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PROGRESSIVE DAMAGE ANALYSIS AND TESTING OF COMPOSITE LAMINATES WITH FIBER WAVES

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ABSTRACT

In this work, the Progressive Damage Analysis (PDA) of composite laminates with waves was developed, experimentally validated, and discussed. PDA using Continuum Damage Modeling (CDM) and Discrete Damage Modeling (DDM) was conducted. In CDM, the material continuum constitutive properties are updated to incorporate the influence of progressive damage. In DDM, the actual damage is modeled, consistent with the progressive damage model analysis and observations. A commercial finite element code ABAQUS was used for all of the analysis with specialty user subroutines for the CDM and DDM. The laminate wave parameters (wavelength and amplitude) were determined from a statistical analysis of as-manufactured laminates from failed composite wind turbine blades. Laminates with waves under tension and compression loading were considered to create a benchmark set of tests for laminates and waves, and to provide an unambiguous comparison between CDM and DDM for this type of defect. Both methods (CDM and DDM) are compared and contrasted with experimental data. It is important to note that no assumed damage (such as a crack or other discontinuity) was necessary for the analysis. The failure mode and progressive damage is a consequence of the analysis. Correlations are found with each, and the pros and cons are evaluated and discussed. Better correlations were found with DDM, but accounting for nonlinear shear in the stress-strain response using CDM in the analysis provided numerical stability and the best experimental/analytical correlations.

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