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SPACETIME INTERFACIAL DAMAGE MODEL FOR ELASTODYNAMIC FRACTURE WITH RIEMANN CONTACT CONDITIONS

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We present an interfacial-damage, cohesive-fracture model, including contact and friction effects, for dynamic failure of brittle materials. The model is implemented within a spacetime discontinuous Galerkin (SDG) finite element method [2] and extends the fracture model in [3]. An adaptive spacetime meshing procedure satisfies a causality constraint to enable a patch-by-patch, advancing-front solution scheme with O(N) computational complexity. Per-element balance properties, local adaptive operations, and the use of Riemann fluxes provide to the SDG method the high accuracy and efficiency required to solve multiscale fracture problems. A two-scale cohesive fracture model replaces the usual traction-separation law with a damage model that represents mesoscale processes of void growth and coalescence. An irreversible, delay equation governs the evolution of a damage parameter D that represents the debonded area fraction on cohesive interfaces.

Uniquely, our model preserves dynamic characteristic structure. Riemann fluxes for the fully-bonded condition are enforced in the undamaged cohesive area fraction (1-D), while Riemann values for contact-stick, contact-slip or separation conditions determine the fluxes in the debonded area fraction. We compute macroscopic cohesive conditions by averaging the mesoscale Riemann values. The Riemann fluxes preserve characteristic structure and treat exactly the non-penetration and tangential slip constraints for crack closure in the continuum formulation. Furthermore, we obtain continuous tangential contact tractions in transitions between contact-stick and contact-slip modes.

The model uses adaptive meshing to control solution accuracy and to freely nucleate and extend cohesive interfaces to track solution-dependent crack paths. A probabilistic model governs nucleation to account for random material defects. The adaptive scheme aligns faces of spacetime elements with arbitrary crack-path trajectories, and two adaptive error indicators ensure the accurate rendering of both the cohesive model and the bulk solution. Thus, our model does not suffer the limited resolution and mesh-dependent effects encountered in most other numerical fracture models. Numerical resuts demonstrate crack propagation, microcrack formation and crack branching. Figure 1 depicts an instance where the main running crack branches to two main cracks which exhibit further microcracking events [1].

REFERENCES

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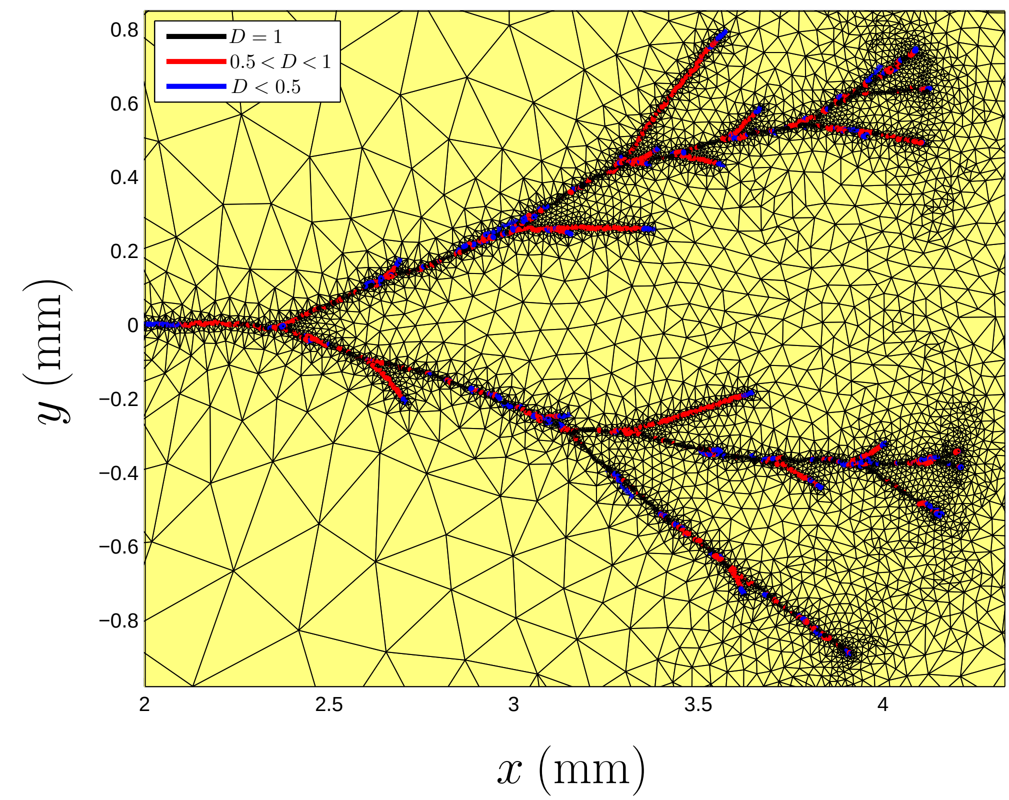

FIGURE 1. The solution–dependent crack nucleation and propagation depicted on the space mesh; the crack trajectory is aligned with element boundaries.