Accepted Manuscript

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PII: S0022-5096(17)30394-0
DOI: 10.1016/j.jmps.2017.10.010
Reference: MPS 3204

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 10 May 2017
Revised date: 4 October 2017
Accepted date: 16 October 2017

Please cite this article as: Babak Kondori, A. Amine Benzerga, Alan Needleman, Discrete Shear-Transformation-Zone Plasticity Modeling of Notched Bars, *Journal of the Mechanics and Physics of Solids* (2017), doi: 10.1016/j.jmps.2017.10.010

Discrete Shear-Transformation-Zone Plasticity Modeling of Notched Bars

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Abstract

Plane strain tension analyses of un-notched and notched bars are carried out using discrete shear transformation zone plasticity. In this framework, the carriers of plastic deformation are shear transformation zones (STZs) which are modeled as Eshelby inclusions. Superposition is used to represent a boundary value problem solution in terms of discretely modeled Eshelby inclusions, given analytically for an infinite elastic medium, and an image solution that enforces the prescribed boundary conditions. The image problem is a standard linear elastic boundary value problem that is solved by the finite element method. Potential STZ activation sites are randomly distributed in the bars and constitutive relations are specified for their evolution. Results are presented for un-notched bars, for bars with blunt notches and for bars with sharp notches. The computed stress–strain curves are serrated with the magnitude of the associated stress-drops depending on bar size, notch acuity and STZ evolution. Cooperative deformation bands (shear bands) emerge upon straining and, in some cases, high stress levels occur within the bands. Effects of specimen geometry and size on the stress-strain curves are explored. Depending on STZ kinetics, notch strengthening, notch insensitivity or notch weakening are obtained. The analyses provide a rationale for some conflicting findings regarding notch effects on the mechanical response of metallic glasses.

Keywords: Shear transformation zone plasticity; Metallic glasses; Shear banding; Notch; Size effects; Finite Element Method

1. Introduction

It has long been established that amorphous materials, such as metallic glasses, deform via local atomic re-arrangements (Cohen and Turnbull, 1959), mediated for instance by free volume (Spaepen, 1977) or local inelastic transformations often called shear transformation zones (Argon, 1979). Such local deformations at "weak spots" result from the lack of long-range atomic order, see Schuh et al. (2007) for a review. Typically, such materials are not

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