IOWA STATE UNIVERSITY
College of Engineering

Wind Energy Initiative (WEI)

Compression Failure in Marcels of Wind Turbine Blades

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Abstract

In order for wind to be a viable renewable energy source, turbine blades that are cheaper stronger, lighter, and longer-lived need to be developed. During blade manufacturing, defects such as dry patches, wrinkles, delamination, poor curing, and fiber misalignment are common. A wrinkle, also known as a marcel, is formed when fiber layers are unable to lay flat during infusion; the result is an outward wrinkle. Previous studies indicate that marcels can significantly decrease the compressive strength and fatigue life of composites. The purpose of this research was to test the influence of marcel size on composite compressibility and failure.

Context

- Blades are exposed to loads from wind and gravity; wind induces bending on blades causing tension and compression while gravity causes tension and compression when blades are in the vertical and horizontal positions. Therefore, wind turbine blades must be able to withstand both extreme and time varying loads over their lifetime.
- During blade manufacturing, wrinkles, also known as marcels, are formed when the fiber layers are unable to lie completely flat during infusion (the process used to make blades); the result is an outward wrinkle. The sizes of the marcels are often characterized by their aspect ratios (AR), a ratio of the wave length to height. Higher AR's correspond to smaller waves.
- Marcels are known to decrease max failure load and fatigue strength of blades.

Figure 1. Side view of two composites with artificially induced marcels. Sample A has an AR of 12 while sample B has an AR of 20

Problem

- There is inconclusive evidence regarding the size (or aspect ratio) of marcels suitable for meeting inspection or performance measures.
- Therefore, the goal of this project was to test the compressibility of fiberglass composite materials with marcels containing AR's of 12-20. The results will improve understanding of the effect of composite fiber waviness on compressive strength.

Approach/Methodology

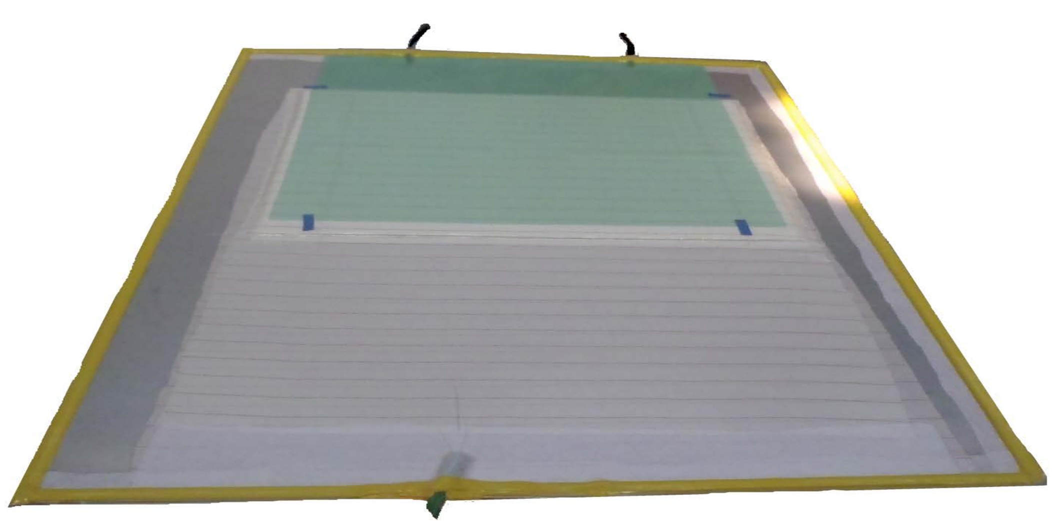


Figure 2. The bag infusion set-up.

Bag infusion for making samples (figure 2)

- Ten layers of unidirectional fiberglass (18"x 24") were placed between two vacuum bags (approximate dimensions of 50" x 30") and laid flat on a table.
- Artificial waves with AR's of 12, 14, 18, and 20 were arranged at the center of the fiberglass layers.
- All openings within the bags were then sealed using tack tap. After that, the system was placed under vacuum (approximately 28 psi) and infused with epoxy. Samples were allowed to cure at room temperature for 24 hours

Compression testing

- Becker's equation for flat plates in compression was used to determine dimensions for preventing buckling:

$$\sigma_{cr} = \frac{\pi^2 \, k_c E}{12\,(1-\nu^2)} \left(\frac{t}{b}\right)^2$$

- Samples for testing were cut to dimensions of 6" (2" + 4 " in clamps) x 0.5423" x .29.

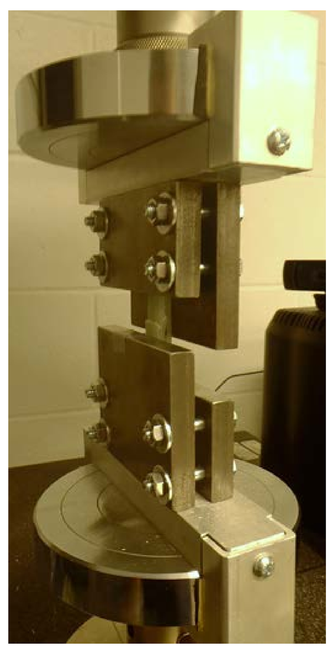
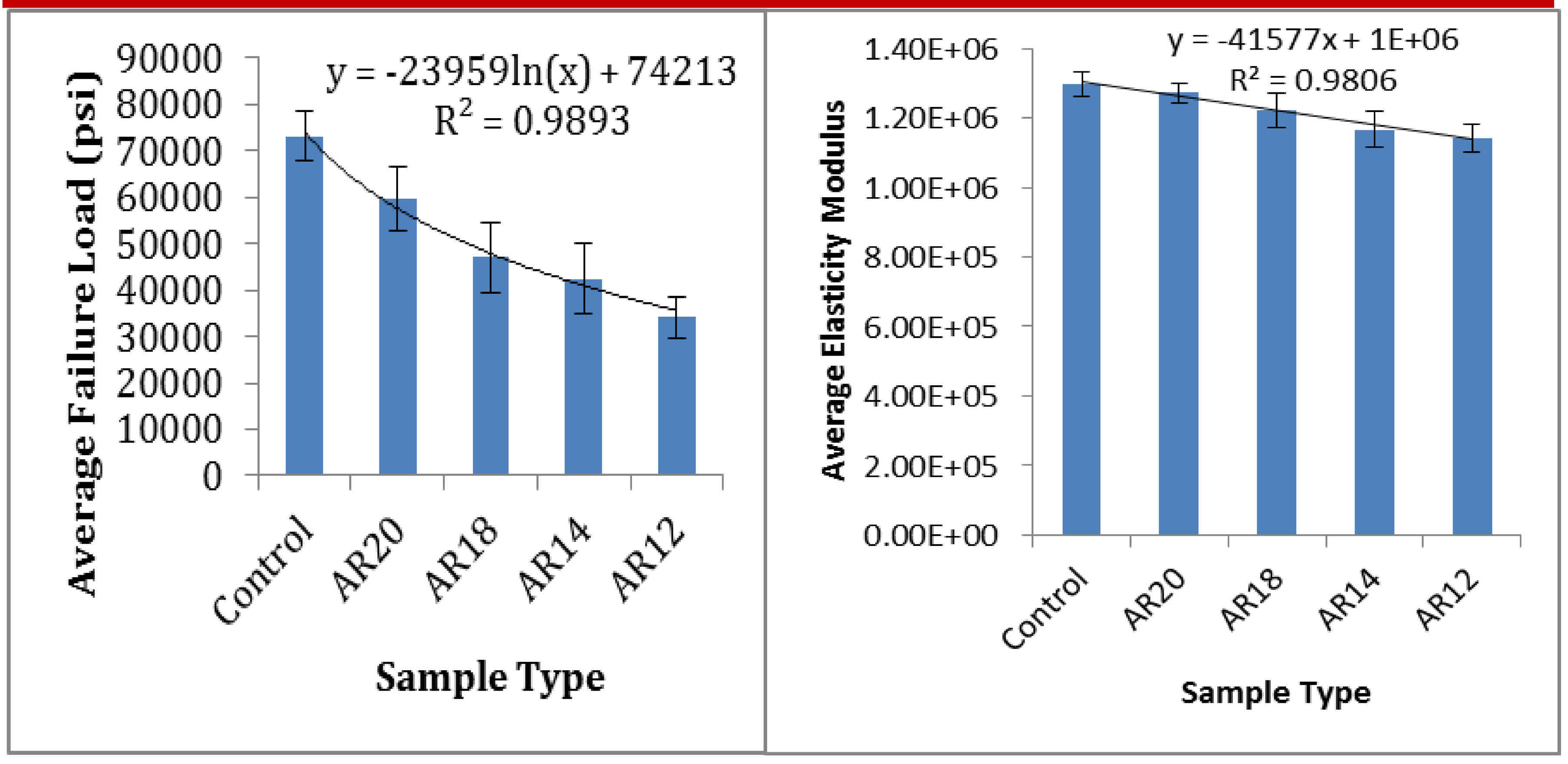


Figure 3. Device designed to clamp and hold samples to Instron plates during compression.

Results



Left Graph: Shows the average failure load for varying AR's. Right: Shows the average elasticity modulus for each AR. One important note is that averages were taken from 16 samples for each AR.

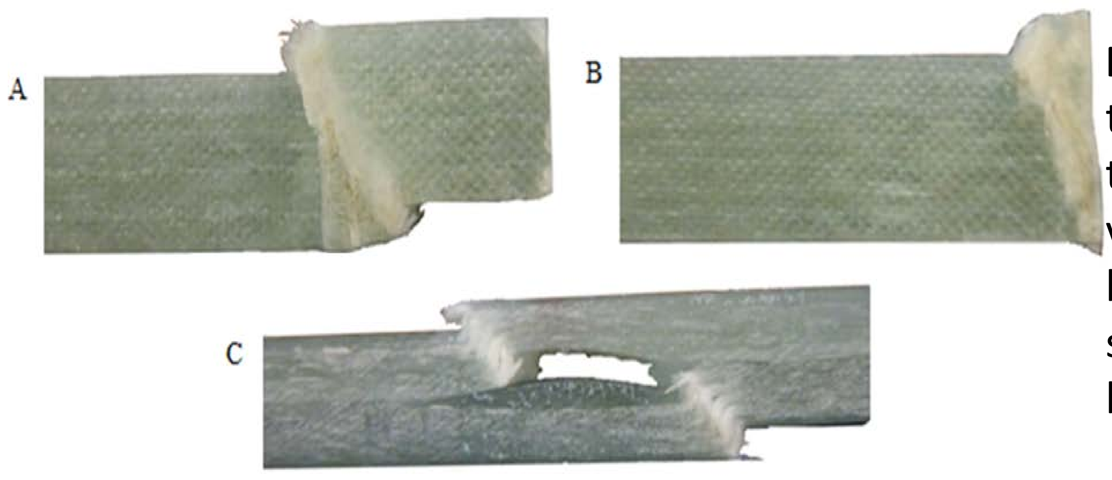


Figure 4. To the left: Shows the types of breaks observed during testing. Figure A and B show the top view of different control sample breaks whereas Figure C shows a side view of a common marcel break.

Conclusions

- The failure loads were correlated to a log curve while the elastic moduli were correlated to a linear curve.
- The control samples had an average failure load of 73,000 psi whereas the AR 12 (biggest wave analyzed) samples had a failure load of approximately 34,000 psi (represents a 53% decline in failure load strength).
- The greatest elastic modulus was observed in the control samples (1.30E+06) and the lowest (1.14E+06) in AR12.
- Theoretically, the use of blades with marcels should be avoided in industry because this study showed that the average failure load significantly decreases with composites containing waves.
- The log curve suggests that even a small wave (AR 20) causes a significant drop in average failure load. However, the decrease in failure load becomes smaller as the wave becomes bigger.

Future Work: Analyze the effects of marcel size on blade fatigue strength.

Acknowledgements

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