Universität Stuttgart

INSTITUT FÜR AERODYNAMIK
UND GASDYNAMIK

IAG

DIREKTOR: PROF. DR.-ING. EWALD KRÄMER

Pfaffenwaldring 21, 70550 Stuttgart, Tel. (0711) 685-63401, Fax 63402, email:kraemer@iag.uni-stuttgart.de

Wind Tunnel Models of Airfoils with Trailing-Edge Flap

UPWIND WP1B3

TECHNICAL NOTE

Deliverable D3.9

Thorsten Lutz
Alexander Wolf, Werner Würz

December 9, 2010

Institute of Aerodynamics and Gas Dynamics
University of Stuttgart
Pfaffenwaldring 21
D-70550 Stuttgart, Germany

1 Motivation

One of the objectives of the European research project UPWIND is the investigations of passive and active load alleviation techniques for large wind turbines. These activities on future “smart rotors” are conducted in work package WP1B3. The task of the Institute of Aerodynamics and Gas Dynamics (IAG), University of Stuttgart in WP1B3 was to design and to verify a new dedicated airfoil with trailing-edge for load control [2], [3]. Elaborate aerodynamic and acoustic wind-tunnel tests were performed in the Laminar Wind Tunnel (LWT) of the institute [1]. Besides measurements on the new airfoil comparative experiments were conducted for a NACA 64-418 reference section [4], [5]. The present note documents the manufacturing of the wind tunnel models used in these experiments.

2 Manufacturing of the Wind-Tunnel Models

2.1 NACA 64-418 with 30% Trailing-Edge Flap

Fig. 1 Negative mold for the NACA wind tunnel model

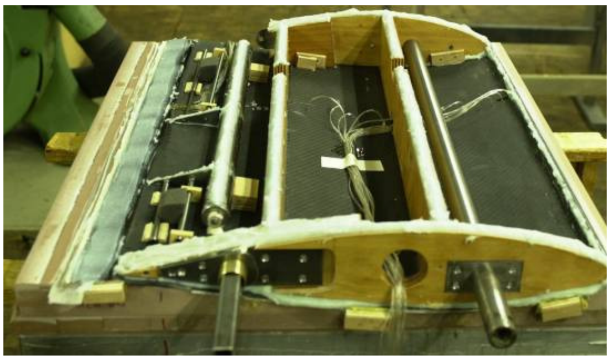

Fig. 2 Complete internal structure of the NACA 64-418 model before glueing

The wind tunnel models of the NACA 64-418 reference section and the new airfoil TL 190-82 were manufactured at the IAG workshop in CNC-milled negative molds to ensure maximum contour accuracy. A chord length of 0.6m was chosen; the span of the model is 0.73m. The material for the molds is SIKA SLABS M600, polyurethane foam with a very high density. A special milling technique with an inclined face cutter provides a surface roughness smaller than +0.02mm. This roughness is smoothed by carefully sanding until all milling tracks disappear (Fig. 1 shows the negative molds). Then epoxy resin is used to remove the porosity of the surface. The shells of the models were built as a symmetrical carbon-fiber/glass-fiber/carbon-fiber sandwich with 6 mm wall thickness. After finishing the remaining roughness heights of the wind tunnel models are in the order of 1.5 µm RMS measured with a high precision surface measuring instrument. For acoustic measurements the trailing edge thickness is an important parameter. It must be kept very thin to avoid blunt trailing edge noise which would otherwise spoil the measurements. The design coordinates of the airfoils were modified by rotation of the upper surface around the leading edge to provide thin trailing edges of 0.3 mm thickness. During the whole manufacturing process great care is taken to achieve a trailing edge thickness as close as possible to the nominal value.

The NACA wind tunnel model was equipped with a row of pressure tabs along the upper and the lower side. Each row is aligned at an 15° angle relative to the freestream. The holes have a diameter of 0.3mm and were drilled making use of a NC-milled template to ensure the correct position and angle of the holes. Fig. 2 shows the complex internal structure of the NACA wind tunnel model.

A flap of 30% was chosen for the NACA model to enable a broad variation of the pressure recovery which was required for complementary fundamental boundary-layer and acoustic measurements performed in UPWIND WP2.5 to improve and validate the noise prediction models developed at the IAG. The flap was cutted from the main part of the wind tunnel model. The nose of the flap was built from SIKA SLABS M600 as a positive part. This peace is exactly circular around the flap hinge and fits tangential to the surface contour on the upper and lower side of the model. The gap between flap and main part has a width of 1mm and allows flap deflections of $\beta = \pm 20°$. An internal sealing made of V-seal tapes provides air tightness of the flap. Figs. 3 and 4 give an overview of the flap mounting.

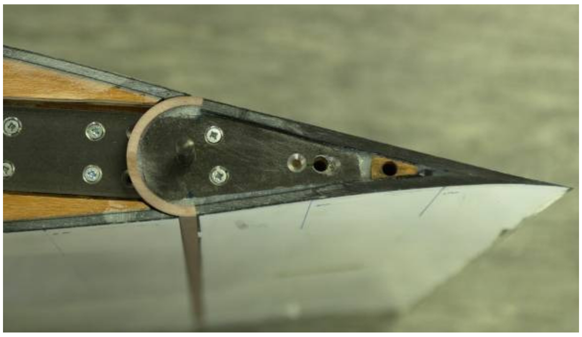

Fig. 3 Top view of the flap conjunction

Fig. 4 Detail of the gap

2.2 New Airfoil TL 190-82 with 10% Trailing-Edge Flap

The wind tunnel model of the new airfoil has a chord length of 0.6m and was built in the same way as described in Sec. 2.1 but without pressure taps. In contrast to the reference section the wind tunnel model of the new airfoil shows a smaller chord of only 10% chord that is considered sufficient for load alleviation purposes. The pivot point is located midway between upper and lower side contour. The gap between flap and main part has a width of 1mm and allows flap deflections of β=+/-20°. An internal sealing made of V-seal tapes provides air tightness of the flap. Fig. 5 shows the negative mold, Fig. 6 gives a closer look of the flap hinge region while Fig. 7 shows side views of the wind tunnel model.

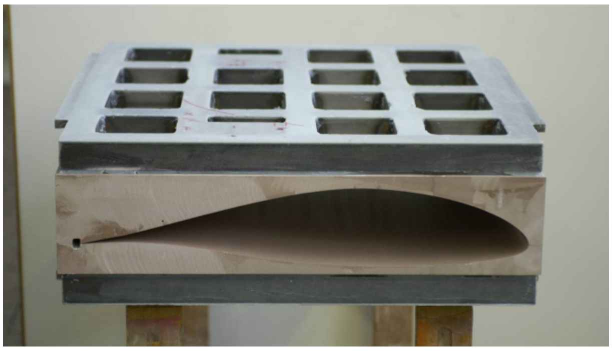

Fig. 5 Negative mold of the TL 190-82 wind tunnel

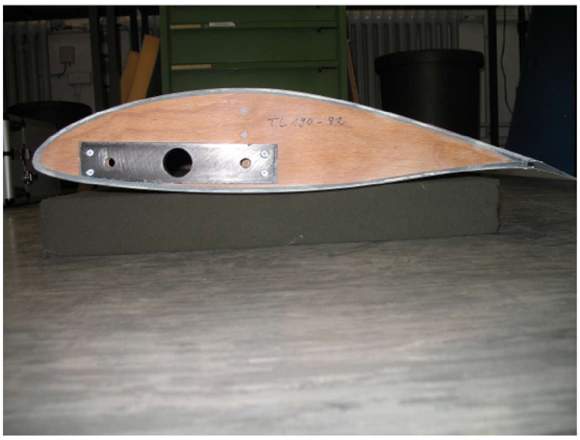

Fig. 6 Flap hinge region of the TL 190-82 wind tunnel model

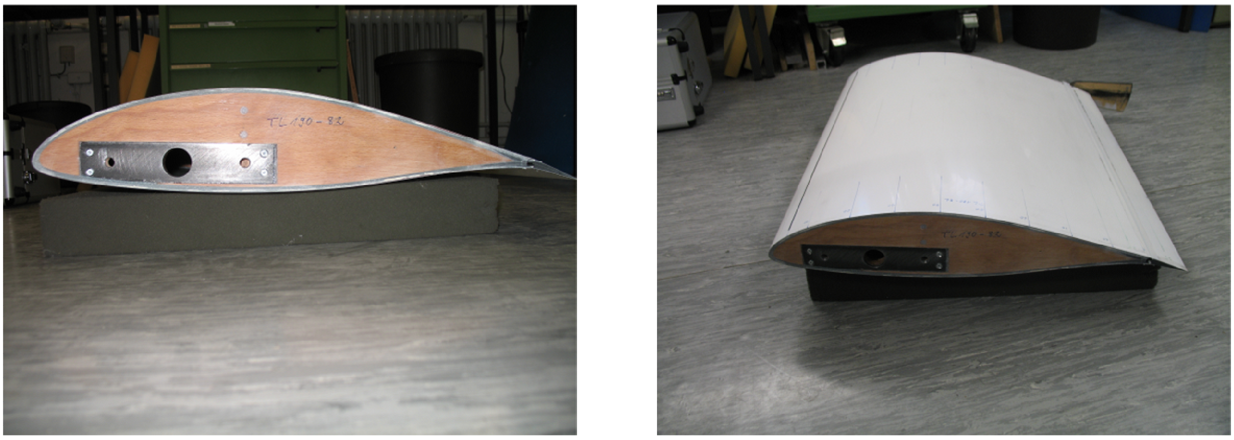

Fig. 7 Side view of the TL 190-82 wind tunnel model

2.3 Wind Tunnel Models Mounted in the LWT

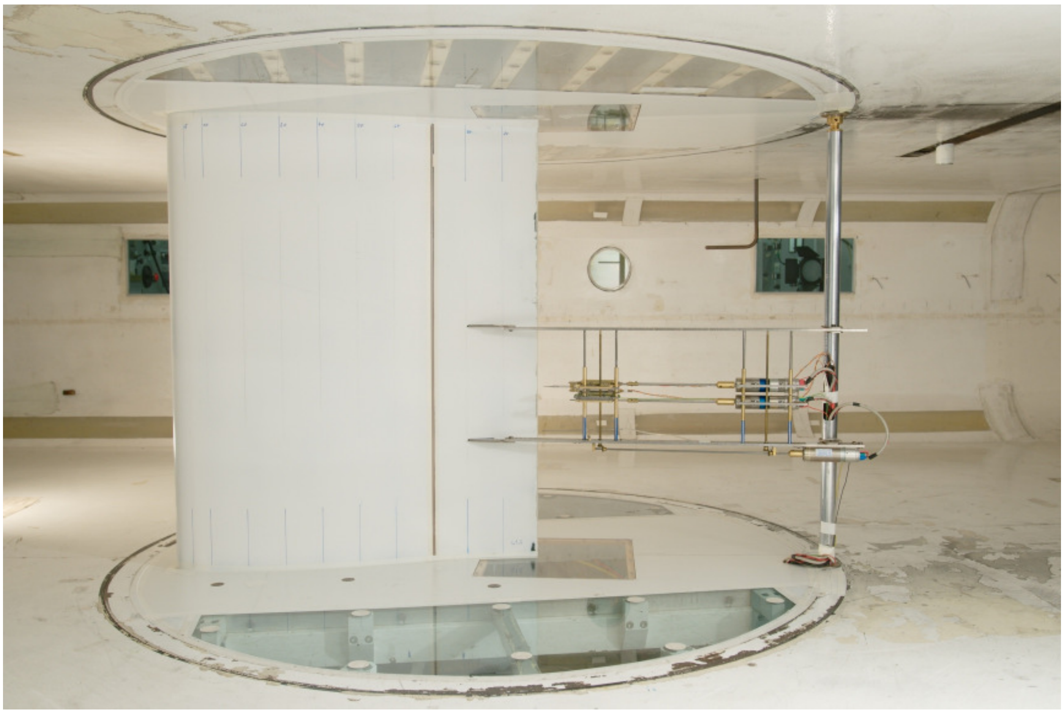

Fig. 8 NACA 64-418 wind tunnel model mounted in the LWT

Fig. 9 TL 190-82 wind tunnel model mounted in the LWT

3 Bibliography

[1] D. Althaus: *„Niedriggeschwindigkeitsprofile“,* ISBN 3-528-03820, Vieweg Verlag Braunschweig/Wiesbaden, 1996.

[2] Th. Lutz and A. Wolf: Aerodynamic and Acoustic Design of Wind Turbine Airfoils with Trailing-Edge Flap, DEWEK, 17-18 November, Bremen, Germany, 2010.

[3] Th. Lutz, A. Wolf, W. Würz: "*UPWIND Work Package 1B3: Design and Verification of an Airfoil with Trailing-Edge Flap",* UPWIND deliverable 3.8, Institute of Aerodynamics and Gas Dynamics, University of Stuttgart, December 2010.

[4] A. Wolf, M. Kamruzzaman, W. Würz, Th. Lutz, E. Krämer: *"Wall pressure fluctuation (WPF) and trailing-edge noise measurements on a NACA* 64_3*-418 airfoil"*, Internal technical report, Institute of Aerodynamics and Gas Dynamics, University of Stuttgart, January 2008.

[5] A. Wolf, M. Kamruzzaman, W. Würz, Th. Lutz, E. Krämer: *"Aerodynamic and aeroacoustic measurements on the TL 190-82 airfoil with 10% trailing-edge"*, Internal technical report, Institute of Aerodynamics and Gas Dynamics, University of Stuttgart, December 2010.