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Thermal Buckling of Three Dimensional FG Plate

Mrinal Gautam [1], Manish Chaturvedi [2]

University Department, Mechanical Engineering, Rajasthan Technical University,

Akelgarh, Kota, Rajasthan, 324010, India[1,2]

Abstract: Thermal buckling is performed for Clamped Free Free Free (CFFF) three dimensional functionally graded plate. It is estimated that each plate's material property varies in axial, longitudinal and thickness direction by power law distribution. COMSOL software was used to finite element analysis . The effect on critical buckling temperature, such as power exponent and boundary conditions on FGM plate are considered.

Keywords: Functionally Graded Material Plate; Thermal Buckling Analysis; Power Law; Finite Element Method

I. INTRODUCTION

Functionally graded material (FGM) is characterized by a compositional gradient of one material into another, which is totally different from the conventional composite materials, which are either homogeneous mixtures that involve a compromise between the properties of the component materials, or two different materials joined together as in the case of laminate composite materials. Functionally graded materials are materials that are designed to meet varying functionalities [1, 2].

Swaminathan [3] reviewed thermo-mechanical buckling analysis of FGPs briefly in a subsection of a wide review that also contains stress and vibration analysis. Nano-FGP and micro-FGPs have been studied for thermo-mechanical buckling by many researchers, for example [4].

Aydogdu [5] studied the conditions for bifurcation buckling to exist in the case of FGPs; concluding that for unsymmetrical FGP, under only in-plane compression load, bifurcation can only occur when all edges are clamped. Gao et.al [6] proposed the nonlocal strain graded theory theoretical frameworks. , Zenkour and Mashat [7] investigated the thermal buckling of ceramic-metal FGM plates based on the sinusoidal shear deformation plate theory (SPT). Malekzadeh [8] investigated the three-dimensional thermal buckling of functionally graded arbitrary straight-sided quadrilateral plates based on the dierential quadrature method.

II. PROPERTY DISTRIBUTION

Consider three- dimensional FGM plate with a width b, length a, and thickness h. The FG plate is made up of two parts: metal and ceramic. In present work, property distribution in x, y and z direction. n_x , n_y and n_z are the gradient index [9].

$$E(z) = (E_c - E_m)\, V_c + E_m \qquad (1)$$

$$V_c = \left(\frac{x}{a}\right)^{n_x} \left(\frac{y}{b}\right)^{n_y} \left(\frac{z}{h} + \frac{1}{2}\right)^{n_z} \qquad (2)$$

III. FEM MODELLING

In present study, tri directional FGM plate dimensions are taken i.e. width b= 1m , length a=1m and thickness h=0.01m. Material properties are for metal phase (Aluminium) E_m=70X10^9 Pa, ρ_m= 2700 kg/m^3 , $\boldsymbol{\alpha_m = 23X10^{(-6)}}$ 1/K κ_m=204 W/m.K and Ceramic phase (Alumina (Al_2O_3)) E_c=380X10^9 Pa, ρ_c= 3900 kg/m^3 , $\boldsymbol{\alpha_c = 7.4\ X10^{(-6)}}$ 1/K, κ_c=10.4 W/m.K. Poission ratio and heat capacity for specific heat are taken ν=0.3 and C_p =900 J/kg.K.

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IV. RESULTS

The FGM plate is being considered for the validation research for reference [10].

Table 1: For tri-directional Al_2O_3/Al Clamped FG plate(a/b =1), Critical Buckling Temperature (ΔT_{cr})

	Boundary Conditions	a/h	(ΔT_{cr})				
			k=0	k=0.5	k=1	k=2	k=5
Present Study	CCCC	50	180.12	103.03	83.821	74.256	74.61
Zao et.al (2009)	CCCC	50	175.817	99.162	82.357	71.013	74.591

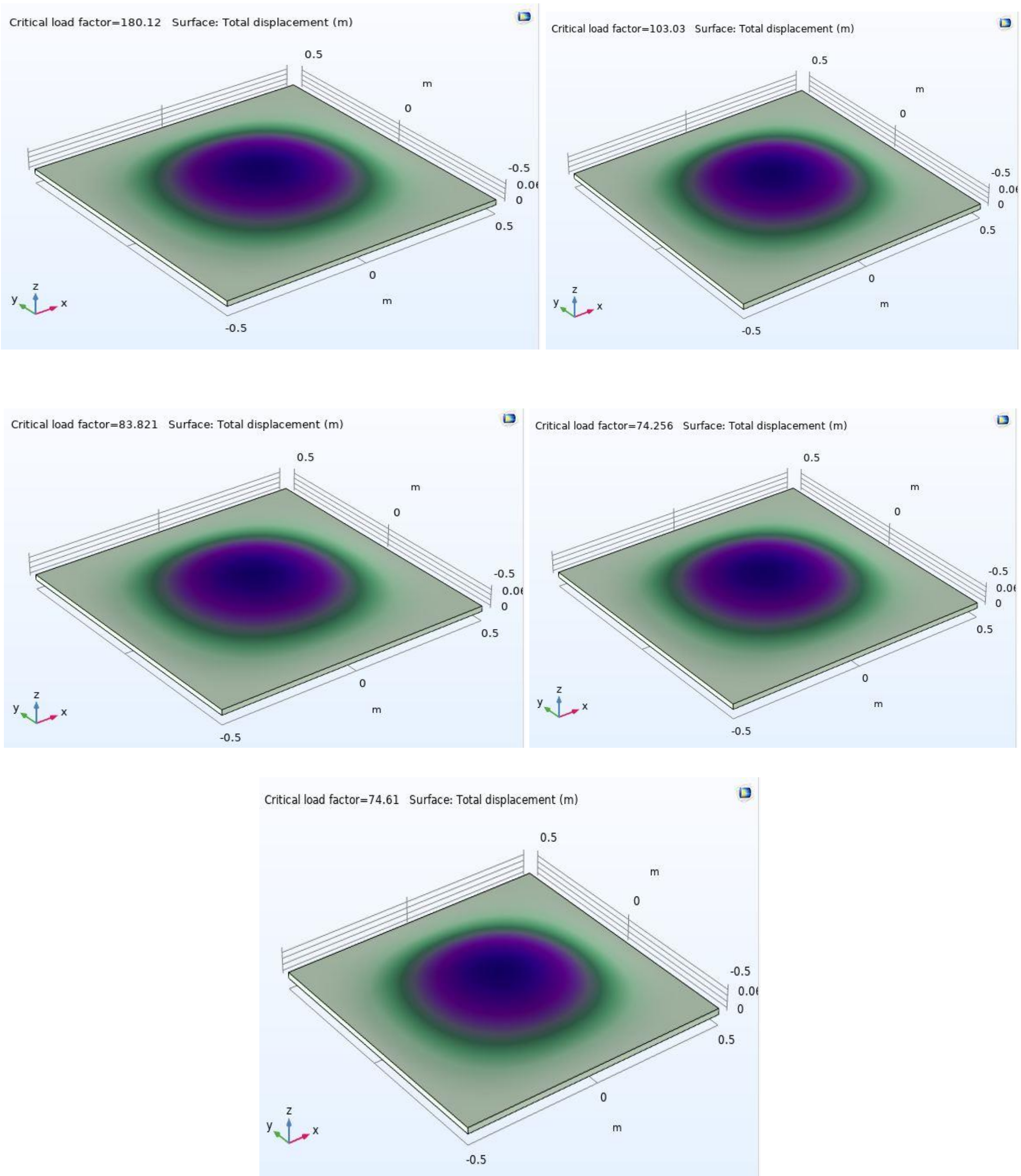

Fig 2: Thermal buckling mode shapes for CCCC Functionally Graded plate (k=0, 0.5,1,2,5 & a/b=1) at critical buckling temperature (ΔT_{cr}) the thickness ratios (a/h=50)

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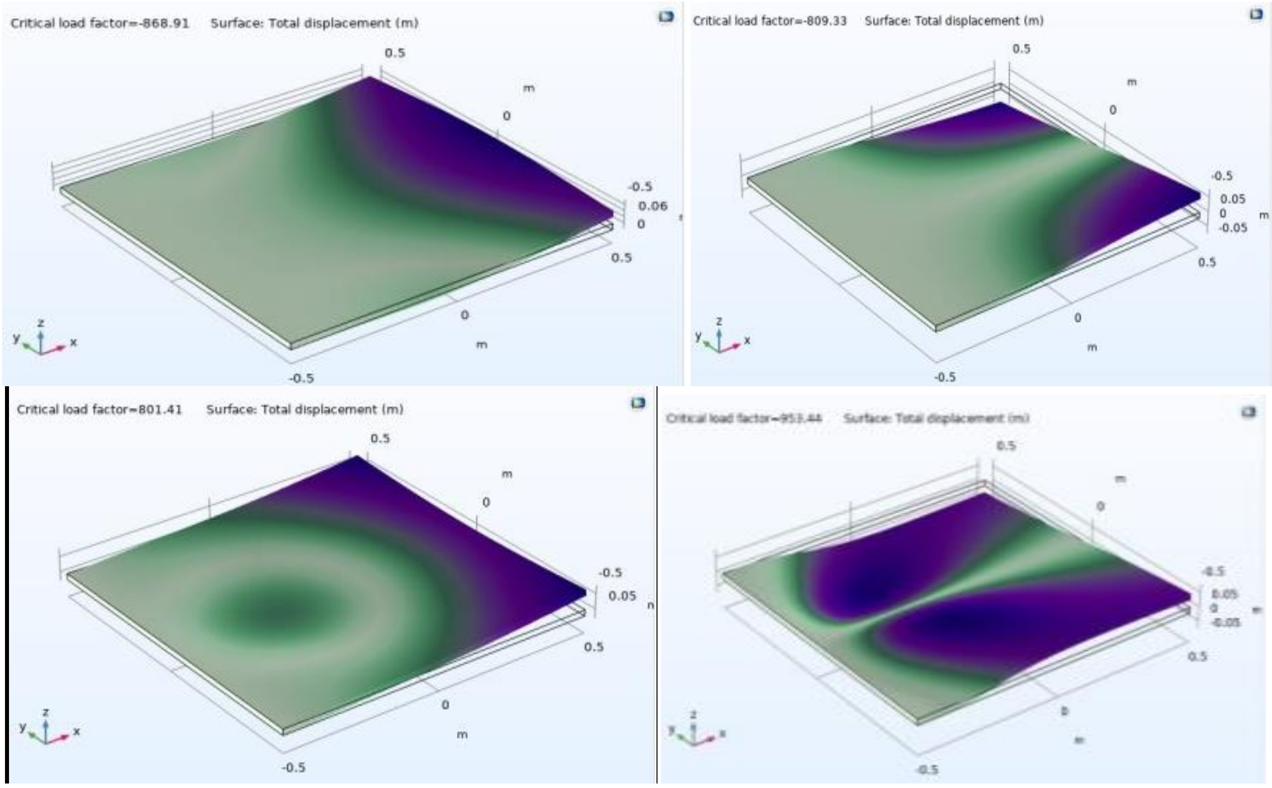

Fig 2: Thermal buckling mode shapes for CFFF Functionally Graded plate (a/b=1& k_x=2, k_y=2, k_z=1) at critical buckling temperature (ΔT_{cr}) the thickness ratios (a/h=50)

As a results Shown (Table 2-3 & Figure 4-7), Thermal buckling mode shapes for Functionally Graded plate (a/b=1& k_x=2, k_y=2, k_z=1) at critical buckling temperature (ΔT_{cr}) the thickness ratios (a/h=100 and a/h=50). In that results, CCCC boundary conditions higher critical buckling temperature than CFCF in first two mode shapes and lower critical buckling temperature than CFFF in 3 and 4 mode shapes.

V. CONCLUSION

The behaviour of thermal buckling of a CFFF functionally graded plate under uniform temperature loading is examined. In a functionally graded plate, property distributions are power law in thickness, length, and width directions. The current representation is created using the COMSOL Multiphysics FEM programme. The current values are compared to the published values. We found that as the gradient index increases, the critical buckling temperature in the CFFF Functionally plate decreases.

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