

A rate-dependent interfacial damage model: Constitutive equation and fracture simulation

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We present a new interfacial damage model, including contact and friction modes, for dynamic fracture simulation of quasi-brittle materials. This sharp-interface model is distinct from bulk damage representations and is an alternative to cohesive models with traction-separation relations (TSRs). It suffers no artificial compliance in the undamaged state at any level of grid refinement and avoids the non-smooth response that might complicate numerical implementations of extrinsic cohesive models.

We use a space-time damage field, D , to describe intermediate conditions between the intact and fully debonded states on fracture surfaces. A delayed-damage relation governs the evolution of D . Both kinetic and kinematic terms contribute to damage evolution in the new model. The first term of damage evolution corresponds to the tractions that act on the bonded part of the interface. These tractions are in turn obtained from the solution to a local Riemann problem. A second term, based on the jump in the velocities of the two sides of the interface, corresponds to kinematically-driven damage evolution. Each term has its own intrinsic time, displacement, and velocity scales. A nondimensional ratio of intrinsic displacement scales of the two models determines the interplay between the kinetic and kinematic terms. Specifically, we show how the relation between tractions and displacements at an interface is affected by the form of impinging stress loads at the interface and the aforementioned nondimensional value. Unlike cohesive models that use a TSR, a fixed relation between traction and separation does not exist. Related to this, our results demonstrate how fracture toughness is affected by the loading rate. Our model can also incorporate contact-stick and contact-slip modes by using dynamically consistent Riemann solutions for the corresponding contact modes. We present numerical results that demonstrate the performance of the method for crack propagation under mixed mode, cyclic loading, and between an interface between two distinct materials. We use an adaptive spacetime discontinuous Galerkin finite element method along with a fracture specific error indicator for our exceptionally accurate fracture simulations.