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Free vibration analysis of FGM plates with opening and stiffener

Mojtaba Shahraki[a], Farzad Shahabian[b*] , Reza Jome Manzari[c]

[a] Structural Engineering Department, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
[b] Structural Engineering Department, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
[c] Graduated in Structural Engineering Department, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran

ABSTRACT: Functionally Graded Materials (FGMs) are kinds of composite materials that due to the continuity of mixture of constituent materials as Functionally Graded, have more effective mechanical properties than multilayered composite materials. The most common use of these materials is in thin-walled structures such as plates and shells. Due to some executive needs, make opening and stiffener in plates might be necessary. Free vibration of a system is performed only under the influence of initial conditions and without any external excitation. A system under free vibration situation vibrates with one or more its natural frequencies. If the frequency of vibration caused by the effect of external excitation is equal to the one of the natural frequencies of the system, resonance state occurs. In this case, there will be a large amplitude fluctuation that can cause fracture of huge structures such as bridges and wings of aircrafts. Therefore, in the present study, the effective parameters on free vibration of FGM plates with opening and stiffener have been studied.

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The FGM plate made of ceramic and metal phases that properties of materials varies smoothly along the thickness (Fig. 1). Using the mixing rule, material properties such as modulus of elasticity *E*, Poisson ratio υ and mass density ρ vary across the thickness and are defined according to the Eqs. (1), (2) and (3).

$$P(z,\ T) = P_c(T)V_c(z) + P_m(T)V_m(z) \tag{1}$$

$$V_c(z) + V_m(z) = 1 \tag{2}$$

$$V_c = \left(\frac{2z + h}{2h}\right)^n \tag{3}$$

where $P_c(T)$ and $P_m(T)$ represent the mechanical properties of ceramic and metal phases, respectivey, n is the volume fraction index, h is the plate thickness, $V_c(z)$ and $V_m(z)$ are volume fractions of the ceramic and metal, respectively [2, 3].

In this research, the type of the FGM composite material is selected as ceramic-metal (Silicon Nitride (Si_3N_4)-Stainless Steel (SUS304)). According to the ASTM-C20 code, mechanical properties of these materials, such as Young's modulus, density, and Poisson ratio, are given in Table 1. The inner and outer surfaces of the plate are metal and ceramic, respectively.

In order to verify the modeling of free vibration analysis of FGM plates, a rectangular plate analyzed by finite element method [4], was modeled in Abaqus software and and it was observed that the results have acceptable accuracy compared to the reference. After assuring the method of modeling and analyzing of the FGM plate, the properties of each layer were calculated according to the mentioned relationships of FGM materials. The plates were modeled using a multilayer equivalent method in 20 layers with simple and fixed boundary conditions [5].

In this study, the issues that were considered less by the researchers, have been investigated. To do this, the effect of important parameters such as the volume fraction index, aspect ratio, thickness and the supporting conditions on the natural frequency of the first five modes were determined and compared with each other. The results of free vibration analysis showed that by increasing the volume fraction index, the natural frequencies have decreased, In such a way that maximum of the frequency in the metal-rich plate ($n = \infty$) and the minimum of that in the ceramic-rich plate ($n = 0$) has occurred. By evaluating the geometrical properties of the FGM plate, it was observed that by increasing the thickness and aspect ratio of the FGM plate, the natural frequencies

*Corresponding author's email: shahabf@um.ac.ir

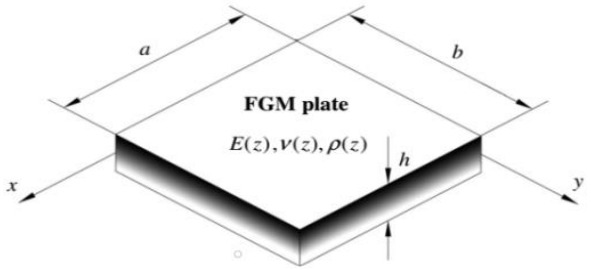

Fig. 1: Schematic of the FGM plate and Cartesian coordinates syste [1].

Table 1: FGM mechanical properties.

Materials properties	Elastic Modulus (GPa)	Density (kg/m³)	Poisson's Ratio
Stainless Steel (SUS304)	201.04	8166	0.3262
Silicon Nitride (Si_3N_4))	348.43	2370	0.23

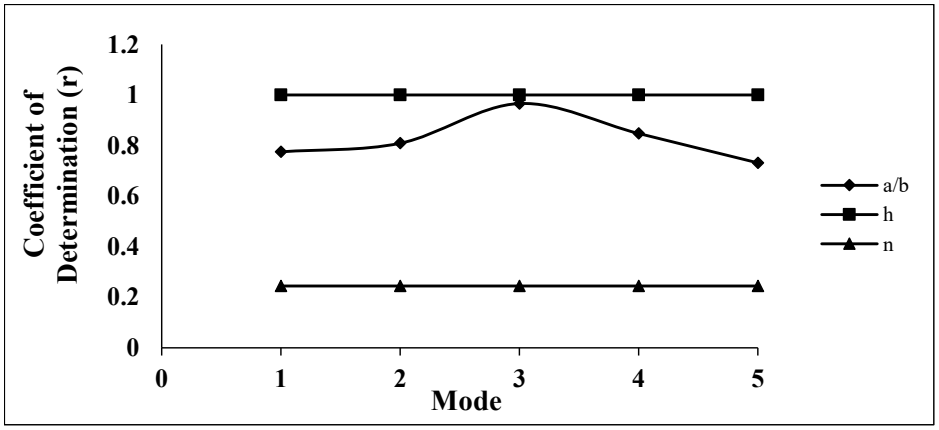

Fig. 2: The effect of each parameters on the natural frequencies of the FGM plate.

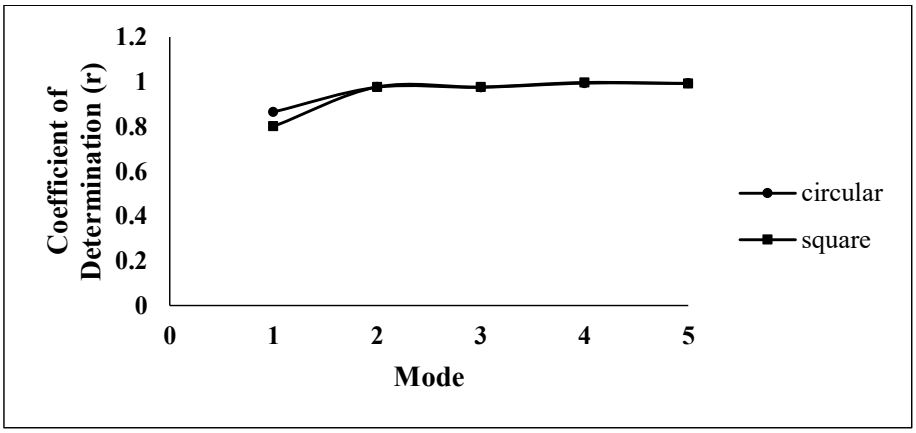

Fig. 3: The effect of Circular and square openings on the natural frequencies of the FGM plate.

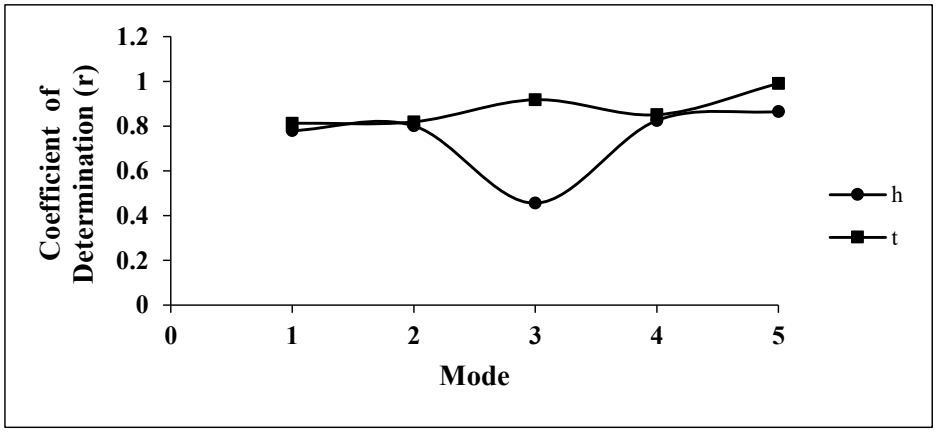

Fig. 4: The effect of height and thickness of the stiffeners on the natural frequencies of the FGM plate.

was increased and decreased, respectively. According to Fig. 2, thickness and volume fraction index have the highest and lowest effects on the natural frequencies of the FGM plate, respectively.

In the following, the effect of the openings on the natural frequencies of the FGM plate was investigated. To do this, in addition to the ratio of openings, common types of openings such as square and circle have been considered.

Free vibration analysis of FGM plates with opening showed that the natural frequencies of the 1 to 4

modes of the plate having square opening is more than circular opening , which is reversed for the mode 5. Also, according to Fig. 3, it is seen that the circular openings have greater effects than the square openings on the natural frequency.

In the analysis of free vibration of FGM plates having stiffeners, the stiffener properties such as height and thickness were studied on the natural frequencies of the first five modes and their effects on the natural frequencies were determined and compared, together with (Fig. 4). The results of free vibration analysis show that the stiffener thickness has a greater effect on the natural frequencies of the FGM plate than its height.

REFERENCES

[1] W.Y. Jung and S.C. Han, "Static and eigenvalue problems of Sigmoid functionally graded materials (S-FGM) micro-scale plates using the modified couple stress theory", *Applied Mathematical Modelling,* Vol. 39, No. 12, pp. 3506-3524, 2015.

[2] X.L. Huang and H.S. Shen, "Nonlinear vibration and dynamic response of functionally graded plates in thermal environments", *International Journal of Solids and Structures,* Vol. 41, No. 9-10, pp. 2403-2427, 2004.

[3] H.S. Shen, "Functionally graded materials: nonlinear analysis of plates and shells", *CRC press*, 2016.

[4] I. Ramu and S. Mohanty, "Study on free vibration analysis of rectangular plate structures using finite element method", *Procedia engineering,* Vol. 38, pp. 2758-2766, 2012.

[5] C. Aksoylar, A. Ömercikoğlu, Z. Mecitoğlu and M. H. Omurtag, "Nonlinear transient analysis of FGM and FML plates under blast loads by experimental and mixed FE methods", *Composite Structures,* Vol. 94, No. 2, pp. 731-744, 2012.

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