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Theoretical buckling analysis of inhomogeneous plates under various thermal gradients and boundary conditions

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Abstract. This study investigates the theoretical thermal buckling analyses of thick porous rectangular functionally graded (FG) plates with different geometrical boundary conditions resting on a Winkler-Pasternak elastic foundation using a new higher-order shear deformation theory (HSDT). This new theory has only four unknowns and involves indeterminate integral variables in which no shear correction factor is required. The variation of material properties across the plate's thickness is considered continuous and varied following a simple power law as a function of volume fractions of the constituents. The effect of porosity with two different types of distribution is also included. The current formulation considers the Von Karman nonlinearity, and the stability equations are developed using the virtual works principle. The thermal gradients are involved and assumed to change across the FG plate's thickness according to nonlinear, linear, and uniform distributions. The accuracy of the newly proposed theory has been validated by comparing the present results with the results obtained from the previously published theories. The effects of porosity, boundary conditions, foundation parameters, power index, plate aspect ratio, and side-to-thickness ratio on the critical buckling temperature are studied and discussed in detail.

Keywords: FG plates; porosity; thermal buckling; Von Karman nonlinearity

1. Introduction

Recently, functionally graded materials (FGMs) have substantial attention due to their heat resistance and excellent properties compared to conventional composites. FGMs are inhomogeneous at a microscopic scale with mechanical properties that change smoothly and continuously from one surface to another. FGMs usually comprise ceramics and metals to meet essential material property requirements.

The buckling phenomenon of FG elements under various loads is indispensable for many practical applications and has attracted considerable attention. Based on the classical plate theory (CPT), Javaheri and Eslami (Javaheri 2002a) analyzed the phenomenon of the thermal buckling of FGM rectangular plates. The same year, (Javaheri 2002b) presented another study on the buckling behavior of FG plates under four forms of thermal loads using the HSDT. For mechanical and thermal buckling behaviors, (Yaghoobi 2014) presented a refined theory with *n*-order shear deformation developed and validated for various numerical examples of FGM plates reposing on an elastic foundation. Using the FSDT, (Lanhe 2004) studied analytically the thermal buckling problem of simply supported rectangular plates made of FGM. The variation of temperature was considered uniform and nonlinear and obtained from solving the 1D Fourier equation for heat conduction. (Matsunaga 2009) proposed a global and 2D higher-order deformation theory for thermal buckling of FG plates. The critical buckling temperatures of a simply supported FG plate exposed to uniform and linear temperature variations were determined. (Bodaghi 2011) demonstrated a guideline solution to resolve the critical buckling temperatures of thick rectangular plates with different boundary conditions. An exact analytical solution has been reported by (Bouhadra 2015) for the thermal buckling analysis of FGM plates with several boundary conditions. The FGM plates were exposed to nonlinear, linear, and uniform temperatures and increased through the thickness of the plate.

Hao *et al*. (2008) researched the bifurcations and chaotic dynamics of a simply supported at the four edges FGM rectangular plate subjected to the in-plane and transversal excitations simultaneously in the uniform thermal environment. The transverse nonlinear oscillations of the FGM plate have been considered to reduce the equations of

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