Modeling Rate Effects in Quasi-Brittle Materials with a Two-term Interfacial Damage Rule

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Rate effects in quasi-brittle materials reflect the time required for the completion of microscopic failure mechanisms such as nucleation, coalescence, and propagation of microscopic cracks and voids on fracture surfaces. We proposed in [1] an interfacial damage model for quasi-brittle fracture in which we use a scalar damage parameter to interpolate between the bonded and debonded states of an interface and the damage evolution is driven solely by the dynamically consistent tractions acting across the interface for bonded conditions. One negative consequence of this traction-based formulation is that, if the tractions fall below a critical threshold, the damage parameter does not tend to unity even in the limit of infinite interface separation; see [2].

In this work, we propose a new two-term damage evolution rule in which tractions acting across a (potential) fracture interface initiate and drive the early stages of damage while the velocity jump across the interface enters as the primary driver of late-stage damage. The two-term model is in qualitative agreement with microscopic fracture mechanisms in real materials which initiate when tractions exceed a local critical threshold but must undergo some subsequent kinematical mechanism before total debonding is attained. The ratio, k, of velocity-driven to traction-driven separation scales (*cf*. [3]) determines the relative importance of the two terms in the damage evolution rule. The fracture response approaches the one-term model [1] as k tends to infinity. As k approaches zero, on the other hand, the fracture response approaches the singular perturbation theory. We present analytical and numerical examples that illustrate the dependence on loading rate of fracture scales, ultimate strength, toughness, *etc*. and compare their asymptotic behavior with the predictions of some other damage and cohesive models.

References:

[1] R. Abedi, R. Haber, and P. Clarke. “Effect of material randomness on dynamic fracture of quasi-brittle materials”, International Journal of Fracture: Special Issue for Integrated Computational Structure-Material Modeling of Deformation & Failure Under Extreme Conditions; An IUTAM Symposium, 2017. In Press.

[2] R. Abedi, O. Omidi, P.L. Clarke, “A numerical study on the effect of loading and randomness on fracture patterns in a tight formation” In: Proceedings 51st U.S. Rock Mechanics/Geomechanics Symposium, ARMA 17-0642, 2017.

[3] R. Abedi and R.B. Haber, “Spacetime dimensional analysis and self-similar solutions of linear elastodynamics and cohesive dynamic fracture”, International Journal of Solids and Structures, 48(13):2076-2087, 2011.