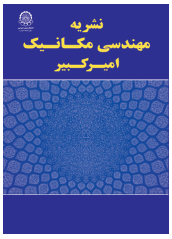

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Buckling and Vibration Analyses of Double-bonded Micro Composite Plates Reinforced by CNTs and BNNTs Based on MSGT

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ABSTRACT: In this work, buckling and free vibration analyses of double-bonded micro composite plates reinforced by boron nitride and carbon nanotubes rested in an orthotropic foundation in presence of initial stresses and electro-magneto-thermal multi-physics fields are investigated based on sinusoidal shear deformation theory. The relation between electro-magneto-thermo-mechanical parameters are presented based on most general strain gradient theory and the governing equations of motions are obtained using Hamilton's principle. With solving the governing equations of motions of double-bonded nanocomposite micro plates the effect of various parameters such as mass scale length parameter, length-to-thickness and width ratios, orthotropic elastic constants, temperature changes and boron nitride and carbon nano tubes volume fractions are considered. The obtained results of this work demonstrate that the natural frequencies and critical buckling load enhance with increasing the mass scale length parameter, orthotropic elastic constants and nanotubes volume fractions and lead to delay the resonance phenomenon. While increasing the temperature changes lead to reduce the micro structure stiffness, natural frequencies and critical buckling load. It can be said that this application can be used in micro electro mechanical and nano electro mechanical systems and provide a great background for more studies.

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1- Introduction

In last decades, composites micro structures reinforced by Boron Nitride and Carbon Nano Tubes (BNNTs, CNTs) have many applications in nanotechnology. Due to the being light with a high strength to weight ratio, these structures have been accepted by many researchers and they are published many studies in this field.

For example, Lei et al. [1] predicted buckling and vibration response of nanocomposite plates reinforced by CNTs and concluded that the equal properties are the same for the Mori-Tanaka approach and mixture rule in 300K.

In this work, buckling and free vibration analyses of double-bonded nanocomposite micro plates reinforced by BNNTs and CNTs rested in an orthotropic elastic foundation under electro-magneto-thermo-mechanical loadings are presented based on Sinusoidal Shear Deformation Plate Theory (SSDT) and Most General Strain Gradient Theory (MGSGT).

2- Methodology

The schematic of double-bonded micro composite plates with length *a,* width *b* and thickness *h* resting in an orthotropic elastic medium under magnetic and electric fields is shown in Fig. 1.

In this work, the micro plates governing equations of motions are derived using SSDT. According to this model, the displacement fields can be written as follows [2]:

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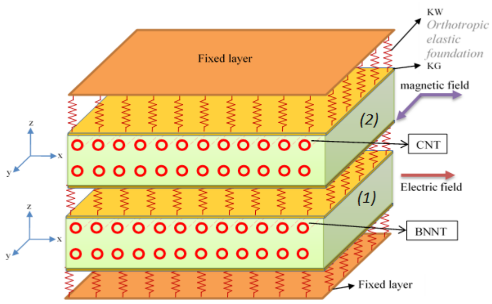

Fig. 1. Geometry of double-bonded micro composite plates reinforced by CNTs and BNNTs

$$\begin{cases} u^{(i)} = u_0^{(i)} - z\dfrac{\partial w_0^{(i)}}{\partial x} + \Phi(z)\theta_x^{(i)} \\ v^{(i)} = v_0^{(i)} - z\dfrac{\partial w_0^{(i)}}{\partial y} + \Phi(z)\theta_y^{(i)} \\ w^{(i)} = w_0^{(i)} \end{cases} \quad \begin{pmatrix} \Phi(z) = \dfrac{h}{\pi}\sin(\dfrac{\pi z}{h}) \\ i = 1,2 \end{pmatrix} \tag{1}$$

Based on MGSGT, the strain energy is a function of both strain and curvature tensors and magnetic and electric vectors. Thus, the first variation of the strain energy can be described as follows [3]:

$$\delta U = \int_{\forall}\left(\sigma_{ij}\delta\varepsilon_{ij} + \tau_{ijk}\delta\xi_{ijk} - \gamma_1 D_i \delta E_i - \gamma_2 B_i \delta H_i\right)d\forall \tag{2}$$

Also, the first variation of the Kinetic energy on the time interval is written as follows [2]:

$$\delta T = \frac{1}{2}\int_{\forall} \delta\left[\rho^i\left((\frac{\partial u^{(i)}}{\partial t})^2 + (\frac{\partial v^{(i)}}{\partial t})^2 + (\frac{\partial w^{(i)}}{\partial t})^2\right)\right] d\forall \quad ; \ (i=1,2) \tag{3}$$

Also, the first variation of work done by external forces can be defined as follows:

$$\delta V = \frac{1}{2}\int_A \delta\left[F_i^{elastic} w_i - N_{0x}(\frac{\partial w^{(i)}}{\partial x})^2\right] dA \tag{4}$$

Where $F_i^{elastic}$ and N_{0x} are the work done by orthotropic elastic foundation and pre-stresses loads, respectively. Finally, by using the strain density, kinetic energy and external works equations, the governing equations of motions of double-bonded micro composite plates reinforces by CNTs and BNNTs in presence of different physical fields are obtained. Then, the semi-analytical Navier's type solution method is employed to solve these equations. For this purpose, the displacement functions are expressed as product of undetermined coefficients and known trigonometric functions so as to satisfy the governing equations. The following expansions of the displacement field are assumed:

$$\begin{cases} (u_0, \theta_x) = \sum_{n=1}^{\infty}\sum_{m=1}^{\infty}(U_{mn}, \theta_{xmn})\cos(\frac{m\pi}{a}x)\sin(\frac{n\pi}{b}y)e^{i\omega t} \\ (v_0, \theta_y) = \sum_{n=1}^{\infty}\sum_{m=1}^{\infty}(V_{mn}, \theta_{ymn})\sin(\frac{m\pi}{a}x)\cos(\frac{n\pi}{b}y)e^{i\omega t} \\ (w_0, \phi_H, \phi_E) = \sum_{n=1}^{\infty}\sum_{m=1}^{\infty}(W_{mn}, \phi_{Hmn}, \phi_{Emn})\sin(\frac{m\pi}{a}x)\sin(\frac{n\pi}{b}y)e^{i\omega t} \end{cases} \tag{5}$$

3- Results and Discussion

In this system, the upper and lower micro plates reinforced by CNTs and BNNTs in presence of the magnetic and electric fields, respectively. The used parameter can be defined as follows:

$l = 17.6\,\mu m$, $l_0 = l_1 = l_2 = l$, $h = 4l$, $a = 10h$, $b = a$, $k_w = 10(\mathrm{GN/m^3})$, $k_G = 10(\mathrm{kN/m})$, $T_0 = 300\mathrm{K}$, $\Delta T = 50$.

Figs. 2 and 3 show the effects of orthotropic elastic foundation on the natural frequencies and critical buckling load, respectively. It is observed that increasing the Winkler spring constant to $k_w = 10(\mathrm{GN/m^3})$ has no important effect on the natural frequencies and critical buckling load. In fact, it can be said that if the Winkler spring constant change $10^2 < k_w < 10^4(\mathrm{GN/m^3})$, the natural frequency and critical buckling load can be controlled by orthotropic elastic medium. Moreover, the effect of Pasternak shear moduli is more than Winkler constant.

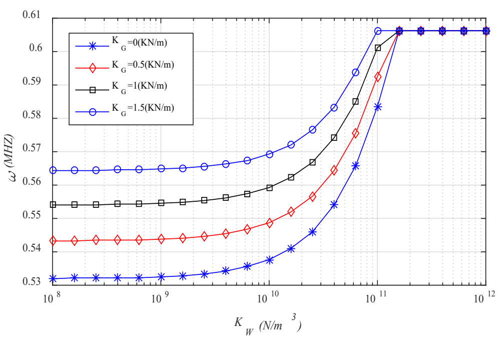

Fig. 2. Effects of orthotropic elastic foundation on the natural frequencies of double-bonded micro plates

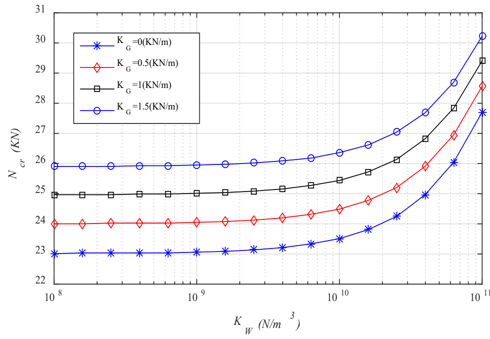

Fig. 3. Effects of orthotropic elastic foundation on the critical buckling load of double-bonded micro plate

Table 1 shows the effects of CNTs and BNNTS in the lower and upper double-bonded micro composite plates. According to this table the natural frequency and critical buckling load are more than the other distribution when the both of micro plates reinforced by CNTs. Thus, it can be say that the presence of carbon nanotube plays special role on the stiffness of micro structures.

5- Conclusion

In this work, electro-magneto-thermo-mechanical buckling and free vibration analyses of double-bonded nanocomposite micro plates reinforced by BNNTs and CNTs rested in an orthotropic medium investigated based on SSDT and MGSGT. The obtained results can be summarized as follows:

1) The BNNTs and CNTs had important effect on the buckling and free vibration behaviors of system. So that, the natural frequency and critical buckling load increased by increasing the volume fraction of nanotubes.

2) The presence of orthotropic elastic foundation led to increase the micro structure stiffness. Thus enhanced the natural frequency and critical buckling load and delayed the resonance phenomenon.

3) Temperature changes had a small effect on the natural frequencies and critical buckling load. In fact, in can be say that the effect of temperature was inconsiderable in comparison of the other multi-physics fields.

Table 1. comparison of various nanotubes distribution in the lower and upper double-bonded micro plates

Type of distribution (Lower-Upper)	Natural Frequency (Hz)	Critical buckling load (N)
CNT-CNT	712249.0	41851.4
CNT-BNNT	532208.0	23036.1
BNNT-CNT	532208.0	23036.1
BNNT-BNNT	532162.0	23032.1

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References

[1] Z.X. Lei, K.M. Liew, J.L. Yu, Buckling analysis of functionally graded carbon nanotube-reinforced composite plates using the element-free kp-Ritz method, *Composite Structures*, 98 (2013) 160-168.

[2] M. Mohammadimehr, B. Rousta Navi, A. Ghorbanpour Arani, Modified strain gradient Reddy rectangular plate model for biaxial buckling and bending analysis of double-coupled piezoelectric polymeric nanocomposite reinforced by FG-SWNT, *Composites Part B: Engineering*, 87 (2016) 132-148.

[3], R. Ansari, R. Gholami, M. Faghih Shojaei, V. Mohammadi, S. Sahmani, Size-dependent bending, buckling and free vibration of functionally graded Timoshenko microbeams based on the most general strain gradient theory, *Composite Structures*, 100 (2013) 385-397.

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