International Journal of Mechanical Sciences 53 (2011) 237–247

Contents lists available at ScienceDirect

International Journal of Mechanical Sciences

journal homepage: www.elsevier.com/locate/ijmecsci

A new hyperbolic shear deformation theory for buckling and vibration of functionally graded sandwich plate

Noureddine El Meiche [a], Abdelouahed Tounsi [a,b,*], Noureddine Ziane [a], Ismail Mechab [a], El Abbes Adda.Bedia [a]

[a] Laboratoire des Matériaux et Hydrologie, Université de Sidi Bel Abbes, Algeria
[b] Département de Génie Civil, Faculté des Sciences de L'Ingénieur, Algeria

ARTICLE INFO

Article history:
Received 19 September 2010
Received in revised form
7 January 2011
Accepted 13 January 2011
Available online 25 January 2011

Keywords:
New plate theory
Shear deformable plate theory
Functionally graded plate theory
Free vibrations
Buckling

ABSTRACT

A new hyperbolic shear deformation theory taking into account transverse shear deformation effects is presented for the buckling and free vibration analysis of thick functionally graded sandwich plates. Unlike any other theory, the theory presented gives rise to only four governing equations. Number of unknown functions involved is only four, as against five in case of simple shear deformation theories of Mindlin and Reissner (first shear deformation theory). The plate properties are assumed to be varied through the thickness following a simple power law distribution in terms of volume fraction of material constituents. The theory presented is variationally consistent, does not require shear correction factor, and gives rise to transverse shear stress variation such that the transverse shear stresses vary parabolically across the thickness satisfying shear stress free surface conditions. Equations of motion are derived from Hamilton's principle. The closed-form solutions of functionally graded sandwich plates are obtained using the Navier solution. The results obtained for plate with various thickness ratios using the theory are not only substantially more accurate than those obtained using the classical plate theory, but are almost comparable to those obtained using higher order theories with more number of unknown functions.

1. Introduction

Composite materials have been successfully used in aircraft and other engineering applications for many years because of their excellent strength to weight and stiffness to weight ratios. Recently, advanced composite materials known as functionally graded material have attracted much attention in many engineering applications due to their advantages of being able to resist high temperature gradient while maintaining structural integrity [1]. The functionally graded materials (FGMs) are microscopically inhomogeneous, in which the mechanical properties vary smoothly and continuously from one surface to the other. They are usually made from a mixture of ceramics and metals to attain the significant requirement of material properties.

Due to the increased relevance of the FGMs structural components in the design of aerospace structures, their buckling and vibration characteristics have attracted the attention of many scientists in recent years. It is observed from the literature that the amount of such work carried out for isotropic plates are considerable, and limited literature is available on composite plates. However, the literature on the analysis of the FGMs plate is very few. Reddy [2] presented the theoretical formulation and finite element models based on third order shear deformation theory for static and dynamic analysis of the FGM plates. He obtained the Navier solutions for a simply supported square plate under sinusoidally distributed load, including the effect of shear deformation. Free vibration, buckling, and deflection analysis of the FG thin plates were presented by Zhang and Zhou [3] on the basis of the physical neutral surface. Woo et al. [4] provided an analytical solution for the nonlinear free vibration behavior of FG square thin plates using the von-Karman theory. Zenkour [5] presented a generalized shear deformation theory for the bending analysis of FG plates in which material properties of the plate are assumed to obey a power-law distribution through the thickness coordinate and in terms of the volume fractions of constituents. Batra and Jin [6] used the first-order shear deformation theory (FSDT) coupled with the finite element method (FEM) to study free vibrations of a functionally graded (FG) anisotropic rectangular plate with the objective of maximizing one of its first five natural frequencies. Roque et al. [7] performed the free vibration analysis of the FGM plates by using the multiquadric radial basis

* Corresponding author at: Laboratoire des Matériaux et Hydrologie, Université de Sidi Bel Abbes, Algeria.
E-mail address: tou_abdel@yahoo.com (A. Tounsi).

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doi:10.1016/j.ijmecsci.2011.01.004