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Detection of initial subsurface defects on coated glass-fiber reinforced composite components by means of active micro-thermography

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Summary:

The surface condition of the leading edge of rotor blades has a significant influence on the lifetime and performance of a wind turbine. The delayed detection of erosion damage results in high maintenance and repair costs. Therefore, a non-destructive in situ measuring method is required for the early detection of erosion damage and initial subsurface. Active thermography fulfills these requirements. First measurement results show that it is possible to visualize damage patterns on rotor blades and to make initial subsurface defects, which often lead to premature erosion, visible.

Keywords: active thermography, edge zone analysis, leading edge erosion, subsurface defects, composite materials

1. Introduction

The impact of rotor blade damages on the lifetime and performance of a wind turbine is significant and the repair of such damage is complex and expensive. The leading edge of a rotor blade is particularly exposed to mechanical and environmental stresses such as during rain, where the drops hit the blade with an impact speed of over 300 km/h. The impact of rain drops gradually removes the coated surface as well as parts of the underlying glass-fiber composite material [1,2]. Figure 1 shows a schematic representation of the structure of the leading edge of rotor blades.

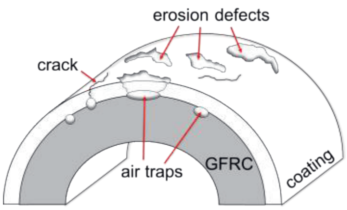

Fig. 1. Schematic sketch of a coated glass-fiber reinforced composite sample with initial defects (air traps) and surface defects

Studies suggest that initial subsurface defects such as pores in the border area between coating and GFRC lead to premature erosion [3]. Current failure analysis is carried out with destructive methods, without taking into account the progress of damage over time and initial subsurface defects in the component [4]. Since maintenance intervals are carried out after visual inspections, defects beneath the surface remain unnoticed. Early detection and evaluation of erosion damage and subsurface defects before major damage occurs up to total failure of the rotor blade leads to a reduction in maintenance and repair costs. For this reason, the possibility of using active thermography to detect initial subsurface defects in the micrometer range on the leading edge of rotor blades is explored.

2. Measurement approach

Active thermography is selected as the measuring method for the contactless, non-destructive examination of erosion damage and subsurface defects [5], since, in opposite to computer tomography (CT), it can also be used in situ. In active thermography, the test sample is first heated by an energy source and in the subsequent cooling phase the different temperature distribution of the test sample is recorded by an IR camera [6]. The thermograms are then compared with optical images to match their information content. In order to select the optimal parameters regarding camera setup, illumination type and duration for later test series, a test rig is also being developed.

3. Experimental setup

For the thermographic investigations, a first version of a test rig was set up as shown in Figure 2. The test sample, which resembles the leading edge of a rotor blade, is fixed in a rotatable clamping device. An InfraTec 8300 series IR camera with 100 mm lens and 2 distance rings (zoom in completely) is directed at the sample so that it is in focus on the image. Fur-

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thermore, a kinematic system is already installed, which is ready for the later integration of a heat source as well as additional sensors. For the first test measurements, heating of the test sample was done off the test rig using a radiant heater. The position of the future heat source integrated in the test rig as well as the position of the future sensors (distance and height) can be controlled by a computer. The IR-camera is also connected to this system to evaluate the acquired image data with the software Irbis3 from InfraTec.

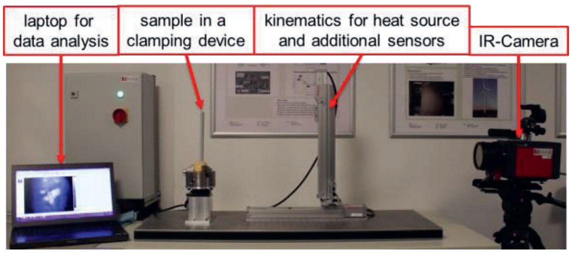

Fig. 2. Current experimental setup for the thermographic examination of test samples

4. Results

The first test measurements were carried out on a sample loaded in the rain erosion system. Figure 3 shows an image of a test sample, an enlarged image section taken with an optical camera and a thermographic image associated with the image section.

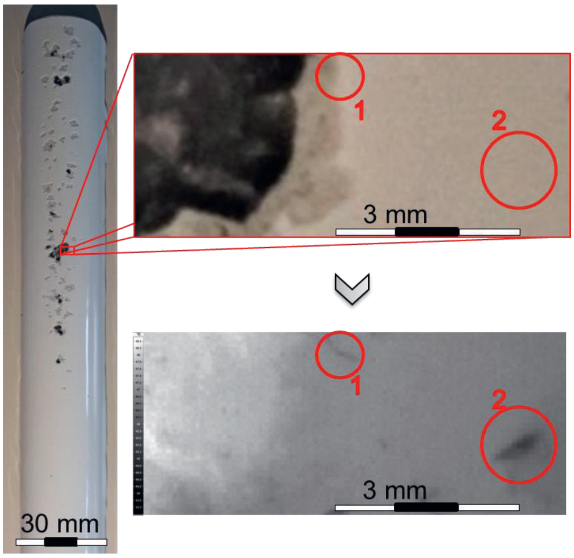

Fig. 3. Left: optical image of the damaged test sample; top right: enlarged optical image of a damaged area; bottom right: thermographic image of the same area; circle 1 and 2: hidden inhomogeneities

Due to the prevailing temperature difference, which is caused during the cooling process by material-dependent heat storage capacities and the resulting different heat transfers, extensive damage to the surface can be detected. Additionally, for example the circles 1 and 2 in the thermogram show areas in the micrometer range with different thermal properties relative to the coating, which are not visible in the optical image and would therefore remain unnoticed. As a result of the high spatial resolution of the camera with a distance between camera lens and test sample of 440 mm, material inhomogeneities with a size of 60 µm were detected. These material inhomogeneities contribute to the initiation of premature damage at the leading edge of the rotor blade due to rain erosion.

5. Conclusion and Outlook

The experiment shows that active microthermography can be used as a non-invasive, non-destructive measuring method to visualize material inhomogeneities in the micrometer range, that remain hidden during a visual inspection of the leading edge of wind turbine rotor blades. Further investigations including CT reference measurements are necessary to determine the influence of these detected inhomogeneities on premature rain erosion. Finally, in-situ measurements and damage analyses will be conducted on the rotor blade leading edge of a real-scale wind turbine.

6. References

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