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FINITE ELEMENTS WITH EMBEDDED DISCONTINUITIES AND BRANCHING FOR THE MODELING OF FAILURE IN SOLIDS

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Summary. The failure of solids and structures is often characterized by the appearance of discontinuous solutions of the mechanical boundary value problem, like the discontinuous displacements associated with cracks in brittle materials or with multi-scale treatments of shear bands and other localization bands in ductile failures. This situation has motivated the formulation of different techniques for the numerical resolution of these solutions. We present in this contribution several recent advances in the formulation of the so-called finite elements with embedded strong discontinuities. Exploiting the aforementioned multi-scale setting, these elements incorporate the kinematics of these highly non-smooth solutions through enhancements that are handled entirely at the element level, preserving the overall multi-scale structure of the problem at hand[1, 2], and thus leading to efficient techniques for the numerical simulation of these failures in solids, that can be also easily incorporated in existing finite element codes.

Specifically, we discuss the formulation of finite elements incorporating high-order interpolations of the displacement jumps along the discontinuity, in both the infinitesimal and finite deformation ranges[5, 7]. The strategy proposed for the strain enhancement allows, in particular, the resolution of the enhanced kinematics without the characteristic overstiff response (or stress locking) that other alternatives may lead to. This strategy consists in the incorporation of the separation modes in the discrete strain field of the element, rather than the definition of a local discontinuous displacement field. A major advantage of this approach is the ability to extend it to cases involving not only the continuum but also diverse kinematics, like the formation of softening hinges in beams and plates[3, 4, 6], as well as other highly complex situations, like the patterns involved in the branching of the discontinuities. In this way, we have recently formulated new finite elements that resolve locally these solutions, which we refer to simply as finite elements with embedded branching[8], and that are particularly appropriate in the modeling of dynamic fracture. After a discussion of all these theoretical aspects, we present a series of representative numerical simulations illustrating the performance of the finite elements.

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