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Cyclic Behavior and Modeling of Small Fatigue Cracks of a Polycarbonate Polymer

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Abstract

The fatigue behavior of a polycarbonate (PC) thermoplastic material was experimentally investigated and modeled using a MultiStage Fatigue (MSF) model that evaluates fatigue crack incubation, Microstructurally Small Crack (MSC) growth, and Long Crack (LC) growth. A set of fully reversed strain controlled tests were conducted, and an analysis of the fracture surfaces was performed using Scanning Electron Microscopy (SEM) in order to quantify the structure-property relationships for the MSF model. Fractography of the microstructure revealed that incompletely melted PC pellets were present in the polymer material that nucleated the cracks along with crazes generated on the surface. Crack lengths and fatigue crack growth rates for the MSC regime were measured from striation observations on the fracture surfaces. Discontinuous crack growth (DCG) cycles between fatigue striations, for the current iteration of the model, are accounted for by the MSF crack incubation regime. Finally, the microstructure sensitive MSF model was implemented using the observed fatigue crack growth measurements. In addition, a Monte Carlo (MC) Simple Random Sampling (SRS) routine was implemented to quantify the model uncertainty for crack growth.

Key Words: Polycarbonate, MultiStage Fatigue, Uncertainty

1. Introduction

Polymers are used in many engineering applications such as aerospace structures, automotive parts, pressure vessels, and military equipment and vehicles. Currently, polymers are attracting much attention because the potential of lightening these mechanical structures. Like other engineering materials, polymers fail as a result of fatigue damage from the nucleation and growth of fatigue cracks. Therefore, an extensive use of polymeric materials requires a better understanding of its fatigue behavior.

Traditionally, fracture mechanics has been employed to characterize the cyclic behavior of polymers (Hertzberg *et al.* 1970, Elinck *et al.* 1971, Hertzberg *et al.* 1980, Skibo *et al.* 1977, Radon 1980, Konczol *et al.* 1984, Schinker *et al.* 1984, Kim *et al.* 1995). The study of fatigue crack propagation in polymers allows a detailed analysis of the fracture process. In addition, the study of fatigue using the fracture mechanics method allows for the separation of the initiation and crack propagation stages (Hertzberg *et al.* 1970, Hertzberg *et al.* 1980). For crack propagation in thermoplastics two different processes have been identified, normal and retarded crack growth (Konczol *et al.* 1990), with both being associated with craze evolution at the crack tip. In the analysis of the fracture surface for polymers there has been observed two types of marks (Schinker *et al.* 1984), which are associated with the two types of crack propagation: