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A BEM model applied to failure analysis of multi-fractured structures ☆

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ABSTRACT

Due to manufacturing or damage process, brittle materials present a large number of micro-cracks which are randomly distributed. The lifetime of these materials is governed by crack propagation under the applied mechanical and thermal loadings. In order to deal with these kinds of materials, the present work develops a boundary element method (BEM) model allowing for the analysis of multiple random crack propagation in plane structures. The adopted formulation is based on the dual BEM, for which singular and hyper-singular integral equations are used. An iterative scheme to predict the crack growth path and crack length increment is proposed. This scheme enables us to simulate the localization and coalescence phenomena, which are the main contribution of this paper. Considering the fracture mechanics approach, the displacement correlation technique is applied to evaluate the stress intensity factors. The propagation angle and the equivalent stress intensity factor are calculated using the theory of maximum circumferential stress. Examples of multi-fractured domains, loaded up to rupture, are considered to illustrate the applicability of the proposed method.

1. Introduction

Engineering structures are designed to withstand the loads they are expected to be subject to while in service. Large stress concentrations are avoided, and a margin of security is taken to ensure that values close to the maximum admissible stress are never attained. However, material imperfections which arise at the time of production or usage of the material are unavoidable, and hence must be taken into account. Indeed, even microscopic flaws, after coalescence process, may affect structures which are assumed to be safe to fail. In this regard, crack growth problems play a central role in engineering, as it can explain the failure of structures. In crack propagation modeling, the main goals are to predict whether and in which manner failure may occur. For complex engineering structures, with complex geometry and boundary conditions, the crack growth modeling cannot be considered by analytical solutions, because these kinds of solutions are not available. Therefore, to deal properly with this problem, numerical techniques are required.

The finite element method (FEM) has been applied to model fracture mechanics problems [1]. This numerical method has demonstrated be accurate in the evaluation of the stress intensity factors [2]. However, for problems involving singularities, such as the one in the stress field at a crack tip, the use of FEM requires a very fine discretization around the crack tip, which makes it expensive in terms of computational time work. Moreover, in a crack propagation analysis, it is generally necessary

☆ This article is dedicated to the memory of Prof. Wilson Sergio Venturini, for his life-time commitment to computational mechanics.

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