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

Mechanical Property Enhancement Predictions for Matrix Material

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Curing results in spatial variability of mechanical properties of composites and uneven cure consolidation when large structures are manufactured. Different properties can be obtained as a function of different processing conditions. During curing residual stress build-up due to mismatch in thermo-mechanical properties of fiber and matrix. Inhomogeneous thermo-mechanical property distribution within the part, along with manufacturing defects such as local variations in volume fraction, voids, porosity and wrinkles may affect composites behavior. All these aspects of manufacturing make the correlation between resin properties and its in-situ behavior at the composite level very difficult to establish. As a result, the trade-off between resin properties and composite performance becomes difficult to achieve in design phase. In order to accurately predict transverse composite properties, we proposed a three-step approach involving 1) material characterization (cure kinetics, stiffness and strength measurement), 2) numerical studies using the Finite Element Method (FEM) of composite microstructures and 3) experimental validation (see Figure 1). Accurate material characterization is fundamental to study curing. Through this study we are creating a material database of thermo-mechanical property evolution as a function of cure. This data can be implemented in FE modeling to predict transverse composite strength and stiffness at the micro-scale while accounting for random fiber distribution and fiber volume fraction variations (see Figure 2). Transverse tensile testing of thin unidirectional laminates is used to establish boundaries of applicability for theory of micromechanics and provide experimental validation for numeric predictions. CT-scans are used to quantify void content within tows in defective specimens and to assess defect morphology. Improved prediction of transverse elastic modulus was used at the blade level to quantify resin benefits in terms of resistance to bending, torsion and buckling loads.

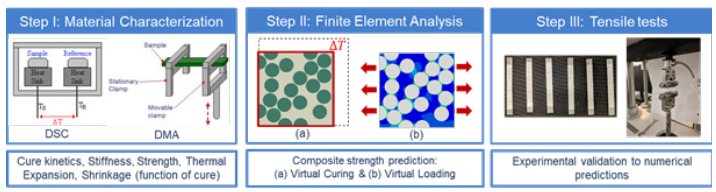
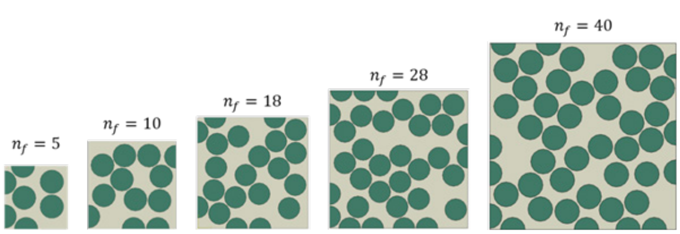
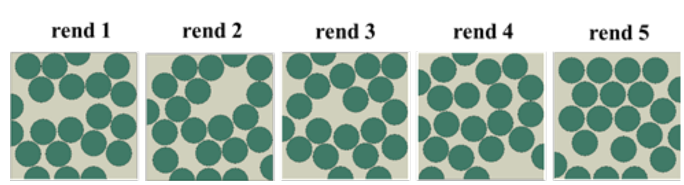


Figure 1:
Three-step approach adopted for enhanced matrix property predictions

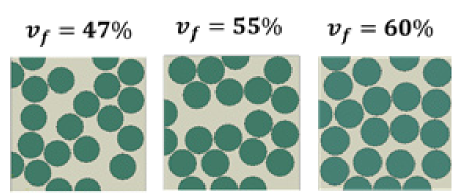
Output of this project will enable resin and composite manufacturers to assess various resin formulations in design phase using minimum testing. Relying on FE models for accurate transverse property predictions will reduce testing in design phase, thus reducing the head cost of the blade.
This study will provide better understanding of the most relevant resin thermo-chemical properties to optimize to achieve enhanced performance across the composite characteristic length scales up to the blade level.



(a) RVE size variation



(b) Different renditions to account for random fiber distribution



(c) Fiber volume fraction variation

Figure 2:
FE modeling of composite microstructure accounting for (a) Representative Volume Element (RVE) size variation, (b) random fiber distribution within an RVE and (c) variation in fiber volume fraction.

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