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

DTU

# Understanding Fatigue of Fiber Reinforced Polymers through Hybrid Simulation and Multi-scale Testing and Modeling

**Alex R. Quinlan**
Department of Civil Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

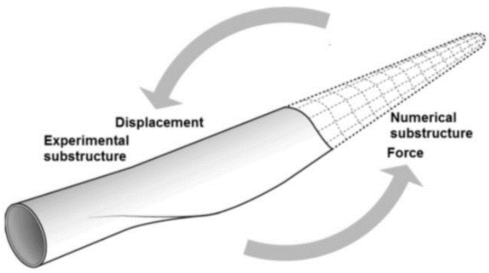
e-mail: alequ@byg.dtu.dk

**Alex R. Quinlan** is a PhD student at DTU Civil Engineering. He received his master's degree in mechanical engineering from Western Michigan University. His interests include mechanics of composites, experimental verification of numerical models, and wind turbine structures.

**Abstract**

The Villum Center for Advanced Structural and Material Testing (CASMaT) launched its Initiation Project in 2017 called "Understanding fatigue through multi-scale testing and modelling." The project focuses on the in-plane fatigue behavior of laminated fiber-reinforced polymer composites (FRPs) and approaches the problem at the micro, macro, sub-structural and structural scales.

The underlying fatigue mechanisms in FRPs share little in common with metals, so different considerations are required for FRP structures. Additionally, the anisotropic and customizable nature of FRPs makes it difficult to create generalized laws for their fatigue behavior. Consequently, there are industry demands to develop a fast and reliable method to validate the fatigue performance of composite structures [1].



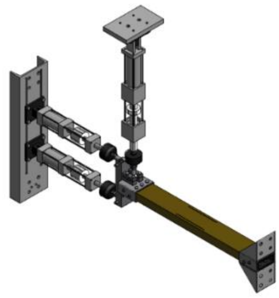



**Figure 1a) Hybrid simulation integrates experimental testing into a numerical model. 1b) A model of a research beam in the DTU test rig**

The first structure to be tested in this project will be a fiberglass research beam, used for system development (Figure 1b). The next structure is a fiberglass power-transmission arm that is a part of an ongoing parallel research project at DTU Mechanical Engineering. This arm offers a simple tapered cylindrical geometry and a consistent laminate schedule. The project will culminate in the testing of a section of a wind turbine blade, which presents an increase in complexity of the geometry, materials, and loading.

Testing at the structural and sub-structural level will use hybrid simulation. Hybrid simulation is a technique that utilizes an experimental sub-structure coupled into an FE model, where calculated displacements are applied to the physical structure and measured reaction forces are returned to the numerical model [2]. While there is an established practice of using hybrid simulation for the control of 1-6 degrees of freedom at a point, the tests in this project will require the more complicated application of loads at a continuous edge. Ideally, the tests will be conducted in real time, which will require efficient communication between components, effective compensation for delays, and predictive extrapolation calculations. The DTU Structural Lab – one of the three lab units in CASMaT - houses a dedicated hybrid simulation rig for testing and tuning the system using a thin-walled fiberglass research beam as the sub-structure.

In a parallel path, full numeric models of the structures will be developed using the finite element method. The modeling will incorporate algorithms to capture the fatigue behavior of the FRP material. The development of these algorithms will be carried out in a collaboration between the two other Initiation Project PhD studies. Iterative and cooperative testing at the micro, macro, and sub-structural and structural scales will provide a platform for capturing and validating the material's fatigue behavior and the concept of the multi-scale modelling and testing.

## References

[1] Cairns, Douglas (2016 November) *Understanding the Materials – Manufacturing – Structural Performance Hierarchy for Composite Materials and Structures*. Presentation at the International Symposium for Multi-Scale Experimental Mechanics, ISMEM, DTU, Denmark.

[2] Waldbjørn, Jacob (2016) *Hybrid Simulation of Wind Turbine Blades*. (PhD Thesis, DTU Civil Engineering)