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Thermoelastic Behavior Analysis of Functionally Graded Materials Sandwich Plates

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Abstract

A current structures complication in Functionally Graded Materials FGM is the analysis of the distribution of the displacement and thermal stresses in the original thickness. The interest of this study is the analysis of thermoelastic behavior of the bending of sandwich plates FGM using third-order plates of travel theories (TSDPT) and sinusoidal theory (SSDPT). In this article we use a type of sandwich plate FGM «Type: Metal / Ceramic / Metal» composite materials. It is assumed that the material properties and the coefficient of thermal expansion of the plate vary continuously in the thickness direction according to a simple power law distribution function of the volume fraction of the components. We can say that the proposed theory is accurate and simple to solve the thermoelastic behavior of the bending of FGM sandwich plates.

1. Introduction

Many natural environments exhibit unidirectional and continuous variations in their elastic properties. Living tissue, the earth's crust, the oceans and even cortical bone are some of them. Drawing their inspiration from the nature that surrounds them, the scientists (researchers and engineers), preferred the advantages of this type of material in terms of mechanical behavior and this is how we quickly appear, in the years 1980, the graded materials evaluated (Functionally Graded Materials "FGM"[1]. They make it possible, for example, to reproduce the structural and material properties of biological tissues such as bone at different stages of its development (growth, aging or pathology).

Functionally Graded Materials (FGMs) are a type of composite material produced by continuously changing the volume fractions in the thickness direction to obtain a well-defined profile. These types of materials, have received much attention recently due to the advantages of decreasing the disparity in material properties and reducing thermal stresses [2]. Continuous variation of mechanical properties confers on the material. optimized behavior. FGMs are particularly used in high technology applications: aeronautics, aerospace, nuclear, semiconductors, and in Civil Engineering and also find biomedical applications [3].

In this paper, an associated theory of shear and strain of sandwich plates is developed for the analysis of thermoelastic bending of sandwich plates made of FGM. This theory is simplified by the application of the boundary conditions of free traction to the plate. The effects of shear deformations are all included for sandwich plates in FGM are presented. The effects of the temperature field on the normal stresses and the tangential stresses of the sandwich plate in FGM are studied.

2. Theoretical Approach

Let us take the case of an FGM plate sandwich composed of three heterogeneous microscope layers as shown in Figure 1. Several hypotheses aimed at simplifying the complexity of the problem are introduced. Those are:

(*) The surface layers of the plate are of graded gradation materials having material properties varying in the z direction (thickness).

(*) The core layer is made of a homogeneous isotropic material.

(*) The plate is symmetrical compared to the median plane z = 0.

(*) The lower and upper layer of the plate is completely made of metal.

(*) The central layer is an entirely ceramic layer.

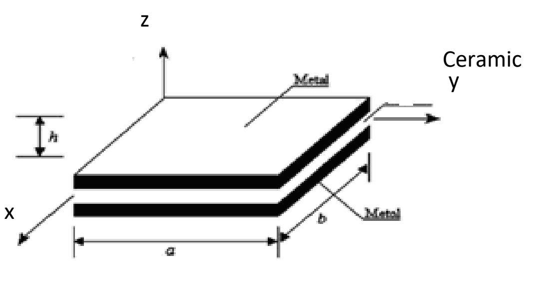

Figure 1. The dimensions of the sandwich plate FGM rectangular.

The effective material properties for the layers, such as Young's modulus, Poisson's ratio, and coefficient of thermal expansion, can be expressed as:

$$E^{(n)}(z) = E_m + \left(E_c - E_m\right) V^{(n)} \quad (1)$$

Where Ec and Em are the corresponding properties of the ceramic and metal.

Numerical results are shown in Table 1 using different plaque theories. We report the values of the dimensionless maximum deflection in the center of the plate for the different types of FGM plates and different values of the material index "n". The thermal loading is assumed to vary linearly through the thickness (T3 = 0).

Numerical results are shown in table 1 using different plaque theories. We report the values of the dimensionless maximum deflection in the center of the plate for the different types of FGM plates and different values of the material index "k".

Table 1. The effect of the dimensionless deflection (w) for different FGM sandwich plates (T_3 = 0).

k	Théorie	La plaque (a)	La plaque (b)	La plaque (c)
0	FSDPT	0.480262	0.480262	0.480262
	TSDPT	0.480262	0.480262	0.480262
	SSDPT	0.461634	0.461634	0.461634
1	FSDPT	0.636667	0.620792	0.592239
	TSDPT	0.636891	0.621067	0.592568
	SSDPT	0.614565	0.599933	0.573327
2	FSDPT	0.671339	0.655893	0.621215
	TSDPT	0.671486	0.656115	0.621544
	SSDPT	0.647135	0.633340	0.601843

The thermal loading is assumed to vary linearly through the thickness (T_3 = 0).

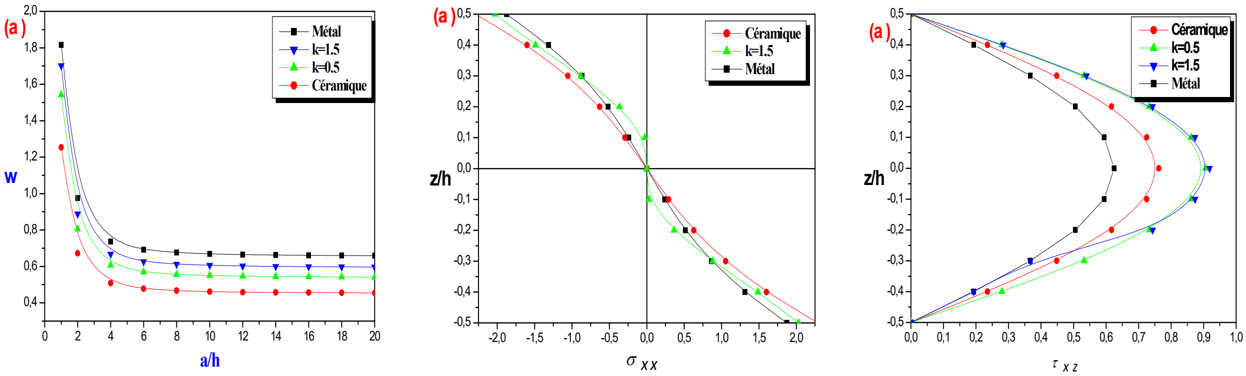

Figure 2. Displacement variation, stress and shear stress

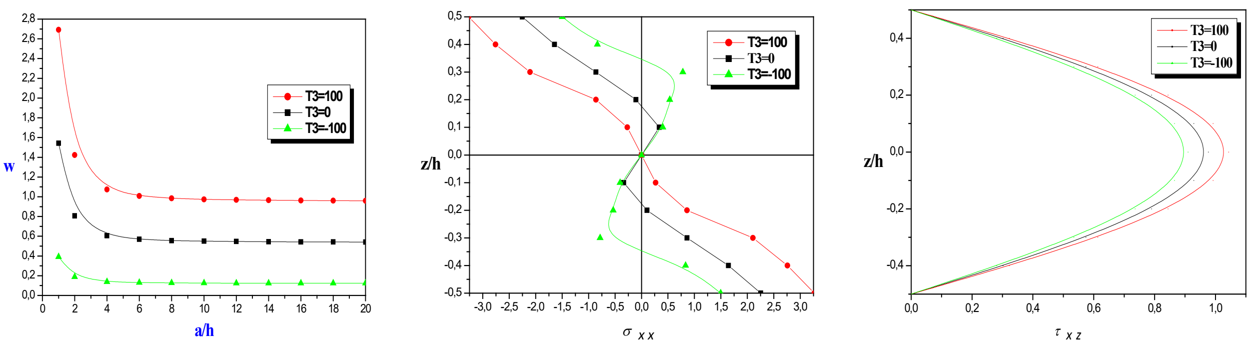

Figure 3. Distribution of normal stress and shear stress across the thickness of the FGM sandwich plate for (n = 1.5).

In the Figure 2, shows that the variation of displacement (w) decreases compared to the thickness (z/h) for the plates in FGM. The decrease is between those of ceramic plates (Al_2O_3) and metal (Al). It can be observed that the deflection of the metal-rich FGM plate is greater compared to the ceramic plate.

Contains the graph of the axial stress (σ_{xx}) through the thickness (z/h) of the thick plates in FGM. The stresses are in tension above the median plane and in compression below the median plane. It is important to observe that the maximum stress depends on the value of the exponent of the volume fraction k.

The transverse shear stresses (τ_{xz}) have been plotted through the thickness distribution (z/h). The maximum value occurs at a point on the median plane of the plate, and its range for a thick FGM plate is greater than, for a homogeneous plate.

In Figure 3, shows the effects of the ratio of the thickness (a/h) on the non-dimensional displacement power plant (w) for the FGM plate and which subjected to a non-uniform temperature distribution field. It can be seen that the thickness ratio effect and the elongation effect are expressed as the displacement variation (w) of the plate under the uniform temperature distribution T_3 = 100; and it is less pronounced at the non-uniform plate of temperature T_3 = -100. But when T_3 = 0, the displacement in the center of the plate takes intermediate values between non-uniform and uniform of the thermal plate.

As we have plotted the distribution of the normal stress (σ_{xx}) and the shear stresses (τ_{xz}) through the thickness of the FGM plate for ($k = 0.5$). These two normal stress and shear curve shows that the variation of the forces (stresses) is very sensitive to the variation of the thermal load T_3.

3. Conclusion

The objective of this paper is to provide a general overview of the thermoelastic behavior of the bending of FGM sandwich plates. The theory presented has strong similarity to classical plate theory in many aspects, and gives a parabolic description of the shear stresses through the thickness while fulfilling the condition of zero shear stresses on the free edges. The results of shear and strain are compared with each other. The present SSDPT, offers precise and reliable solutions for the analysis of FGM sandwich plates by comparing with the other shear strain theories. It is seen that the deviations of the plates which correspond to the properties intermediate to that of metal and of ceramic necessarily lie between that of ceramic and metal.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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