DESIGN OF WINGLETS FOR RETROFITTING WIND TURBINE ROTOR BLADES

cand.-Ing. F. Richter, Dr.-Ing T. Rische
cp.max Rotortechnik GmbH & Co. KG, Großenhainer Straße 92, 01127 Dresden, Germany
Tel.: +49(0)351-8589345, E-Mail: info@cpmax.com

Summary

Most of the current wind turbine rotor blade tips feature semi-elliptical planforms to reduce noise emission. Non-planar or swept blade tips, such as winglets, promise to reduce tip vortices while maximizing lift in the outer region of the rotor blade. This work focuses on designing winglets that maximise power output by reducing induced drag at the blade tip. Size and bending moments of this winglet type allow modifying existing wind turbine blades of the popular 1.5 MW range.

1. Investigation of the flow behaviour and design restrictions

Tell tails were placed on the surface of the outer 5m of a rotor blade to facilitate studying the flow in the outer regions of the blade (see Fig. 1). There was no significant cross flow; but a slight difference between the flow vectors of suction and pressure side due to tip circulation could be detected.

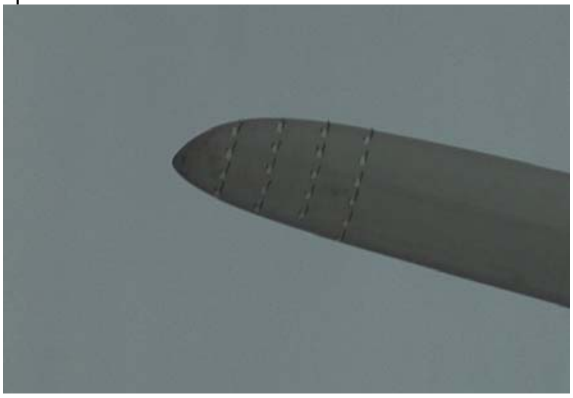

Fig. 1 Tell tails on blade tip

The shape of the winglet is most significantly restricted by the fact that there must be a safe distance between blade even under extreme load conditions to avoid collision. As the structure of modern wind turbine blades is already built to the limits of these restrictions, there is no way to retrofit the rotor with winglets pointing to the suction side of the blade. Thus, only tip shapes pointing to the pressure side away from the tower were further investigated.

2. Winglet airfoils

In order to account for the reduced Reynolds numbers and higher lift coefficients in the winglet tip regions two new airfoils were designed. According to XFoil (see Fig. 2) both seem to be superior to the original FX 79-W-151 A, especially at high angles of attack. Still, their characteristics (zero lift angle and moment coefficient) are very similar to the above, making them very suitable for winglet applications.

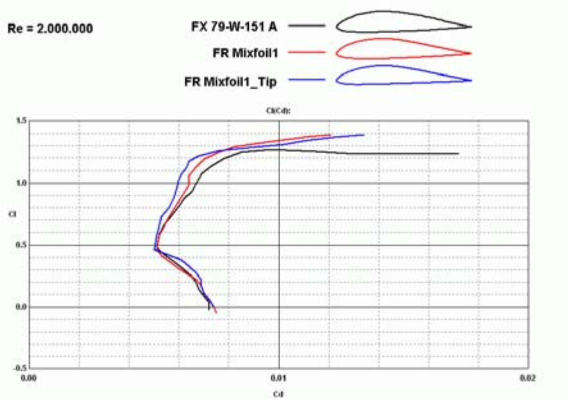

Fig. 2 Airfoil polar comparison

3. Computational methods of simulation

Two approaches were taken to simulate, compare and optimize different wing tip shapes: The first one incorporates vortex-lattice modelling while the second uses finite element methods.
Vortex-lattice modelling as shown in Fig. 3 with AVL software allows optimization of the lift distribution with very little computer time needed but doesn't involve airfoil characteristics in the calculation.
Finite element methods can be very accurate but also quite time-consuming. The software used here is COSMOS FloWorks of the SolidWorks Corporation.

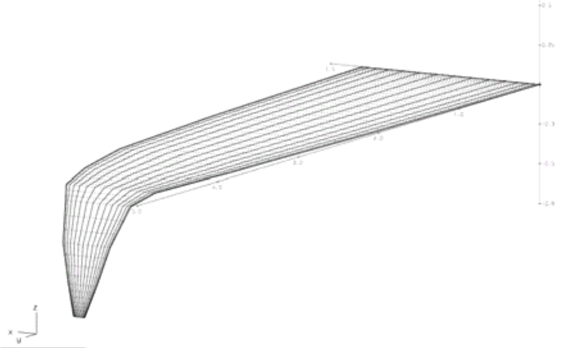

Fig. 3 Vortex-lattice model of winglet

Fig. 4 CAD model of winglet

To provide accurate meshing and results within given computer performance limits only the outer 5m of the rotor radius were analysed.

Both computational methods show that the winglet variants tested are superior to the original tip shape.

4. Wind tunnel verification

The final winglet and the original tip shape were compared in wind tunnel experiments to verify the computational results. Interchangeable 1:4 scale models were put on a blade segment representing the outer 2,5m of the rotor blade. As rotational effects are quite small in the outer parts of the rotor radius a linear wind tunnel analysis is very close to reality.

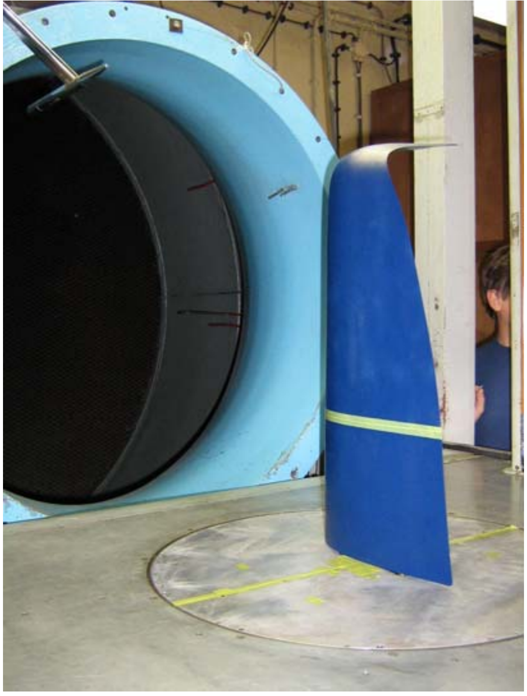

Fig. 5 Tip section in wind tunnel

The forces and moments seen with the wind tunnel experiments confirm the benefits of the winglet over the conventional tip.

Boundary layer visualisation using fluorescent paraffin (see Fig. 6) showed that there are no early flow transition or separation effects on the winglet. It even tolerated higher angles of attack before stalling than the conventional tip.

Fig. 6 Boundary layer visualisation

5. Results and prospects

Computational results as well as wind tunnel tests show improvements of the lift to drag ratio between 8% and 15% in the tip region.

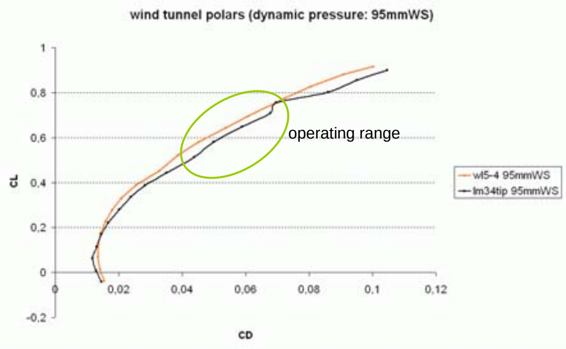

Fig. 7 Polar comparison of wind tunnel tests

The estimated overall output power boost for the rotor is between 2 and 3% depending on the wind speed.

The next step will be to structurally design and build a prototype, to equip a real wind turbine with the new winglet and to monitor the power output under varying wind and turbulence condition.