An interface crack in piezoelectric bimaterial with an electrically conductive and two electrically permeable zones at its faces

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Abstract A mode III partially electroded interface crack between two different piezoelectric materials under the action of anti-plane mechanical and in-plane electric loadings is analyzed. From the point of view of the boundary conditions on the crack faces, one zone of the crack faces in such crack can be considered as electrically conductive while the other parts are electrically permeable. Using special representations of field variables via sectionally analytic vector-functions, a homogeneous combined Dirichlet-Riemann boundary value problem is formulated. An exact analytical solution of this problem is obtained. Analytical expressions for the shear stress, electric field and also for the crack faces sliding displacement jump are derived. The intensity factors for stress and electric fields are determined as well. The dependencies of the mentioned values on the magnitude of the external electric loading and different ratios between the electrically conductive and electrically permeable crack face zone lengths are also demonstrated.

Keywords: Antiplane problem, Piezoelectric material, Interface crack, Field intensity factors

1. Introduction

It is well known that piezoelectric materials produce an electric field when deformed and undergo deformation when subjected to an electric field. Due to this intrinsic coupling effect, piezoelectric materials are widely used in design of various modern electromechanical devices, such as transducers, capacitors, sensors, and actuators. These smart devices often have a composite structure; therefore, because of the brittleness and the low strength of piezoelectric materials, interface delamination can appear during the manufacturing process or during service by impact electric and mechanical loadings. These delaminations can lead to interface cracks, which are the most dangerous kind of defects in such structures, and, therefore, it is a very important field of investigation.

In some cases, the stress-strain state occurring in the piezoelectric composites is related to anti-plane deformation, which has stimulated an important theoretical effort for the investigation of piezoelectric composites operating in such conditions. In this light, a wealth of theoretical works has been devoted to the analysis of the interface anti-plane shear cracks in piezoelectric materials. For example, anti-plane problems for electrically permeable and impermeable cracks situated at the interface between piezoelectric layers or between a piezoelectric layer and an elastic layer were considered in the works by Narita and Shindo [1999], Soh et al. [2000], Kwon and Lee [2001], Li and Tang [2003a; 2003b], Wang and Sun [2004], Feng et al. [2011]. The papers by Chen et al. [1997], Fil'shtinskii and Fil'shtinskii [1997], Hou and Mei [1998], Gao and Wang [2001] are devoted to the consideration of the mode III interface crack problems for a piezoelectric compound subjected to piecewise uniform anti-plane mechanical loading combined