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Further development of measuring techniques in the RWT and verification by means of airfoil measurements

(potential assessment of forced transition using turbulators to avoid the increase of the aerodynamic drag due to laminar separation bubbles)

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1. Modification of the measurement technique

The first step, was the improvement of the experiment setup to ensure accurate, significant test results.

After upon investigation two chosen pressure sensors shaped up to be inappropriate, because the maximum occuring pressure and the measuring range didn't accord sufficiently. As a consequence two more suitable sensors came into operation. The inital startup demanded several operations concerning calibration of the sensors and engineering and design of the sensor boxes. In this vein a reliable measurement technique could have been established.
Now the quality of the test results bear any comparison with considerable windtunnels more than ever.

pressure sensor	maximum occuring pressure	measuring range
Setra 1	- 36 Pa to 65 Pa	0 Pa to 250 Pa
Setra 2	15 Pa to 340 Pa	0 Pa to 38000 Pa
Setra 3	38 Pa to 360 Pa	0 Pa to 38000 Pa
Setra 4	-13 Pa to 18 Pa	0 Pa to 38000 Pa

Fig. 1: Mismatch of measurement range and occuring pressure (primitive state)

pressure sensor	maximum occuring pressure	measuring range
Setra 1	- 36 Pa to 65 Pa	0 Pa to 250 Pa
Setra 2	15 Pa to 340 Pa	0 Pa to 1200 Pa
Setra 3	38 Pa to 360 Pa	0 Pa to 38000 Pa
Setra 4	-13 Pa to 18 Pa	0 Pa to 300 Pa

Fig. 2: matching of measurement range and occuring pressure (after sensor exchange)

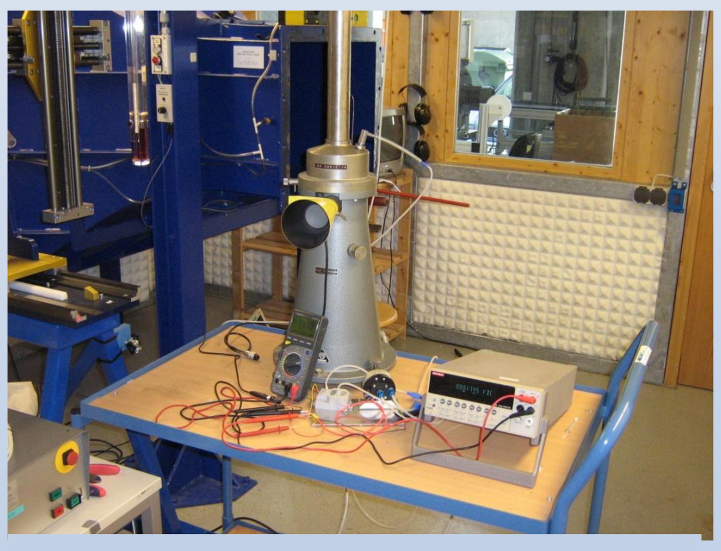

Fig. 4: calibration setup: pressure sensor, circuit analyser, barometer, and windtunnel

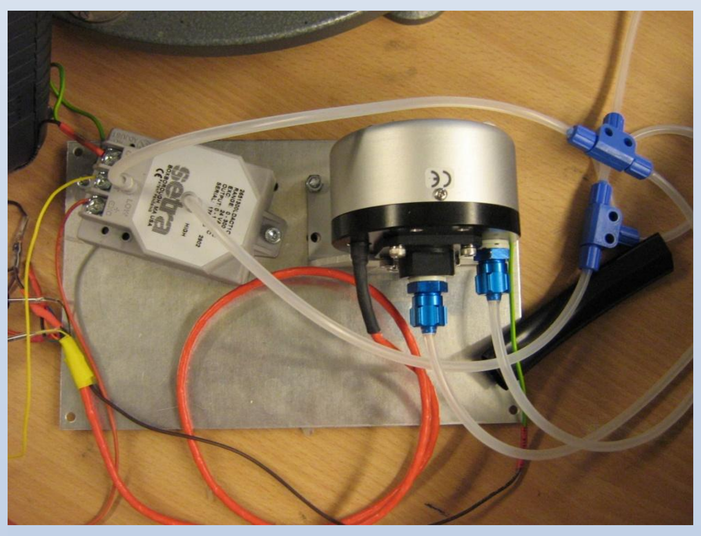

Fig. 3: semifinished sensor box with two sensors within

2. Laminar separation bubble

The performance of airfoils is strongly influenced by laminar separation bubbles, which may occur at low Reynolds numbers. Such a separation bubble is caused by a strong adverse pressure gradient (pressure rise along the surface), which makes the laminar boundary layer to separate from the curved airfoil surface. The pressure rise is related to the velocity drop towards the trailing edge of the airfoil, which can be seen in the velocity distribution of the airfoil through Bernoulli's equation. The boundary layer leaves the surface approximately in tangential direction, resulting in a wedge shaped separation area. The separated, laminar flow is highly sensitive to disturbances, which finally cause it to transition to the turbulent state. The separation bubble thickens the boundary layer and thus increases the drag of the airfoil. The drag increment can be several times the drag of the airfoil without a separation bubble [MH10].

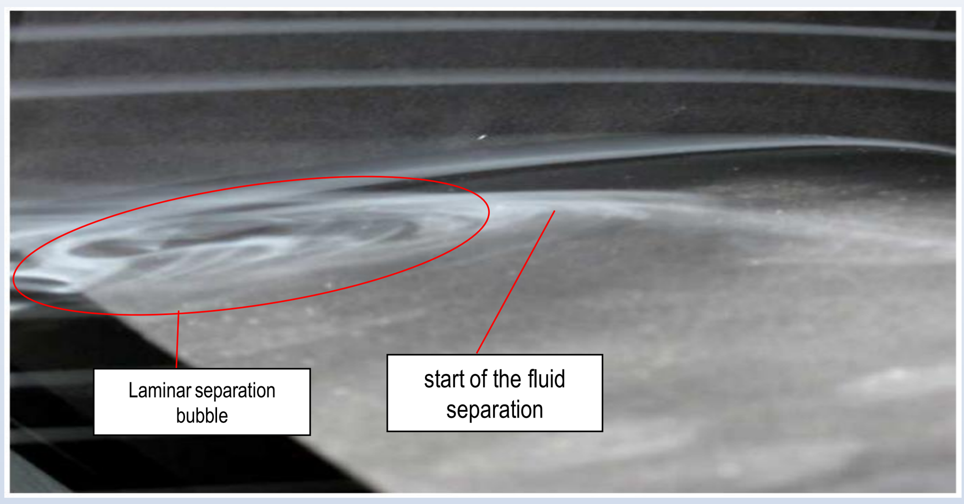

Fig. 5: laminar separation bubble [CS07]

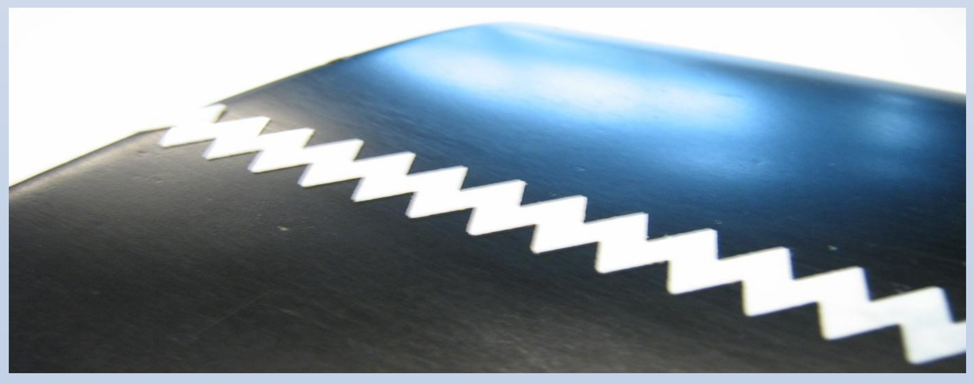

Fig. 6: Turbulator on airfoil RG15

The additional drag, which arises from laminar separation bubbles, can be eliminated, by avoiding them or by reducing their size, using forced transition by artificial disturbances, e.g. a turbulator. This device will usually be attached just before the region of laminar separation and has to introduce enough disturbances to cause transition into the turbulent state, before the laminar separation can occur. In so doing the aerodynamic drag can be reduced. This high potential to optimise rather common airfoils, has been analysed in RWT.

3. Test result and conclusion for airfoil RG15

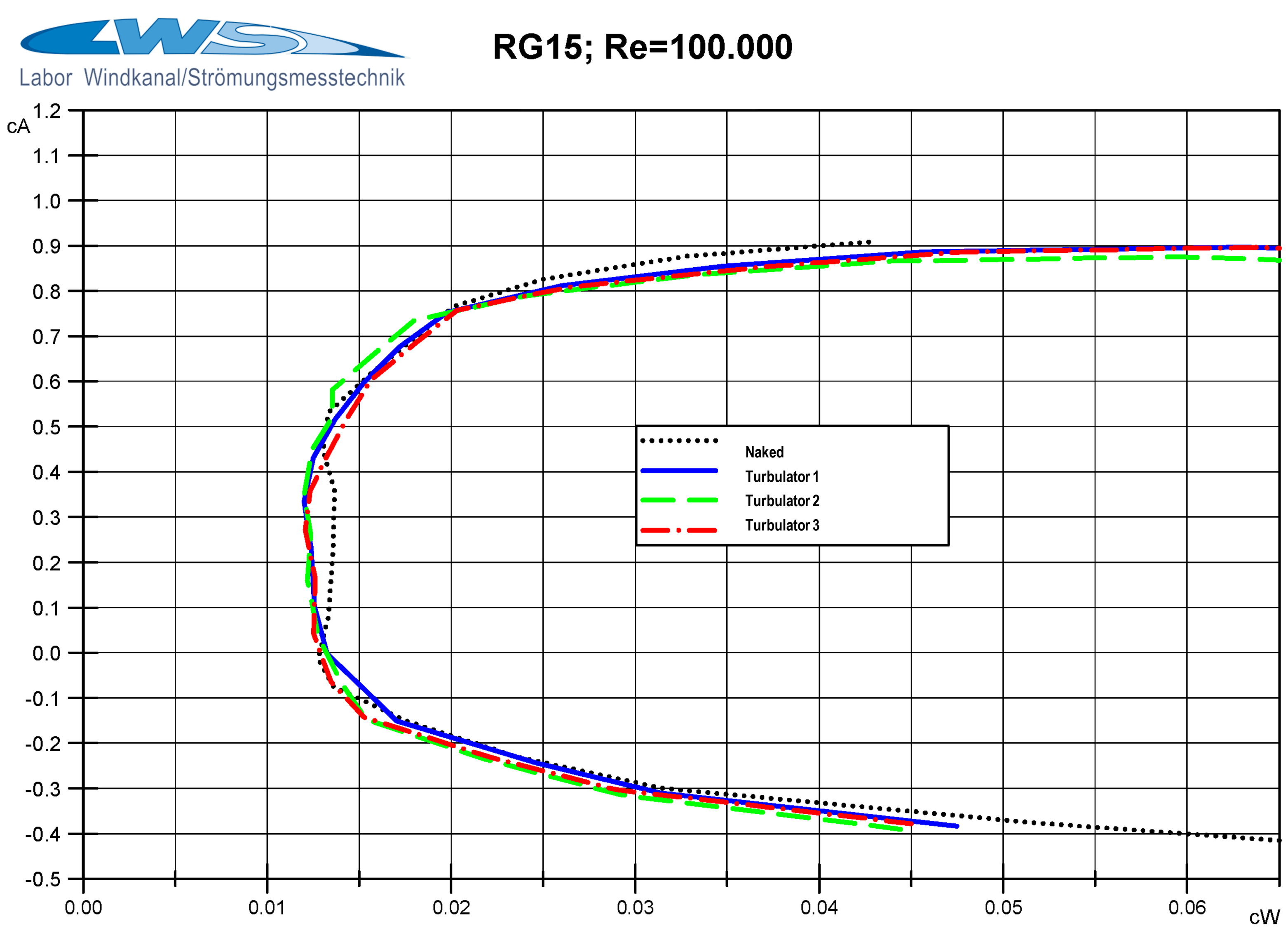

Fig. 7: drag/lift relationship within a reynolds number of 100.000

The airfoil RG15 has been analysed within reynolds numbers of 100.000 and 200.000 and by dint of 3 different turbulator types. The perfomance boost regarding the drag-lift relationsship is impressive. The aerodynamic drag can be reduced up to 17% of the face value without turbulator. The results achieved during the measurements prove the huge potential of forced transition.

4. Test result and conclusion for airfoil SL09

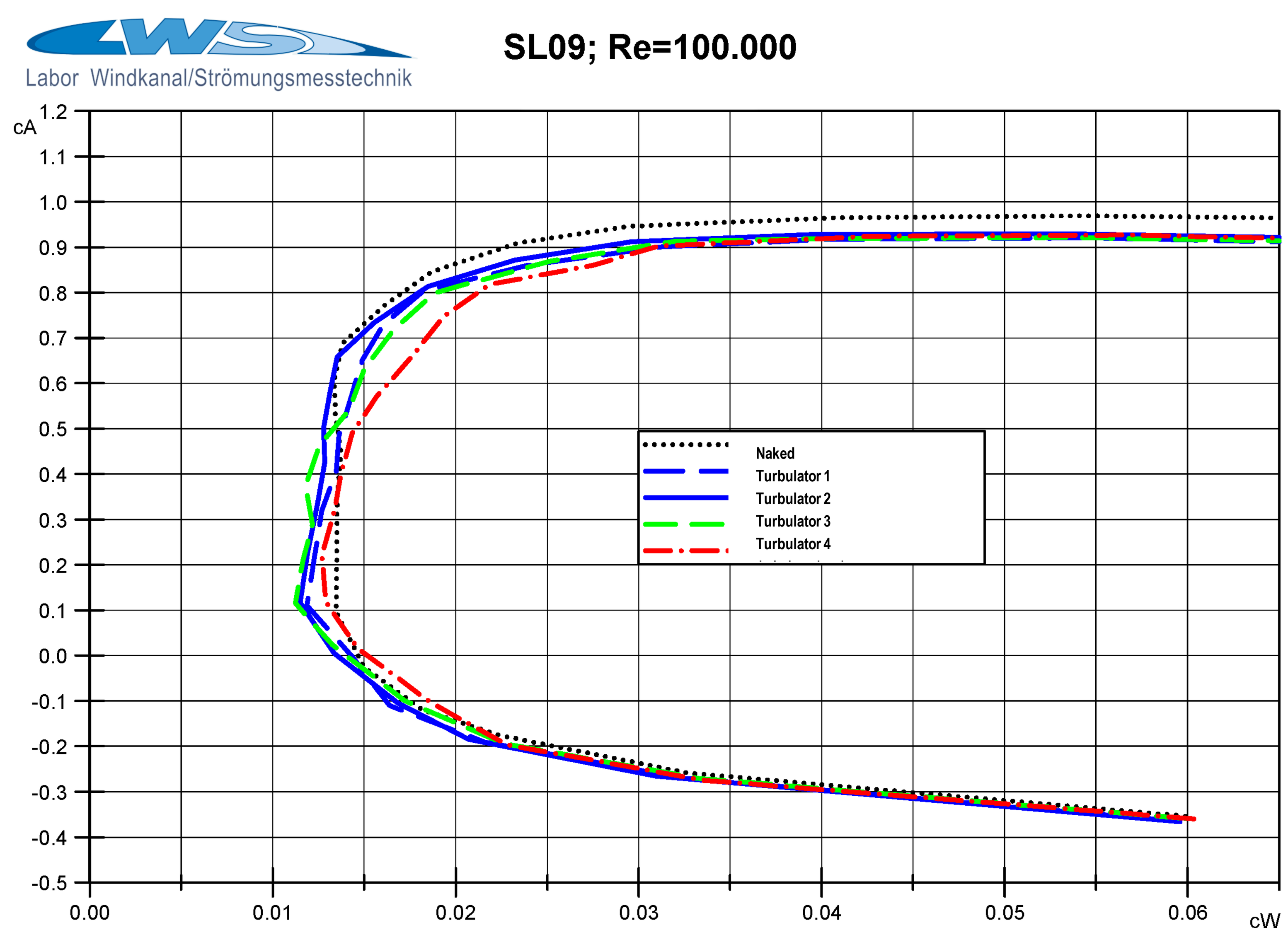

Fig. 8: drag/lift relationship within a reynolds number of 100.000

The airfoil SL09 has also been analysed within reynolds numbers of 100.000 and 200.000, however by dint of 4 different turbulator types. The perfomance boost regarding the drag-lift relationsship was just as well. The aerodynamic drag can be reduced actually up to 18% of the face value without turbulator. The results can be the basis for extensive research in th future.

References: [CS07] Schosser C.; Messtechnische Bestimmung von Profilpolaren, [MH10] http://www.mh-aerotools.de/airfoils (Date: 07.07.2010)