STRAIN LOCALIZATION IN CIRCUMFERENTIALLY NOTCHED SAMPLES OF TWO POROUS SANDSTONES

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The behavior of open fractures under compressive loading can play an effective role in nucleating compactive failure in the form of discrete or diffuse compaction bands, as well as high-angle conjugate shear bands. This scenario may be important in the development of deformation bands and their geometric complexity in the field, and may apply to the development of borehole breakout. Expanding on the work of *Vajdova and Wong* (2003) [1], we investigated how strain localization develops from a structural and stress heterogeneity in cylindrical samples containing a V-shaped circumferential notch. We conducted triaxial compression tests at confining pressure optimum for compactive failure in the Bentheim and Berea sandstones. The critical stresses for initial yield map out a cap with a negative slope in the stress space, and the presence of the notch enhanced the local stress which induced damage to occur at remote stresses significantly lower than in the unnotched sample. We observed in the Bentheim sandstone discrete compaction bands that propagated through the sample cross-section with episodic force drops, and in the Berea sandstone conjugate diffuse bands accompanied by strain hardening. Compactive yield was marked by an upsurge in acoustic emissions, corresponding to the formation of a process zone at the notch tip extending 3-4 grains or 0.3 to 0.5 times the notch depth in both sandstones.

To probe the initial yield behavior and geometry of the process zone we developed a micromechanical model using linear elastic fracture mechanics. Given that the geometric attributes of the damage zones from microstructural observations seem to be similar we expect the initiation model to apply to both sandstones. We applied our generalized LEFM solution for a notch with a finite inclusion angle ? under axisymmetric compression to obtain a first order description of initiation of localization. The asymptotic stresses at the tip of a generic notch (in a polar coordinate system centered at the notch) are proportional to the radial vector r characterized by the exponent ?, where the singularity decreases from a value of -0.5 to -0.456 as the angle ? increases from 0 to $\pi/2$. The stress intensity factor K_I is somewhat higher in the notch configuration than in the limiting case of a crack. In accord with microstructural observations, the model predicts a process zone extending 0.3-0.5 of the notch depth. Analysis of the stress path from the model reveals the potential activation of multiple localization modes around the notch tip, implying that propagation of a localized structure in the sandstones may be fundamentally different depending on which mode satisfies the failure criterion.

Our mechanical and microstructural data for the Bentheim and Berea sandstones demonstrate the spectrum of failure modes and depict the initiation and propagation of localization from stress concentration. The energy required to develop a discrete compaction band was inferred to range from 6-27 kJm^{-2} in the Bentheim sandstone and showed an inverse dependence on the confining pressure (ranging from 250 to 350 MPa), in apparent agreement with recent energy release model [2]. We also determined an energy of 43 kJm^{-2} for the compactive deformation band observed in the Berea sandstone.

References

[1] Vajdova, V., and T.-f. Wong (2003), Incremental propagation of discrete compaction bands: Acoustic emission and microstructural observation on circumferentially notched samples of Bentheim sandstone, *Geophys. Res. Lett.*, *30*, 1775.

[2] Rudnicki, J.W., and K.R. Sternlof, (2005), Energy release model of compaction band propagation, *Geophys. Res. Lett.*, *32*, L16303.

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