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Challenges in experimental fatigue testing of glass-fibre reinforced polymer matrix composites for wind turbine industry

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Abstract

The wind turbine industry always strives to increase the performance of wind turbines. To design longer and lighter wind turbine blades, one of the key factors is the fatigue design limit of the composite materials used in the load carrying structures. The fatigue design limits are based on the variance of the fatigue test results on composite materials specimens. Options to improve the design limits of the composite materials are either to improve the material quality, or to decrease the variance and improve fatigue test results by improving the fatigue test methods. In recent years, extensive work has been done to improve the quality of the composite materials used in wind turbine blades. This improvement has been achieved by

incorporating high performance glass fibres with improved sizing and exploring new resin formulations. However, the current standardised fatigue test methods still show low reproducibility and high scatter (high variance). Therefore, in order to improve the design limits to reflect the high performance of the composite materials, it is critical to develop improved fatigue test methods.

There are three types of uniaxial fatigue test methods, tension-tension, compression-compression and tension-compression. Specific challenges exist for each test type regarding the experimental set-up and specimen geometry. Issues for the experimental setup include alignment and load introduction into the specimen. Issues for the test specimen include obtaining a specimen geometry that leads to failure in the gauge section. An example of a geometry issue is the length of the specimen. For tension-tension testing, it is beneficial if the gauge length of the specimen is as long as possible to obtain a homogeneous stress state in the test area and to have a long gripping area to be able to introduce the load through shear stresses without getting high shear stress concentrations causing shear failure in the gripping region. In compression-compression testing, the gauge length of the specimen is limited by the Euler buckling limit and the load introduction also has to be considered to avoid failure in the gripping region e.g. by transferring part of the load through the specimen's ends and partly through shear stresses. Work on optimizing the specimen geometry and the experimental setup has been done on tension-tension fatigue by Korciakosky et al. (2016) and on compression-compression fatigue by Fraisse and Brøndsted (2017) resulting in lower scatter. However, limited work has been done on uniaxial tension-compression fatigue test methods although recent demands for wind turbine-material qualification require tension-compression fatigue testing.

The current work presents the challenges in development of experimental tests, which give reproducible results in tension-compression fatigue. Considerations from the developed methods for tension-tension and compression-compression fatigue have been included, and it is found that compromises have to be made in order to be able to successfully test uniaxial composites in tension-compression fatigue. Based on experiments and finite element simulations, the geometry of test specimen as well as optimization of mounting and geometry of tabs are discussed. A presentation of the state of the art experimental methods and current test challenges will be given.

References

- Korciakosky, S., Brøndsted, P. Sarlin, E. and Saarela, O. (2016) Influence on specimen type and reinforcement on measured tension-tension fatigue life of unidirectional GFRP laminates *International Journal of Fatigue* 85, pp. 114-129
- Fraisse, A. and Brøndsted, P. (2017) Compression fatigue of wind turbine blade composite materials and damage mechanism *21th Int. Conf. on Comp. Mat. (ICCM21), Xi'an, China, 20-25 August*.