deflection $\gamma = +16^o$, photo ©Aeroklub Polička

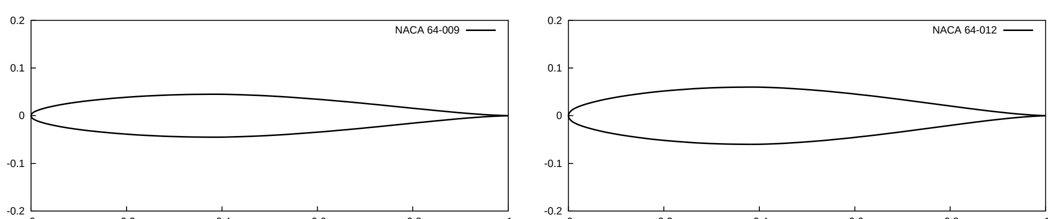

Figure 13: Geometry of NACA 64-009 (horizontal stabilizer) and NACA 64-012 airfoils (vertical stabilizer)

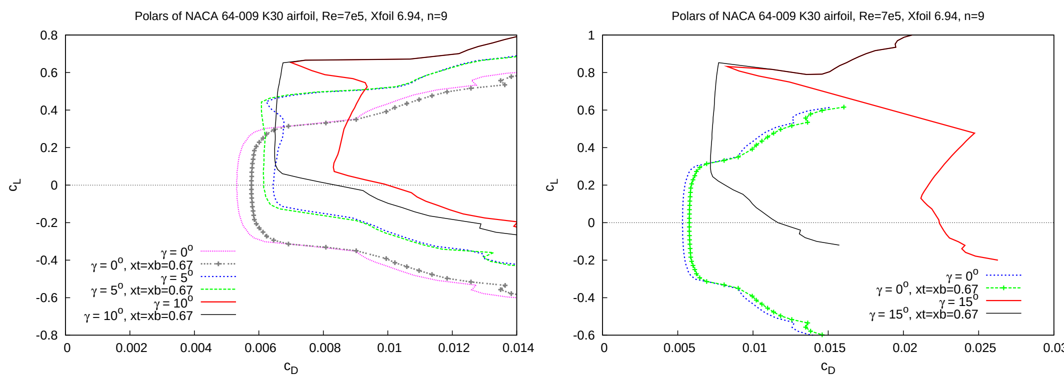

Figure 14: Polars of NACA 64-009 airfoil, $Re = 7 \cdot 10^5$

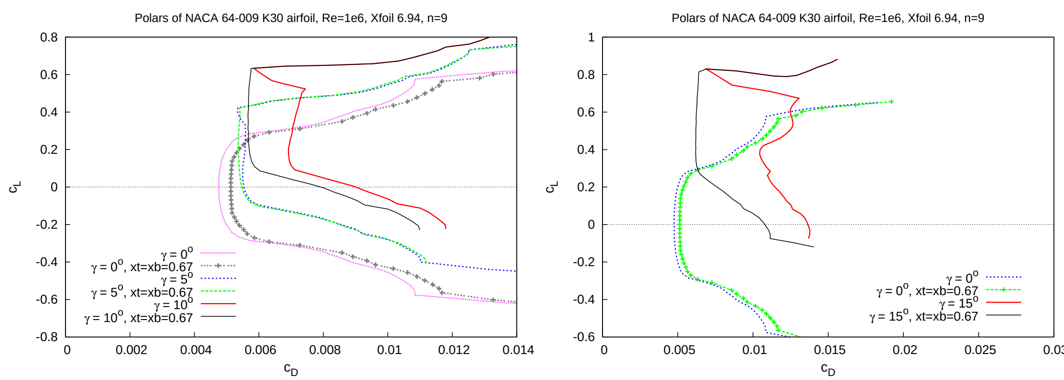

Figure 15: Polars of NACA 64-009 airfoil, $Re = 10^6$

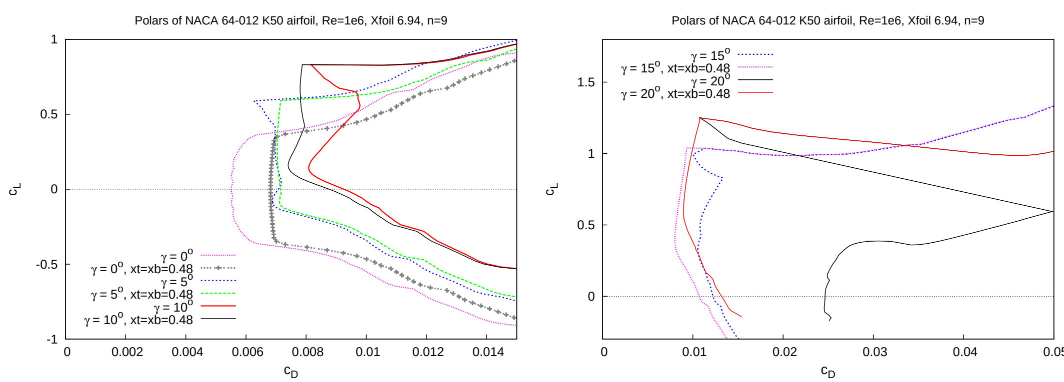

Figure 16: Polars of NACA 64-012 airfoil, $Re = 10^6$