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Numerical estimation of stress intensity factors in cracked functionally graded piezoelectric materials - a scaled boundary finite element approach

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Abstract

The stress intensity factors and the electrical displacement intensity factor for functionally graded piezoelectric materials (FGPMs) are influenced by: (a) the spatial variation of the mechanical property and (b) the electrical and mechanical boundary conditions. In this work, a semi-analytical technique is proposed to study the fracture parameters of FGPMs subjected to far field traction and electrical boundary conditions. A scaled boundary finite element formulation for the analysis of functionally graded piezoelectric materials is developed. The formulation is linearly complete for uncracked polygons and can capture crack tip singularity for cracked polygons. These salient features enable the computation of the fracture parameters directly from their definition. Numerical examples involving cracks in FGPMs show the accuracy and efficiency of the proposed technique.

Keywords: Scaled boundary finite element method, polygons, functionally graded materials, peizoelectric, stress intensity factors, electrical displacement intensity factor

1. Introduction

Piezoelectric materials have the property of inherently converting the electrical energy into mechanical energy and vice versa making them widely used as **actuators, sensors, transducers etc** [1–3]. This is accomplished by bonding piezoelectric materials with **substrates** [4]. The performance of such structures depends on the bond strength. Such a construction also leads to high level of stress concentration at the substrate - piezoelectric material interface. This can be attributed to the abrupt change in the mechanical and electric materials, leading to stress discontinuities and displacement jumps, which could be potential sites for crack initiation and propagation. The aforementioned difficulty can be alleviated by continuously changing the material properties along certain direction, that can result in improved toughness, high strength, low thermal expansion coefficient and low dielectric current [5, 6].

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