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THREE DIMENSIONAL NUMERICAL MODELLING OF BRITTLE FRACTURE IN SOLIDS

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Brittle or quasi-brittle fracture usually occurs when a material reaches the limit of its strength and no plastic deformation has been observed prior to failure. Obviously this is one of the worst kinds of failure, since fracture takes place before any visible damage is noticed. This behavior is observed in different kinds of materials, such as concrete, ceramics or rocks at low temperatures and low pressures.

Considering this brief description of brittle fracture, it is evident that one needs at least two essential steps to capture such behavior numerically. The first step is based on the description of propagating discontinuities in a continuum mechanics finite element setting. The second step regards the computation of the fracture propagation direction, associated with the geometrical description of the failure surface.

In recent years some promising techniques have been developed to handle the first mentioned step, such as embedded discontinuities [1], the extended finite element method introduced by Belytschko and coworkers [2] as well as some versions of the discontinuous Galerkin methods (DG-Method). In this contribution we focus on the approach introduced by Hansbo & Hansbo [3] which basically belongs to the group of discontinuous Galerkin methods. By essentially doubling the degrees of freedom in the discontinuous elements, this approach allows for arbitrary strong discontinuities which are not restricted to inter-element boundaries. Moreover, we use the concept of cohesive traction separation laws to capture a possible inelastic behavior of the fracture process.

What is unfortunately not yet as well established is the aforementioned second step. We suggest linear tetrahedral elements and furthermore a principal stress based Rankine criterion for the computation of the crack propagation direction. Accordingly, we obtain the crack surface as an accumulation of discrete planar triangle or quadrilateral crack surfaces in the reference configuration. Clearly, the most cumbersome issue related to this discrete geometrical representation is therefore the choice of an appropriate tracking algorithm to achieve a smooth or continuous representation of the crack surface.

For this topic, a couple of approaches are available [4, 5]. Currently, one of the most promising algorithms is the global tracking algorithm introduced by Oliver [6]. Since the global tracking scheme introduces an additional field of unknowns, additional boundary conditions have to be prescribed. The physical interpretation and the appropriate choice of these Dirichlet boundary conditions are the most essential ingredients of the global tracking scheme, ensuring solvability of the overall system. Therefore, a considerable part of this contribution is based on the description of how to choose appropriate Dirichlet boundary conditions. Consequently, this is clarified by means of classical benchmark problems in brittle fracture mechanics.

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