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A physically-based constitutive model for anisotropic damage in rubber-toughened glassy polymers during finite deformation

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ABSTRACT

The present work focuses on the development of a physically-based model for large deformation stress–strain response and anisotropic damage in rubber-toughened glassy polymers. The main features leading to a microstructural evolution (regarding cavitation, void aspect ratio, matrix plastic anisotropy and rubbery phase deformation) in rubber-toughened glassy polymers are introduced in the proposed constitutive model. The constitutive response of the glassy polymer matrix is modelled using the hyperelastic–viscoplastic model of Boyce et al. (1988, 2000). The deformation mechanisms of the matrix material are accounted for by two resistances: an elastic–viscoplastic isotropic intermolecular resistance acting in parallel with a visco-hyperelastic anisotropic network resistance, each resistance being modified to account for damage effects by void growth with a variation of the void aspect ratio. The effective contribution of the hyperelastic particles to the overall composite behaviour is taken into account by treating the overall system in a composite scheme framework. The capabilities of the proposed constitutive model are checked by comparing experimental data with numerical simulations. The deformation behaviour of rubber-toughened poly(methyl methacrylate) was investigated experimentally in tension at a temperature of 80 °C and for different constant true strain rates monitored by a video-controlled technique. The reinforcing phase is of the soft core–hard shell type and its diameter is of the order of one hundred nanometers. The particle volume fraction was adjusted from 15% to 45% by increments of 5%. The stress–strain response and the inelastic volumetric strain are found to depend markedly on particle volume fraction. For a wide range of rubber volume fractions, the model simulations are in good agreement with the experimental results. Finally, a parametric analysis demonstrates the importance of accounting for void shape, matrix plastic anisotropy and rubber content.

1. Introduction

Amorphous thermoplastic polymers have become important engineering materials in recent years (e.g. Haward and Young, 1997). For this purpose, rubber particles are commonly incorporated into thermoplastic polymers in order to promote energy dissipation processes in an otherwise brittle glassy polymer matrix. The sequences of events, namely, cavitation of the dispersed rubber particles, crazing and shear yielding in the polymer matrix, contributing to the inelastic deformation of rubber-toughened glassy polymers, are not very well understood yet. There is considerable qualitative understanding of

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