Numerical Modelling of 3-D Fracture Propagation and Damage Evolution in Brittle Materials

Pre-existing flaws and material heterogeneity have important ramifications on the process of fracturing and stability in many applications; for instance, to investigate mine safety, to analyse material failure in manufacturing and construction and to understand the behaviour of pre–existing fractures on hydraulic fracturing in oil and gas extractions. Therefore, there is great interest in numerical modelling of rock fracture and the underlying mechanisms. We develop numerical tools to investigate the effect of different factors on material failure, including the heterogeneity of rock by allowing Young's modulus to vary spatially, and the geometry of a pre–existing fracture on the stress–strain response and damage evolution in rocks. We solve a system of partial differential equations (PDE)s using the finite element method (FEM). We use continuum damage mechanics to model material damage and failure, and apply it to brittle materials for three different loading experiments. We employ a non–local implicit gradient damage formulation using a split–operator approach to analyse the mesh sensitivity of the damage response for the 3 brittle materials. The basic concept of the non–local implicit gradient model is that the strain at a given point depends not only on the strain at that point but also on the nearby strain field. Standard "local" continuum damage models tend to predict a response in which the fracturing process localises into an ever–decreasing volume as the mesh is further refined and show mesh sensitivity. In these examples, we demonstrate that the implementation of a non–local implicit gradient damage model using the split–operator method can successfully be applied to complex, 3–D geometries requiring large–scale unstructured FEM meshes, and eliminate this mesh dependence.