Engineering Analysis with Boundary Elements 35 (2011) 200–206

Contents lists available at ScienceDirect

Engineering Analysis with Boundary Elements

journal homepage: www.elsevier.com/locate/enganabound

Analysis of cracked transversely isotropic and inhomogeneous solids by a special BIE formulation

C.Y. Dong [a], X. Yang [a], E. Pan [b,*]

[a] Department of Mechanics, School of Aerospace Engineering, Beijing Institute of Technology, China
[b] Department of Civil Engineering, University of Akron, Akron, OH, USA

A R T I C L E I N F O

Article history:
Received 8 March 2010
Accepted 2 June 2010
Available online 24 August 2010

Keywords:
BEM
BIE formulation
Transverse isotropy
Inhomogeneity
Crack
Stress intensity factor

A B S T R A C T

In this paper, a special boundary integral equation (BIE) formation is proposed to analyze the fracture problem in transversely isotropic and inhomogeneous solids. In this formulation, the single-domain boundary element method (BEM) is utilized to discretize the cracked matrix and the displacement BEM to the surface of the embedded inhomogeneity. The two regions are then connected through the continuity conditions along their joint interface. The conventional and three special nine-node quadrilateral elements are utilized to discretize the inhomogeneity–matrix interface and the crack surface. From the crack-opening displacements on the crack surface, the mixed-mode stress intensity factors (SIFs) are calculated, using the well-known asymptotic expression in terms of the Barnett–Lothe tensor. In the numerical analysis, the distance between the inhomogeneity and the crack as well as the orientation of the isotropic plane of the transversely isotropic media is varied to show their influences on the mixed-mode SIFs along the crack fronts.

1. Introduction

Mechanical behaviors of heterogeneous materials such as composites, rock structures, porous and cracked media have been widely investigated, using various boundary integral-related methods. Bush [1] investigated the interaction between a crack and a particle cluster in composites, using the boundary element method (BEM). Also applying the BEM, Knight et al. [2] analyzed the effects of the constituent material properties, fibre spatial distribution and microcrack damage on the localized behavior of fibre-reinforced composites. Dong et al. [3,4] presented a general-purpose integral formulation in order to study the interaction between the inhomogeneity and crack embedded in two-dimensional (2D) and three-dimensional (3D) isotropic matrices. Based on a symmetric-Galerkin BEM, Kitey et al. [5] investigated the crack growth behavior in materials embedded with a cluster of inhomogeneities. Phan et al. [6] used the symmetric-Galerkin BEM to calculate the stress intensity factors (SIFs) for the 2D crack-inhomogeneity interaction problem. Lee and Tran [7] applied the Eshelby equivalent inclusion method to carry out the stress analysis, when a penny-shaped crack interacts with inhomogeneities and voids. Interface cracks in two or more isotropic materials were also studied by Sladek and Sladek [8] and Liu and Xu [9].

So far, however, only a few studies exist when the inhomogeneous material is of anisotropy, e.g., transverse isotropy. Berger and Tewary [10] studied the interface crack problems in 2D anisotropic bimaterials. Huang and Liu [11] used the eigenstrain method to obtain the elastic fields around the inclusion and further studied the interactive energy in the system. Pan and Yuan [12] investigated the fracture mechanics problems in 3D anisotropic solids, using the combined displacement and traction integral representations (i.e., the single-domain BEM). Ariza and Dominguez [13] obtained the boundary traction integral equation for cracked 3D transversely isotropic bodies, in which explicit expressions for the fundamental traction derivatives were presented. Yue et al. [14] calculated the 3D SIFs of an inclined square crack within a bimaterial cuboid, using the single-domain BEM. Chen et al. [15,16] studied the fracture behavior of a cracked transversely isotropic cuboid also using 3D BEM. Benedetti et al. [17] presented a fast dual BEM for cracked 3D problems.

While the interaction between the inhomogeneities and cracks embedded in a transversely isotropic medium is important, there is no existing literature on this topic. Therefore, in this paper, the effect of a spherical inhomogeneity on the SIFs of a square-shaped crack, both being embedded in a transversely isotropic matrix, is studied using a special BIM formulation. The influence of the distance between the inhomogeneity and the square-shaped

* Corresponding author.
E-mail address: pan2@uakron.edu (E. Pan).

0955-7997/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enganabound.2010.08.005