EFFECTIVE MECHANICAL PROPERTIES OF MATERIALS WITH BRANCHED AND INTERSECTING CRACKS

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1. Introduction

Real materials can contain high density of branched and intersecting microcracks. The density of microcracks has influence on strength of cracked materials and their stiffness. Usually overall properties of cracked materials are analysed by analytical methods by assuming that the cracks are straight and separated (Kachanov [7]).

Single branched or intersecting cracks in finite or infinite plates were analyzed in several works. Cheung et al. [2] formulated the stress functions, which consists of two parts: a solution of the Fredholm integral equation for the crack problem in an infinite plate and the weighted residual method for a general plane problem. The method was applied to crucifix cracks, two perpendicular cracks and star-shaped cracks in finite plates. Chen and Hasebe [1] applied a point dislocation at the branch point and distributed dislocations along the branches. Next they formulated a singular integral equation to solve the branch crack problem. The method was applied to star-shaped cracks, symmetric branched cracks and two intersecting cracks. Daux et al. [3] presented the extended finite element method (X-FEM) to analysis of cracks with multiple branches and cracks emanating from holes. The method allows the modelling of discontinuities independently of the mesh.

Effective properties of materials containing separated cracks were analysed by different computational methods. Yin and Ehrlacher [10] applied the variational approach of the displacement discontinuity boundary element method to calculate overall moduli of cracked solids. They studied the influence of crack discretization, size and density. Renaud et. al. [9] applied the indirect boundary element method (BEM) to compute effective moduli of brittle materials weakened by microcracks. Structures with microcracks of different size, location and orientation were investigated. Huang et. al. [6] used the boundary element method and the unit cell method to calculate effective properties of solids with randomly distributed and parallel microcracks. In the BEM the modified fundamental solutions were used.

In the present work microcracks in two-dimensional, linear-elastic, isotropic and homogenous solids are analysed using the dual boundary element method (DBEM) [8]. In this approach only boundaries of the body and crack surfaces are divided into boundary elements. In the DBEM the relations between boundary displacements and tractions are expressed by the displacement and traction boundary integral equations. The method was applied by Fedeliński [5] for computation of effective elastic properties and an analysis of stress intensity factors for representative volume elements (RVE) with randomly distributed microcracks. The microcracks having the same length, randomly distributed, parallel or randomly oriented were considered. The influence of density of microcracks on the effective Young modulus, the effective Poisson ratio and stress intensity factors was presented. Fedeliński [4] presented the influence of density of parallel cracks perpendicular to the applied dynamic loading on wave propagation in the RVE.

In this work the DBEM is applied to analysis of branched and intersecting microcracks. The accuracy of the method is verified for single branched or intersecting cracks in finite plates by comparison with available results presented in the literature. The original part of the work is an analysis of effective properties of materials containing randomly distributed high density cracks, which include intersecting microcracks.

2. Numerical example

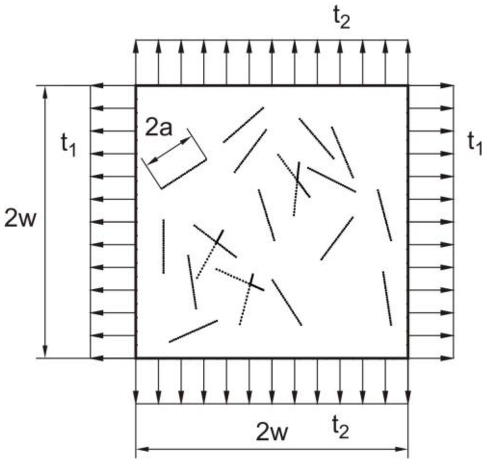

Figure 1. Random microcracks in a representative volume element (3 pairs of intersecting cracks)

A square representative volume element contains 20 randomly distributed microcracks, as shown in Fig. 1. The length of the edges of the RVE are $2w$ and the length of the cracks is $2a$. The ratio of dimensions is a/w=0.2. The RVE is in plane stress conditions and is subjected to the horizontal t_1 or vertical t_2 uniformly distributed tractions. The external boundaries of the RVE are divided into 40 boundary elements and each crack edge into 8 boundary elements. For the considered material cracks reduce the effective Young modulus by 56% in the horizontal direction and by 39% in the vertical direction.

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