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Dynamic Analysis of Crack Problems in Functionally Graded Materials Using a New Graded Singular Finite Element

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Abstract

In this research a recently developed graded singular element is used for studying dynamic crack problems in linear elastic isotropic functionally graded materials (FGMs) with spatially varying elastic parameters. The formulation for the graded singular element is obtained by analyzing the crack tip stress field using the Westergaard stress function method. Shape functions are extracted by presenting expressions for displacements near the crack tip in terms of the complex functions with unknown coefficients. The stiffness and consistent mass matrices for the singular element are then determined based on the principle of minimum potential energy and kinetic energy of the element, respectively. The global stiffness and mass matrices are then generated by assembling matrices for the singular and adjacent regular elements by considering the displacement continuity at their common boundary. The results from the current method are compared with existing solutions to evaluate the accuracy of the technique. A set of simulations are performed using this element for analyzing dynamic crack problems in FGMs whose elastic properties vary normal to the crack line. Compared with traditional elements, the proposed element includes higher order terms in addition to the singular term, which leads to accurate description of the stress field near the crack tip. It also significantly reduces the calculation time needed in comparison with using very fine mesh of traditional elements. With the use of the singular element, no post processing technique is required for calculating fracture parameters such as stress intensity factors, energy release rate, and mode mixity.

Keywords: Functionally graded material; Dynamic fracture parameters; Singular finite element; Graded element

1. Introduction

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