Accelerated rain erosion of wind turbine blade coatings - DTU Orbit (07/01/2019)

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During operation, the fast-moving blades of wind turbines are exposed to continuous impacts with rain droplets, hail, insects, or solid particles. This can lead to erosion of the blades, whereby the electrical efficiency is compromised and expensive repairs may be required. One possible solution to this problem is elastic blade coatings, which are able to absorb the impact energy without crack formation. The purpose of the work presented in this thesis has been to design and construct a laboratory experimentation device, which allows an accelerated and reliable evaluation of existing or novel blade coating formulations. Results of experiments are compared to data obtained in the larger-size whirling arm rig, which is the present industrial standard for blade coating evaluation. The whirling arm rig consists of three fastmoving horizontal rotors rotating in a heavy artificial rain fall. There are four chapters in the thesis. In chapter 1, a literature survey provides background information to the field. Topics discussed are the global wind energy development, possible wind turbine constructions, blade structures and materials, blade coatings, and liquid erosion mechanisms. In chapter 2, the design, construction and evaluation of a new laboratory setup for fast screening of 22 coating samples simultaneously is described. The device is based on a principle of discrete water jet slugs. A review of previous rain erosion testing equipment is also included. To provide a basis for comparison of the new setup with the whirling arm rig, a dimensional analysis was conducted and experiments with two polyurethane-based blade coatings carried out. Results showed that water jet slug velocity and impact frequency are the most influential parameters on the coating erosion rate. Furthermore, very small coating surface defects, often present on the specimens tested, appeared to play an important role in the erosion mechanism. The evaluation of the coatings under conditions where impact frequency and water hammer pressure were “matched” could not be directly correlated with the results obtained with the whirling arm rig. This may be attributed, among other contributing factors, to the different contact modes in the two setups, i.e. the movement of coated panels against rain drops versus the movement of water drops against coated specimens. The results endorse the complex nature of the rain erosion phenomenon, which is the consequence of the simultaneous combination of complex mechanisms and as such, it is difficult to reproduce at the laboratory scale. In chapter 3, the experimental investigation was expanded to a study on the effects of three important process parameters on coating erosion: water cushioning, substrate curvature, and water nozzle-coating distance. In addition, to map the influence of physical properties on rain erosion, mechanical measurements to characterize selected blade coatings, including tensile strength, flexibility, impact, hardness, and abrasion experiments, were conducted. The investigations showed that in some cases water cushioning (the presence of a liquid film on the coating surface prior to impact) is important. Contrary to this, substrate curvature and the water nozzle-coating distance (< 10 cm) did not influence the results to any significant degree. The ranking of abrasion resistance of the blade coatings was in agreement with the ranking of rain erosion resistance measured in the whirling arm rig and is an interesting indication for future work. Finally, in chapter 4, conclusions are drawn and suggestions for further work provided.

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