Icing Problems of Wind Turbine Blades in Cold Climates

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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**Experimental investigation of ice accretion on wind turbine blades**

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**Ice Accretion on Wind Turbine Blades**
In this paper, both experimental and numerical simulations of the effects of ice accretion on a NACA 64-618 airfoil section with 7° angle of attack are presented. The wind tunnel tests were conducted in a closed-circuit climatic wind tunnel at Force Technology in Denmark. The changes of aerodynamic forces were monitored as ice was building up on the airfoil for glaze, rime and mixed ice. In the first part of the numerical analysis, the resulted ice profiles of the wind tunnel tests were compared to profiles estimated by using the 2D ice accretion code TURBICE. In the second part, Ansys Fluent was used to estimate the aerodynamic coefficients of the iced profiles. It was found that both reduction of lift coefficient and increase of drag coefficient is a nearly linear process. Mixed ice formation causes the largest flow disturbance and thus the most lift degradation. Whereas, the suction side of the rime iced ice profile follows the streamlines quite well, disturbing the flow the least. The TURBICE analysis agrees fairly with the profiles produced during the wind tunnel testing.

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Climate Change Adaptation: A Report on Climate Change Adaptation Measures for Low Volume Roads in the Northern Periphery

The European Union ROADEX Project 1998 – 2012 was a trans-national roads co-operation aimed at developing ways for interactive and innovative management of low traffic volume roads throughout the cold climate regions of the Northern Periphery Area of Europe. Its goals were to facilitate co-operation and research into the common problems of the Northern Periphery. This report is an output of the ROADEX “Implementing Accessibility” project (2009-2012). It gives a summary of the results of research into adaptation measures to combat climate change effects on low volume roads in the Northern Periphery. The research was carried out between January 2000 and March 2012.

One of the biggest challenges that mankind has to face is the prospect of climate change resulting from emissions of greenhouse gases. These gases trap energy in the atmosphere and cause global surface temperatures to rise. This warming in turn causes changes in other climatic variables such as rainfall, humidity and wind speed that impact on the functioning of infrastructure such road networks.

This paper discusses the climate changes predicted by the world’s meteorological organisations and considers how these may impact on the public and forest road networks of the Northern Periphery. It includes:

• A summary of the projected climate changes
• A discussion on how these changes could impact of the road networks of the Northern Periphery
• Good practice and adaptation measures that can be used The paper reports the results of a Questionnaire circulated to the ROADEX Partners to get their views and concerns on how climate change might impact their local low volume road networks.

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• Good practice and adaptation measures that can be used The paper reports the results of a Questionnaire circulated to the ROADEX Partners to get their views and concerns on how climate change might impact their local low volume road networks.
Bibliographical note
This is a final report from Task RE1 of the ROADEX "Implementing Accessibility" project, a technical trans-national cooperation project between The Highland Council, Forestry Commission Scotland and the Western Isles Council of Scotland; The Northern Region of The Norwegian Public Roads Administration; The Northern Region of The Swedish Transport Administration and the Swedish Forest Agency; The Centre of Economic Development, Transport and the Environment of Finland; The Government of Greenland; The Icelandic Road Administration; and The National Roads Authority and Department of Transport of Ireland. The lead partner in the project was The Northern Region of The Swedish Transport Administration and project consultant was Roadscanners Oy from Finland.

Wind Tunnel Tests on Ice Accretion on Wind Turbine Blades

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Lime Stabilization of Fine-Grained Greenlandic Sediments in Relation to Construction Projects

Thick deposits of fine-grained marine sediments exist in large areas of western Greenland. Many places these sediments are located above sea-level, and now complicate construction projects in urban areas. The mineralogy of the sediments is very different from that of European sediments, mainly due to the cold climate, and it is therefore of great interest to study possible methods to improve the stability of the fine-grained sediments. This presentation will include results of laboratory studies of lime stabilization on a clay soil from Kangerlussuaq, western Greenland. The result includes tests of the optimum lime mixture in relation to both reaction time and temperature influence.

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