Adaptive Dynamic Fracture using Nonlinear Cohesive Zone Modeling

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Research Objectives

- Develop an integrated, multiscale computational framework for dynamic fracture, microbranching, and fragmentation
- Employ the potential-based constitutive model for mixed-mode cohesive zone modeling
- Develop systematic adaptive mesh refinement and coarsening (AMR+C) schemes for dynamic cohesive fracture simulation in two and three dimensions
- Employ adaptive topological operators such as nodal perturbation, edge-swap, edge-split and vertex removal

Adaptive Topological Operators

- Nodal Perturbation
- Edge Split (Refinement)
- Edge Swap
- Vertex Removal (Coarsening)

PPR: Potential-Based Cohesive Model

\[ \psi = \min(\phi, \phi_0) + \left[ \Gamma_\alpha \left(1 - \frac{\Delta \phi}{\phi_0} \right)^{\alpha} + \Delta \phi - \phi_0 \right] + \left[ \Gamma_\beta \left(1 - \frac{|\Delta \phi|}{\phi_0} \right)^{\beta} + \Delta \phi - \phi_0 \right] \]

\[ T_\alpha(\Delta \phi, \Delta \phi_0) = -\frac{\beta}{\phi_0} \left(1 - \frac{|\Delta \phi|}{\phi_0} \right)^{\beta} - \frac{|\Delta \phi_0|}{\phi_0} \left(1 - \frac{|\Delta \phi_0|}{\phi_0} \right)^{\beta} \]

Fracture parameters
- Fracture Energy: \( \phi, \phi_0 \)
- Cohesive Strength: \( \sigma_x, \sigma_t \)
- Shape Parameters: \( \alpha, \beta \)

Softening region

\[ T_\alpha(\Delta \phi, \Delta \phi_0) = -\frac{\beta}{\phi_0} \left(1 - \frac{|\Delta \phi|}{\phi_0} \right)^{\beta} - \frac{|\Delta \phi_0|}{\phi_0} \left(1 - \frac{|\Delta \phi_0|}{\phi_0} \right)^{\beta} \]

Constitutive relationship

- Fracture parameters: \( \phi = 100 \text{N/m}, \phi_0 = 200 \text{N/m} \)
- Shape parameters: \( \alpha = 5, \beta = 1.3 \)
- Cohesive strength: \( \sigma_x = 40 \text{MPa}, \sigma_t = 30 \text{MPa} \)

Cohesive elements randomly inserted at 20% of the facets

Time to insert cohesive elements scales linearly with mesh size

Conclusions and Extensions

- The potential-based constitutive model with adaptive operators (nodal perturbation, edge-swap, edge-split, and vertex-removal) leads to an effective and efficient computational framework to simulate physical phenomena associated with fracture.
- The topological data structure and adaptive topological operators support the extension of this work to three dimensions.

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References