**Advances in Materials Research**, *Vol.4, No.1 (2015) 31-44*
DOI: http://dx.doi.org/10.12989/amr.2015.4.1.31 

# Thermal buckling of functionally graded plates using a n-order four variable refined theory

Z. Abdelhak[*1], L. Hadji[1,2], T.H. Daouadji[1,2] and E.A Bedia[2]

[1]*Université Ibn Khaldoun, BP 78 Zaaroura, 14000 Tiaret, Algérie.*
[2]*Laboratoire des Matériaux & Hydrologie, Université de Sidi Bel Abbes, 22000 Sidi Bel Abbes, Algérie.*

*(Received December 2, 2014, Revised January 28, 2015, Accepted February 25, 2015)*

**Abstract.** This paper presents a simple n-order four variable refined theory for buckling analysis of functionally graded plates. By dividing the transverse displacement into bending and shear parts, the number of unknowns and governing equations of the present theory is reduced, and hence, makes it simple to use. The present theory is variationally consistent, uses the n-order polynomial term to represent the displacement field, does not require shear correction factor, and eliminates the shear stresses at the top and bottom surfaces. A power law distribution is used to describe the variation of volume fraction of material compositions. Equilibrium and stability equations are derived based on the present n-order refined theory. The non-linear governing equations are solved for plates subjected to simply supported boundary conditions. The thermal loads are assumed to be uniform, linear and non-linear distribution through-the-thickness. The effects of aspect and thickness ratios, gradient index, on the critical buckling are all discussed.

**Keywords:** nth-order four variable refined theory; functionally graded plates; thermal buckling

## 1. Introduction

Functionally graded materials (FGMs) are new inhomogeneous materials which have widely used in many engineering applicants such as nuclear reactors and high-speed spacecraft industries (Yamanouchi *et al*. 1990). The mechanical properties of FGMs vary smoothly and continuously from one surface to the other. Typically these materials are made from a mixture of ceramic and metal or from a combination of different materials. The ceramic constituent of the material provides the high-temperature resistance due to its low thermal conductivity. The ductile metal constituent on the other hand, prevents fracture caused by stresses due to the high temperature gradient in a very short period of time. Furthermore a mixture of ceramic and metal with a continuously varying volume fraction can be easily manufactured (Fukui 1991, Koizumi 1997). With the developments in manufacturing methods (Fukui *et al*. 1991, Fukui *et al*. 1997 and El-Hadek *et al*. 2003) functionally graded materials seem to have great potential in sandwich structures. The analysis of these materials has been considered by many researchers. The functionally graded (FG) plates are commonly used in thermal environments; they can buckle under thermal and mechanical loads. Thus, the buckling analysis of such plates is essential to

∗Corresponding Author, Professor, E-mail: had_laz@yahoo.fr


http://www.techno-press.org/?journal=amr&subpage=7 ISSN: 2234-0912 (Print), 2234-179X (Online)

thickness ratio increases $a/h$.

- The critical buckling temperature difference $t_{cr}$ for FG plates is increased by increasing the aspect ratio $a/b$.
- The higher order shear deformation theory underestimates the buckling load compared with the classical plate theory.
- The critical buckling temperature of FG plate under non-linear temperature rise across the thickness increases as the temperature exponent $\gamma$ increases.

## References

Bouiadjra, M.B., Sid Ahmed, M.H. and Abdelouahed Tounsi, A. (2012), "Thermal buckling of functionally graded plates according to a four-variable refined plate theory", *J. Thermal Stresses*, **35**, 677-694.

El-Hadek, M. and Tippur, H.V. (2003), "Dynamic fracture parameters and constraint effects in functionally graded syntactic epoxy foams", *Int. J. Solids Struct.*, **40**, 1885-1906.

Fukui, Y. (1991), "Fundamental investigation of functionally gradient material manufacturing system using centrifugal force", *Int. J. Japanese Soci. Mech. Eng.*, **3**, 144-148.

Fukui, Y., Yamanaka, N. and Enokida, Y. (1997), "Bending strength of an AI-AI3Ni functionally graded material", *Composites: Part B*, *28B*, 37-43.

Javaheri, R. and Eslami, M.R. (2002a), "Buckling of functionally graded plates under in-plane compressive loading", *ZAMM*, **82**(4), 277-283.

Javaheri, R. and Eslami, M.R. (2002b), "Thermal buckling of functionally graded plates", *AIAA*, **40**(1), 162–169.

Javaheri, R. and Eslami, M.R. (2002) "Thermal buckling of functionally graded plates based on higher order theory", *J. Therm. Stress.*, **25**(1), 603-625.

Klouche Djedid, I., Benachour, A., Houari, M.S.A., Tounsi, A. and Ameur, M. (2014), "An-order four variable refined theory for bending and free vibration of functionally graded plates", *Steel Compos. Struct.*, **17**(1), 21-46.

Koizumi, M. (1997). FGM Activites in Japan, Composite: Part B, **28**(1), 1-4.

Samsam Shariat, B.A. and Eslami, M.R. (2005), "Effect of initial imperfection on thermal buckling of functionally graded plates", *J. Therm. Stress.*, **28**, 1183-1198.

Sohn, K.J. and Kim, J.H. (2008), "Structural stability of functionally graded panels subjected to aero-thermal loads", *Compos. Struct.*, **82**, 317-325.

Xiang, S. and Kang, G.W. (2013), "A nth-order shear deformation theory for the bending analysis on the functionally graded plates", *European J. Mech. A/Solids*, **37**, 336-343.

Yamanouchi, M., Koizumi, M. and Shiota, I. (1990), *In Proc. First Int. Symp. Functionally Gradient Materials*, Sendai, Japan.

Zenkour, A.M. and Sobhy, M. (2010), "Thermal buckling of various types of FGM sandwich plates", *Compos. Struct.* , **93**, 93-102.

Zenkour, A.M. and Mashat, D.S. (2010), "Thermal buckling analysis of ceramic-metal functionally graded plates", *Nat. Sci.*, **2**, 968-978.

*OP*