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A Nonlinear Model for Dynamics of Delaminated Composite Beam with Account of Contact of the Delamination Crack Faces, Based on the First Order Shear Deformation Theory

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Abstract: In this work, a new approach is developed for dynamic analysis of a composite beam with an interplay crack, in which a physically impossible interpenetration of the crack faces is prevented by imposing a special constraint, leading to taking account of a force of contact interaction of the crack faces and to nonlinearity of the formulated boundary value problem. Longitudinal force resultants in the delaminated parts of the beam are taken into account also, which is another source of the nonlinearity. The shear deformation and rotary inertia terms are included into the formulation, to achieve better accuracy. The model is based on the first order shear deformation theory, i.e. the longitudinal displacement is assumed to vary linearly through the beam's thickness. A variational formulation of the problem, nonlinear partial differential equations of motion with boundary conditions, a weak form for the partial differential equations and a finite element formulation on the basis of the weak form are developed. An example problem of a clamped-free beam with a piezoelectric actuator is considered, and its finite element solution is obtained. 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. Besides, linear eigenvalue analysis shows decrease of natural frequencies upon increase of the crack length, and crack opening and closing during the vibration in higher mode shapes, beginning from the fifth one.

Keywords: *Composite delaminated beam; piezoelectric actuator; contact of crack faces; Lagrange multipliers; penalty function method; shear deformation theory; nonlinear partial differential equations; nonlinear finite element analysis.*

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