NICE - Reduction of ice formation by nanostructuring of surfaces with an ultrashort pulse laser

According to the current report of Task 19 of the IEA Wind TCP, more than 130 GW of wind energy have already been installed internationally at locations with icing conditions and an annual increase of 12 GW is expected. In Austria, practically all wind turbines installed so far are at least affected by moderate icing conditions, posing a considerable challenge to both the project development and the operation of wind turbines.

The three main aspects are:

- Risk to life and limb caused by ice throw or fall
- Decreased yield due to deterioration of aerodynamic properties
- Imbalances causing increased mechanical stress

In a number of countries, such as Austria, as soon as icing is detected on a wind turbine, the turbine is shut down and stays out of operation until the ice melts or is actively removed. The state of the art in de-icing wind turbine is heating the rotor with hot air or with electrical resistance heating on the rotor blade surface. These measures are costly and are only effective for a limited range of meteorological conditions (temperature, wind speed, liquid water content etc.). Preliminary investigations have shown that hydrophobic surfaces can hinder icing or reduce the duration of icing. Hydrophobic surfaces on rotor blades of wind turbines could thus potentially by a method to reduce ice buildup or to improve the efficiency of de-icing methods.

Within the scope of the NICE project, an ultrashort pulse laser was used to generate sub-µm nanostructures in various formation, periodicity and composition on test sample surfaces, which proved to be highly hydrophobic and potentially ice-phobic. The effects of different structuring on the wetting behavior of water droplets on different sample materials were analyzed with a contact angle measuring device. In addition, a pre-existing simulation model of the wetting behavior of surfaces was extended into the sub-µm range to enable the identification of optimal structures, reduce the number of experiments and improve the general understanding of the physical processes. The ice adherence properties of the nanostructured samples were then investigated under laboratory conditions.

The most promising laser-processed samples and unprocessed reference samples were then tested under harsh weather conditions in different field tests. The samples were continuously monitored together with corresponding meteorological data and the ice formation on the sample surface was quantitatively measured in the range of "0" for no icing to "6" for maximum icing. This allowed statements about the degree of ice formation and the duration of icing under conditions near practical use. The investigation of surface profiles and the hydrophobic behavior before and after exposure allowed statements about changing properties and the lifetime of the nanostructures.

The results of the field tests in conjunction with the laboratory tests and simulations have shown differences in ice formation and duration as a function of the structure formation, periodicity and composition, but not in a significant extent as to allow formulating a clear dependence or advising on ice-phobic surface treatment in general. More research is necessary to clarify the relation between (super-)hydrophobic surface properties and characteristics of ice accretion and ablation processes.

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