Dynamic Fracture in Quasi-brittle Materials with Random Defects

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The fracture response of quasi-brittle materials is highly sensitive to the presence and distribution of microstructural defects. We study two approaches to model these inhomogeneities. In the first, we model the defects as explicit, crack-like features in the description of the analysis domain with random distributions of size, location, and orientation. In a second method, we use a probabilistic nucleation technique based on the Weibull model to spontaneously generate seed cracks during the course of an analysis. Either approach can model media with preferred directions for crack nucleation and propagation.

We combine an asynchronous Spacetime Discontinuous Galerkin (aSDG) method [1] with a novel, rate-dependent interfacial damage model to study crack nucleation and propagation. The method's powerful adaptive meshing capabilities ensure accurate resolution of crack-tip fields and eliminate mesh dependency during crack nucleation and propagation. Thus, the aSDG method models dynamic fracture in problems where crack-path oscillation, microcracking, and crack bifurcation make computational modeling particularly challenging. We introduce a new rate-dependent interfacial damage model in which the damage rate depends on both the traction acting on the interface and the opening/slip velocity across the interface. The former factor controls the onset of damage, while the latter models later, inertia-driven stages of the fracture process.

Numerical examples illustrate the influence of material inhomogeneities on fracture patterns and demonstrate the ability of the aSDG scheme to capture complex fracture topologies. We also describe a parallel–adaptive, and synchronization-barrier-free implementation of the aSDG method in which adaptive spacetime meshing and finite element solution share a common fine-scale granularity.

References

[1] Reza Abedi, Robert B. Haber, and Boris Petracovici. A spacetime discontinuous Galerkin method for elastodynamics with element-level balance of linear momentum. *Computer Methods in Applied Mechanics and Engineering*, 195:3247–3273, 2006.