Labor Windkanal/Strömungsmesstechnik

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Recommendations for Robust Aerodynamic Wing Section Design

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1. Outline

From wing section measurements, it is known that the aerodynamic performance of manufactured wings often lacks with respect to the simulated performance of the theoretical geometry. It is still not clear if this discrepancy can be attributed to the simulation softwares, to the equipment of test section of the wind tunnel or to the geometrical imperfections caused by the production process of the test article.

Therefore, the goal is to find out which one of this parameters counts effectively for performance differences. This goes trough a deep analysis of the manufactured model's geometry and the investigation of the common causes of the geometrical imperfections during the production process.

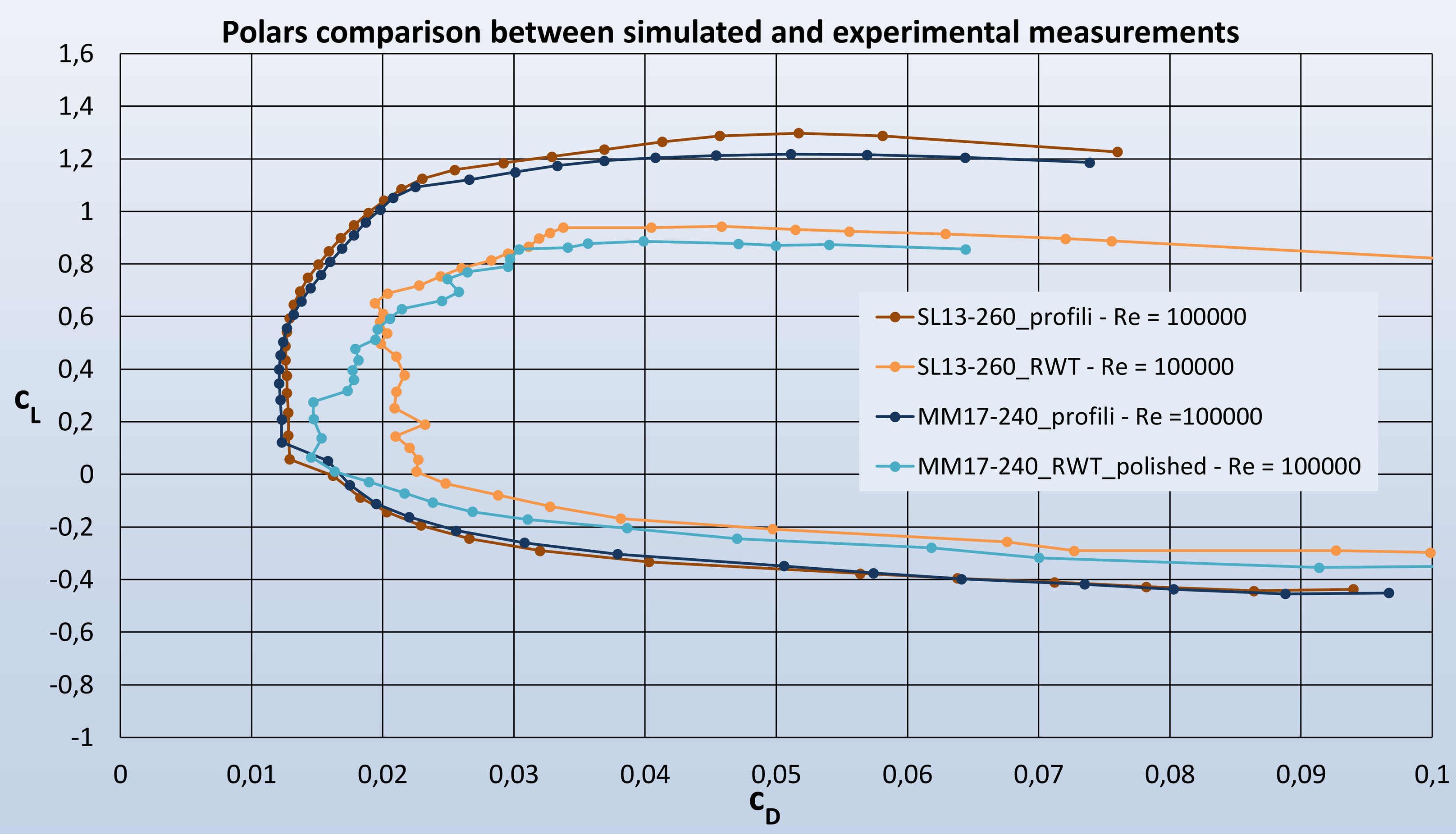

Fig. 1: Graphical comparison of the polar measurement for SL13-260 and MM17-240 wing sections between the simulation in *Profili* and the experimental measurement of the RWT

2. Effects of geometrical deviation on airfoils

A Matlab code has been implemented in order to deliberately add different kind of geometrical deviations (constant, linear, sinusoidal) on the airfoils, by modifying the coordinate points.

With the simulations in *Profili* and *Xfoil* it is possible to understand the effect of the geometrical imperfections on the airfoil's drag and lift coefficients and on performance parameters such as best glide ratio and best sink rate.

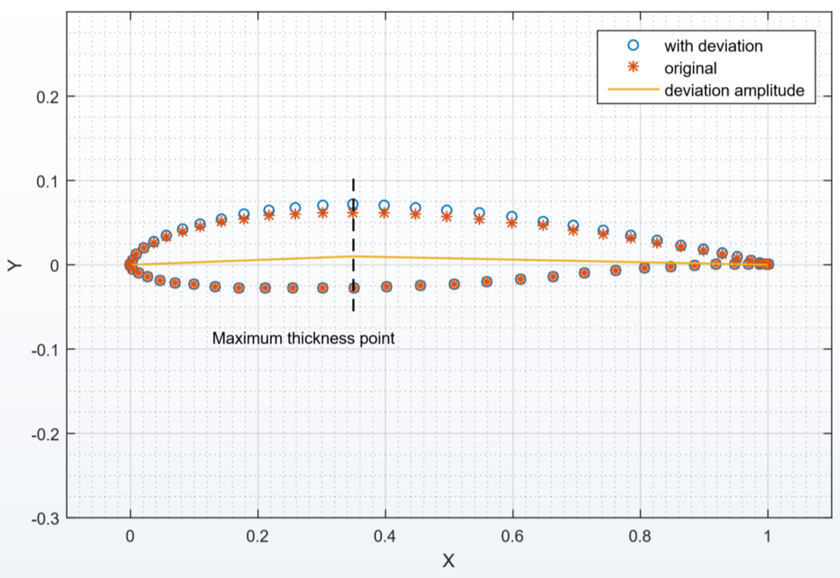

Fig. 2: Example of linear deviation application

By changing the design parameters of the airfoil (thickness, camber, leading edge radius, …) it has been investigated which is their relation with the effect of a constant deviation. Both symmetrical and cambered wing section have been simulated, to give possible guideline solutions on how to modify the airfoil design in order to limit the effect of geometrical deviation.

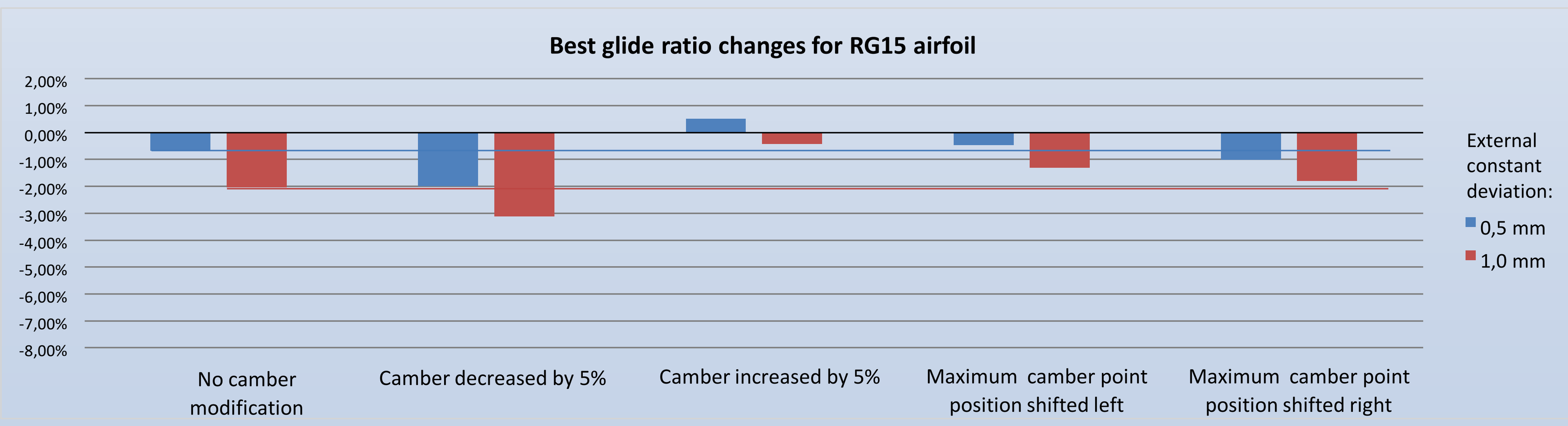

Fig. 3: Effect of the constant deviation on best glide ratio after camber design modification for RG15 airfoil. The left and right shifting refers to the orientation of the airfoil shown in fig. 2. A constant deviation can happen if the upper and lower mould are put together with a gap of 0,5 mm or 1,0 mm, that means a deviation of Δ/l = 0,25% and 0,5% respectively, for a chord length l = 200 mm.

3. Design of a new wing section

An advanced airfoil has been designed, starting with the contour of the SL13-260. Performance targets are as follows:

- Less cambered profile (less than original 2,60%)
- Better glide ratio for low-lift values (Cl = 0,2 to 0,4)
- Similar best sink rate and best glide ratio achievable
- Not influenced by a constant deviation

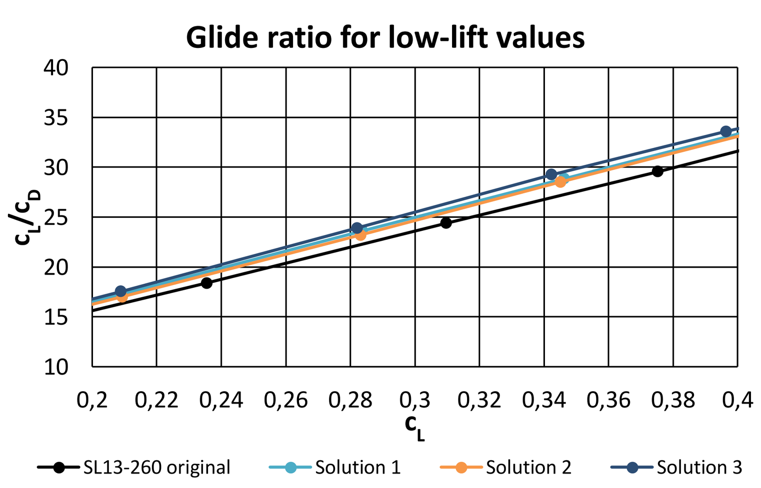

Fig. 4: Comparison of the glide ratio at low-lift values for different design solutions

Once chosen the best design solution (MM17-240), two different prototypes for experimental validation were designed, in such a way it is possible to reproduce the effect of a constant deviation on the airfoil's geometry. The steel model is divided in two halves, making possible to insert a sheet metal plane in between and to test the airfoil with different thickness configuration. The trailing edge part is produced with 3D-printing.

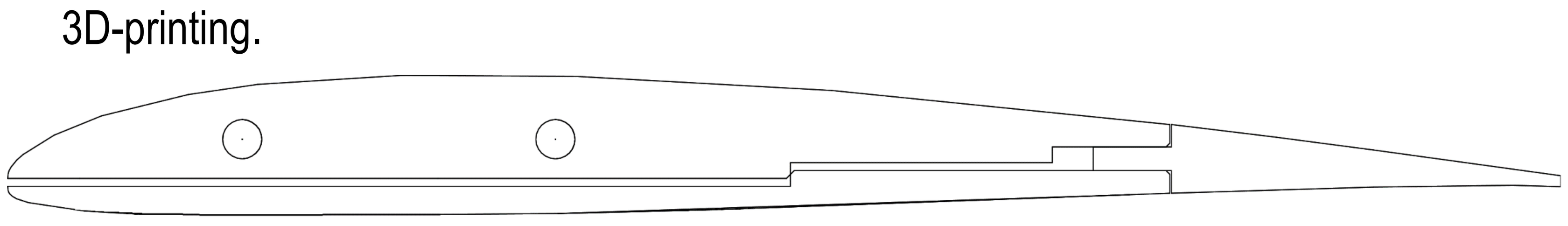

Fig. 5: Steel metal prototype of the MM17-240 airfoil, with 3D-printed trailing edge. Constant deviation can be introduced by a spacer plate and an adapted trailing edge.

The fully 3D printed models is produced in 3 different thickness configuration and each one of them is divided in 3 parts of the same length that are coupled with metal spines.

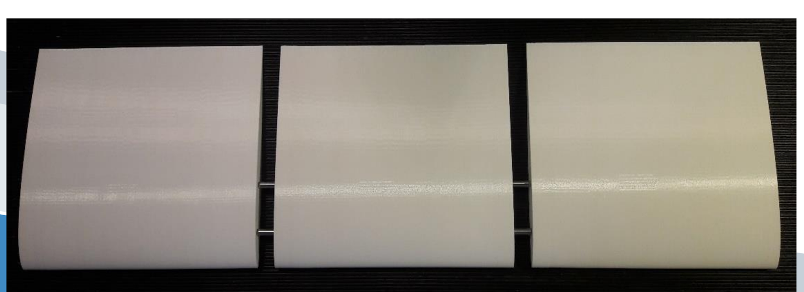

Fig. 6: Fully 3D-printed prototype coupling

4. Experimental validation

The 3D-printed models have been tested in the closed wall test set-up *Polamax* of the RWT, in order to validate the results of the simulations. The results evidence an increase of over 20% of the glide ratio at low-lift values. Moreover, it turned out that the experiments rather exhibit a performance improvement instead of a more or less unaffected performance as targeted and promised by simulation. Overall performance is judged by best glide ratio and best sink rate.

Fig. 7: Polamax closed wall test section of the RWT

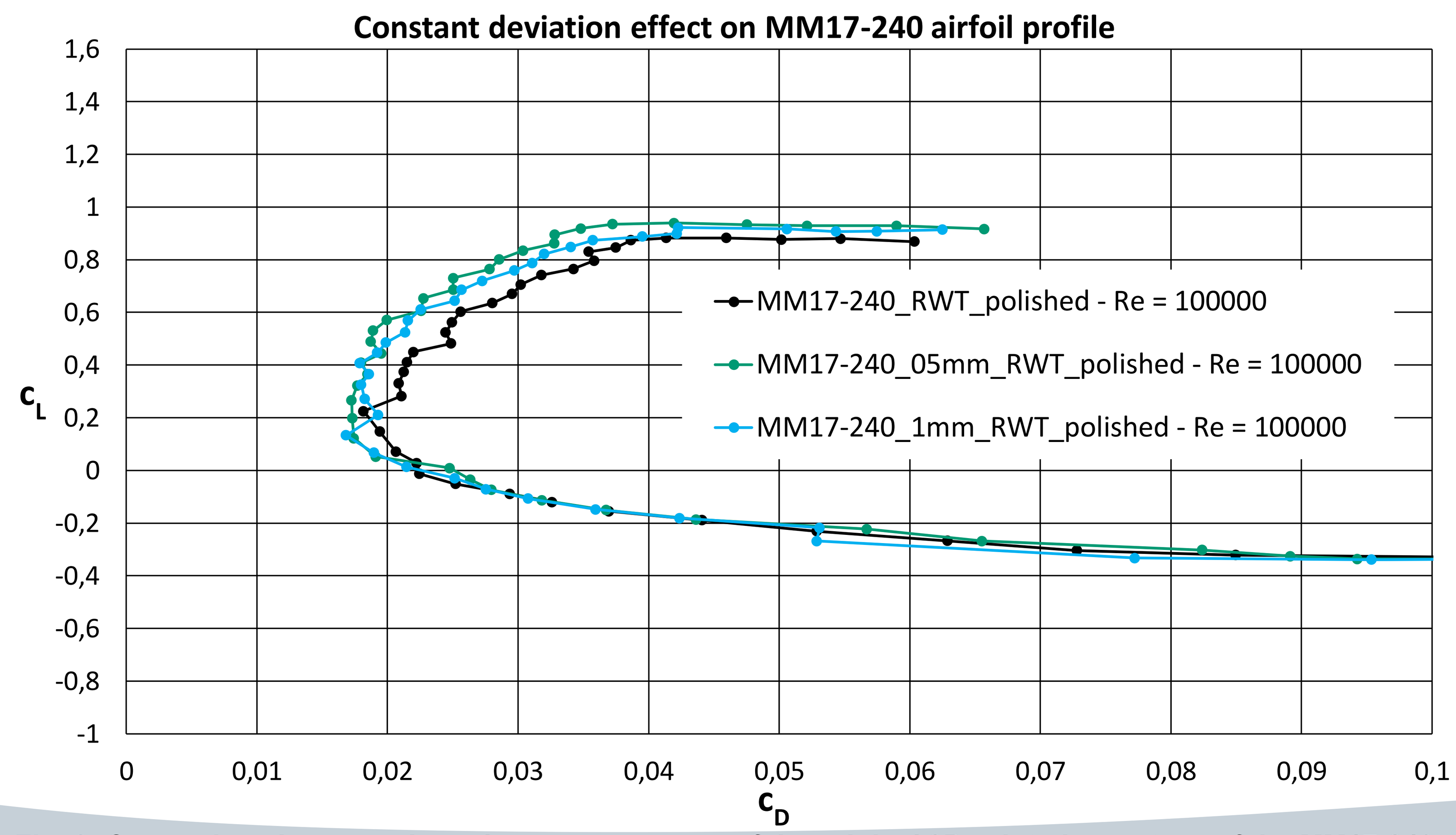

Fig. 8: Comparison between the polar measurements of the original 3D-printed prototype of the MM17-240 airfoil and the models with added constant deviation of Δ/l = 0,25% and 0,5%, respectively Δ = 0,5 mm and 1,0 mm w.r.t. a chord length l = 200 mm.

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