Testing and Analysis of Low Cost Composite Materials Under Spectrum Loading and High Cycle Fatigue Conditions

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ABSTRACT:

This paper provides an overview of the results of a twelve-year experimental study of low-cost composite materials for wind turbine blades. Wind turbines are subjected to 10^9 or more potentially damaging fatigue cycles over a typical service lifetime of 30 years. Stress conditions cover the range from tension dominated to compression dominated, with associated differences in and potential interactions between failure modes. Wind turbine design codes typically assume a Miner's rule linear damage law to predict failure from constant amplitude test data, which appears to be significantly non-conservative. The paper summarizes results from three areas. First, an extensive constant amplitude database including over 8800 test results with varying R-value (minimum stress / maximum stress) on over 150 materials, including variations in type of fiber and matrix, fiber content, reinforcement architecture, environment, flaws, and manufacturing method. Second, for a single E-glass/polyester material system, a study of spectrum loading effects. The third area is a study of high cycle fatigue behavior, including some specialized tests to 10^{10} cycles.

New results are presented comparing typical wind turbine loads from a long term study, resolved by R-ratio, with a detailed data set for a typical structural laminate, tested at thirteen R-values. These results allow a direct comparison of turbine loads and material fatigue resistance at each R-ratio. The Goodman diagram is the most detailed to date, including several loading conditions which have been poorly represented in earlier studies. The new data should allow more accurate lifetime prediction under spectrum loading.