Ultimate strength of a large wind turbine blade - DTU Orbit (23/01/2019)

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The present PhD project contains a study of the structural static strength of wind turbine blades loaded in flap-wise direction. A combination of experimental and numerical work has been used to address the most critical failure mechanisms and to get an understanding of the complex structural behaviour of wind turbine blades. Four failure mechanisms observed during the fullscale tests and the corresponding FE-analysis are presented. Elastic mechanisms associated with failure, such as buckling, localized bending and the Brazier effect, are studied. In the thesis six different types of structural reinforcements helping to prevent undesired structural elastic mechanisms are presented. The functionality of two of the suggested structural reinforcements was demonstrated in full-scale tests and the rest trough FE-studies. The blade design under investigation consisted of an aerodynamic airfoil and a load carrying box girder. In total, five full-scale tests have been performed involving one complete blade and two shortened box girders. The second box girder was submitted to three independent tests covering different structural reinforcement alternatives. The advantages and disadvantages of testing a shortened load carrying box girder vs. an entire blade are discussed. Changes in the boundary conditions, loads and additional reinforcements, which were introduced in the box girder tests in order to avoid undesired structural elastic mechanisms, are presented. New and advanced measuring equipment was used in the fullscale tests to detect the critical failure mechanisms and to get an understanding of the complex structural behaviour. Traditionally, displacement sensors and strain gauges in blade tests are arranged based on an assumption of a Bernoulli-Euler beam structural response. In the present study it is shown that when following this procedure important information about distortions of the cross sections is lost. In the tests presented here, one of the aims was to measure distortion of the profile, also called 'local deformations', to verify a more complex response than that of a Bernoulli-Euler Beam. A large number of mechanical displacement sensors and strain gauges were mounted inside and outside the structure. These measurements further proved highly useful when validating Finite Element based analysis and failure mechanisms should be decided. Finally, comparisons of the ultimate failure loads observed in the full-scale tests are presented and conclusions are drawn based on the mechanisms found. The thesis consists of a comprehensive summary and a collection of three papers and four patent applications.

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