JOURNAL OF NANO- AND ELECTRONIC PHYSICS
Vol. 14 No 5, 05016(6pp) (2022)
ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ
Том 14 № 5, 05016(6cc) (2022)

# Effect of Phase Contrast and Geometrical Parameters on Bending Behavior of Sandwich Beams with FG Isotropic Face Sheets

M. Chitour[1,*], A. Bouhadra[2,3], S. Benguediab[4], A. Saoudi[2,5], A.R. Menasria[2,3], A. Tounsi[1,3]

[1] *Djillali Liabes University, Sidi Belabbes, 22000 Algeria*
[2] *Abbes Laghrour-Khenchela University Khenchela, 40004 Algeria*
[3] *Materials and Hydrology Laboratory, Djillali Liabes University, Sidi Bel Abbés, Algeria*
[4] *Tahar Moulay University, Saida, 20000 Algeria*
[5] *Engineering and Advanced Materials Science Laboratory (ISMA), Abbes Laghrour Khenchela University, P.O. Box 1252, 40004 Algeria*

(Received 29 July 2022; revised manuscript received 20 October 2022; published online 28 October 2022)

Our work is to study the bending behavior of sandwich beams with functional gradient by constituting an isotropic material whose material properties vary smoothly in the $z$ direction only (FGM), where the central layer presents purely a homogeneous and isotropic ceramic. The mechanical properties of FG sandwich beams are assumed to be progressive in thickness according to a power law (P-FGM). Generally, the principle of virtual works is used to obtain the equilibrium equations, and their solutions are obtained based on Navier's solution technique. The present model is based on a shear deformation theory of 2D and 3D beams which contains four unknowns to extract the equilibrium equations of FG sandwich beams. In addition, analytical solutions for bending are used and numerical models are presented to verify the accuracy of the present theory. All the results obtained show that the stiffness of the FG beam decreases as a function of the increase in the volume fraction index k, leading to an increase in the deflections. However, FG beams become flexible by increasing the proportion of the metal to the ceramic part. Furthermore, the influences of material volume fraction index, layer thickness ratio, side-to-height ratio, and the effect of the phase contrast, on the deflections, normal and shear stress of simply supported sandwich FG beams are taken into investigation and discussed in detail. Finally, all our results obtained are in agreement with other previous theoretical works.

**Keywords:** FG sandwich beams, Bending behavior, Phase contrast, Virtual works, Navier's solution.

DOI: 10.21272/jnep.14(5).05016 PACS numbers: 46.70.De, 81.05. – t, 62.20.F

## 1. INTRODUCTION

Sandwich beams are a structural element composed of a two-sided layer and a core. Due to its low weight and high stiffness, this type of structural member has been widely used in several industries [1].

Functionally graded materials (FGM) are a class of composites in which the properties of the material gradually change over one or more Cartesian directions [1, 2], the combination of which results in an assembly with higher performance than components taken separately [2], FGMs are widely used in many scientific and engineering fields, such as aerospace, automobile, electronics, optics, chemistry, biomedical engineering, nuclear engineering and mechanical engineering [3]. By gradually varying the volume fractions of the constituents, the mechanical properties of FGM exhibit a smoothly and continuously change from one surface to the other, thus distinguishing them from laminated composite materials, which have a mismatch of mechanic properties across in interface due to two discrete materials bonded together [4]. The last two decades there has been considerable research reports on thermal stresses, fracture, thermo-mechanical response, buckling, free vibration of FGM structural elements [5]. Sobhy [6] studied thermomechanical bending and free vibration analyses of single-layered graphene sheets embedded in an elastic foundation based on sinusoidal shear deformation plate theory. Based on the local model, Bourada et al. [7] presented buckling analysis of functionally graded plates by employing a novel higher-order shear deformation theory (HSDT). Sankar [8] developed a beam theory similar to simple Euler-Bernoulli beam theory for functionally graded beams with elastic properties to vary exponentially and evaluated thermal stresses. Mantari et al. [9] developed an analytical solution for the bending behavior of FGPs using a trigonometric based HSDT. Kettaf et al. [10] examined the thermal buckling response of FG sandwich plates by proposing a new model of hyperbolic displacement. The present theory is employed to extract the equilibrium equations of the FG sandwich beams. Analytical solutions for bending are obtained. Numerical examples are presented to verify the accuracy of the present theory.

## 2. FUNCTIONALLY GRADED SANDWICH BEAM

A functionally graded sandwich beam of length $L$, width $b$, and thickness $h$ is shown in Fig. 1. The face layers of the FG sandwich beam are made of an isotropic material with material properties varying smoothly in the $z$ direction only (FGM). The core layer is made of an isotropic homogeneous material (ceramic).

The material properties of the FGM sandwich beam, such as Young's modulus ($E$) and mass density ($q$), are assumed to be continually graded through the thickness direction according to the following well-known rule of mixture [11]:

* chitour.mourad@univ-khenchela.dz

 