Title: Innovations in Computational Fracture Mechanics

Abstract:
Understanding the fracture phenomena, i.e., catastrophic material failure, remains a major challenge in a variety of fields within science and engineering. While limited analytical solutions exist for fracture mechanics problems and experiments are often costly in many practical cases, computational methods and simulations are commonly used in practice for analysis, design, and optimization of materials, structures, buildings, and vehicles. Therefore, it is imperative to develop accurate, efficient, and robust predictive models for simulating the response of solids and structures in real-world scenarios such as in extreme conditions involving large deformation, fracture, and fragmentation (e.g. blast events). Computational fracture mechanics has been an active area of research for several decades. Novel methods have emerged over the last two decades for solving fracture mechanics problems such as the peridynamic (PD) theory, the extended finite element method (XFEM), and phase-field fracture models. The continuum PD model, which is based on an integro-differential formulation, has increasingly attracted the attention of researchers in computational solid mechanics due to its natural capabilities in handling material discontinuity and autonomous crack growth. In this talk, peridynamic modeling of large deformation and ductile fracture is discussed. A rigorous verification and validation procedure is carried out via the Sandia Fracture Challenge, which involves blind prediction of the behavior of an additively manufactured metal with a complex geometry under the dynamic tensile experiments performed by Sandia National Laboratories. An iterative inverse technique is applied to calibrate the model parameters using the standard test data provided by Sandia. A blind prediction of the deformation and failure behavior of the challenge geometry is performed by embedding the calibrated model in a PD simulation. Upon comparison of the blind simulation results with the experimental data, shortcomings of the model are identified and addressed with a novel stabilized and high-order meshfree recipe for correspondence-based PD. The new PD formulation of the solid is coupled with Isogeometric Analysis (IGA) for the simulation of blast fluid-structure interaction (FSI). An immersed approach is utilized to capture the interaction of the meshfree PD solid in the foreground domain with the fluid flow on the background NURBS mesh. Numerical examples are provided to illustrate the performance of the proposed air-blast FSI framework. Current research directions, including the extension of the modeling approaches to underwater explosion FSI and its integration with machine learning, are discussed.