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Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

ISMEM 2017
- 2nd International Symposium on Multiscale Experimental Mechanics: Multiscale Fatigue

Multi-scale testing of composite steel interfaces for blade root bushing connections

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Abstract

Given the societal, environmental and design requirements, there is an ever increasing interest in designing wind turbine blades. To this end, given the increasing length of wind turbine blades, lightweight and high performance designs of the blade root end are essential to connect wind turbine blades to the rotors. However, an increase in the ratio of length to diameter of wind turbine blade exerts higher loads on the connections located at the maximum moment location. The carrot joint root bushing connection type is becoming popular in the wind industry, since if placed relatively close together, they do not have any adverse effect on the root blade strength. The static and dynamic strength of the root bushing connections are commonly determined experimentally by a sub-component test, which typically is carried out by a static and cyclic fatigue pull-out test of the bushing according to the Germanischer Lloyd standard [1].

In this work, the root bushing connections in a wind turbine blade under multi-axial loading are analyzed using fracture mechanical analysis methods. The required material properties, such as the critical energy release rates for mode-I, mode-II and mixed-mode are characterized experimentally through Double Cantilever Beam specimens with Uneven Bending Moments (DCB-UBM). In the intermediate step, the obtained results from DCB-UBM tests are used to analyze and validate the cohesive interface between the metallic and composite substrates in Double Strap Joint (DSJ).

Next, the validated results from DCB-UBM and DSJ tests are used to analyze the cohesive interface between the metallic bushings and composite root body using cohesive elements in FEA. The model outputs are further validated by testing an actual wind turbine bushing under multi-axial loading (see figure 1). This developed analysis model can be used to forecast failure of the root end bushings in terms of their circumferential location in wind turbine blade root.

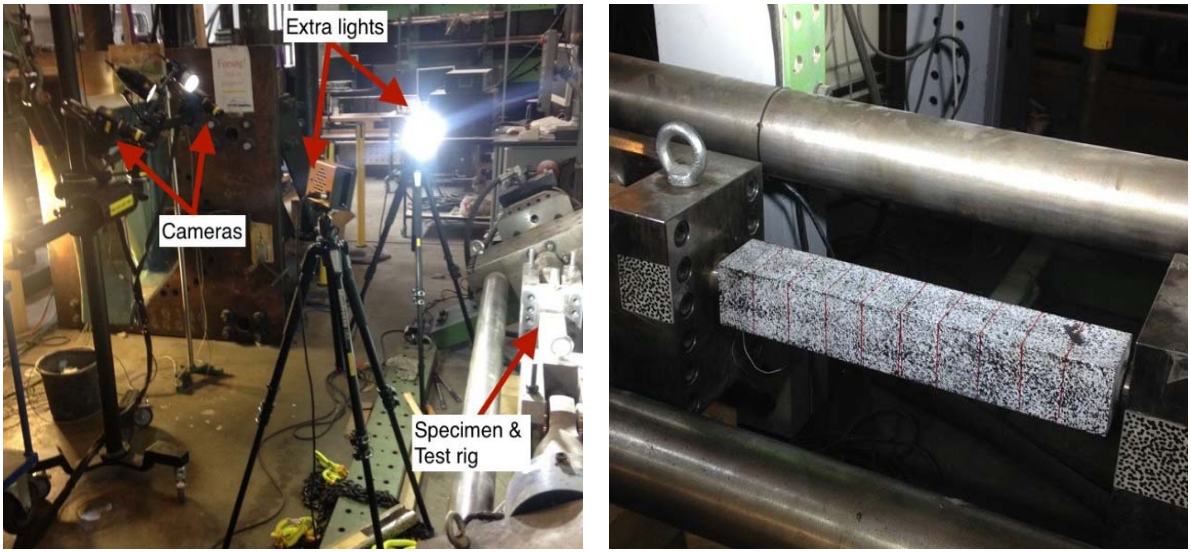

Figure 1. Test set-up for testing of wind turbine root bushing under multiaxial loading

REFRENCES

[1] Germanischer Lloyd, “Fibre Reinforced Plasticd (FRP) and Bonded Joints,” in *Guideline for the Certification of Wind Turbines*, 2010, pp. 5-26