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Recent Developments of Hybrid Crack Element: Determination of Its Complete Displacement Field and Combination with XFEM

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ABSTRACT

The hybrid crack element (HCE) [1] is one of the most accurate and convenient finite elements (FEs) for the direct calculation of the stress intensity factor (SIF) and coefficients of the higher order terms of the Williams expansion [2, 3]. It represents a crack by only one super-element which is connected compatibly with the surrounding elements. It is very efficient for analysing bodies with many cracks [4]. The HCE is formulated from a simplified variational functional using truncated asymptotic crack tip displacement and stress expansions and interelement boundary displacements compatible with the surrounding regular elements. In the implementation, a general FE mesh can be used by forming the HCE from elements surrounding the crack tip [5]. The HCE can thus be included in any commercial package as conveniently as normal hybrid stress elements.

However, the exclusion of the rigid body modes in the truncated asymptotic displacements creates jumps between these displacements and element boundary displacements. In this study, the rigid body modes are recovered by minimising these jumps via a least squares method.

If the HCE only is used, the part of the crack inside the HCE need not conform to the mesh. However, crack faces away from the crack tip (outside the HCE) need to conform to the mesh. This disadvantage can be avoided by combining the HCE with the extended FEM (XFEM) [6]. The XFEM enriches the standard local FE approximations with a displacement discontinuity across a crack, and the asymptotic solution at the crack tip, with the use of the partition of unity (PU). It avoids using meshes conforming with the discontinuity and also adaptive remeshing as the discontinuity grows as is the case with the FEM. XFEM offers great flexibility in the modelling of the fracture process. However, the accuracy of the displacements and/or stresses in a few layers of elements surrounding the crack tip is low. The combined method using both HCE and XFEM inherits the flexibility of the XFEM and the high accuracy of the HCE. Typical static and propagating crack problems will be presented to demonstrate the efficiency and accuracy of this method.

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