
Aging-Induced Embrittlement in Short-Fiber Reinforced Thermoplastics: A Micromechanical Approach Using Numerical Homogenization

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Abstract

Aging studies are critical for ensuring that engineering plastic components can endure physico-chemical degradation under operating conditions. The degradation kinetics can be assessed by exposing parts to aging environments and testing them afterwards. However, this empirical approach is time-consuming and costly. An advantageous approach would be to simulate those aging tests. The aim of this research program is to develop a simulation method for virtualizing the aging tests of injection-molded thermoplastic parts, specifically addressing aging of the mechanical behavior at the component level. To achieve this in the framework of finite element (FE)-based mechanical simulations, it is crucial to establish failure criteria based on local aging descriptors. This work is focused on the hydrolytic degradation of polyamide 6.6, reinforced with 30 wt.% short glass fibers. Hydrolytic aging of 4 mm thickness PA66-GF30 part results in non-limited diffusion hydrolysis leading to a uniform reduction in molecular weight of the polymer matrix, causing progressive embrittlement, which manifests as a reduction in strain at break during uniaxial tensile tests. To achieve accurate simulations, the research aims to develop a failure criterion based on local aging descriptors. Using micro-mechanical analysis of a 3D representative volume element (RVE), the study links local degradation effects (such as molecular weight reduction) with the overall mechanical response of the composite. This approach allows finite element (FE) simulations to predict aged component failure. The study also discusses the construction of the RVE, which accounts for fiber microstructure, and the identification of the elastoplastic constitutive law for the PA66 matrix. The focus is on proposing a physics-based failure criterion that correlates with damage initiation under various levels of hydrolytic degradation.

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