A study of dynamic cohesive fracture using a spacetime discontinuous Galerkin model

MS 105 - Session 1: Numerical Techniques for the Modeling of Failure in Solids

We present numerical studies of elastodynamic fracture using a cohesive damage model implemented within a spacetime discontinuous Galerkin (SDG) finite element framework. The SDG formulation features linear computational complexity in the number of spacetime elements, element-wise balance properties, high-order accuracy on a compact stencil, scalability for parallel computation, and efficient adaptive meshing on unstructured spacetime grids with zero projection error. Special error indicators drive the adaptive solution process to limit the overall numerical dissipation as well as the error in the work of separation due to mismatch between the cohesive traction-separation relation and the finite element stresses. The adaptive SDG method supports high-fidelity simulations of cohesive elastodynamic fracture at resolutions that generally exceed those available in previous numerical studies.

In our initial investigations of the problem studied by Xu and Needleman, the predicted response differed from that reported in the original study in two respects: (i) the acceleration of the crack tip following crack-growth initiation was more gradual and (ii) we observed an apparent singularity in the velocity field for a running crack tip that appears to match the inverse root of r form of the velocity singularity generated by a dynamically growing and mathematically sharp crack tip. Due to limitations of our software at the time, we were unable to determine the long-term crack-tip kinetics and unable to further investigate the core structure of the apparent singularity.

We present new results from more recent studies that illuminate the singular structure of the velocity response. In particular, we investigate whether the velocity field exhibits a true singularity or if it has, instead, a non-singular core. We report on the influence of the relative stiffness of the cohesive interface with respect to the bulk material on the size of the singular zone and study the long-term kinetics of the cohesive crack tip and its dependance on selected material parameters.

Finally, we discuss prospects for a parallel hp-adaptive implementation of the SDG cohesive fracture model as well as an extended SDG implementation capable of tracking arbitrary, solution-dependent crack trajectories.