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Free Vibration Analysis of Composite Material Plates with Porosities Based on the First-Order Shear Deformation Theory

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Abstract

This article presents the free vibration analysis of Composite Material Plates simply case of a typical functionally graded ceramic/metal FG plates porous using a first-order shear deformation theory. In is work the material properties of the porous plate FG vary across the thickness. The Hamilton's principle will be used herein to determine the equations of motion. Since, the plate are simply supported the Navier procedure will be retained. To show the precision of this model, several comparisons have been made between the present results and those of existing theories in the literature for non-porous plates. Effects of the exponent graded and porosity factors are investigated.

Introduction

Composite materials are known as the modern materials which are composed of two or more different materials, to have the desired properties in specified applications. The lightweight composite materials known as fiber-matrix laminated composites have been used successfully in aircraft, automotive, marine industries and other engineering applications. To remedy such defects, Functionally Graded Materials (FGMs), within which material properties vary continuously, have been proposed. The concept of FGM was proposed in 1984 by a group of materials scientists, in Sendai, Japan, for thermal barriers or heat shielding properties. In recent years, extensive studies relevant to FG plates are carried out by using the Classical Plate Theory (CPT) and First-Order Shear-Deformation Plate Theory (FSDT). Despite the simplicity of the CPT (or the Kirchhoff-Love theory), the CPT disregards shear deformations and rotary inertia, resulting in unreliable results for thick and moderately thick plates. The FSDT (or Reissner-Mindlin plate theory) supports transverse shear effects by using a shear correction factor and hence is appropriate for analysis of both moderately thick and thin plates.

However, in the manufacture of FGMs, micro-porosities or voids can occur in the materials during the sintering process. This is due to the large difference in solidification temperature between the material constituents [1]. *Wattanasakulpong et al.* [2] also gave a discussion of the porosities that occur within FGM specimens made by a sequential multi-step infiltration technique. Therefore, it is important to take into account the effect of porosity in the design of FGM structures subjected to static and dynamic loads [3-5]. The analysis of the free vibration of FG plates by considering the porosities that can occur inside the materials with gradient properties (FG) at during their manufacture based on the first-order shear deformation theory is present in this paper. Analytical solutions are obtained for the FG pallet by the present theory and its accuracy is verified by comparing the results obtained with those reported in the literature. The effects of various parameters on the free vibration of FG plates are all discussed.

Mathematical Model and Results & Discussions

Consider a thick rectangular plate FG of length a, width b and thickness h made of functionally graded material as shown in Figure 1 together with the adopted coordinate system. The material properties of the plate FG, such as Young's modulus E, are assumed to be function of the volume fraction of constituent materials. The properties of the FGM vary continuously due to the progressive volume fraction of the constituents of the materials (ceramic and metal), generally in the direction of the thickness.

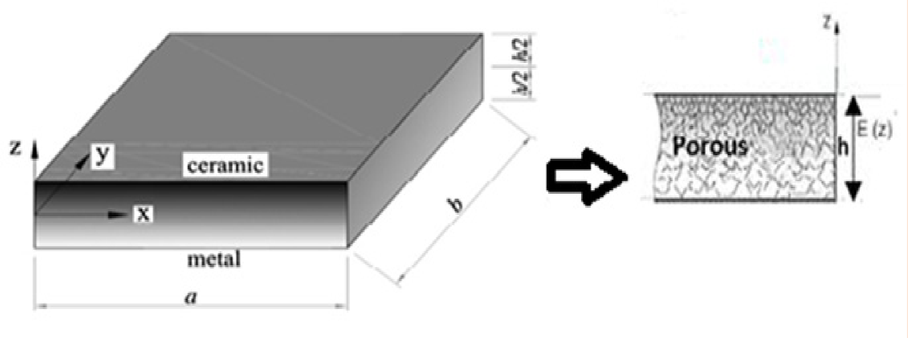

Figure 1: Geometric configuration of plate FG with porosity.

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Consider an imperfect FG with a volume fraction of porosity, α , (0 ≤ α ≤ 1) distributed uniformly between metal and ceramic, the law of the modified mixture proposed by Wattanasakulpong and Ungbhakorn [3] is used as:

$$E(z)=E_m\left(1-V-\frac{\alpha}{2}\right)+E_c\left(V-\frac{\alpha}{2}\right) \quad \text{and} \quad (1a) \qquad V=\left(\frac{1}{2}-\frac{z}{h}\right)^p$$

$$\rho(z)=\rho_m\left(1-V-\frac{\alpha}{2}\right)+\rho_c\left(V-\frac{\alpha}{2}\right) \quad \text{and} \quad (1b) \qquad V=\left(\frac{1}{2}-\frac{z}{h}\right)^p$$

where E_c and E_m are the corresponding properties of the ceramic and metal, and ρ density of material, respectively, and "P" is the volume fraction exponent which takes values greater than or equal to zero. In this section various numerical examples are presented and discussed to verify the accuracy of the present theory in predicting the free vibration responses of simply supported FG plates. One type of FG plates of Al/ZrO_2 is used in this study in the given Table 1.

Table 1: Non-dimensional natural frequencies $\hat{\omega}=\omega h\sqrt{\rho/G}$ for simply supported isotropic square plate (a/b=1, a/h=10) and the porosity coefficients α=0.

m	n	CPT	FSDPT	Present
1	1	0,0955	0.0930	0,0930
1	2	0,2360	0.2219	0,2220
2	2	0.3732	0.3406	0,3406
1	3	0.4629	0.4149	0,4151
2	3	0.5951	0.5206	0,5208
3	3	0.8090	0.6834	0,6840

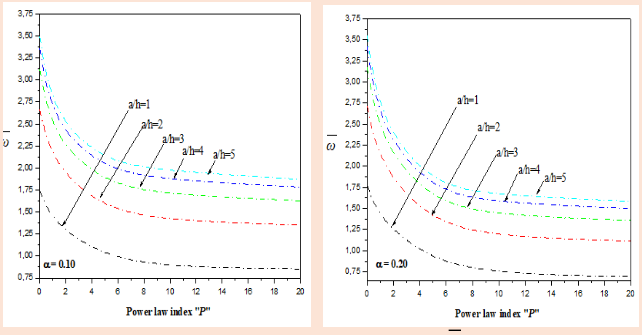

Figure 2: Non-dimensional fundamental natural frequency $\bar{\omega}$ of FG plates as function of power law index P for different (a/h) and different porosity factor α.

The non-dimensional frequency of FG plate and power law index P for various values of side-to-thickness ratios (a/h) and different porosity factor are plotted in Figure 2 based on the present first order shear deformation theory. As shown, the frequency decreases significantly with the increase of P. It is basically attributable to the fact that Young's modulus of ceramic is higher than metal.

Conclusion

In this work, the analysis of the free vibration of porous plates FG (Ceramic-Metal) is examined by a simple theory of first-order shear deformation. The law of the modified mixture covering the porosity phases is used to roughly describe the properties of plate FG with porosity. On the basis of the present theory of the plate, the equations of motion are derived from the principle of virtual works and the principle of Hamilton. From this work, we can say that the present theory of plate FG proposed is accurate and simple for the resolution of the mechanical behavior of FG plates with porosity.

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