



Rate dependent finite strain constitutive model of polyurea

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ARTICLE INFO

Article history:

Received 7 October 2009

Received in final revised form 7 October 2010

Available online 16 October 2010

Keywords:

Constitutive modeling

Polyurea

Nonlinear viscoelasticity

Finite strains

ABSTRACT

Continuous loading and unloading experiments are performed at different strain rates to characterize the large deformation behavior of polyurea under compressive loading. In addition, uniaxial compression tests are carried out with multistep strain history profiles. The analysis of the experimental data shows that the concept of equilibrium path may not be applied to polyurea. This finding implies that viscoelastic constitutive models of the Zener type are not suitable for the modeling of the rate dependent behavior of polyurea. A new constitutive model is developed based on a rheological model composed of two Maxwell elements. The soft rubbery response is represented by a Gent spring while nonlinear viscous evolution equations are proposed to describe the time-dependent material response. The eight material model parameters are identified for polyurea and used to predict the experimentally-measured stress–strain curves for various loading and unloading histories. The model provides a good prediction of the response under monotonic loading over wide range of strain rates, while it overestimates the stiffness during unloading. Furthermore, the model predictions of the material relaxation and viscous dissipation during a loading–unloading cycle agree well with the experiments.

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1. Introduction

Polyurea is used to mitigate structural damage during impact loading because of its good damping performance. In addition, it is utilized by various industries because of its fast setting time as well as its good chemical and fire resistance. It has found applications in army vehicles for blast protection because of its high toughness-to-density ratio at high strain rates. Several researchers reported that polyurea shows a highly nonlinear viscoelastic behavior at finite strains (e.g. Amirkhizi et al., 2006; Bogoslovov and Roland, 2007; Roland et al., 2007; Shim and Mohr, 2009). The mechanical properties of linearly viscoelastic materials may be described by the relaxation modulus (or creep compliance) which is independent of strain magnitude. However, nonlinear viscoelasticity is characterized by a decrease (or increase) of the relaxation modulus (or creep compliance) with increasing strain or decreasing stress (e.g. Brinson and Brinson, 2008).

Most finite viscoelasticity models of elastomers are formulated using either (1) the so-called hereditary integral approach or (2) the framework of multiplicative decomposition of the deformation gradient. Motivated by linear viscoelastic models, hereditary integral models are formulated in terms of relaxation or memory functions (e.g. Lockett, 1972). Widely used single integral theories are the theory of Finite Linear Viscoelasticity (Coleman and Noll, 1961) and the Bernstein, Kersley and Zaps (BKZ) Theory (Bernstein et al., 1963); both make use of several relaxation/memory functions. Significant efforts have been made to improve these theories and to reduce the number of required material parameters (e.g. Lianis, 1963; McGuirt and Lianis, 1970; Leonov, 1976; Johnson et al., 1994; Haupt and Lion, 2002). Nonlinear viscoelastic behavior is often considered as the superposition of a rate-independent nonlinear elastic response (so-called equilibrium part) and a

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