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Combined stability analysis of phase-field dynamic fracture and shear band localization

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Abstract

Dynamic fracture of metals is a fascinating multiphysics-multiscale problem that often results in brittle and/or ductile fracture of structural components and under high strain rates may also suffer from shear banding. While fracture events are mostly driven by tensile loading, shear bands are driven by shear heating caused by inelastic deformations and associated with high temperature rise. These processes are characterized by different failure modes with distinct spatial and temporal scales.

A recent unified model developed by the authors attempts to capture dynamic fracture and shear banding failure modes using implicit, mixed finite element formulations. In this model, fracture is modeled with a novel phase field formulation coupled to a set of equations that describe shear bands. While fracture is governed by a strong length-scale that propagates with a fast time scale, shear bands are dominated by a weak length-scale and propagate slower.

In this work, we analyze the physical stability of both failure modes and their interaction using a linear perturbation method. The analysis provides insight into the dominant failure mode and can be used as a criterion for mesh refinement.

Several numerical results with different geometries and a range of strain rate loadings demonstrate that the stability criterion predicts well the onset of failure instability in dynamic fracture applications.

For the example problems considered, if a fracture instability precedes shearbanding, a brittle-like failure mode is observed, while if a shear band instability is initiated significantly before fracture, a ductile-like failure mode is expected. In any case, fracture instability is stronger than a shear band instability and if initiated will dominate the response.

Keywords: Dynamic fracture, Phase field, Shear band, Instability, Linear perturbation

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