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Free vibration analysis of sandwich structures reinforced by functionally graded carbon nanotubes

Alireza Pourmoayed*[1], Keramat Malekzadeh Fard[2a] and Borhan Rousta[3b]

[1]*Department of Mechanical Engineering, University of Khatamul-Anbiya Air Defense, Tehran, Iran*
[2]*Department of Aerospace Engineering, MalekAshtar University of Technology, Tehran, Iran*
[3]*Institute of Aviation Industry, Tehran, Iran*

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Abstract. In this research, the behavior of free vibrations of sandwich structure with viscoelastic piezoelectric composite face sheets reinforced by Functionally Graded Carbon Nanotubes (FG-CNTs) and simply supported boundary conditions using a new improved higher-order sandwich panel theory were investigated. The viscoelastic sandwich structure is rested on viscoelastic foundation. There are 33 freedom degree based on higher order plate theories for top, center and bottom of the sandwich plate. To calculate exact solution, all of the stress components were engaged. The governing equations and boundary conditions were derived via the Hamilton's principle and finally, these equations solved by Navier's method. The accuracy of the present solutions is verified by comparing the obtained results with the existing solutions. The effect of different distributions of carbon nanotubes on non-dimensional natural frequency were inquired. Also, the effect of some important parameters such as those of length-to-thickness ratio and volume percentages of fibers, core thickness, elastic foundation, temperature and humidity changes, magnetic field, viscosity and voltage on free vibration response of sandwich structure were investigated.

Keywords: free vibration; sandwich structures; carbon nanotubes; viscoelastic foundation; piezoelectric

1. Introduction

Nowadays, sandwich structures vastly are used in aerospace, marine and automobile industries. Nano sandwich structures are the nanocomposite structures that are made of one or several materials with different shapes so that they result in lower weight, higher strength and good dynamic properties. Among these materials, polymeric sandwich nanostructures have higher performance and in various industries can be used. Also, in order to improve properties of mechanical, thermal and electrical various reinforces, including nanomaterials to these composite materials are added. In Mahi and Tounsi (2015), bending and free vibration analysis of isotropic, functionally graded, sandwich and laminated composite plates using a new hyperbolic shear deformation theory are presented. They accurate free vibration frequencies using a set of boundary characteristic orthogonal polynomials associated with Ritz method are calculated. In Ebrahimi and Farazmandnia (2018),

*Corresponding author, Assistant Professor, E-mail: pourmoayed@mut.ac.ir
[a]Professor, E-mail: kmalekzadeh@mut.ac.ir
[b]Ph.D., E-mail: Borhanrousta@yahoo.com

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$$\delta\lambda_5 w_{0t} + \frac{h_t}{2} w_{1t} + \left(\frac{h_t}{2}\right)^2 w_{2t} - w_{0c} + \frac{h_c}{2} w_{1c} - \left(\frac{h_c}{2}\right)^2 w_{2c} = 0$$

$$\delta\lambda_{10} \frac{\partial w_{0b}}{\partial x} + (h_b/2) \frac{\partial w_{1b}}{\partial x} + (h_b/2)^2 \frac{\partial w_{2b}}{\partial x} + u_{1b} + h_b u_{2b} + 3(h_b/2)^2 u_{3b} = 0$$

$$\delta\lambda_{16} Q_{55}^b \left(\frac{\partial w_{0b}}{\partial x} + \left(-\frac{h_b}{2}\right) \frac{\partial w_{1b}}{\partial x} + \left(\frac{h_b}{2}\right)^2 \frac{\partial w_{2b}}{\partial x} + u_{1b} - h_b u_{2b} + 3\left(\frac{h_b}{2}\right)^2 u_{3b}\right) - G_{xz}^c \left(\frac{\partial w_{0c}}{\partial x} + (h_c/2) \frac{\partial w_{1c}}{\partial x} + (h_c/2)^2 \frac{\partial w_{2c}}{\partial x} + u_{1c} + h_c u_{2c} + 3(h_c/2)^2 u_{3c}\right) = 0$$

Appendix C

$$\begin{aligned}
\lambda_1(x,y,t) &= \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \lambda_1^{mn}\, e^{i\omega t} \sin(n\pi y/b)\cos(m\pi x/a) \\
\lambda_3(x,y,t) &= \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \lambda_3^{mn}\, e^{i\omega t} \cos(n\pi y/b)\sin(m\pi x/a) \\
\lambda_8(x,y,t) &= \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \lambda_8^{mn}\, e^{i\omega t} \sin(n\pi y/b)\cos(m\pi x/a) \\
\lambda_{11}(x,y,t) &= \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \lambda_{11}^{mn}\, e^{i\omega t} \sin(n\pi y/b)\sin(m\pi x/a) \\
\lambda_{15}(x,y,t) &= \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \lambda_{15}^{mn}\, e^{i\omega t} \cos(n\pi y/b)\sin(m\pi x/a) \\
\lambda_{16}(x,y,t) &= \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \lambda_{16}^{mn}\, e^{i\omega t} \sin(n\pi y/b)\cos(m\pi x/a)
\end{aligned} \tag{C1}$$