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Long-term Thermo-Oxidative Degradation of High-Temperature Polymers and their Composites

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Abstract

Thermal oxidation is a significant degradation mechanism that limits the service life of high-temperature polymers and their composites. The diffusion and reaction of atmospheric oxygen with the polymer cause morphological and mechanical behavior changes, which lead to damage initiation and eventual failure. A methodology that considers the coupled physical, chemical, and mechanical interactions taking place in the material during oxidation is required for accurate prediction of in-service life. We have developed a diffusion-reaction-conversion model that predicts the oxidation state in the material at any time and temperature. Furthermore, we coupled a mechanics model that determines the stress fields and damage state to simulate degradation. Both oxidation and damage growth predictions are verified with isothermal aging experiments on several high-temperature polymer systems. Using the developed framework, the oxide layer growth can be predicted for neat resins and their composites at lamina and laminate scales. Results are presented for polyimide and bismaleimide polymer systems and their composites reinforced with carbon fibers.