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

Mechanical Property Enhancement Prediction for Matrix Materials

Principal Investigator:
Alireza V. Amirkhiz, University of Massachusetts Lowell

Co-Principal Investigator:
Christopher Hansen, University of Massachusetts Lowell

Student Researcher:
Joshua Morris, University of Massachusetts Lowell

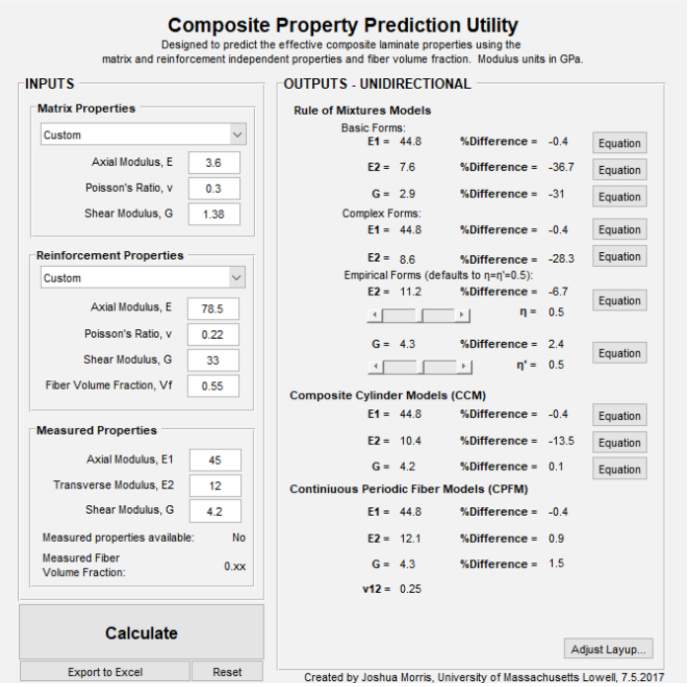
IAB Mentors:
Stephen Nolet, TPI Composites
Hui Zhou, Huntsman
Marc Chouhinard, Huntsman

Optimization of the resin properties could offer a substantial boost to wind turbine blade transverse and shear strength. Failure modes with complex deformations, such as twisting, experience high transverse and shear stresses that can cause delamination or trailing edge splitting. The composites resistances to these stresses are heavily dependent on the resin mechanical properties. Micromechanical models that could be used to predict composite stiffness properties and guide resin research efforts are critically inaccurate for transverse and shear response. A more reliable micromechanical model needs to be developed that can be used to characterize the influence of the resin properties on a full scale turbine blade.

Traditional micromechanical models were examined for discrepancies and improved upon using a newly developed model called the Continuous Periodic Fiber Model (CPFM). The model was validated using experimentally obtained data provided by TPI Composites. The difference between the measured moduli and the CPFM determined moduli is 3% for the axial tensile modulus, 12% for transverse, and 3% for shear. This is twice the accuracy of the next best model. A tool was created in MATLAB that performs the modulus prediction and applies layup adjustments to accurately determine the effective composite properties using several micromechanical models, including CPFM. The sensitivity of the results indicate the need for an accurate micromechanical model, namely CPFM, in order to correctly analyze the influence of resin on the blade response.

A numerical study was performed to determine the effective composite stiffness dependence on the resin properties. The study was performed for several resin modifications and layups so that a catalog of expected influence factors could be created. An increase of the resin Young's modulus, and proportionally its shear modulus, was determined to be the most beneficial pathway to improving the composite transverse and shear response. For a 20% increase to the matrix Young's modulus, the composite's effective transverse and shear moduli rose by 16%. Applying this enhanced resin in structural analysis of a utility scale wind turbine blade presented various distinct advantages, such as higher calculated buckling load and higher structural rigidity (as measured by tip displacement for a unit load).

This research indicates that optimization of the resins used to produce composite wind turbine blades is a suitable pathway to strengthen blades against transverse and shear failure modes. Researchers and manufacturers can use the tool and analysis results to determine whether materials with enhanced properties can be economically introduced and enable the potential advances to blade design that result.


Composite Property Prediction Utility
Designed to predict the effective composite laminate properties using the matrix and reinforcement independent properties and fiber volume fraction. Modulus units in GPa.

INPUTS

Matrix Properties
Custom
Axial Modulus, E 3.6
Poisson's Ratio, v 0.3
Shear Modulus, G 1.38

Reinforcement Properties
Custom
Axial Modulus, E 78.5
Poisson's Ratio, v 0.22
Shear Modulus, G 33
Fiber Volume Fraction, Vf 0.55

Measured Properties
Axial Modulus, E1 45
Transverse Modulus, E2 12
Shear Modulus, G 4.2
Measured properties available: No
Measured Fiber Volume Fraction: 0.xx

OUTPUTS - UNIDIRECTIONAL

Rule of Mixtures Models
Basic Forms:
E1 = 44.8 %Difference = -0.4
E2 = 7.6 %Difference = -36.7
G = 2.9 %Difference = -31
Complex Forms:
E1 = 44.8 %Difference = -0.4
E2 = 8.6 %Difference = -28.3
Empirical Forms (defaults to η=η'=0.5):
E2 = 11.2 %Difference = -6.7
η = 0.5
G = 4.3 %Difference = 2.4
η' = 0.5

Composite Cylinder Models (CCM)
E1 = 44.8 %Difference = -0.4
E2 = 10.4 %Difference = -13.5
G = 4.2 %Difference = 0.1

Continiuous Periodic Fiber Models (CPFM)
E1 = 44.8 %Difference = -0.4
E2 = 12.1 %Difference = 0.9
G = 4.3 %Difference = 1.5
v12 = 0.25

Created by Joshua Morris, University of Massachusetts Lowell, 7.5.2017

PROJECT ID: A5-16