A mechanism-based thermomechanical cohesive zone approach for modeling ductile fracture

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Ductile fracture in metals has been observed to result from the nucleation, growth, and coalescence of voids. The evolution of this damage is inherently history dependent, affected by how the time-varying stress state drives the formation of defect structures in the material. At some critically damaged state, the softening response of the material leads to strain localization across a surface that, under continued loading, becomes the faces of a crack in the material. Modeling localization of strain requires introduction of a length scale to make the energy dissipated in the localized zone well-defined. In this work, a cohesive zone relation is used to describe the evolution of material within the localized zone during the post-bifurcation regime of deformation. The relations are developed within a thermodynamically consistent framework that incorporates temperature and rate-dependent evolution relationships motivated by dislocation mechanics. As such, we do not prescribe the evolution of tractions with opening displacements across the localized zone *a priori*. The evolution of tractions is itself an outcome of the solution of particular, initial boundary value problems. The stress and internal state of the material at the point of bifurcation provides the initial conditions for the evolution of the cohesive zone. The model is motivated by *in-situ* scanning electron microscopy of three-point bending experiments using 6061 aluminum. The *in-situ* observations of the initiation and evolution of fracture zones reveal the scale over which the failure mechanisms act. In addition, these observations are essential for motivating the micromechanically-based model of the decohesion process that incorporates the effects of loading mode mixity, temperature, loading rate, and load reversals. The response of these new cohesive zone relations is demonstrated with coupled-thermomechanical simulations of fracture under both quasi-static and dynamic loading conditions.