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TOWARDS A MORE REALISTIC FATIGUE LOADING FOR LABORATORY TESTING OF WIND TURBINE BLADES

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A novel procedure for conducting wind turbine blade fatigue testing is investigated. It features simultaneous loading in the main two directions ? flapwise and edgewise ? and uses the blade natural frequencies to force cyclic fatigue loads. This experimental scheme is modelled and studied with a finite element approach, using a full 3D blade model. Experimental strain distribution outputs are used to validate the model. The simulations are then used to examine the performance and relevance of the dual-axis test method for wind turbine blades.

Fatigue testing of wind turbine blades provides extremely valuable data for both blade manufacturers and turbine end-users in terms of design validation and certification for in-service requirements. However, existing tests using only one loading direction at a time are a gross simplification of the fatigue experienced by blades in service. To address this, NaREC has created a new technology whereby a blade can be loaded in two axes simultaneously, using a hydraulically powered resonance actuation system. This creates a test where the blade experiences a combination of flapwise and edgewise loads that are more in-keeping with the variable load combinations endured in operation. A real-time vision tracking system was developed to monitor the blade motion during the test. This vision data is integrated with real-time strain gauge data to provide the means for monitoring and controlling the test on the blade.

In parallel, in the project Supergen Wind, STFC-RAL has developed a general, flexible, parametric, finite element model for wind turbine blade analysis. Within this model, the blade external geometry, internal structural shape, materials, loads, mesh, analysis type and post-processing operations can all be adjusted independently by the user. In particular, the application of industry standard materials and layups are compared with the use of more innovative materials. The model represents the basic operational conditions due to gravity, centrifugal and aerodynamic loads. The aerodynamic loading is applied as a fully distributed pressure field, resulting from constant user-specified wind speed, but accounting for wind shear and tower shadow effects, as well as a 2D aerofoil potential flow solution.

For this collaboration work, the innovative dual-axis NaREC loading system has been included within the STFC-RAL finite element model and analyses conducted to explore its performance characteristics. In the computational simulations, the blade model is loaded in a similar fashion to the dual-axis experiment; the analysis is time-based, non-linear and dynamic, featuring sinusoidal inertial load inputs as well as gravity. Experimental strain distributions measured during a dual-axis test are compared with the numerical predictions for the same load situation as well as for selected simple service load conditions produced computationally. Conclusions are drawn regarding the benefits of dual-axis resonant testing and its relevance for fatigue testing of large wind turbine blades. Furthermore, this work constitutes an element of validation for the finite element blade structural dynamics modelling tool.