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Fixed Leading Edge Auxiliary Wing as a Performance Increasing Device for HAWT Blades

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1. Introduction

Current composite wind turbine blades are produced as two halves with large single piece moulds. In order for the two halves of the blades to connect and form the actual blade, the moulds need to precisely "meet" each other and thus form the closed blade structure. Due to the use of this blade manufacturing process, however, it is not possible to create highly twisted blades. Most of the blades therefore have a limited root twist in the range of 8° - 11°. This is far less than the optimal value, therefore the root section of commercial wind turbine blades operates at high angles of attack (often in the post stall regime).

The rotation of the wind turbine blade induces three dimensional flow phenomena at the blade root region. When the blade root operates at high AoA and stalls, the 3D root flow transports the separated boundaries from the root towards the middle region of the blade. Such a phenomenon has adverse effect on the efficiency and performance of the wind turbine blade. Until now this phenomenon was considered as an unavoidable property from the wind turbine blade designers. The solutions to encounter this phenomenon were the design of airfoils with desirable stall and post stall characteristics and the intensive implementation of vortex generators as a means of stall delay. The proposed solution in this paper is the implementation of a fixed auxiliary leading edge airfoil which can prevent separation at the root section of the blade. Such an implementation would reduce/eliminate the local flow separation and consequently increase the blade performance. The performance of the blade sections near the root would also benefit from the additional lift produced by the auxiliary airfoil.

In order to investigate parametrically the implementation of an auxiliary airfoil to a wind turbine blade root, a precise wind tunnel constant chord test wing was machined based on the DU97W300 airfoil. A full span auxiliary wing was also precisely machined, based on the NACA 22 fixed slat airfoil. Special side plates were fitted to the test wing, which allowed the variation of angle and position of the auxiliary wing. Parametric wind tunnel investigations were performed at the large wind tunnel facilities of the Hermann-Föttinger Institute of the TU-Berlin. The wind tunnel results were corrected for solid blockage and wake blockage and the baseline measurements with the single DU97W300 wing were compared to previous wind tunnel measurements found in the literature.

The wind tunnel test results were also compared with steady state CFD investigations using the OpenFOAM CFD toolbox with the simpleFOAM solver. Computations with both Spalart Allmaras and k-omega SST turbulence models were performed in order to investigate the turbulence model sensitivity of the solutions. A grid sensitivity analysis was also performed in order to assure grid-insensitive flow simulation results. Based on the wind tunnel and CFD data, a ``baseline'' wind turbine blade design was modified in order to include the root section with the auxiliary wing. Both the baseline and the modified blades were imported in a custom Blade Element Momentum Theory (BEM) code where the blade and turbine performance was simulated. The BEM simulation showed in a quantitative way the benefits of the auxiliary wing implementation.