Damage Evolution due to Thermal Oxidation of Laminated Polymeric Matrix Composites

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Abstract

Thermal oxidation is a major cause for damage initiation and propagation in polymer composites operating at elevated temperatures. A methodology for simulating the initiation and propagation of discrete cracking due to oxidation-- induced strains is presented in this poster. The orthotropy in the stiffness and strength of the laminate as well as the shrinkage strains induced by the chemical changes in the oxidizing resin lead to complex damage patterns that initiate from the surfaces exposed to oxidative environment. The rate of penetration of oxidation zone into the thickness of the composite and the rate of discrete crack growth are closely coupled. The morphological changes due to oxidation are computed as a function of the aging time using a finite element model. The oxygen diffusion into the composite from the surface and the reactions between dissolved oxygen and polymer cause chemical changes that lead to shrinkage strains. The stress states in the composite due to chemically induced strains are computed using extended finite element technique (XFEM). Oxidation state dependent stiffness, strength and toughness properties are then used to determine initiation and propagation characteristics of discrete cracks. A probabilistic strength distribution model is considered for randomly and preferentially initiating discrete cracks at weak points on the oxidizing surfaces. Simulations are performed for cross--ply laminates with polyimide matrices and the results are validated with previously published experimental results. Simulations are also shown for laminates with open holes, which are exposed to oxidative environments. The model for determining the damage evolution presented in this paper can be used for the prediction of use-life and durability of composites structures operating at high temperatures.