Vibration Analysis of Skew Plates of Generally Varying Thickness Subjected to Uniaxial In-Plane Forces

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(Received 12 November 2002; accepted 7 April 2003)

The finite strip transition matrix technique is developed for the analysis of flexural vibration of a skew plate of varying thickness subjected to in-plane force. First, convergence studies and comparisons with results available from the literature are reviewed. Second, a parametric study is presented which investigates the influence of the aspect ratio, the skew angle and the tapered ratio on the natural frequencies of skew plates without in-plane forces for different plate configurations. Finally, the influence of the in-plane force on the natural frequencies of such plates is considered. The results presented in this paper confirm the accuracy, generality, and reliability of the above technique.

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1. INTRODUCTION

Skew plates of varying thickness are very important elements in many engineering applications. The accurate determination of the natural frequencies and the mode shapes of such plates are essential for the designer. In recent years, numerous authors have studied the free vibration of rectangular plates; see, for example, the excellent review papers by Leissa.[1-4] Also, the free vibration of skew plates of uniform thickness has attracted many researchers.[5-9] Moreover, many investigators have considered the free vibration of rectangular plates of varying thickness.[10,11] However, the free vibration of skew plates of varying thickness has received less attention.

In this paper, we will confine our review to a skew plate of varying thickness. Chopra and Durvasula[12] considered simply supported skew plates having a linear variation in thickness in one direction by employing the double Fourier series in oblique co-ordinates to represent the deflection surface in Lagrange's equations. Banerjee[13] determined the natural frequencies of vibrating clamped skew plates with linearly varying thickness using an approximate solution by applying the Galerkin procedure. Matsuda and Sakiyama[14] presented an approximate method to determine the frequencies of skew Mindlin plates with varying thickness for two different configurations, namely 1) plates clamped on all sides, and 2) plates which are clamped on two opposite sides and are simply supported on the other two sides. The solution of the partial differential equations is obtained in discrete form by transforming the differential equations into integral equations and applying numerical integration. They presented the fundamental frequency of such plates in graphical form only. Liu and Chang[15] used the finite element transfer matrix method to investigate the vibration of cantilever plates. Singh and Saxena[16] used the Rayleigh-Ritz method to study the transverse vibration of skew plates of varying thickness with four different combinations of boundary conditions.

Another objective of this paper is to investigate the effect of uniaxial plane force on the transverse vibration of a skew plate of varying thickness. Bassily and Dickinson[17] have applied the perturbation technique to investigate the vibration of plates subjected to in-plane forces. They have derived accurate frequency equations for different combinations of the boundary conditions. Gutierrez and Laura[18] have applied the differential quadrature method to determine the fundamental frequency of a rectangular plate of linearly varying thickness in the x-direction subjected to in-plane shear forces. However, the matrix of the eigenvalue problem became ill conditioned for some cases. Gorman[19] has applied the superposition method to obtain the natural frequencies for a family of elastically supported plates subjected to one-directional uniform in-plane loading.

Farag and Ashour[7] demonstrated the accuracy of the finite strip transition matrix technique for a skew plate of uniform thickness and Ashour[10] employed the Finite Strip Transition Matrix technique (FSTM) method to study the free vibration of rectangular plates of variable thickness. In this paper the FSTM method is extended to investigate the free vibration of a skew plate of generally varying thickness and subjected to in-plane forces.

2. FORMULATION OF THE PROBLEM

Consider an isotropic skew plate of generally varying thickness in the y-axis as shown in Fig. 1.

According to the classical deformation theory, the equation of motion of a thin plate subjected to uniaxial plane force is given by

$$\frac{\partial^2}{\partial x^2}\left[D(y)\left(\frac{\partial^2 W}{\partial x^2}+\nu\frac{\partial^2 W}{\partial y^2}\right)\right]+\frac{\partial^2}{\partial y^2}\left[D(y)\left(\frac{\partial^2 W}{\partial y^2}+\nu\frac{\partial^2 W}{\partial x^2}\right)\right]$$
$$+2\frac{\partial^2}{\partial x\partial y}\left[D(y)(1-\nu)\frac{\partial^2 W}{\partial x\partial y}\right]-N_x\frac{\partial^2 W}{\partial y^2}=-\overline{m}\frac{\partial^2 W}{\partial t^2}, \quad (1)$$

where $W(x,y)$ is the transverse displacement, $\overline{m}=\rho h(\eta)$ is the mass per unit area, $h(y)$ is the thickness at any point y and N_x