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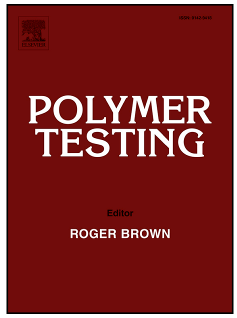

DMA based characterization of stiffness reduction in long fiber reinforced polypropylene

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Test Method

DMA based characterization of stiffness reduction in long fiber reinforced polypropylene

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ABSTRACT

This paper describes an experimental technique based on dynamic mechanical analysis (DMA) that is shown to be useful in separating nonlinear viscoelastic effects from the characterization of irreversible stress-induced damage responsible for stiffness reduction in fiber-reinforced polymer composites. In this work, we characterize the damage evolution of polypropylene (PP) reinforced with long, discontinuous glass fibers (GF) produced by the Direct Long-Fiber Thermoplastic/Compression Molding (D-LFT/CM) process. The experimental technique is comprised of three phases: 1) dynamic stabilization at low load to measure the time-dependent storage and loss moduli, followed by 2) a frequency sweep to provide rate-dependent viscoelastic properties and 3) a quasi-static application of a peak load. These three phases are repeated with the peak load of Phase 3 increased in each iteration. Experimental results for D-LFT/CM PP/GF30 presented here show a direct correlation between peak load and the irreversible stiffness reduction. Furthermore, the stabilization phase following peak load application is shown to lead to a stiffness recovery of up to 40% due to nonlinear viscoelastic recovery.

Keywords: fiber reinforced polymer, composites, LFT, DMA, damage, viscoelasticity

1 Introduction

With densities often well below 2 g/cm^3, fiber-reinforced polymers can have mass-specific stiffness and strength levels that compete with metallic alternatives and are, therefore, receiving considerable attention in the mass-reduction strategies of the transportation sector. While the stiffest and strongest composites are based on continuous fiber reinforcements, the geometric freedom and significantly reduced cycle times of discontinuous fiber composite manufacturing processes are more amenable to high-volume automotive applications. The Direct, Long-Fiber Thermoplastic process, coupled with compression molding (D-LFT/CM) is one such process that offers sub-minute cycle times and considerable geometric design freedom [1].

Challenges associated with the application of D-LFT/CM composites are related to the mechanical anisotropy that results from flow-induced fiber orientation distribution in the compression molding operation, and the characterization of the viscoelastic behavior inherent in the thermoplastic matrix material. Fiber orientation distribution has been characterized by techniques such as computed microtomography [1,2]. Microstructure based