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Effect of stabilizers on the failure behavior of glass fiber reinforced polyamides for mounting and framing of solar energy applications

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Abstract

In the present paper, the influence of stabilizers on the fatigue crack growth (FCG) behavior of glass fiber reinforced polyamides (PA) for mounting and framing of photovoltaic modules, photovoltaic/thermal modules and other thermal collectors was investigated. A proper polymer stabilization is essential for a sophisticated substitution of commonly used materials (aluminum, stainless steel) to ensure longer product lifetimes. The implementation of polymeric materials to such applications induce the advantages of lightweight and cost-effectiveness. In total, five different glass fiber reinforced PA grades differing in their stabilizer packages were characterized. As a benchmark material, a commercial grade with a low stabilizer content was used. To establish the other four materials, this PA grade was modified with masterbatches varying in their stabilizer packages. While one masterbatch contained no stabilizer, the three remaining masterbatches comprised phenolic- and amino-based stabilizers. Tests were performed at the temperatures 80°C and 95°C in the environmental media air and water with compact type specimens. The effect of loading conditions on FCG behavior was investigated showing significantly reduced resistance with increasing temperature and a slightly lower resistance in water environment. Moreover, an influence of the used stabilizer package on the FCG kinetics was obtained. Inferior FCG resistance was determined for the PA modified with the non-stabilized masterbatch. The PA grade containing the phenolic-based stabilizer package exhibited a significantly superior FCG resistance compared to the benchmark material.

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Keywords: polyamide; mounting system; stabilizer; glass fiber reinforced; photovoltaics

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1. Introduction

The state of the art materials for mounting and framing of photovoltaic (PV) modules, photovoltaic/thermal (PV/T) modules and other thermal collectors are stainless steel and aluminum [1-3]. In the context of cost-effectiveness and lightweight opportunities, polymeric material solutions play a decisive role in substitution of commonly used materials. To additionally ensure a long-term performance of the polymeric materials, a proper stabilizer package is essential [4,5].

Besides the mechanical loads (e.g., due to the weight of the mounted solar energy application) the mounting and framing materials have to bear up environmental loads (e.g., temperatures, environmental media) [6]. Both loading types are strongly affecting the performance of advanced polymeric materials [7-10]. Further research work [8,11-13] already showed detailed investigations on the effect of mechanical loads superimposed with different environmental loads.

Thus, a major area of interest within this paper is the effect of the stabilizer package on the fracture mechanics behavior of different glass fiber reinforced polyamide (PA) grades in critical environmental conditions. In previous research projects [8,12,14] a test setup was developed and adopted allowing superimposed mechanical-environmental loads. With this equipment, the fatigue crack growth (FCG) resistance of different polyamide types differing in their stabilizer package (e.g., phenolic-based stabilizer, amino-based stabilizer) was investigated under cyclic loading in service near environmental conditions.

2. Background

Mechanical quasi-brittle failure caused by crack initiation and slow crack propagation can be characterized with the concept of linear elastic fracture mechanics [11,15,16]. In this concept, the crack growth rate (da/dN) indicates the crack growth per cycle. The stress field occurring at the crack tip can be described by the stress intensity factor K (see eq. 1). Equation 1 contains σ, the applied stress, Y, a geometry factor and a, the crack length.

$$K = \sigma \cdot Y \cdot \sqrt{a} \tag{1}$$

For this quasi-brittle failure, three different regions are observable in the crack growth curve and are commonly depicted in a double logarithmic plot (see Fig. 1). In region I, the crack growth rate is decreasing with a decreasing load K_I until reaching the threshold value $K_{I,th}$.

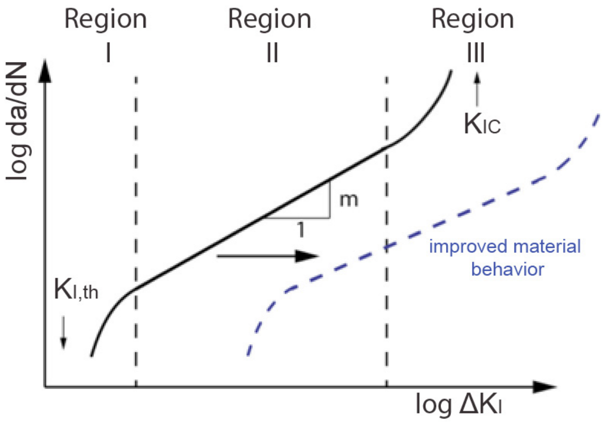

Fig. 1. Schematic plot of the crack growth rate da/dN as a function of the stress intensity factor ΔK_I.