Icing Problems of Wind Turbine Blades in Cold Climates

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In cold climate areas, where the temperature is below 0°C and the environment is humid for larger periods of the year, icing represents a significant threat to the performance and durability of wind turbines. It is highly important to have a clear view of the icing process and the environmental conditions, which influence the ice accretion in order to act properly. The PhD study covers relevant issues of icing of wind turbine blades in these areas. The work itself can be divided into two fundamentally different parts. The first part compares different techniques, which can identify icing events based on environmental and meteorological parameters such as temperature, relative humidity and wind speed measurements. A small demonstration was performed with data collected in Nanortalik, in South-Greenland. Based on the results, icing occurs during periods with low wind speed, high relative humidity and subzero or close to freezing point temperatures, during night or foggy/cloudy and thus darker days. Icing might be relevant problem for the operation of wind turbines in the area, therefore when the decision is made to install wind turbines in a specific location, a detailed and dedicated risk analysis has to be carried out.

The other, larger part is the consists of experimental and numerical investigations of the process of ice accretion on wind turbine blades along with its impact on the aerodynamics. The experimental study was performed on a NACA 64-618 airfoil profile at the Collaborative Climatic Wind Tunnel located at FORCE Technology. The aerodynamic forces acting on the blade during ice accretion for different angles of attack at various air temperatures were measured along with the mass of ice and the final ice shape. For all three types of ice accretion, glaze, mixed and rime ice, the lift coefficient decreased dramatically right after ice started to build up on the airfoil due to the immediate change of the surface roughness. With increasing angle of attack the degradation of the instantaneous lift coefficient increases as well. Both the reduction of the lift coefficient and the accumulation of the ice mass are nearly linear processes. It was also seen that the shape and rate of ice is highly dependent on the angle of attack. The largest ice accretion and thus the largest lift degradation was seen for mixed ice tests. The results of the experimental investigation demonstrated that the type of the ice accretion has significant impact on the degree of the reduction of the lift coefficient and ice accumulation has strong negative influence on the flow field around the airfoil.

At the end of each simulation, the shape of the ice profile was documented by contour tracing that was then used during the numerical study. First, the collected profiles and the settings of the wind tunnel were validated by results of a numerical ice accretion model, TURBICE from VTT, Technical Research Centre of Finland. The wind tunnel parameter value, the median volume diameter, was found to be underestimated. However, after correcting the input parameters for LWC and MVD, the rime ice profiles were in good agreement with the results of the numerical modelling. Then, CFD simulations with Ansys Fluent were carried out to numerically analyse the impact of ice accretion on the flow behaviour and on the aerodynamic characteristics of the airfoil. The trend of the reduction of lift coefficients agrees quite well with the wind tunnel test results, although based on the measured and the numerical lift coefficients of the clean airfoil, the presence of the wind tunnel walls had significant influence on the measurements requiring a correction. A significant change in the flow pattern was observed for all cases and the most significant flow disturbance was caused by mixed ice accretion. It was also shown that the lift coefficient is highly dependent on the angle of attack on which the profiles were collected. Furthermore, it can be concluded that even one hour of ice accretion can significantly reduce the lift coefficient of an airfoil and the angle of attack at which the ice builds up on the surface is highly important.

The final lift curves of rime ice accretion from both experimental and numerical investigation were used in a demonstration of the transformation model of Seifert and Richert [1997]. It was found that the transformed lift curve fits much better to the one from the CFD analysis and the method could be further developed into a very useful aerodynamic coefficient transformation model.

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