Flow Control Using Plasma Actuators at The Root Region of Wind Turbine Blades

O. Eisele, G. Pechlivanoglou, C.N. Nayeri, C.O. Paschereit
Institut für Strömungsmechanik und Technische Akustik, TU Berlin

The near root region of a wind turbine blade significantly influences the overall performance of the blade. Because of limitations in the mechanical design the aerodynamic of this blade region strongly suffers. Thick profiles lead to early separation. In the separated region the air is exposed to high centrifugal forces, which are much higher than inertia forces. Thus separation propagates span-wise from the near root region of the blade to the midspan parts. Hence also sections of the blades far away from the root are affected by this cross flow.

This paper investigates the feasibility of flow control using dielectric barrier discharge plasma actuators at the near hub region of wind turbine blades. Thereby the root region of the blade was simulated by a circular cylinder model made of a PVC-tube and a thick cambered airfoil model (DU97W300) made of glass fibre reinforced plastic. Both models were equipped with plasma actuators at different positions in order to realize a high frequency unsteady momentum injection to the boundary layer flow. Thus Tollmien-Schlichting as well as Kelvin-Helmholtz instabilities could be triggered dependent on the position of momentum injection. Force measurements and flow visualizations using the smoke wire method were accomplished to capture the effect of the momentum injection to the flow around the models. In case of the circular cylinder model stream-wise, radial and counter stream-wise momentum injection for different azimuthal actuator positions was considered. Further more the results were compared with measured data resulting from measurements with the same circular cylinder equipped with a laminar-turbulent transition tripping element. The cylinder measurements were conducted at low Reynolds numbers in the order of 10^5. Significant drag reduction and lift increase was observed for actuator positions towards the natural separation point for all directions of unsteady momentum injection. The visualization results show a significant narrowing of the cylinder wake, when the flow is controlled by the actuator.

Force measurements with the DU97W300 airfoil model were accomplished with two different actuator configurations. The first configuration was equipped with one unsteady stream-wise blowing actuator on the suction side at 10% chord length. In a second measurement an additional actuator was mounted on the pressure side at 20% chord length. The results were compared with the results of baseline measurements. Drag reduction and lift enhancement was observed at angles of attack higher than the angle of stall which was identified during the baseline measurements. Thus the shear layer after the separation point is directly manipulated by the actuator and Kelvin-Helmholtz instabilities are subsequently triggered. The flow visualization results exhibit a significant delay of separation in case of a controlled flow. Measurements at higher Reynolds numbers however showed dramatic decrease and eventual absence of the plasma actuator control authority to the flow.