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Development of Decoupled Equations Method to Calculate Stress Intensity Factors in 2D problems

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Abstract

This study presents a novel application of the decoupled equations method (DEM) to model crack issues. Accurate stress intensity factors (SIFs) based on linear elastic fracture mechanics (LEFM) are directly computed using the DEM, which is based on stress redistribution. However, in fracture mechanics (e.g., crack issue) problems, the concept of redistribution is not applicable, due to infinite stress in the crack tip. To overcome this problem, an analytical function is proposed to represent infinite stress in crack tip, so redistribution concept may be applied. Consequently, when the local coordinates origin (LCO) is located at the crack tip, SIFs can be determined directly without further processing, in which to present infinite stress in crack tip, a new body force function is proposed. Validity and accuracy of this method is fully demonstrated through a benchmark problem which is successfully modeled using a few numbers of degrees of freedom. The numerical results agree very well with the results from existing numerical methods available in literature.

Keywords: Decoupled equations method, Stress redistribution concept, Stress intensity factors, Linear elastic fracture mechanics, crack.

1. INTRODUCTION

The existence of crack and notch is a significant subject in analyze and design of solids and structures. In order to analyze this category of engineering issues, the stress intensity factors (SIFs) have been used which consider singularity in crack tips. As most of these problems do not have closed form solution, the numerical solving approach is a current subject dealing with fracture mechanic problems. Since some of these numerical methods are time consuming and have a complicated formula, the extension and improvement of them is unavoidable and necessary. Some classes of numerical methods such as finite element method (FEM), boundary element method (BEM), extended finite element method (XFEM), meshless methods and the more recent scaled boundary finite element method (SBFEM) have been widely used in determination of SIFs of crack tips and simulating crack problems in brittle or quasi-brittle materials based on linear elastic fracture mechanics (LEFM).

Currently, the FEM is used frequently in the analysis of fracture mechanics problems because of its accuracy and flexibility [1-2]. Some disadvantages of FEM have been caused to develop other numerical methods. Due to complexities of remeshing techniques to predict crack propagation, XFEM is extended [3], and due to fine crack tip meshes or special crack tip elements, time consuming and high expensive computation of FEM, the BEM is widely used in fracture analysis as an alternative method. The BEM requires a fundamental solution for the governing differential equations and advanced mathematical techniques to deal with the singular integrals [4]. Early application of the BEM to generate crack problems were limited, as a straightforward, applying of the BEM to crack problems leads to a mathematical challenges, whereas the two crack surfaces are consider co-planer. To tackle this problem the dual boundary element method (DBEM) developed [5].

Over the last decade, the meshless methods have been paid more attention and have became as another attractive alternative for mechanic problems, which they do not require a mesh to discretize the problem domain, and the approximate solution is constructed entirely by a set of scattered nodes. The principal attraction of the meshless methods is flexibility in dealing with moving boundaries and ease in using the enriched basis functions based on the asymptotic displacement field near the crack tip[6].