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Free vibration analysis of rectangular plates with internal columns and uniform elastic edge supports by pb-2 Ritz method

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ABSTRACT

Free vibration analysis of rectangular plates with internal columns and elastic edge supports is presented using the powerful pb-2 Ritz method. Reddy's third order shear deformation plate theory is employed. The versatile pb-2 Ritz functions defined by the product of a two-dimensional polynomial and a basic function are taken as the admissible functions. Substituting these displacement functions into the energy functional and minimizing the total energy by differentiation, leads to a typical eigenvalue problem, which is solved by a standard eigenvalue solver. Stiffness and mass matrices are numerically integrated over the plate using the Gaussian quadrature. The accuracy and efficiency of the proposed method are demonstrated through several numerical examples by comparison and convergency studies. Many numerical results for reasonable natural frequency parameters of rectangular plates with different combinations of elastic boundary conditions and column supports at any locations are presented, which can be used as a benchmark for future studies in this area.

1. Introduction

Rectangular plates with inner column supports and edge elastic supports are extensively used in mechanical, civil, ships and aircraft manufacturing. A good understanding of the dynamic behaviors of these structural components is crucial to the design and performance evaluation of mechanical systems. With its potential applications, the vibration characteristics of such kinds of plates have received considerable attention from researchers.

A vast body of literature for free vibration studies of plates is available. Excellent reviews have been made by Leissa [1–3] and Liew et al. [4]. Most of the previous studies, however, have been confined to plates having unique simple plan-forms with simple uniform boundary conditions. It is well known that the classical boundary conditions such as clamped, simply supported and free are relatively easy to formulate, but difficult to apply in practice. However, the boundary conditions may have significant influences to the free vibration characteristics of rectangular plates. Therefore, it is necessary to establish new models to evaluate the dynamic behaviors accurately. Considerable researchers use elastic springs to model the plate boundary conditions, and numerous papers have been presented to study the free vibration of plates using this model. Gorman [5,6] studied the free vibration of rectangular plates with elastic edge supports based on the classical plate theory and the Mindlin plate theory using the superposition method. Xiang et al. [7] used polynomials and basic functions as the admissible functions to investigate the free vibration of rectangular Mindlin plates with elastic boundary conditions by the Ritz method. Saha et al. [8] used the vibrating Timoshenko beam functions, and Zhou [9] applied the static Timoshenko beam functions, as the admissible function to analyze the same problem by the Rayleigh–Ritz method. In the seventies of the last century Laura et al. [10,11] presented the pioneer work on the free and forced vibration of circular plates having flexible supports. Recently, Laura and Avalos [12] investigated the transverse vibration problem of circular plates with an eccentric rectangular cutout elastically restrained against rotation and translation on both edges. The Raleigh–Ritz method was employed to obtain the first four frequency coefficients.

About the internal column support, there are several models to describe the effect of a column on the vibration of a plate. The simplest model is to take the column as a rigid point support, which takes the stiffness of the column as infinite in axial direction. Gorman [13,14] presented the solutions for rectangular plates with point supports, based on thin plate theory and the Mindlin plate theory by the superposition method. Liew et al. [15] investigated the Mindlin plates of arbitrary shapes with internal point supports by the Rayleigh–Ritz method. Kim and Dickinson [16] used the Lagrangian multiplier method combined with the orthogonally generated polynomials to study the rectangular plates with point supports. Zhou and Cheung [17,18] studied the free vibrations of tapered rectangular plates and composite

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