A Nonlinear Model of Composite Delaminated Beam with Piezoelectric Actuator, with Account of Nonpenetration Constraint for the Delamination Crack Faces

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Abstract: In this work, a new approach is developed for dynamic analysis of a composite beam with an inter-ply crack, in which a physically impossible interpenetration of the crack faces is prevented by imposing a special constraint, leading to nonlinearity of the formulated boundary value problem and to taking account of a contact interaction of the crack faces. A variational formulation of the problem and partial differential equations of motion with boundary conditions are developed, and solutions of example problems for a piezo-actuated cantilever beam are presented in a form of series in terms of eigenfunctions of the associated non-self-adjoint eigenvalue problem. A noticeable difference of forced vibrations of the delaminated and undelaminated beams due to the contact interaction of the crack faces is predicted by the developed model.

Keywords: Composite beam; delamination; nonpenetration constraint for the crack faces; nonlinear dynamics; series solution; modal analysis.


1 Introduction

In this work, a new variational formulation and differential equations of motion with boundary conditions for a beam with through-width delamination are developed, in which a constraint is introduced that does not allow opposite faces of the crack to penetrate each other, leading to a nonlinear formulation of the problem and to taking account of contact interaction of the crack faces. An equation, which expresses this constraint, is written with the use of the Heaviside function in one of its analytical forms, and the