THE UNIVERSITY of NEW MEXICO

ME 591 Graduate Seminar

Department of Mechanical Engineering
The University of New Mexico

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A New Computational Methodology for Simulating the Pervasive Failure of Materials and Structures Under Extreme Loading Conditions

Abstract

Dynamic material and structural failure is a highly nonlinear process involving complex material constitutive behavior, material softening, localization, new surface generation, and ubiquitous contact. Examples include impact, penetration, and structural collapse due to blast loading. The simulation of these events is critical for design of weapons systems and the assessment of structural vulnerability . Currently, there is a very limited set of computational tools available to even attempt to simulate dynamic pervasive failure events in structures. Common industrial techniques include ‘element death’ in Lagrangian codes and ‘void insertion’ in Eulerian codes. A prime verification question is whether a numerical model that purports to model dynamic failure can converge with mesh refinement. Without demonstrated mesh convergence to ‘engineering accuracy’, numerical results are non-objective and suspect. A pure Lagrangian finite-element methodology has been developed that simulates the pervasive dynamic failure of quasibrittle materials (e.g. concrete) by allowing fracture surfaces to nucleate only at the interelement boundaries of a random polyhedral mesh. The polyhedral mesh consists of finite elements with a variable number of facets whose shape functions are generated by a procedure based upon the reproducing kernel particle method. The polyhedral elements are created using a Voronoi tessellation of the domain. The Voronoi tessellation provides a random edge basis that minimizes mesh induced bias in the direction of crack growth. In order to properly handle material softening, two methods for regularizing the governing equations are studied: (1) cohesive zone-elements, and (2) an integral-form non-local material model. Both methods result in finite energy dissipation during material softening, and introduce a length scale that allows simulations to match observed macroscopic scaling laws. A number of two- dimensional explicit-dynamics verification and validation examples are considered. Convergence behavior with respect to both mesh design and mesh refinement is discussed.