Master projects at WMC

Duration: min. 6 months
Level: HBO/WO
Competences: Aerospace/Mechanical Engineering, good understanding of structural and material mechanics, interest in combination of experimental and numerical work, good reporting skills (English)
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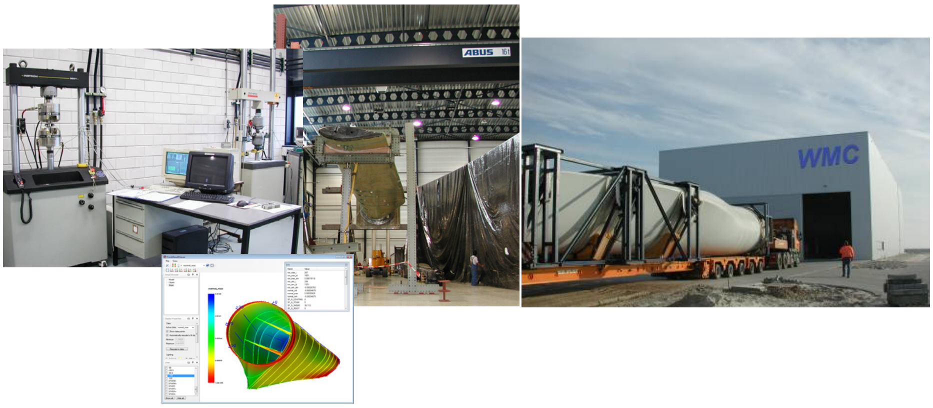
What is WMC?

The Knowledge Centre Wind turbine Materials and Constructions is a foundation originating from Delft University of Technology (TUD) and the Energy Research Centre of the Netherlands (ECN). WMC performs full-scale mechanical tests on rotor blades and other large (wind turbine) structures. In addition, WMC has a long history of coordinating and participating in international scientific materials research projects. Moreover, WMC is active in software engineering for the (wind) industry.



Master thesis projects at WMC

The following projects are part of the research programme of WMC. During project, the students will learn about the framework in which these projects are carried out and the nature of scientific research projects. Some programs require more experimental work than others, but the common denominator between all projects is the important link between model, analysis and experiment. All projects start after mutual agreement, the minimum duration is 6 months, but this can be extended to longer periods. For the projects including experimental work, a tentative planning is listed. The work will be carried out at WMC. The brief descriptions below can be further elaborated with the student.

1. Crack propagation in wind turbine composites

Currently, wind turbine rotor blade materials are predominantly investigated in terms of 'bulk' material properties. However, properties of adhesive bonds and (interlaminar) crack growth data are becoming more and more of interest to the industry. These data are also used in micro- and mesomechanical modeling of composites.

Obtaining these data requires dedicated tests, for instance to measure the energy release rate (G_{Ic}). A test set-up will be designed and built for testing G_{Ic} in the WMC test frames, including design and manufacturing of specimens. In a later stage, the possibility of providing $G_{II/IIIC}$ values will be investigated. Tests will first focus on static testing, then on fatigue testing.

Tentative planning: Where-who-what: 1 month; Manufacturing: 2 months; Testing: 2 months; Modeling, reporting and analysis: 1 month.

2. Damage tolerance; application of aerospace concepts in wind turbine industry

Composite materials have been in use within the aerospace industry long before the wind energy industry boom started. Many analysis and design concepts in wind turbine rotor blades have originated from the aerospace industry. However, economics and differences in perception of fatigue of composites might hamper complete synchronization of design concepts.
Recently, the application of damage tolerance concepts has gained new interest in the wind industry. It is not clear, however, in how far the abovementioned industry differences affect the feasibility of damage tolerance concepts in the wind industry. The student is required to make a thorough comparison and an investigation of the possible pitfalls. Notably, the implications for materials, subcomponent, and blade testing should be investigated.

3. Finite element modeling of test specimens

Material test specimen design is done mainly on the basis of experience and rules-of-thumb. Nevertheless, the strain distribution in the specimen, as well as the boundary conditions during the test can have significant influence on the results. A finite element model will be made of a reference specimen to analyse the effects of several geometrical parameters, including a sensitivity analysis of the results to natural variations in material properties. Experiments will be conducted to obtain as many material parameters for input in the model, minimising the amount of assumptions to be made in the study.

Tentative planning: Where-who-what: 1 month; Manufacturing: 1 month; Obtaining material parameters: 1 month; Modeling, reporting and analysis: 3 months.

4. Effect of manufacturing defects on laminate performance

In order to have reliable design data, tests should be performed on laminates manufactured as much as possible in the same conditions as the full rotor blade. However, it is attractive from a testing point of view to use a double-sided mould instead of a single sided mould, and to avoid contamination by voids or foreign materials.
To assess the influence on laminate performance, especially in fatigue, this assignment encompasses manufacturing of reference specimens, as well as contaminated specimens, and/or to investigate the difference in performance of specimens manufactured in a double-sided vs. single-sided mould. In terms of contamination, some possibilities to choose from are dust, voids (poor de-gassing of resin), inclusion of water (infusion at high humidity conditions), etc.

Tentative planning: Where-who-what: 1 month; Manufacturing: 2 months; Testing: 2 months; Modeling, reporting and analysis: 1 month.

5. Thickness effect

Laminate thicknesses are increasing rapidly, as wind turbine blades become longer. One of the questions currently under investigation is whether the test results for material characterisation, obtained for relatively thin (3-4 mm) specimens are representative for these thicknesses (10-30 cm). Experimental work on thick laminates suggests that they are not. On a smaller scale, this assignment will compare performance of specimens with different numbers of layers, e.g. 2, 4 or 6 layers, focussing on fatigue. Connected to the current manufacturing issues, the influence of fabric areal weight will also be included; in other words, is the (fatigue) performance of specimens with equal thickness, made of 3 or 6 layers, the same?

Tentative planning: Where-who-what: 1 month; Manufacturing: 2 months; Experimental: 2 months; Modeling, reporting and analysis: 1 month.

6. Buckling of sandwich cross-sections

The internal structure of a wind turbine rotor blade consists of unidirectional-dominated material that bears the normal stresses (concentrated in the blade spar), and panels whose primary function is to maintain the aerodynamic shape and to bear buckling loads. These panels, but also the web in the blade spar, consist of sandwich material. Various numerical tools exist and have been used to predict the buckling behaviour of (closed) cross-sections, but experimental validation is scarce. This assignment focusses on experimentally and numerically assessing failure in compression of sandwich-dominated cross-sections, using readily available numerical tools. The experimental work includes design, manufacturing, and testing of the specimens.

Tentative planning: Where-who-what: 1 month; Manufacturing: 2 months; Experimental: 1 month; Modeling, reporting and analysis: 2 months.

7. Statistical analysis of test data

In recent and current material research projects, vast amounts of test results of various nature are recorded. Each test result contains a large number of parameters. For example, for all fatigue tests, frequency and number of cycles to failure (fatigue life) is known, and for most tests temperature is recorded. It is suspected, that there is a relationship between frequency or temperature and fatigue life. A model can be formulated, and the model parameters can be found either by dedicated tests, or through statistical analysis of already available data (which are not necessarily specifically designed for validation of this model).
It is foreseen, that multiple non-linear regression of the various databases will aid the definition of models for dependencies as mentioned above. Such an analysis has to be implemented to demonstrate the feasibility of supporting dedicated test programmes with advanced statistical tools.

8. Effect of load introduction saddles on the failure during full scale blade tests

During a full scale blade test the loads are introduced at a limited number of locations simulating the distributed operational load. To apply these concentrated forces during the test saddles are used. These saddles or load introduction fixtures are mostly wooden blocks formed to the local airfoil shape and clamped by a steel framework. As such these saddles may unintendedly strengthen and/or stiffen the blade locally in a circumferential way and by that delay failure such as local buckling. To asses this effect numerical simulations (FEM) of the failure of the blade with and without these saddles have to be compared for different situations. For modeling the blade the design package FOCUS will be used for automated FE mesh generation. The result can be input for the international standard on full scale blade tests (IEC-TC88- 61400-23). It may also give guidelines to improving the load introduction during these tests.

Tentative planning: Where-who-what: 1 month; Modelling the blades and saddles: 2 months; Analysing the results: 2 months; reporting: 1 months.

9. Mechanical characterization of thick adhesives

Wind turbine blades are mainly made of glass fibre reinforced polymers, manufactured in two big parts and bonded together using special adhesives. Depending on the design of the blade, the adhesives are differentiated in structural and non-structural bond-lines. The structural bond-lines contribute to the mechanical integrity of the blade playing a key-role in its reliability. Therefore, a deep knowledge of the adhesives' mechanical behaviour is crucial to optimize the blade's design. Below, three master projects are presented which focus on the mechanical characterization of thick adhesives.

a. Mechanical characterization of thick adhesives – Quasi-static failure envelope

Uniaxial tension, compression and torsion tests of bulk adhesive tubes should be performed in order to obtain the mechanical properties of the material system. In addition, the adhesive tubes should be subjected to biaxial tension-torsion and compression-torsion, using different ratios, in order to simulate complex stress states. The goal of the project is the design/calculation of the biaxial failure envelope and the comparison with existing analytical failure models. Furthermore, numerical validation of the proposed model should be performed using Finite Element Modeling.

Tentative planning: Where-who-what: 1 month; Manufacturing: 1 months; Experimental: 1 months; Modeling, analysis and reporting: 3 month.

b. Mechanical characterization of thick adhesives –Long term properties

The adhesive material system is usually epoxy-based bonding paste and exhibits mechanical properties which are between the two ideal cases, i.e. perfectly elastic and perfectly viscous, and hence it is termed as viscoelastic. In a viscoelastic material the stress is a function of strain and time and is expressed in the long-term behaviour under constant and cyclic loads. In this project, the student will investigate the viscoelastic behaviour by performing creep and relaxation tests. In addition, constant amplitude (CA) cyclic tests using different R (R = 10, -1, 0.1) ratios should be performed in order to determine the material response under cyclic loading. The aim is to define the equations which describe the S-N curves, and to calculate the linear viscoelastic threshold studying the effect of different stress levels.

Tentative planning: Where-who-what: 1 month; Manufacturing& Experimental: 4 months; Modeling, reporting and analysis: 2 months.

10. Structural health monitoring of wind turbine blades subcomponents during fatigue tests

One of the most critical components of the wind turbine is the blade. Monitoring the health condition of the blade becomes more important as the cost of maintenance is dramatically increasing, in particular for the offshore placements. The monitoring efforts are based on Non-Destructive Testing (NDT) techniques. One of the most commonly used NDT technique for monitoring the wind turbine in service is Acoustic Emission (AE) technique. The current project deals with the development of a Structural Health Monitoring (SHM) system using acoustical methodologies. The first step will be the mapping and the instrumentation of the system. The second step will focus on the development of efficient algorithms to extract information for the integrity of the structure. Finally the SHM system will be implemented during fatigue tests of wind turbine blades subcomponents.

Tentative planning: Where-who-what: 1 month; instrumentation: 2 months; experiments: 1 month; post-processing and reporting: 2 months.