Abstract

Composite materials have become a material of choice for wind turbine blade designers and manufacturers. The main load carrying structure in the wind turbine blade is the spar and is made primarily of unidirectional (UD) fibers to resist the predominantly flap wise bending loads. This poster will describe some of the work done at GE, to develop a fundamental understanding of the effect of fiber waves on the compressive strength of the UD composite.

Causes for Defects

Wind turbine industry deals with very large composite parts in terms of thickness and length. The combination of large part thickness and long length scales can lead to introduction of defects in the manufactured blade, which can be detrimental to blade designs driven to maximize the specific strength.

Commonly Observed Defects in UD Composites

- Fiber waves or wrinkles
- Voids or delaminations

The presence of defects can lead to significant reduction in the compressive strength design margins causing premature failure of the blade structure.

Objectives

- To develop a fundamental understanding of the effect of fiber waves on the compressive strength of the UD composites as a function of the fiber wave geometric parameters by
  - Conducting controlled experiments at coupon level with predefined defects
  - Developing a micromechanical finite element model and validating it with coupon data
  - Using the combination of experiments and micromechanical models to develop transfer functions for compressive strength of UD composites with defect waves

Methods

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<th>Fiber Elastic Properties</th>
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<td>Youngs Modulus, E</td>
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<td>Poissons ratio, ν</td>
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Results

Experimental Results

- Compressive tests on defect coupons with premanufactured defect inserts indicated that
  - The predominant failure mode is by kinking of fibers.
  - Some cases combined kinking-fracture was also observed
  - Real time optical strain imaging using digital image correlation was performed on test coupons
  - Optical strain maps show strain localization prior to kink band formation
  - Tests indicated the failure mechanism by fiber microbuckling leading to kink band formation

Micromechanical Model Predictions

Micromechanical finite element models were evaluated for different defect geometries and locations. The results from the fully nonlinear model were compared with test coupon data

- The 2D FE model simulated the kink band failure mode
- The model strength predictions were comparable to the failure strengths observed during testing of defect coupons

Conclusions

The combined test and modeling data indicates a significant correlation between compressive strength and defect magnitude and location

- The compressive strength drops by 40% when the sharpness of the wave increases by four times
- For the same defect geometry thicker defects will lead to lower failure strength
- Further modeling work is needed to characterize the strength dependency on the resin properties and to develop a probabilistic strength model

References