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Advances in the Extended Finite Element Method (XFEM)

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ABSTRACT

Advances in the extended finite element method (XFEM) [1] are described. XFEM, in a general sense, is a method for easily introducing discontinuities and enrichments in finite elements. This makes possible versatile modeling of problems such as crack growth, dislocations, and shear bands. We describe here several of these application areas and the challenges involved.

The XFEM method has recently been applied to dynamic crack growth in shells and plates [2, 3, 4]. Comparisons with experiments show that the method is able to capture the correct crack propagation speeds and branching when it is found in experiments. In these solutions, a cohesive law has been applied in the XFEM setting. Time integration methods have been studied and we have been able to develop procedures that yield a converged fracture energy. Some of the implementations are based on the Hansbo and Hansbo approach [5], which is advantageous in explicit codes when the progression of the crack is element to element [6]. We show that the basis functions are identical to that of the XFEM approach [7].

XFEM has also been applied to dislocations [8, 9, 10]. Two approaches have been developed. In the first approach [8, 9], the entire dislocation is modeled as a discontinuity and a regularization is employed at the core of the dislocation to maintain a bounded energy. In the second approach [10], the discontinuity is combined with an exact solution or an accurate solution around the core. This approach is somewhat more difficult to implement but it simplifies the computation of the Peach-Koehler force. In contrast to existing methods, the XFEM approach to dislocations has many advantages. The computation of the Peach-Koehler force is much faster, since it does not involve any summation. Furthermore, the method is applicable to problems with complicated geometries and nonlinearities and to anisotropic materials.

XFEM also provides a powerful method for treating shear bands [6, 11, 12]. In most engineering problems, the scale of the shear bands is much smaller than the scale of the body, and resolution of the shear band requires extremely fine meshes. In the XFEM approach, the shear band can be modeled directly as a discontinuity with a cohesive law. The cohesive law can either be obtained a priori, or concurrently with the computation of the macro-response in a multiscale framework [13]. Results for dynamic fracture, dislocations and shear bands will be presented.

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