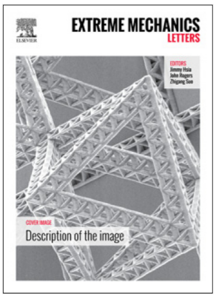
A mechanism of failure in shear bands

Mohammad E. Torki, Ahmed Amine Benzerga



PII: S2352-4316(18)30089-0
DOI: https://doi.org/10.1016/j.eml.2018.06.008
Reference: EML 385

To appear in: *Extreme Mechanics Letters*

Received date : 24 April 2018
Revised date : 12 June 2018
Accepted date : 21 June 2018

Please cite this article as: M.E. Torki, A.A. Benzerga, A mechanism of failure in shear bands, *Extreme Mechanics Letters* (2018), https://doi.org/10.1016/j.eml.2018.06.008

A Mechanism of Failure in Shear Bands

Mohammad E. Torki[a,b], Ahmed Amine Benzerga[a,b,c,*]

[a] *Department of Aerospace Engineering, Texas A&M University, College Station, TX 77843*
[b] *TEES Center for intelligent Multifunctional Materials and Structures (CiMMS), College Station, TX 77843*
[c] *Department of Materials Science & Engineering, Texas A&M University, College Station, TX 77843*

Abstract

We have carried out dilatant plasticity simulations to investigate the process of void-mediated failure inside a shear band. The constitutive model accounts for possibly inhomogeneous flow within the band, void rotation and void elongation. We found that the material in the band may soften with no increase in the void volume fraction. For a given matrix hardening capacity, the rate of softening was found to depend strongly on the ratio of shear band width to in-plane void spacing. The emergent softening led to complete loss of load bearing capacity thereby providing a physical mechanism of failure in shear bands. The mechanism is consistent with essential features of shear-fractured specimens in terms of surface roughness, porosity and dimple shape.

Keywords: Ductility; void growth; void coalescence; Lode angle; triaxiality

---

1. Introduction

Failure by shear banding is ubiquitous and occurs in complex fluids [1], granular materials [2, 3], rocks [4] polycrystals [5, 6], polymers [7] and metallic glasses [8, 9]. However, mechanisms of material separation inside shear bands have remained elusive. Elucidating a possible mechanism will not only potentially retard shear fractures, if desired, but also impact other applications where failure occurs under shear dominated loadings, as would arise in metalworking, ballistic penetration, etc. The stress state in shear bands is generally complex depending on the loading path prior to the onset of strain localization [10]. Correspondingly, shear bands are generally dilational. While arbitrarily large tension-to-shear ratios may be encountered inside shear bands, here we focus on situations of vanishingly small tension-to-shear ratios and aim to present a physical model of complete material separation.

Voids are the main defects mediating ductile fracture [11, 12]. The plastic enlargement of these defects dominates at moderate to high ratios of tension-to-shear stress (tension-dominated loading), Fig. 1a. Voids are also believed to play an important role at low tension-to-shear ratios (shear-dominated loading), Fig. 1b. However, a specific mechanism by which failure occurs is still lacking. Void nucleation is material specific and will not be addressed here.

Well-established micromechanical models of void growth and coalescence [13, 14] predict infinite ductility under shear loading. This is due to two idealizations: (i) that the void volume fraction, f, is the sole internal parameter representing the defects; and (ii) that void coalescence occurs upon attainment of a critical value of f. Since the rate of growth of f is

---

[*] Corresponding author
Email address: `benzerga@tamu.edu` (Ahmed Amine Benzerga)