Labor Windkanal/Strömungsmesstechnik

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Advancement of the Closed Wall Wind Tunnel Test Set-Up followed by Investigation of Boundary Layer Trips

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https://hps.hs-regensburg.de/las39261/

1. Goals

The closed test section of the Regensburg Wind Tunnel (RWT) offers the possibility to determine polars and the effect of airfoil modifications on lift and drag.

The test rig was already at a highly automated state before this thesis started, but several modifications were implemented in order to start higher scale measurement series.
These wind tunnel experiments included basic preliminary tests as well as investigation of boundary layer trips to reduce the laminar separation bubble provoked drag.
The first objective is to reduce the overall airfoil's drag of the main wing at selected operating points. The goal for the V-tail's airfoil is the reduction of the deadband effect around zero lift to gain better handling characteristics in controlled flight.

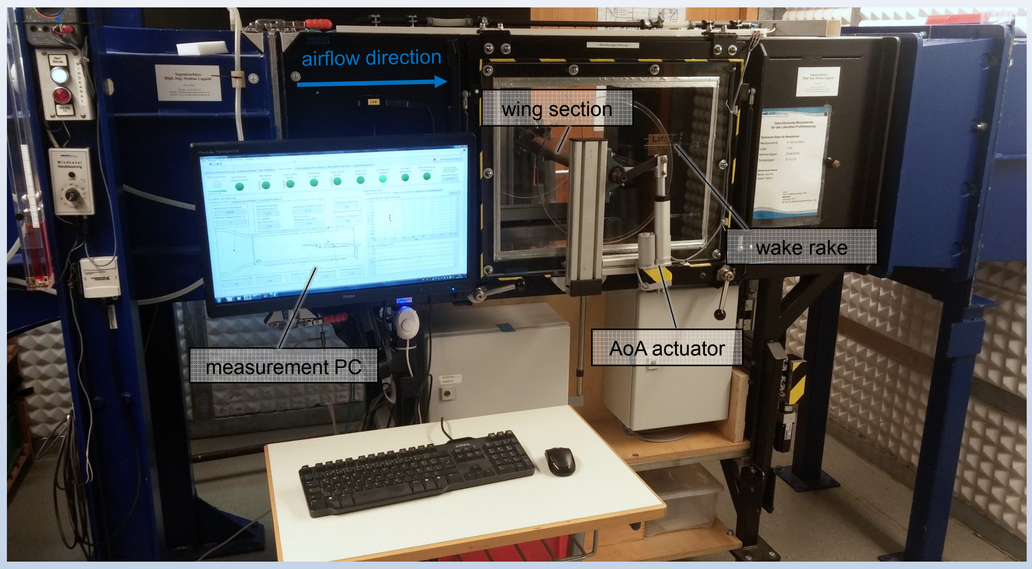

Fig. 1: The closed test section in the Regensburg Wind Tunnel (RWT) at OTH Regensburg. The lift is measured contact free by mean pressure difference between the upper and lower wall. The drag is measured by a wake rake. Tests were carried out from Re = 60,000 to Re = 350,000.

2. Stability Analysis

XFLR5 is an aircraft simulation software based on the vortex lattice method (VLM). It helpes to calculate operating points of the airplane for a given stability margin and in dependence of several main wing's and tailplane's flaps angles.

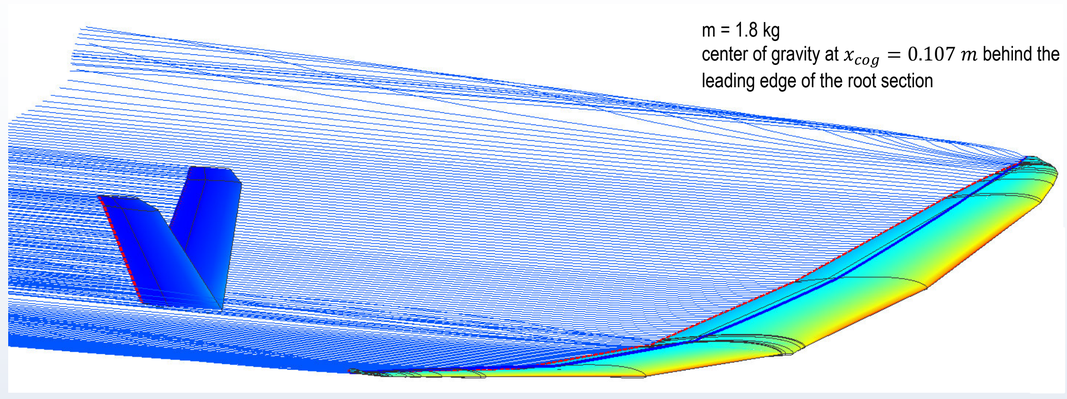

Fig. 2: XFLR5 model of the airplane showing the pressure distribution and streamlines. The narrow fuselage is not discretized.

Fitting curves based on the simulation results were created in order to find the wind speed and angles of attack for the airfoils at different operating points.

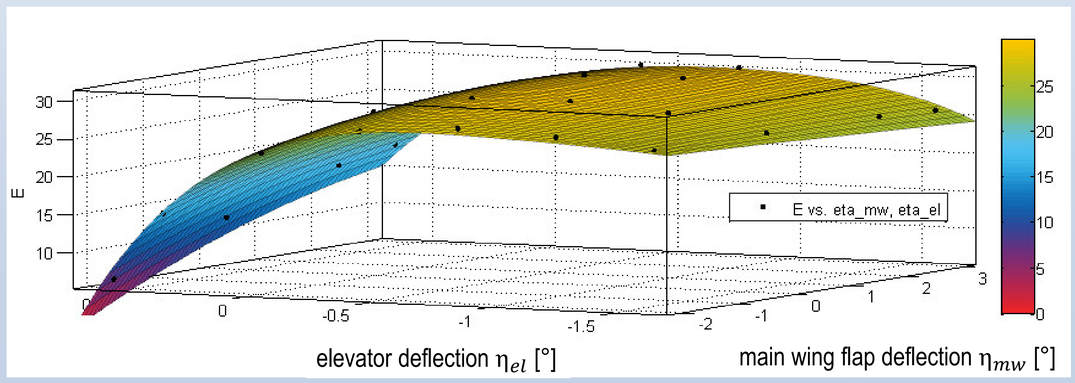

Fig. 3: Fitting curve for the glide ratio E vs. the flap angles of the main wing and elevator.

3. Wind Tunnel Experiments

2D and 3D boundary layer transition trips were investigated, but especially for 2D trips a parameter study was done. The effect of the trip on the laminar separation bubble is very sensitive to the trip's thickness and its location. A trip configuration could be found, which helps to reduce the bubble effected drag. The airfoil's overall drag reduction with this trip is about 8% at the operating point of best glide ($c_l \approx 0.5$).

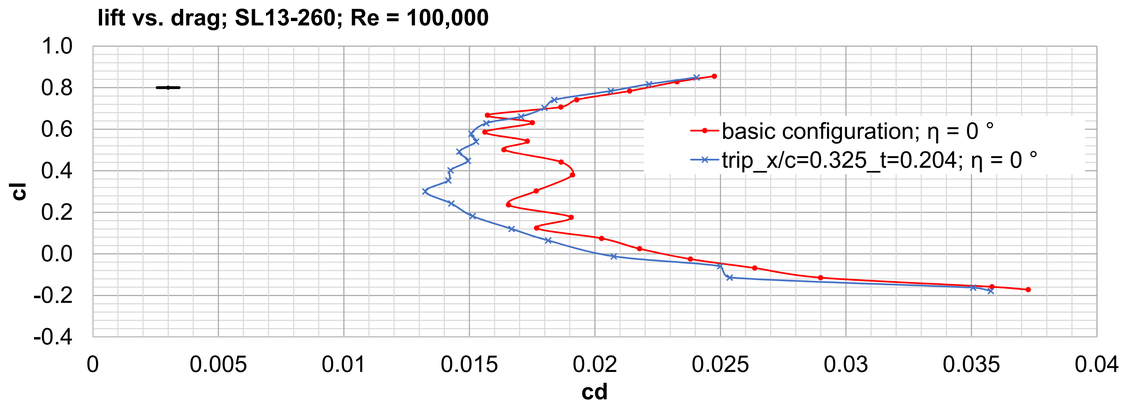

Fig. 6: Polar with and without trip at Re = 100,000. Flap deflection of the main wing $\eta_{mw} = 0$ °. Measurement started at $\alpha_{min} = -5$ ° to $\alpha_{min} = 6$ °.

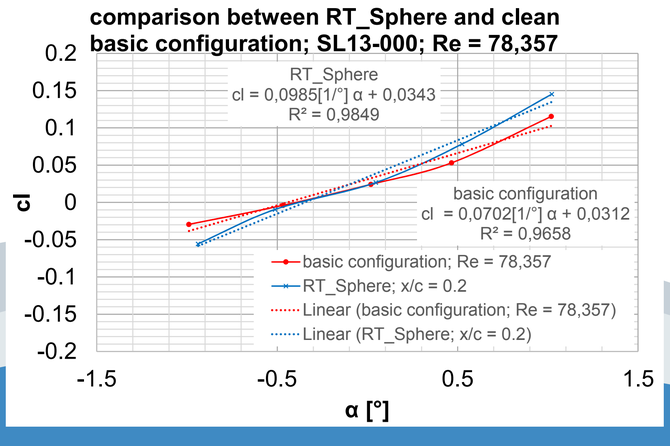

Fig. 6: Lift curve with and without trip for low angles of attack , Note the larger slope for the tripped airfoil around zero lift.

For the V-tail's symmetric airfoil, 3D trips like the RT_Sphere show up with good results as they can eliminate the laminar separation bubble. The lift over angle of attack slope could be increased by 43.3 % for the RT_Sphere, a trip with spanwise distributed hemispherical bumps on it. Further investigations, especially parameter studies, are recommended.

4. Oil Paint Visualization

A mixture of soot and petroleum can be used to visualize the flow pattern on the airfoil's surface. The visualization reveals a reduction of the laminar separation bubble's size for an drag-optimized 2D trip. 3D trips may avoid the occurrence of the bubble completely. During the experiments, the wing model was vertically aligned in the ¾-open wind tunnel test section.

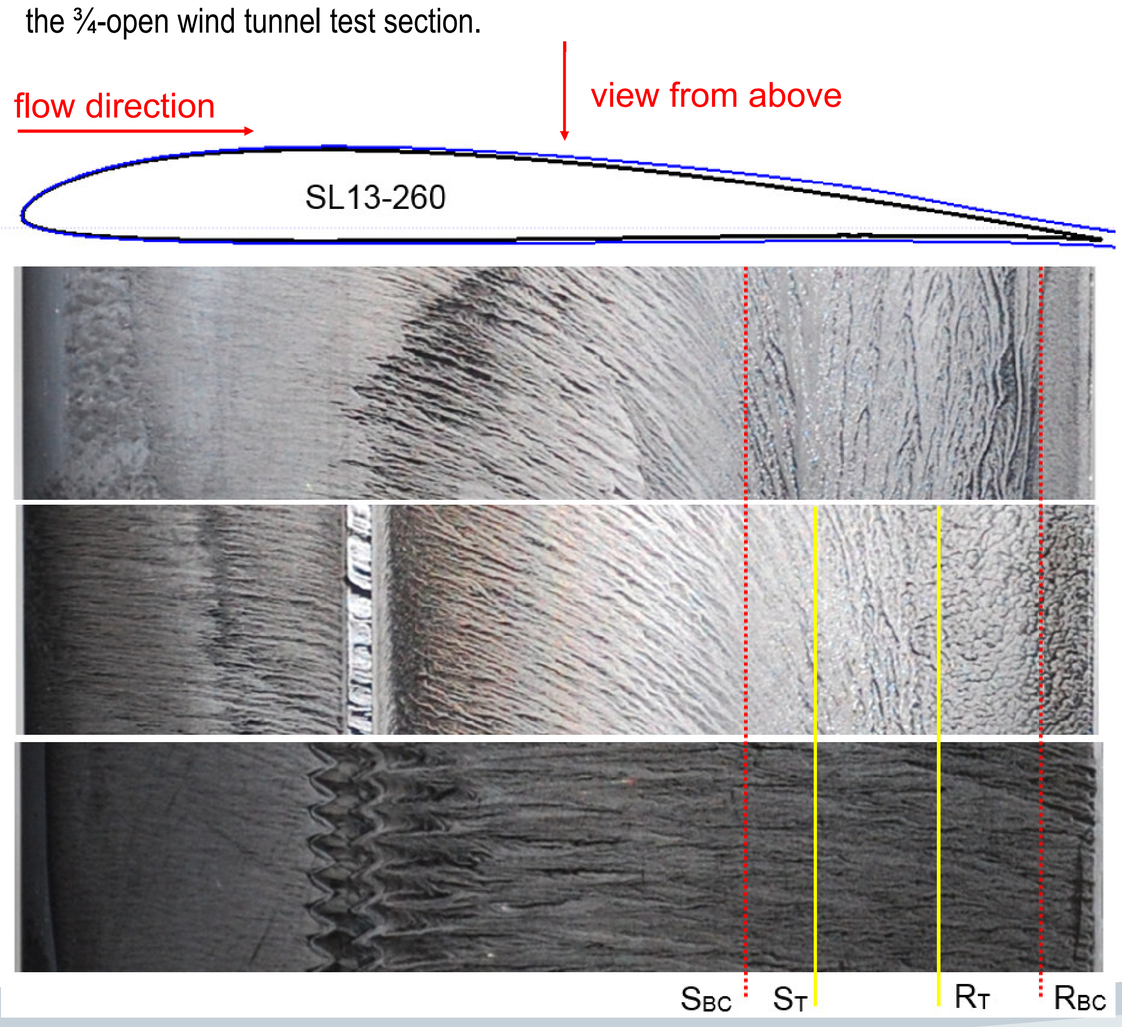

Fig. 8: Flow pattern on the airfoil's upper surface without (BC) boundary layer trip (top), with a 2D (T) and 3D trip applied (bottom). S = Separation, R = Reattachment