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Influence of Temperature on the Deformation of a Two-Layer Beam Functionally Graded under Electrostatic Loading

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ABSTRACT

In this paper, the study of the deformation of the structures is the important reason for each researcher, our structure is composed of two layers, active and substrate, the law of power is used for determined different term, the deformation of the functionally gradedbeam is calculated according to the temperature, the temperature varies along the thickness of this structure, the terms of inertia are calculated according to the height of the two layers, Electrostatic charging is used so that most of the time it is working with intelligent mechanisms in important structures, results were found is interpreted in this study.

1. Introduction

Mismatch of material properties across an interface of two discrete materials bounded together in composites, causes stress concentrations under mechanical and thermal loadings. The use of gradual variation of material constituents and accordingly gradual variation of the physical and mechanical properties can eliminate these effects. Materials whose properties vary gradually to achieve a functional performance are called functionally graded materials (FGMs). FGMs feature gradual transitions in microstructure and composition, which are engineered so as to meet functional performance requirements that vary with location within a single component and to optimize the overall performance of the component. Plasma facing materials, propulsion system of planes, cutting tools, engine exhaust liners, aerospace skin structures, thermal barrier coatings of turbine blades and thermal resistant tiles are all examples where materials have to operate in extremely high temperature transient environments. Conventional super heat resistant materials, such as those found in the exterior part of the space shuttles, consist of heat resistant ceramic tiles bounded on metal structures. In these materials, temperature gradients cause stress concentrations in interfaces and the stress concentration cause ceramic tiles to peel off or crack.

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Compared to the layered system, e.g., a ceramic coating on a metal substrate, FGM avoid the discontinuity in material properties across the interface and hence reduce these stress concentrations [1,2].

A lot of research and development have been carried out to investigate Functionally Graded Materials FGMs for various applications using gradients in physical, chemical, biochemical, and mechanical properties. The main characteristic that distinguishes FGMs from conventional composite materials is the possibility of tailoring the graded composition and microstructure in an intentional manner, destined to achieve the desired function. The design of FGM structures is based on an attempt to take the best benefit from the integration of the functions of refractoriness, high wear resistance hardness, thermal shock resistance, and corrosion resistance of ceramics on the one hand as well as the high strength and toughness of metals on the other hand. This has led to a variety of structural applications [3]. FGMs that are made from a mixture of metal and ceramics are typically characterized by a smooth and continuous change of the mechanical, physical, and chemical properties from one side to the other [4–6].

Functionally graded materials (FGMs) are microscopically inhomogeneous composite materials, in which the volume fraction of the two or more materials is varied smoothly and continuously as a continuous function of the material position along one or more dimensions of the structure. These materials are mainly constructed to operate in high temperature environments. In conventional laminated composite structures, homogeneous elastic lamina are bonded together to obtain enhanced mechanical and thermal properties. The main inconvenience of such an assembly is to create stress concentrations along the interfaces and more specifically when high temperatures are involved. This can lead to delaminations, matrix cracks, and other damage mechanisms which result from the abrupt change of the mechanical properties at the interface between the layers [7].
In this study the results are found analytically, the variation of the material is considered continuous along the thickness.

Low thermal conductivity of convectional heat transfer fluid is a primary limitation in efficient heat dissipation of devices that utilize these fluids as working fluids. To overcome the limitations stated above, a lot of research has been conducted to increase the thermal carrying capacity of convectional heat transfer fluid and one of the ideal ways is to disperse nano-size particles in to the base fluid [8].

Research on nanofluids has been quite intensive in the past decade. Whilst there have been many studies analyzing the performance of nanofluids, the behavior of nanofluid confined in complicated geometry, especially those using numerical simulation, are scarce[9]. Literature records include research on such problem since 1969 until today [10]. Turbulent flows are the most challenging topics which occur in many situations in nature and real engineering application. The turbulence problem is tough to be realized regarding to physical understanding and mathematical solutions or in terms of the engineering accuracy needed for different applications. Recently, the microscopic dynamics approaches have attracted significant attention [11]. Energy is conserved in every device and in every action we are doing. The energy itself cannot be abandoned nor destroyed. However, energy conservation alone by using the first law of thermodynamics is insufficient in order to depict the internal losses for maximizing energy usage [12]. In order to prove the efficiency of a solar heater, exergy analysis is used rather than the energy conservation theory. The quality of energy, which is how much energy could be extracted to use for work [13], is the major concern in exergy analysis. With the development of modern technology, there is high need to develop efficient way of regulating heat content in many engineering equipment such as heat exchangers, transformers, electronic devices, auto mobile engines and diesel generators. Low thermal conductivity of convectional heat transfer fluid is a primary limitation in efficient heat

dissipation of devices that utilize these fluids as working fluids [14]. To overcome the limitations stated above, a lot of research has been conducted to increase the thermal carrying capacity of convectional heat transfer fluid and one of the ideal ways is to disperse nano-size particles in to the base fluid [15].
The stress-strain relationship in this case is given by:

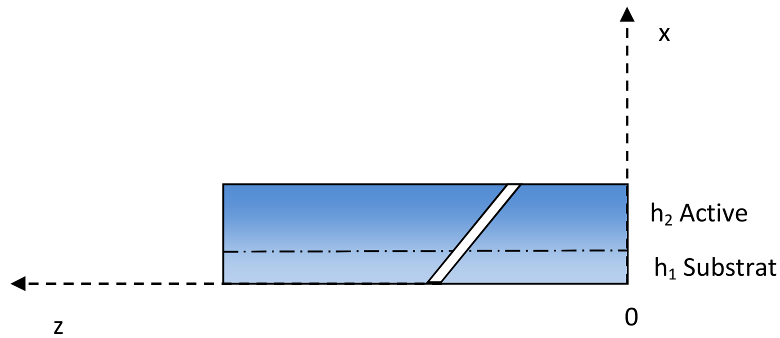

Fig. 1. Functionally graded Beam

$$\sigma(z)=Q(z)\left[\varepsilon-\alpha\Delta T-d_{31}(z)E_z\right] \tag{1}$$

We integrate equation (1) along the thickness are obtained

$$\int_0^{h_1+h_2}\sigma(z)dz=\int_0^{h_1+h_2}Q(z)\left[\varepsilon-\alpha\Delta T-d_{31}(z)E_z\right]dz=0 \tag{2}$$

The power law used for the different terms is written as follows

$$P(z)=P_1+(P_2-P_1)\cdot V(z)\quad for\quad 0\le z\le h_1+h_2 \tag{3}$$

The expression of the volume fraction is given by

$$V(z)=\left(\frac{z}{h_1+h_2}\right)^2 \tag{4}$$

(a) denotes active and *(s)* denotes substrate, the terms of the elastic modules for the two active and substrate layers are given by

$$Q(z)=Q_s+(Q_a-Q_s)\cdot\left(\frac{z}{h_1+h_2}\right)^2 \tag{5}$$

Similarly to the piezoelectric strain coefficient

$$d_{31}(z)=d_{31}^s+(d_{31}^a-d_{31}^s)\cdot\left(\frac{z}{h_1+h_2}\right)^2 \tag{6}$$

We apply the power law, equation (2) is written

$$\int_0^{h_1+h_2} \sigma(z)dz = \int_0^{h_1+h_2} (Q_s + \Delta Q \cdot V(z))\left[\varepsilon - \alpha\Delta T - (d_{31}^s + \Delta d_{31} \cdot V(z))E_z\right]dz = 0 \tag{7}$$

It integer each part separately, then

$$\int_0^{h_1+h_2} \sigma(z)dz = \varepsilon \int_0^{h_1+h_2} (Q_s + \Delta Q \cdot V(z))dz - \int_0^{h_1+h_2} \left[\alpha\Delta T + (d_{31}^s + \Delta d_{31} \cdot V(z))E_z\right]dz = 0 \tag{8}$$

We replace each term by are expression we obtain

$$\int_0^{h_1+h_2} \sigma(z)dz = \varepsilon I_0 - J_0 = 0 \tag{9}$$

$$\varepsilon I_0 - J_0 = 0 \tag{10}$$

$$\varepsilon = \frac{J_0}{I_0} \tag{11}$$

With

$$I_0 = \int_0^{h_1+h_2} Q(z)dz \tag{12}$$

and

$$J_0 = \int_{0_1}^{h_1+h_2} d_{31}(z)Q(z)dz \tag{13}$$

2. Results and Discussion

$E_1=214.10^3$, $E_2=380.10^3$, $\alpha_1=15.4.10^{-6}$, $\alpha_2=7.4.10^{-6}$, $h_1=1m$, $h_2=2m$.

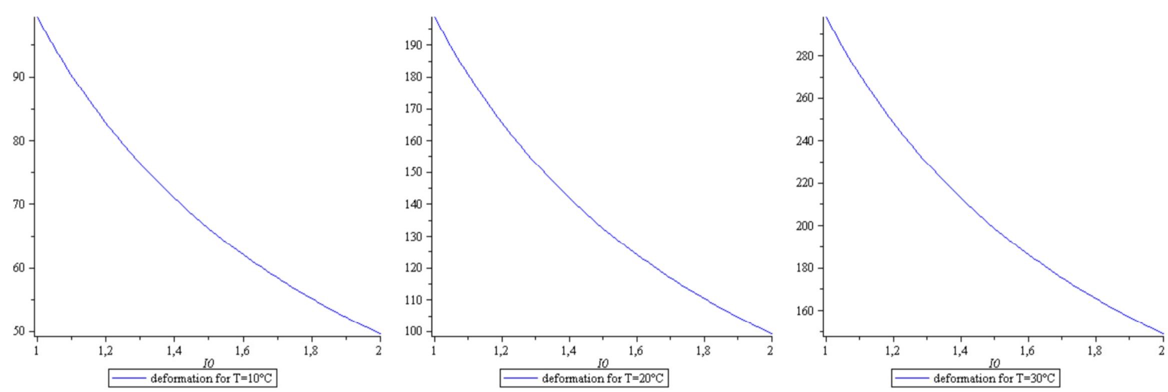

Fig. 2. Variation of the strain as a function of I_0 with *T = 10 ° C - 30 ° C*,

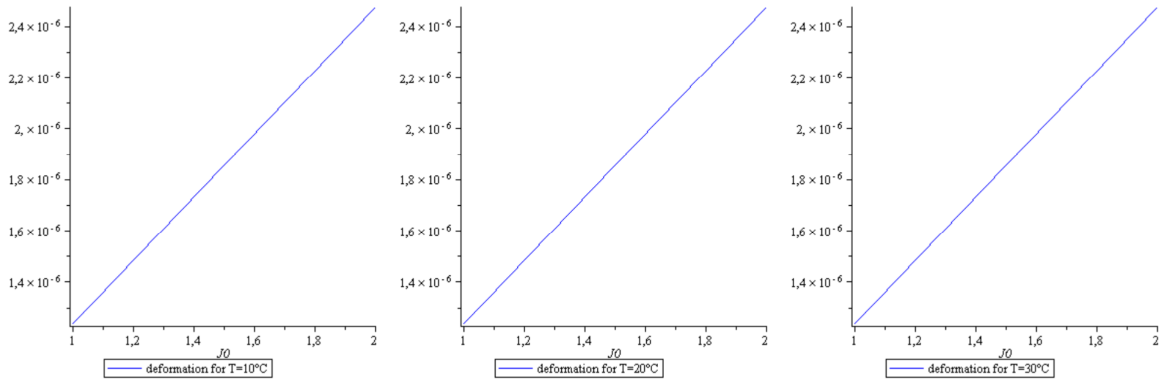

Fig. 3. Variation of the strain as a function of J_0 with *T = 10 ° C - 30 ° C*.

Figures 2 show the variation of the strain as a function of the term I_0, varying T with an interval of 10, the variation is parabolic, the strain of the structure increases with high values of T and decreases with the increase of I_0, in contrast in Figures 3, the variation is a straight line, the strain is very small, the deformation increases with the increase of J_0.

3. Conclusion

This study shows that the use of graded structures (FGM) is important in civil engineering, because of these mechanical and geometrical characteristics and it is able to withstand high temperature values despite the lightness of its weight, due to electrostatic loading present on structure and material is degraded to elevated temperature; deformation is excessive at high temperature at an average temperature in the study structure, deformation values for any structure are the essential role of all researchers.

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