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Dynamic fracture of a rectangular limited-permeable crack in magneto-electro-elastic media under a time-harmonic elastic P-wave

Pei-Wei Zhang *

Department of Engineering Mechanics, School of Civil Engineering, Southeast University, No. 2, Sipailou Street, Nanjing 210096, PR China

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ABSTRACT

The dynamic behavior of a rectangular limited-permeable crack deeply embedded in transversely isotropic magneto-electro-elastic media was investigated under an incident harmonic stress wave using the generalized Almansi's theorem and the Schmidt method. With the help of the Fourier transform, this problem was formulated into three pairs of dual integral equations with the jumps in displacement across the crack surfaces as the unknown variables. By directly expanding the jumps in displacement across the crack surfaces into a series of Jacobi polynomials, the solution to the dual integral equations was derived. Finally, the dynamic response of a rectangular crack under a harmonic wave was analyzed, and the effects of the electric permittivity and the magnetic permeability of air inside the crack, the geometric shape of the rectangular crack and the characteristics of the harmonic wave on the stress, the electric displacement and the magnetic flux intensity factors in magneto-electro-elastic media were concluded.

1. Introduction

Magneto-electro-elastic materials are a class of important functional materials with its root in the early work of Vansucht (1972), who proposed that the combination of piezoelectric and piezomagnetic phases might exhibit a new material property: the electromagnetic coupling effect. These materials have drawn significant interest in recent decades due to their special magneto-electro-mechanical coupling effects and their rapid development and application in smart materials/intelligent structures. Magneto-electro-elastic materials are widely used as electric packaging, magnetic field probes, hydrophones, medical ultrasonic imaging, and actuators with the functionality of magneto-electro-mechanical energy conversion (Wu and Huang, 2000). When subjected to mechanical, magnetic and electrical loads in work, they easily fail prematurely due to some defects, such as inclusions, holes and cracks arising during their manufacturing process and operation. Therefore, researching the fracture behavior of magneto-electro-elastic materials under coupling loads is very worthwhile (Sih and Song, 2003; Song and Sih, 2003).

Since Vansucht (1972) proposed the electromagnetic coupling effect, magneto-electro-elastic composites, such as $BaTiO_3$–$CoFe_2O_4$ composites, have been investigated by many researchers. Much of the work in the investigation of magneto-electro-elastic materials is focused on their electromagnetic transformation properties, production process, structural optimization and static fracture performance. Although the transient response of piezoelectric materials with cracks has been widely investigated (Shindo et al., 1996; Chen and Yu, 1997; Li, 2001; Wang, 2001; Zhao and Meguid, 2002; Yang and Lee, 2004), to our knowledge, the transient response of cracks in magneto-electro-elastic media has not been extensively studied. Hou and Leung (2004) analyzed the plane strain dynamic problem of a magneto-electro-elastic hollow cylinder by virtue of the separation of variables, the orthogonal expansion technique and the interpolation method. Buchanan (2003) considered the free vibration problem of an infinite magneto-electro-elastic cylinder.

For mode-III cracks, some researchers (Li, 2005; Su et al., 2007; Feng and Pan, 2008; Chen, 2009) have investigated the transient responses of magneto-electro-elastic materials weakened by a/multiple crack (s) under anti-plane mechanical and in-plane electromagnetic impacts, respectively. Using the moving crack model, a few of works (Hu and Li, 2005; Hu et al., 2006; Zhong and Li, 2006; Tupholme, 2009) have dealt with the corresponding anti-plane dynamic problems of cracked magneto-electro-elastic solids, respectively. Zhou et al. (2005) addressed the dynamic analysis of two collinear cracks between two dissimilar magneto-electro-elastic materials under anti-plane waves. Du et al. (2004) obtained the scattered fields of SH waves by a partially debonded magneto-electro-elastic cylindrical inhomogeneity, and determined the numerical results of crack opening displacement. Zhang et al. (2007a,b), by using Schmidt method (Morse and Feshbach, 1958), studied the magneto-electro-elastic dynamic behavior of two collinear interface

* Tel.: +86 025 83792248.
E-mail address: zhangpeiwei@seu.edu.cn

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