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Free vibration analysis of moderately thick antisymmetric cross-ply laminated rectangular plates with elastic edge constraints

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ABSTRACT

This study presents a simple formulation for studying the free vibration of shear-deformable antisymmetric cross-ply laminated rectangular plates having translational as well as rotational edge constraints. The aim is to fill the void in the available literature with respect to the free vibration results of *antisymmetric cross-ply laminated rectangular plates*. The spatial discretization of the resulting mathematical model in five field variables is carried out using the two-dimensional Differential Quadrature Method (DQM). Several combinations of translational and rotational elastic edge constraints are considered. Convergence study with respect to the number of nodes has been carried out and the results are compared with those from past investigations available only for simpler problems. Effects of stiffness parameters, geometrical features, moduli ratio and lamination schemes on the natural frequencies are studied.

1. Introduction

Laminated composite plates have found wide applications in structural elements used in various fields like aeronautics, space, automobile, etc. Bending, buckling and vibration problems of laminated plates of various shapes subjected to various combinations of boundary conditions have been the subject of many research papers [1–35].

It is a well known fact that the boundary conditions play a defining role in such problems. Most of the research, including the most recent ones [7–14], have been carried out using the classical boundary conditions. In these classical boundary conditions, corresponding to every degree of freedom, either the corresponding force (natural boundary conditions) or the displacement (essential boundary condition) is prescribed [35]. The more realistic boundary condition is the one which involves some suitable relationship between a displacement component and the corresponding force. These more realistic edge conditions are being investigated by several researchers [15–25] with the help of a model being termed as 'elastic edges.'

Liew et al. [15] presented apparently the first known results of free vibration analysis of symmetrically laminated cross-ply rectangular plates with edges having uniform elastic restraints—translational as well as rotational. Shu and Wang [17] applied generalized differential quadrature method for the vibration analysis of thin isotropic plates with mixed and non-uniform boundary conditions. Gorman [16] applied superposition-Galerkin method and Zhou [18] applied the Rayleigh–Ritz method along with static Timoshenko beam functions for obtaining the natural frequencies of isotropic Mindlin rectangular plates. Ashour [19] did the vibration analysis of isotropic plates having variable thickness in one direction with edges elastically restrained against both rotation and translation using the finite strip transition matrix technique. Karami et al. [20] studied the natural frequencies of moderately thick symmetric laminated plates with elastically restrained edges using the Differential Quadrature Method (DQM). Ohya et al. [21] presented the natural frequencies and mode shapes of the rectangular isotropic Mindlin plates with internal columns resting on uniform elastic edge supports using the superposition method. They achieved the compatibility between the plate and the column by requiring that the column and plate rotations be equal.

Using one- and two-dimensional Fourier series expansions for the implicit spatial discretization, Li et al. [22] presented an exact series solution for the transverse vibration of isotropic thin rectangular plates with general elastic boundary supports. Li and Yu [23] developed an empirical formula based on the analytical results obtained from the Rayleigh–Ritz method for predicting natural frequencies of a thin orthotropic rectangular plate with uniformly restrained edges. Zhang and Li [24] studied the vibration of thin isotropic rectangular plates with arbitrary non-uniform elastic edge restraints, again, using two-dimensional Fourier series expansions. Hsu [25] presented the free vibration

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