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A variational approach for evaluation of stress intensity factors using the element free Galerkin method

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ABSTRACT

A variational meshfree method has been developed to evaluate the stress intensity factors of mixed mode crack problems. The stiffness is evaluated by regular domain integrals and shape functions are determined by both the radial basis function (RBF) interpolation and the moving least-square (MLS) method. The stress intensity factors are obtained by two boundary integrals with variation of crack length. Applications of the proposed technique to two-dimensional fracture mechanics have been presented and comparisons are made with benchmark solutions. Finally, the application of the proposed method to modelling fatigue crack growth is presented.

1. Introduction

The fundamental postulate of linear elastic fracture mechanics (LEFM) is that the behaviour of cracks is determined by the value of stress intensity factor. Furthermore, the knowledge of the stress intensity factor is necessary for the evaluation of the residual strength of cracked structural components, the evaluation of the critical crack-lengths and the determination of rates of crack-growth in fatigue.

There are several popular numerical methods that can be used for the evaluation of stress intensity factors. They include the Finite Element Method (Henshell and Shaw, 1976; Hellen, 1975; Moran and Shih, 1987), the Boundary Element Method (Aliabadi et al., 1989; Portela et al., 1992; Sladek and Sladek, 1995; Sollero and Aliabadi, 1995; Wen et al., 1998a,b,2008), Extended Finite Element Method (Belytschko and Black, 1999; Asferg et al., 2007) and a recently developed Material Force Method (Steimmann, 2000). A review of different methods for the evaluation of stress intensity factors can be found in Aliabadi and Rooke (1991).

Recently, meshless or meshfree approximations (Belytschko et al., 1994; Atluri and Zhu, 1998) have received much interest since they eliminate the need for a structured grid and are hence considerably less user intensive than the traditional finite element method. The moving least squares (MLS) approximation is generally considered as one of several schemes to interpolate discrete data with a good accuracy. The order of continuity of the MLS approximation is given by the minimum between the orders of continuity of the basis functions and that of the weight function. Therefore, continuity can be tailored to a desired value (Sladek et al., 2009). The treatment of crack discontinuities has been analysed in different ways in the meshless approximation (Organ et al., 1996; Ferro and Ventura, 2003).

A recent approach used for modelling discontinuities due to cracks in both meshless and FEM is based on the introduction of discontinuous enrichment functions (Organ et al., 1996). Carpinteri et al. (2003) proposed the method where the crack is virtually extended in the direction of the tangent at the crack tip. Another application of meshfree method to linear elastostatic fracture mechanics, that is, evaluation of stress intensity factors and analysis of crack growth were reported by Fleming et al. (1995) and Rao and Rahman (2001) using enriched basis functions in the moving least-square interpolation. However, their method is computationally time consuming as the coefficient matrix must be inverted at each Gauss integration point. To overcome this difficulty, Wen and Aliabadi (2007) developed a meshfree Galerkin method using enriched radial basis function for pure mode fracture problems. Other contributions to the application of meshfree and meshless methods to fracture mechanics can be found in Sladek et al. (2005), Mohit et al. (2010), Wen and Aliabadi (2009), Rao and Rahman (2003), Simonsen and Cerup (2004), Xu and Saigal (1998) and Hardy (1971).

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