Wind-Energy Science, Technology, and Research
Industry/University Cooperative Research Center

Mechanical Properties Enhancement Prediction for Matrix Materials

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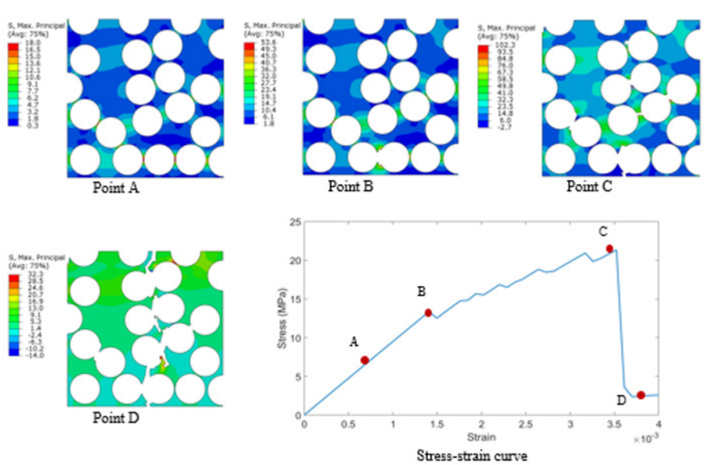
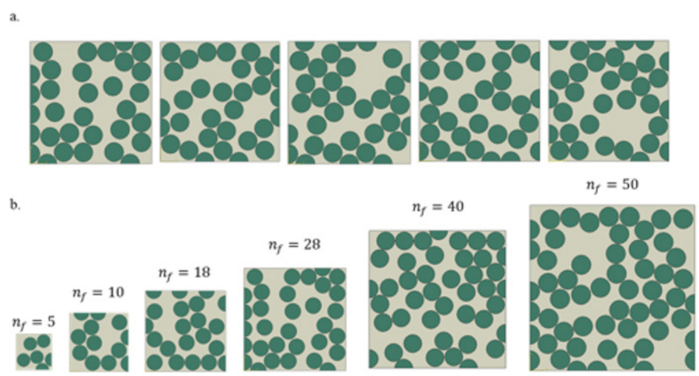
Uniform curing of matrix material during wind turbine blade manufacturing is a challenge as the thermal field is spatially dependent and non-uniform. The potential for localized, non-uniform cure states could affect blade performance and result in premature failure. Resin material is primarily responsible for the transverse response of the composite materials used in blade manufacturing. The blade can undergo high transverse and shear stresses which can cause delamination or trailing edge splitting. Micromechanical analysis to predict the transverse response of the composite as a function of degree of cure of the resin material was the focus of this project.

Previous WindSTAR work determined the effective composite stiffness dependence on the resin properties by employing the Continuous Periodic Fiber Model (CPFM). A MATLAB tool was created that performed modulus prediction and applied layup adjustments to accurately determine the effective composite properties using several micromechanical models, including CPFM. This was followed by a numerical study to predict the effect on stiffness response of the composite due to the change in stiffness of the resin material. It showed that for a 20% increase in the matrix Young's modulus, the transverse stiffness rose by 16%. This approach, although valuable, can be employed only to estimate the stiffness of the composite based on component properties. To predict failure in the blade as a function of curing, a more sophisticated approach is required, and this has been completed in this project.



Maximum principle stress contour showing the crack initiation and propagation through an 18 fiber RUC composed of 100% cured RIMR 135/RIMH 137 resin and E-glass fibers. Stress strain response indicating Point A: Initial stress build-up during loading, Point B: Crack initiation in the RUC, Point C: Micro-cracking and stress concentration before failure and Point D: Final cracked RUC.



a. Five realizations of randomly distrubuted 28 fiber RUC, b. RUC size variation

A combined experimental-micromechanical analysis approach was employed to characterize the matrix material in-house and use the experimental results for matrix material as an input to the micromechanical model. The characterization began with cure kinetic study to accurately predict the cure of the matrix material when subjected to a thermal cycle. This characterization task was followed by stiffness measurement using a Dynamic Mechanical Analyzer (DMA). Combining the cure kinetics with the DMA, the stiffness of the matrix material as a function of cure was obtained. Finally, the strength of the matrix material was measured by tensile testing specimens subjected to different thermal cycles which eventually yielded strength measurements as a function of cure state. The mechanical response (strength and stiffness) of the neat matrix material for different degrees of cure were used as inputs to the micromechanical model to predict failure of the composite material.

Closely packed fibers act as stress rises which could lead to crack initiation in the composite. Thus, a random fiber distribution was modeled to investigate the effect of fiber packing on the strength and failure of the composite. In order to ensure convergence, the number of fibers were increased from 5 fibers in a repeating unit cell (RUC) to 50 fiber RUC, while keeping the fiber volume fraction constant. Convergence was achieved for the 50 fiber RUC, which could accurately predict the strength and stiffness of the composite material based of individual components. This approach was employed for two different resin formulation, RIMR 135/RIMH 137 and RIMR 135/RIMH 1366, prior being the baseline system for the analysis.

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