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Jean-Luc Bouvard, Esteban B. Marin, Douglas J. Bammann, Mark F. Horstemeyer

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FORMULATION AND VALIDATION OF A THERMOMECHANICAL VISCOPLASTIC CONSTITUTIVE MODEL FOR AMORPHOUS GLASSY POLYMER

J.L. Bouvard[a], E.B Marin[b], D.J. Bammann[b], M.F. Horstemeyer[b]

[a] CEMEF Mines ParisTech, France, jean-luc.bouvard@mines-paristech.fr

[b] Center for Advance Vehicular Systems, US, ebmarin@cavs.msstate.edu, bammann@cavs.msstate.edu, mfhorst@me.msstate.edu

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Introduction

Polymers exhibit a rich variety of mechanical behaviour originating from their particular microstructure. To capture such intricate structure properties, a number of polymer constitutive models have been proposed and implemented into finite element codes in an effort to solve complex engineering problems. However, developing improved constitutive models for polymers that are physically-based has proven to be a challenging area with important implications for the design of polymeric structural components.

Objectives

The objectives of this work is to develop a constitutive model able to capture: i) the time temperature dependence of glassy polymers; ii) the stress-state dependence of the material under compression/ tension/torsion conditions; iii) the thermomechanical behaviour of the material at medium strain rate; and iv) the mechanical behaviour under high strain rates (using Split Hopkinson Pressure Bar setup).

Methodology

In this work, a hierarchical multiscale modeling strategy is being developed to bridge nanoscale mechanisms to the macroscale/continuum by introducing structure-property relationships. First, molecular dynamics (MD) simulations were used to study deformation mechanisms during uniaxial tensile deformation of an amorphous polyethylene polymer [1]. Information obtained from the nanoscale was then used to develop a continuum level constitutive model. The material model accounts for the thermomechanical viscoplastic behavior of the glassy polymers. The constitutive model uses a formalism based on internal state variable methodology and departs from the spring-dashpot representation generally used to characterize the mechanical behaviour of polymers.

Results and analysis

The model has been validated with compression, tension, creep, torsion, impact, and high strain rate loading (using Split Hopkinson Pressure Bar setup) test data on an amorphous polycarbonate (PC) deformed at different temperatures and strain rates [2]. As shown in Fig. 1, the model was able to capture a large variety of test conditions that included different strain rates, temperatures, and stress states. However further improvements need to be considered in order: i) to bring more physics in the model (e.g. by using a non-Gaussian statistic chain approach of entangled polymer network [3]); ii) to extend the model to polymers behaviour in their rubbery state (following recent effort from [4]).
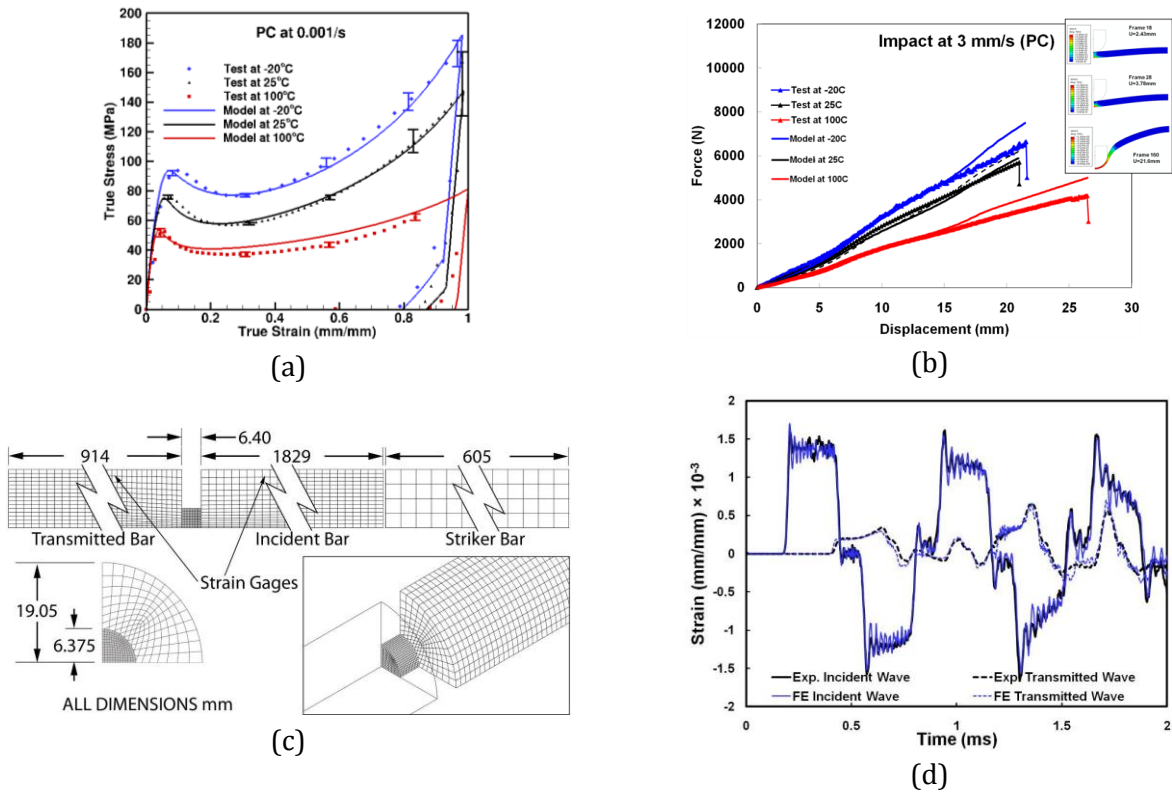
Fig. 1 Comparison between model predictions and experiments for (a) compression, (b) impact, (c) layout of the compression SHPB experiment and (d) simulation results

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