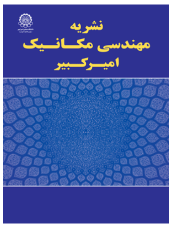
Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 54(2) (2022) 77-80
DOI: 10.22060/mej.2022.20132.7174



Free Vibrations of Embedded Functionally Graded Graphene Platelets Reinforced Porous Nanocomposite Plates with Various Shapes Using P-Ritz Method

M. Z. Doust Abed[1], R. Gholami[2] , R. Ansari[1]

[1] Department of Mechanical Engineering, University of Guilan, Rasht, Iran
[2] Department of Mechanical Engineering, Lahijan Branch, Islamic Azad University, Lahijan, Iran

ABSTRACT: In this study, the free vibrations of functionally graded graphene platelet-reinforced porous nanocomposite plates with various shapes such as rectangular, elliptical, and triangular ones embedded on an elastic foundation are analyzed. To mathematically model the considered plate and elastic foundation, the first-order shear deformation plate theory, and Pasternak model are used, respectively. Three types of graphene nanoplatelet distribution patterns and porous dispersion types through the thickness are considered for the nanocomposite plate. To obtain the effective material properties of the considered nanocomposite, a micromechanical model is employed. Then, the energy functional of considered functionally graded graphene platelet-reinforced porous nanocomposite plates are expressed, and the analytical P-Ritz method is used to solve the vibration problem corresponding to different shapes and boundary conditions, the influences of porosity coefficient, the weight fraction of graphene nanoplatelets, elastic foundation coefficients and also the lengths-to-width and -thickness ratios on the natural frequency are analyzed. It is illustrated that the plate with non-uniform and symmetric of first type porosity distribution pattern and the first type graphene nanoplatelets has a higher natural frequency. Also, by increasing the porosity coefficient, the natural frequency of the plate associated with all patterns of graphene nanoplatelets is reduced.

Review History:

Received: Jun. 05, 2021
Revised: Oct. 27, 2021
Accepted: Dec. 20, 2021
Available Online: Jan. 26, 2022

Keywords:

Free vibration
Porous nanocomposite plates
Plates with various shapes
Elastic foundation
P-Ritz method.

1- Introduction

In recent years, many studies have been conducted on mechanical behaviors of Functionally Graded (FG) graphene platelets reinforced porous nanocomposite beams, plates, and shells. The effects of the geometry of nanoplatelets, weight fraction, porosity distribution, and geometric parameters on bending, buckling, and vibrational behaviors have been investigated [1].

Literature review shows that no study has been performed on free vibration of nanocomposite plate Reinforced Graphene Nanoplatelets (GPL) with arbitrary shapes including rectangular, elliptical, and isosceles triangular. In the present study, based on the first order shear deformation theory and using the p-Ritz method, the free vibration of arbitrary-shaped porous nanocomposite plates embedded on an elastic foundation is investigated. The elastic foundation is formulated using the Winkler-Pasternak model. Three types of distribution for pores and graphene nanoplatelets through the thickness are considered. The modified Halpin-Tsai micromechanics model and extended rule of the mixture are used to determine the effective material properties of the porous nanocomposite.

After convergence study and verifying the accuracy of the present results, a comprehensive parametric investigation is performed to study the influence of the weight fraction and geometric parameters of GPL nanofiller and porosity coefficient on the vibrational behavior of porous nanocomposite plates with various shapes.

2- Problem Formulation

In this paper, three types of FG porous plates along with the even porosity distribution case, denoted by $\acute{u}_{ü}$, , are considered. To further strengthen the mechanical properties, the metal matrix of the composite plate is reinforced by GPLs. And the distribution of GPLs in the metal matrix may be uniform or non-uniform by adjusting the volume fraction along the plate thickness. Three different GPLs patterns are also considered for each porosity distribution which are [1].

Three distributions of internal pore inside of the proposed porous plates and three GPL dispersion patterns regarding the varying nanofillers volume contents $V_{ü}$ across the thickness are assumed.

The variation of Young's module, shear module, and mass density through the thickness direction for different porosity distribution can be described by Eq. (1) and N_0 is the coefficients of porosity.

*Corresponding author's email: gholami_r@liau.ac.ir

$$E(z)=E_{\max}\left(1-N_0\phi(z)\right)$$
$$G(z)=G_{\max}\left(1-N_0\phi(z)\right) \quad (1)$$
$$\rho(z)=\rho_{\max}\left(1-N_m\phi(z)\right)$$

The effective Young's module and mass density are obtained based on the Halpin-Tsai micromechanics model.

The adopted admissible P-Ritz functions which satisfy at least boundary condition for the deflection and rotation of plate are given by Eq. (4) [2]:

$$w(\tau,\xi,\eta)=\sum_{q=0}^{p}\sum_{i=0}^{q}c_m(2\xi)^i(2\eta)^{q-i}\phi_b^w(\xi,\eta)e^{i\omega\tau}$$
$$\phi_x(\tau,\xi,\eta)=\sum_{q=0}^{p}\sum_{i=0}^{q}d_m(2\xi)^i(2\eta)^{q-i}\phi_b^x(\xi,\eta)e^{i\omega\tau} \quad (2)$$
$$\phi_y(\tau,\xi,\eta)=\sum_{q=0}^{p}\sum_{i=0}^{q}e_m(2\xi)^i(2\eta)^{q-i}\phi_b^y(\xi,\eta)e^{i\omega\tau}$$

According to the P-Ritz method, the minimizing of total potential energy with respect to unknown displacement parameters yields:

$$\Pi^*=\frac{\Pi}{\Delta}=\bar{U}+\bar{V}_e-\bar{K} \quad (3)$$

The governing equation for free vibration analysis is expressed as:

Table 1. Comparting of natural frequencies of the elliptical homogenous plate under simply supported boundary conditions

	[3]		Present	
a/b	$\upsilon=0/5$	$\upsilon=0/25$	$\upsilon=0/5$	$\upsilon=0/25$
1	5/219	4/865	5/21929	4/865272
1/2	4/442	4/157	4/44171	4/157386

$$\left(\left[K\right]-\omega^2\left[M\right]\right)\begin{Bmatrix}\{c\}\\\{d\}\\\{e\}\end{Bmatrix}=0$$
$$\omega=\Omega a\sqrt{\frac{I_{110}}{A_{110}}} \quad (4)$$

3- Results and Discussion

At the first step, the natural frequencies of the elliptical homogenous plate without pore and graphene platelet nanofillers are compared with those given in reference [3], as given in Table 1. An excellent agreement can be found between the provided results and those given in the literature.

The variation of the dimensionless natural frequency of the elliptical plate versus the GPL weight fraction is illustrated in Fig. 1 for different porosity and graphene platelets distribution patterns. Fundamental frequency increases by an increase in GPLs weight fraction. Compared to patterns B and C, the effect of GPLs with symmetric pattern A on the natural frequency is more considerable.

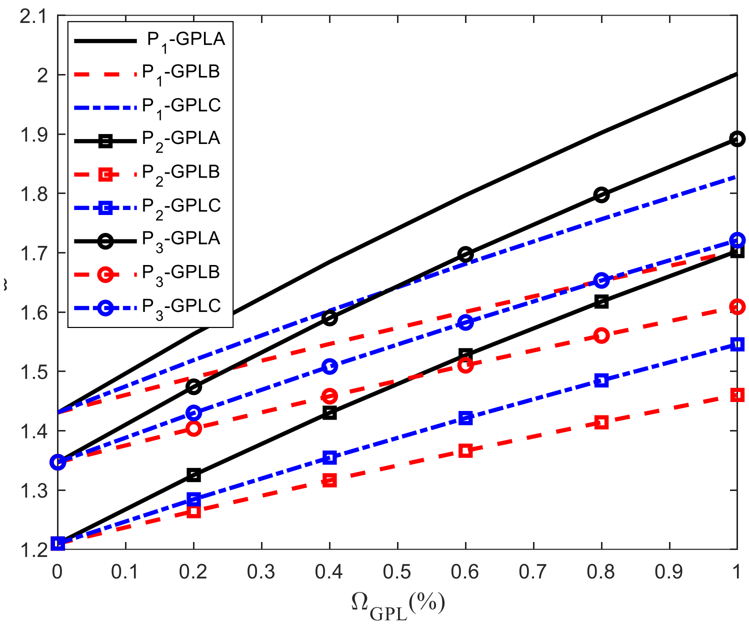


Fig. 1. Comparison of the natural frequency of elliptical plate versus the GPL weight fraction for the clamped boundary conditions

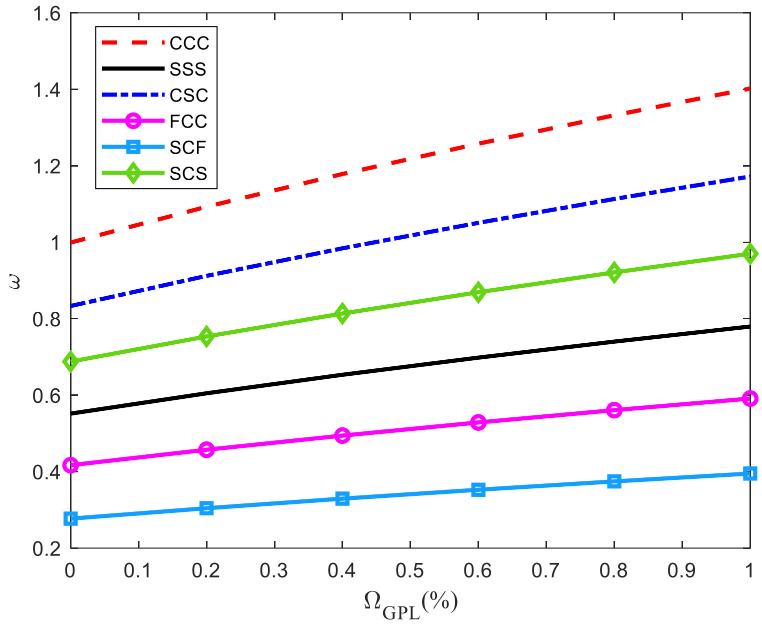


Fig. 2. Comparison of the natural frequency of isosceles triangular plate versus the GPL weight fraction for various boundary conditions

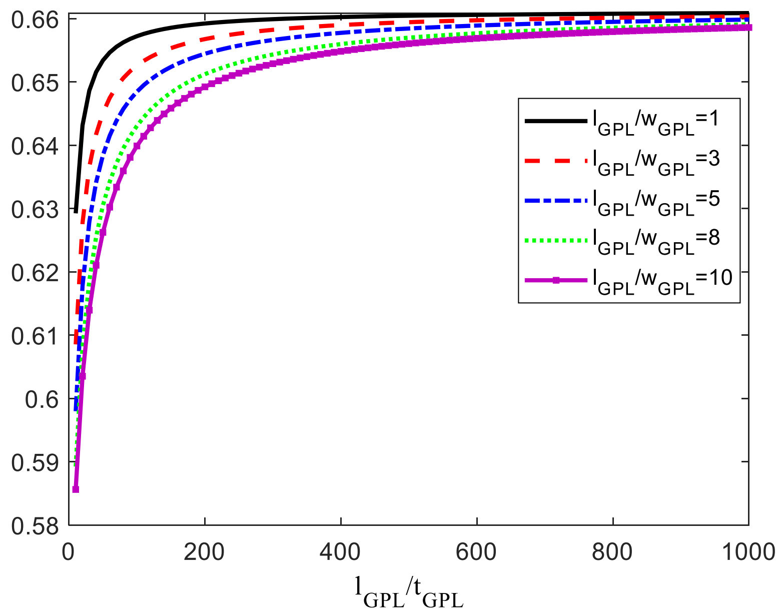


Fig. 3. Comparison of the natural frequency of rectangular plate versus the length to thickness ratio of GPLs under CSCS boundary conditions for GPL pattern

Fig. 2 depicts the variation of the dimensionless natural frequency of porous nanocomposite isosceles triangular plate versus the GPL weight fraction for various boundary conditions. Also, Fig. 3 illustrates the variations of the dimensionless natural frequency of porous nanocomposite rectangular plate versus the GPL shape ratio l_{GPL}/t_{GPL} for various l_{GPL}/w_{GPL} . It can be seen that for higher values of l_{GPL}/t_{GPL} , increasing l_{GPL}/w_{GPL} , the differences between the natural frequencies are negligible.

4- Conclusions

•The maximum frequencies can be achieved for the no-uniformly symmetric porosity distribution 1 and GPL pattern A.

•An increase in the weight fraction leads to an increase in the natural frequencies of porous nanocomposite plates.

•Increasing the and ratios result in increasing and decreasing the natural frequencies of porous nanocomposite plates, respectively.

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HOW TO CITE THIS ARTICLE

M. Z. Doust Abed, R. Gholami , R. Ansari , Free Vibrations of Embedded Functionally Graded Graphene Platelets Reinforced Porous Nanocomposite Plates with Various Shapes Using P-Ritz Method, Amirkabir J. Mech Eng., 54(2) (2022) 77-80.

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