Transient Wave Propagation in a Damaged Functionally Graded Material Ring: Spectral Element Modelling and Analysis

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Abstract

Functionally graded materials (FGMs) are new composite materials with elastic properties depending on spatial coordinates. Elastic wave propagation through the FGM structures is of considerable interest in many fields. The most typical example of engineering application is the detection of damage in the FGM structures. By studying the propagation behavior of waves, the damage type, location and extent can be determined. Analytical modeling of wave propagation in FGMs is limited to very simple problems. It is not a feasible approach to analyze structures with complex shapes and defects [1].

In this paper, a time-domain 2D curved edge spectral finite element method (SFEM) is introduced for modeling wave propagation in a damaged FGM ring. The proposed element nodes are at Gauss-Lobatto-Legendre (GLL) points. Lagrange interpolation polynomials are used as shape functions and GLL quadrature rules are used. This provides the capability to model the spatial variation of material properties and leads to a diagonal mass matrix. In order to better represent the real curved boundary, the quadratic Lagrange polynomial is used to transfer global physical coordinate to local element parametric coordinate. The effects of material microstructural components, damage degree, damage starting position, and damage zone length on the wave propagation and arrival time of the first wave were analyzed. It is shown that different material components, damage degree, damage starting position, and length of damage zone significantly affect received first wave amplitude and arrival time of the first wave. Results can provide a theoretical basis for nondestructive testing and performance evaluation of FGM ring structures based on transient wave propagation.

Keywords: Damage detection, Functionally graded materials, Spectral element method, Structural health monitoring, Numerical simulation

References

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