University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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"High Fidelity Micromechanics-Based Statistical Analysis of Composite Material Properties"

Department of Mechanical Engineering

Thursday, March 31, 2016
10:00 A.M.
David Turpin Building
Room A137

Supervisory Committee:
Dr. Curran Crawford, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Afzal Suleman, Department of Mechanical Engineering, UVic (Member)
Dr. Abbas S. Milani, School of Engineering, UBC Okanagan Campus (Outside Member)

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Dr. Silvestre Pinho, Department of Aeronautics, Imperial College, London

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Dr. Abdul Roudsari, School of Health Information Science, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Composite materials are being widely used in light weight structural applications due to their high specific stiffness and strength properties. However, predicting their mechanical behaviour accurately is a difficult task because of the complicated nature of these heterogeneous materials. This behaviour is not easily modeled with most of existing macro mechanics based models. Designers compensate for the model unknowns in failure predictions by generating overly conservative designs with relatively simple ply stacking sequences, thereby mitigating many of the benefits promised by composites.

The research presented in this dissertation was undertaken with the primary goal of providing efficient methodologies for use in the design of composite structures considering inherent material variability and model shortcomings. A micromechanics based methodology is proposed to simulate stiffness, strength, and fatigue behaviour of composites. The computational micromechanics framework is based on the properties of the constituents of composite materials: the fiber, matrix and fiber/matrix interface. This model helps the designer to understand in-depth the failure modes in these materials and design efficient structures utilizing arbitrary layups without a reduced requirement for supporting experimental testing. The only limiting factor in using a micromechanics model is the challenge in obtaining the constituent properties. The overall novelty of this dissertation is to calibrate these constituent properties by integrating the micromechanics approach with a Bayesian statistical model.

The early research explored the probabilistic aspects of the constituent properties to calculate the stiffness characteristics of a unidirectional lamina. Then these stochastic stiffness properties were considered as an input to analyze the wing box of a wind turbine blade. Results of this study gave a gateway to map constituent uncertainties to the top-level structure. Next, a stochastic first ply failure load method was developed based on micromechanics and Bayesian inference. Finally, probabilistic SN curves of composite materials were calculated after fatigue model parameter calibration using Bayesian inference.

Throughout this research, extensive experimental data sets from literature have been used to calibrate and evaluate the proposed models. The micromechanics based probabilistic framework formulated here is quite general, although here the specific application is to a wind turbine blade. The procedure may be easily generalized to deal with other structural applications such as storage tanks, pressure vessels, civil structural cladding, unmanned air vehicles, automotive bodies, etc. which can be explored in future work.