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OPTIMIZATION PROCEDURE FOR SAILPLANE WING SECTIONS

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Summary: *The article describes procedure of sailplane airfoil optimization with use of available numerical and experimental methods. Comments are given on calculation of boundary layer transition, integral parameters, measurement of maximum lift coefficient, visualization and flow control.*

1. Introduction

Initial stage of sailpane design, as every aircraft, forms pronounced need of agile and reliable analysis methods implemented in optimization process. Athough wind-tunnel measurement can offer all required parameters, cost effective numerical methods are of paramount imporatnce.

2. Optimization

Criteria established for club and training class, *Popelka (2004)*, devides the demands on airfoil into three regimes and defines their importance:

Regime	Club class	Training class
Low-turbulent free stream	31%	36,7%
Increased level of turbulence	35,7%	29,3%
Insect contamination of leading edges	33,3%	34%

Resolved into manner of coefficients, we search for minimum c_D at 24 given c_L (circling and glide), maximum c_L at 3 angles of attack (landing), and $c_{L_{max}}$ itself. Furthermore we are interested in docile stall characteristics. All requirements are summed up into target function F, which we wish to maximize.

3. Parameters acquired by numerical modelling

Xfoil code, *Drela & Youngren (2001)*, is considered as sort of standard tool; we should prove correct capture of differences between investigated $/_i$ and reference $/_{ref}$ airfoil, merely than absolute values.

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If we define: $f = \frac{c_{Di}}{c_{Dref}}$, we are interested in $f_{exp}/f_{num} = 1$. Sufficient amount of proven wind tunnel data are available for comparison, *Athaus & Wortmann (1981)*, *Athaus (1996)*. Accuracy with common $n = 9$ is acceptable for given purpose. Location of transition process completion is computed correctly as well.
Athough augmented level of outer flow turbulence has been objective of numerous studies, data concerning effect on laminar wing sections are scarce. Findings of *Johnson (1984)* have been used for n-factor adjustment in transition criteria.
Studies of *Athaus (1981)* and *Johnson (1977), (1978)* on roughness due to insect are not fully consistent with each other, we can reach at least quantitative agreement with the latter.

4. Parameters acquired by wind-tunnel measurement

Maximum lift coefficient and behaviour in the stalled regime remains to be obtained from experimental investigation in all three regimes.
With few reasonable assumptions we can reduce test programme into one regime only. Static pressure measurement has been carried out on reference Wortmann FX66-17AII-182, Fig. 1 and two new PW series airfoils, Fig. 2 and 3, in 2D 1200x400mm CTU FME wind tunnel. Integration and application of tunnel corrections yields lift curves. It has been shown, that new designs offer at least same $c_{L_{max}}$ as FX66/S02 family.
Extent of laminar boundary layer and separation bubbles can be traced from flow visualization, as seen on results from 750x550mm CTU FME wind tunnel, Figs. 5 and 6. PW212-163 and 311-161 can be considered superior to FX66-17AII-182 in this respect.
Though flight conditions were not achieved, created methodology and models are fully transferrable into closed-circuit wind tunnel 865x485mm IT AS, with Reynolds numbers reaching at least $1,5 \cdot 10^6$.

5. Results

Target functions have been obtained for wings of club class and training sailplanes conceptual studies. Best published airfoil has been always set to $F = 100\%$ and comparison with other well-known and widely used wing section has been carried out. Presented values emphasize the

Airfoil	**F**
PW212-163	104,3%
NACA 63A-615	100%
E603	99,7%
FX73-170	95,4%
FX S 02-196	94,5%

Table 1: Target functions for wing of conceptual study L of a training sailplane

importance of appropriate airfoil selection and possibility of considerable gains to be achieved.

6. Flow control

Passive flow control of bondary layer transition has been succesfully applied as proved by visualization and pressure distribution measurement. Presented methodology has shown it’s eligibility in experimental projects which are now under way of preparation, concerning implementation of synthetic jet actuator into flapped sailplane airfoil, test case for locations of turbulators, effect of outer stream turbulence on drag and simplified methodology for integral parameters evaluation.

7. Summary

Presented article has shown details concerning the procedure of wing section design with use of experimental and numerical methods. The methodology can be easily extended to other classes of sailplanes and further to other categories in sport aviation. Beneficial role in the feasibility studies in associated projects of the department has been mentioned.

8. Acknowledgment

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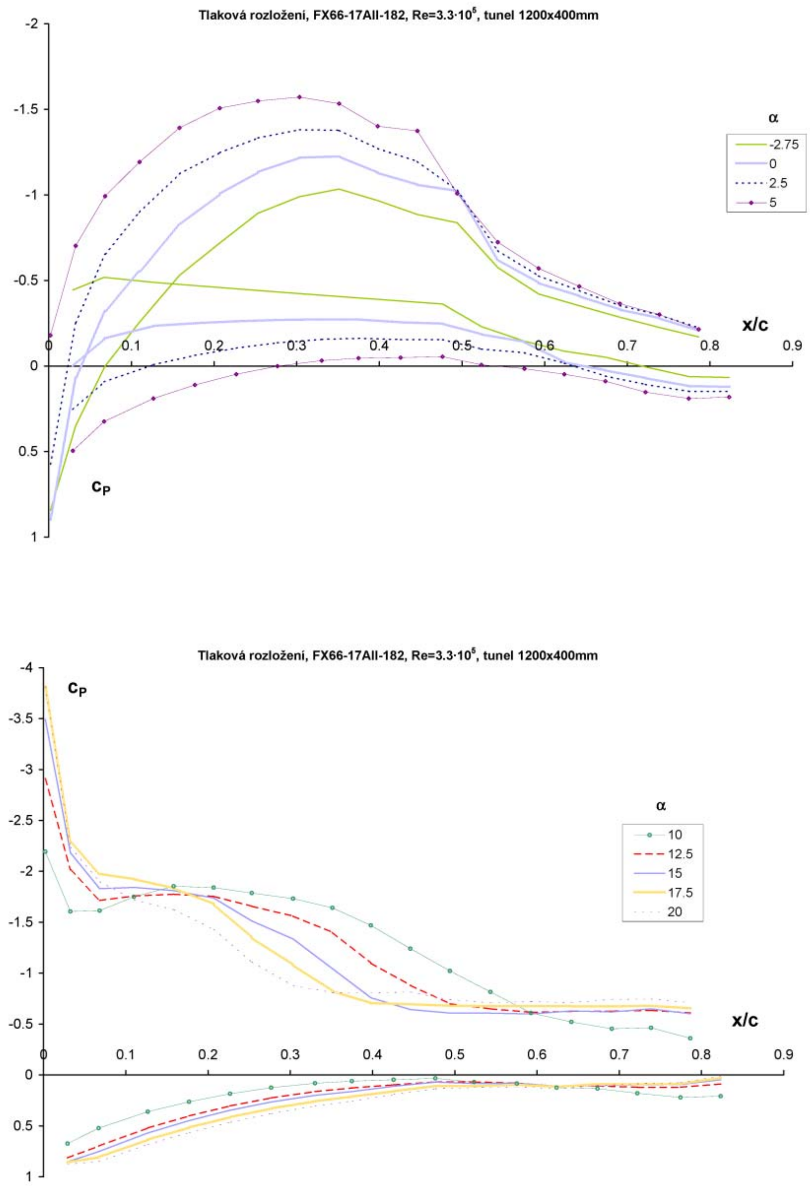

Figure 1: Measured pressure distribution, FX66-17AII-182, $Re = 3,3 \cdot 10^5$, $I_u = 1.2\,\%$

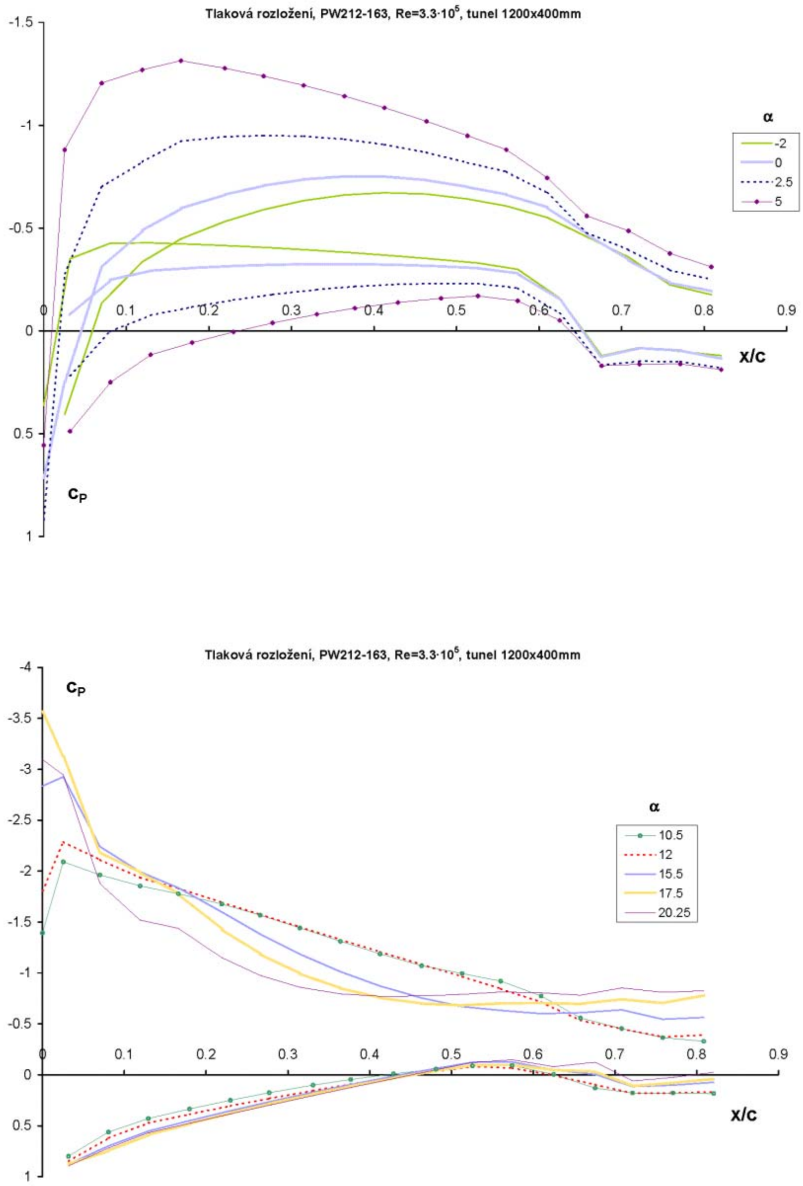

Figure 2: Measured pressure distribution, PW212-163, $Re = 3,3 \cdot 10^5$, $I_u = 1.2\,\%$

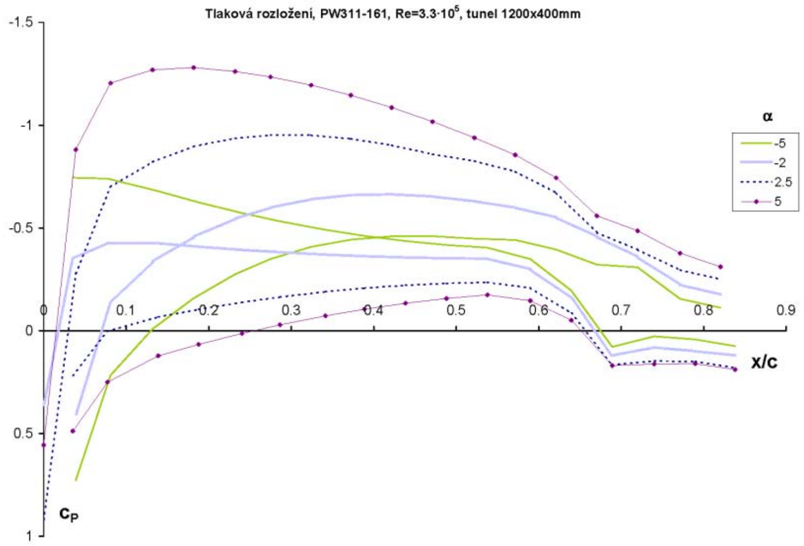

Figure 3: Measured pressure distribution, PW311-161, $Re = 3,3 \cdot 10^5$, $I_u = 1.2\,\%$

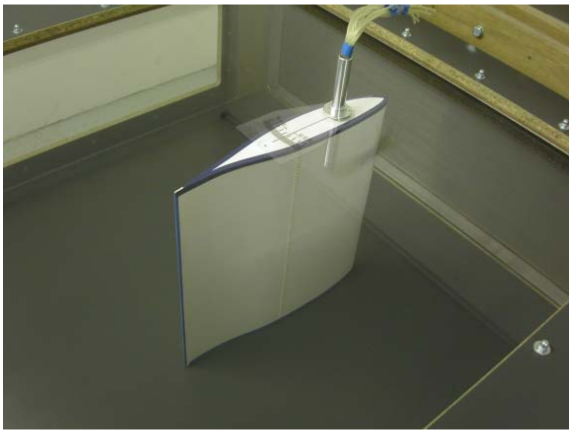

Figure 4: Test section of the wind tunnel 1200x400mm

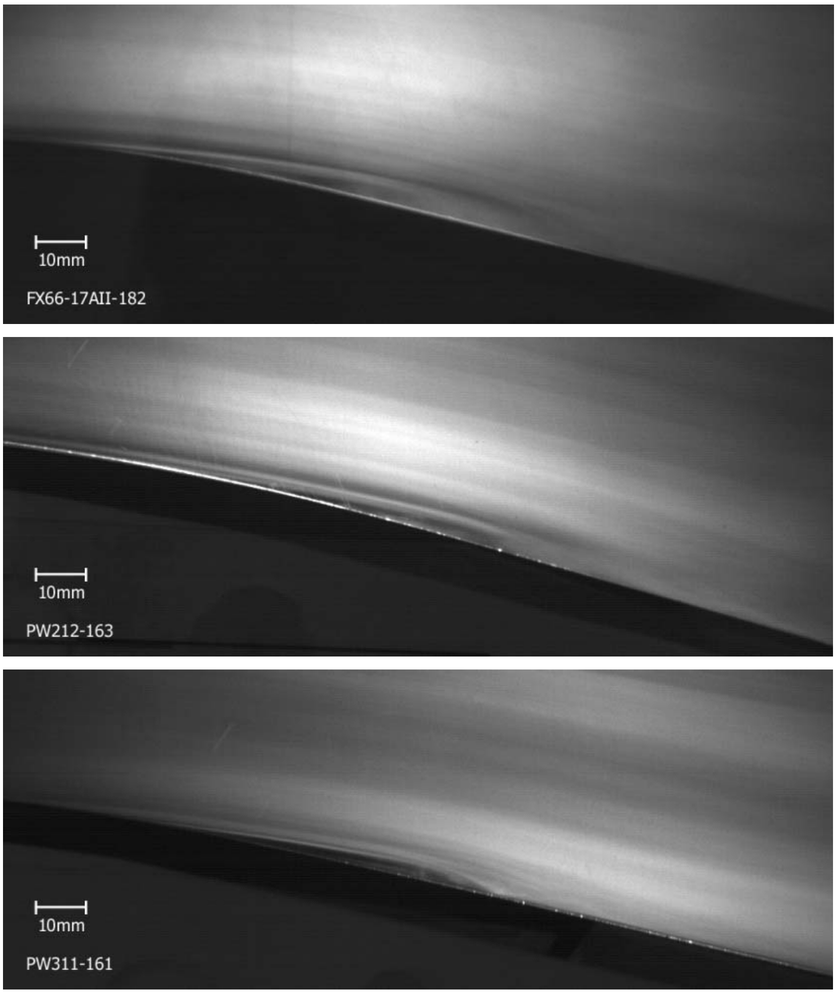

Figure 5: Airfoils FX66-17AII-182, PW212-163, PW311-161, visualization along upper surface, $\alpha = 0^o$, $Re = 1,7 \cdot 10^5$, $Tu = 1\%$

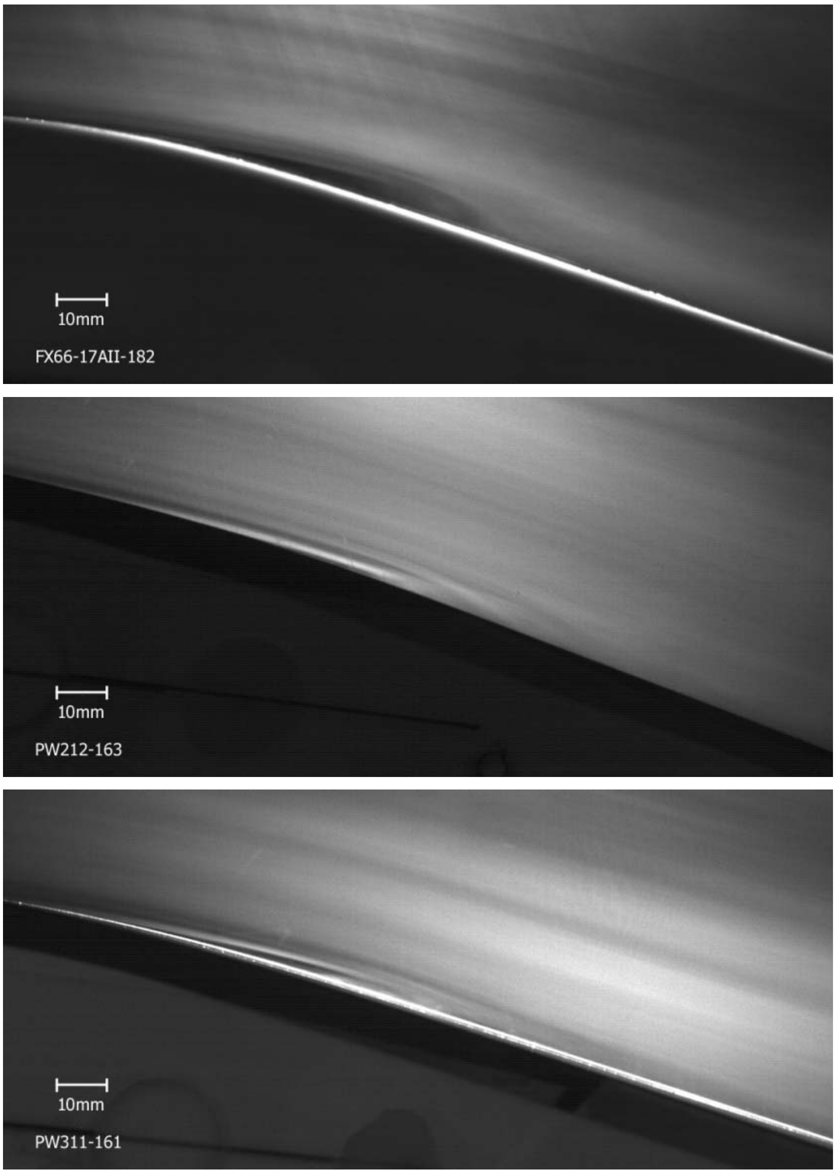

Figure 6: Airfoils FX66-17AII-182, PW212-163, PW311-161, visualization along upper surface, $\alpha = 5^o$, $Re = 1,7 \cdot 10^5$, $Tu = 1\%$