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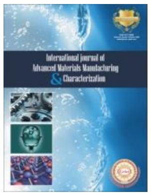

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Free Vibration of Woven Fiber Composite Angular Plates in Adverse Hygrothermal Environment

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A R T I C L E I N F O

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A B S T R A C T

The present study deals with numerical investigation on vibration and buckling behavior of laminated composite angular plates subjected to varying temperature and moisture concentration. Quantitative results are presented to show the effects of geometry, material and lamination parameters of woven fiber laminate on vibration and buckling of composite plates for different temperature and moisture concentrations.

Introduction

Fiber-reinforced composite materials are extensively used in thin walled structural components of various modern engineering structures in the high performance application areas, aerospace, submarines, automobiles and other application areas in which it reduce the overall operational cost have necessitated a strong need to understand their Vibration and Buckling characteristics. Chen and Chen [1] studied the free vibration of the laminated rectangular composite plate exposed to steady state hygrothermal environment. Sai Ram and Sinha [2] investigated the effects of moisture and temperature on the free vibration of laminated composite plates using finite element method. The analysis also accounts for lamina material properties at elevated moisture concentration and temperature. Shen *et al* [3] discussed the dynamic response of shear deformable laminated plates in hygrothermal environments based on a micro-mechanical model. Fakhari and Ohadi [4] studied the large amplitude vibration of functional graded material (FGM) plates under thermal gradient and transverse mechanical loads using finite element method.Zhen and Wanji [5] proposed with a mathematical model for determination of the buckling analysis of angle-ply composite and sandwich plates. Analysis is based on the global-local higher order theory with combination of geometric stiffness matrix. Pandey *et al.* [6] studied the hygrothermoelastic post buckling response of laminated composite plates. The quadratic extrapolation technique and first converging finite double chebyshev series are used for linearization and spatial discretization of the governing non linear equations of equilibrium. Jones [7] proposed the thermal buckling of uniformly heated unidirectional and symmetric cross-ply laminated fiber reinforced composites uniaxial in-plane restrained simply supported rectangular plates. Dash *et al.* [8] presented an experimental study on the effects of corrosion on elastic buckling and post buckling response of unidirectional E-glass/epoxy composite rectangular plates subjected to compressive load and liquid environment exposure.

II. Mathematical formulation

The mathematical formulation for buckling effects of laminated composite plates subjected to moisture and temperature are presented. Consider a laminated plate of uniform thickness 't' consisting of a number of thin lamiae, each of which may be arbitrarily oriented at an angle 'θ' with reference to the X-axis of the co-ordinate system as shown in Figures 1.

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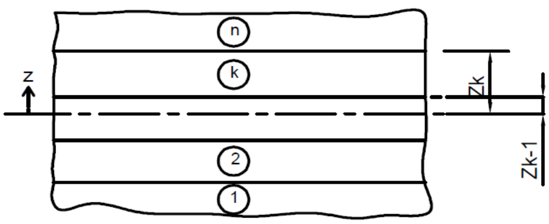

Figure 1. Geometry of an n-layered laminate.

A. Governing Equations

The governing equations for the structural behavior of the laminated composite plates are derived on the basis of first order shear deformation theory. The constitutive relations for the plate subjected to moisture and temperature are given by:

$$\{F\} = \{N_x, N_y, N_{xy}, M_x, M_y, M_{xy}, Q_x, Q_y\}^T$$

$$\{F^N\} = \{N_x{}^N, N_y{}^N, N_{xy}, M_x{}^N, M_y{}^N, M_{xy}{}^N, 0, 0\}^T$$

$$\{\varepsilon\} = \{\varepsilon_x, \varepsilon_y, \gamma_{xy}, K_x, K_y, K_{xy}, \varphi_x, \varphi_y\}^T$$

$$\{F\} = [D]\{\varepsilon\} - \{F^N\}$$

(1)

Where

Where, $N_x, N_y, N_{xy} =$ in-plane internal stress resultants. (2)

$M_x, M_y, M_{xy} =$ internal moment resultants.

Q_x, Q_y = transverse shear resultants.

$N_x{}^N, N_y{}^N, N_{xy}{}^N =$ in-plane non-mechanical stress resultants due to moisture and temperature.

$M_x{}^N, M_y{}^N, M_{xy}{}^N =$ non- mechanical moment resultants due to moisture and temperature.

$\varepsilon_x, \varepsilon_y, \gamma_{xy}$ = in-plane strains of the mid-plane.

K_x, K_Y, K_{xy} = Curvature of the plate

φ_x, ϕ_y = Shear rotations in x-z and y-z planes, respectively.

B. Derivation of Element matrices

The element matrices are derived as given below:

Element stiffness matrix

$$[K_e] = \int_{-1}^{+1}\int_{-1}^{+1}[B]^T[D][B]J|d\xi d\eta \tag{3}$$

Element initial stress stiffness matrix (due to non mechanical loads)

$$[K_g] = \int_{-1}^{+1}\int_{-1}^{+1}[G]^T[S][G]J|d\xi d\eta \tag{4}$$

Element mass matrix

$$[M] = \int_{-1}^{+1}\int_{-1}^{+1}[N]^T[P][N]J|d\xi d\eta \tag{5}$$

The element load vector due to hygrothermal forces and moments is given by

$$\{P_e{}^N\} = \int_{-1}^{+1}\int_{-1}^{+1}[B]^T\{F^N\}J|d\xi d\eta$$

(6)

III. Results and Discussions

As shown in figure 2 and 3 the frequency of vibration for different lamination sequence are studied numerically with increase in temperature and moisture concentration respectively. It is observed that the anti-symmetric laminates are stiffer due to their bending stretching and coupling effects. With increase in temperature and moisture frequency of vibration decreased for all laminates.

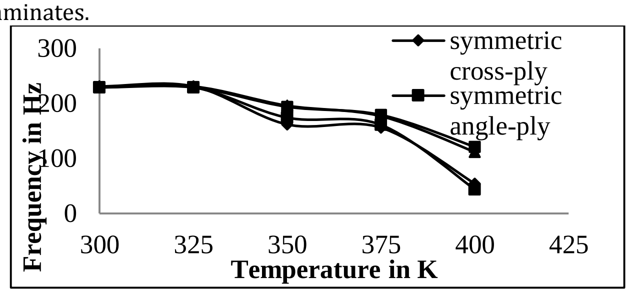

Figure- 2. Variation of frequency with temperature for clamped boundary condition (c-c-c-c) laminates.

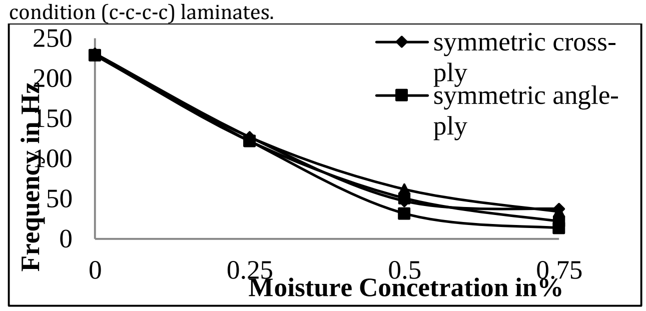

Figure- 3.Variation of frequency with moisture concentration for clamped boundary condition (c-c-c-c) laminates.

As shown in figure 4 and 5 the critical buckling load for different lamination sequence are studied numerically with increase in temperature and moisture concentration respectively. It is observed that the anti-symmetric laminates are stiffer to their bending stretching and coupling effects. With increase in temperature and moisture buckling loads decreased for all laminates.

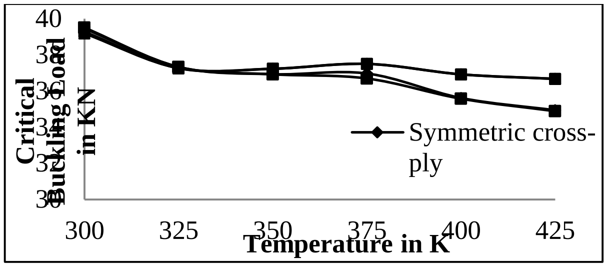

Figure- 4. Variation of critical buckling load with temperature for clamped boundary condition (c-c-c-c) laminates

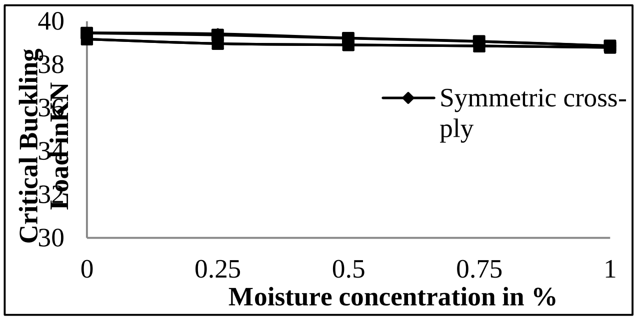

Figure- 5. Variation of critical buckling load with moisture concentration for clamped boundary condition (c-c-c-c) laminates

Conclusions

- There is a good agreement between the experimental and numerical results for natural frequencies and buckling of laminated composite plates at different temperature and moisture.
- The fundamental frequencies of vibration decrease for symmetric laminates compared to anti-symmetric laminates.
- The critical buckling load in KN for anti-symmetric laminate is more in compared to symmetric laminates**.**

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