International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No. (02), January 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Investigation On vibrational Analysis of FGM Annular Plate Under C-F Boundary Condition

Mahak Farhan Ansari[1], Dr. Pankaj Sharma[2]

[1]PG Student, [2]Assistant Professor, Mechanical Engineering Department,

Rajasthan Technical University, Kota, Rajasthan (India)

ABSTRACT

This present paper investigated the modal analysis of FGM annular plate under thermal effect. The material properties are assumed to have temperature dependent and varying in accordance with power law distribution. The finite element software COMSOL is used to obtain the natural frequencies of FGM annular plate under clamped - free boundary condition. The effects of temperature and power index on the natural frequency are reported.

I. INTRODUCTION

Functionally graded materials are mixing of metal and ceramic, ceramic gives high temperature resistance and metal provides high mechanical strength and low fracture. Due to high performance of FGM they changed their mechanical and thermal properties over the traditional material [1]. Various researchers are investigated vibration analysis of annular plates with different theories such as simple higher order shear deformation plate theory (HSDT), first-order shear deformation plate theory (FSDT) and other so many other theories. Therefore, they are using in aerospace, defence, nuclear reactors and other high temperature application. FGM annular plate under thermal effect has not been dealt before.

II. LITERATURE SURVEY

Yang k. et. al. [2] reported analytical approach of functionally graded material structures for thermal stress BEM analysis. In this paper elastic modulus are used and the resulting integral equations include domain integrals due to the non-homogeneity and temperature variations of the material.

Yangzhan Yang [3] investigated temperature -dependent thermo-elastic analysis of multi dimenstional functionally graded materials. Material properties are temperature-dependent estimated by the modified WT model.

Malekzadeh. P [4] investigation of free vibration of multi - layered FG annular plates in thermal environment. differential quadrature method (DQM) and elasticity theory are used. The material properties are temperature dependent assumed to vary according to power law distribution in the thickness direction.

Reddy J.N. et al. [5] examined dynamic response of FGMs cylindrical shell. Governing equations were derived using FSDT. Material constants were varied according to power law distribution.

Hosseini-Hashemi. Sh. et al. [6] investigated vibrational analysis of functionally graded circular/annular plates. The Mindlin's first-order shear deformation plate theory used for different boundary conditions. The material properties change continuously through the thickness of the plate, which can vary according to a power-law distribution.

III. RESULTS AND DISCUSSION

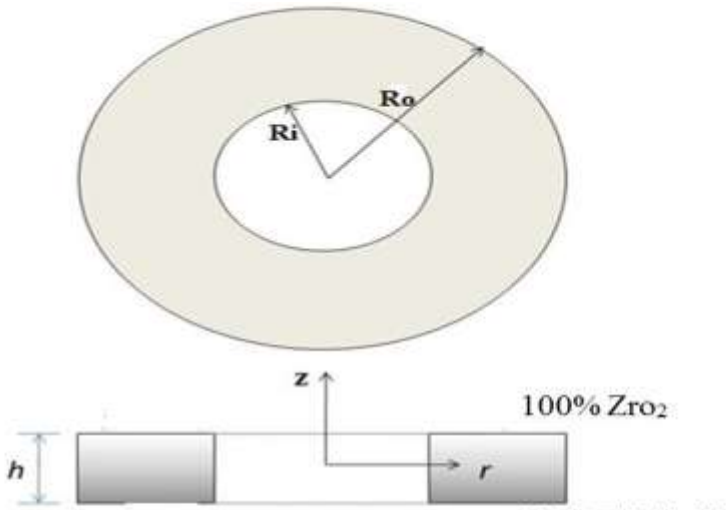


Figure 1 FGM annular plate

The geometry of FGM annular plate is given in Fig 1. The upper surface is made of 100% metal and lower surface is made of 100% ceramic. In between, the material properties are varying in thickness direction in accordance with power law distribution. The temperature of upper surface is varies and temperature of lower surface is kept at constant room temperature. The temperature-dependent properties for annular plate at upper and lower surface may be expressed as function of temperature [5].

$$Q = Q_0\,(Q_{-1}T_{-1}+1+Q_1T+Q_2T_2+Q_3T_3) \qquad (1)$$

Here, Q_{-1}, Q_0, Q_1, Q_2, Q_3 represent coefficients of temperature. The E, P, K are representing Young's modulus, density, thermal conductivity. The material properties are assumed to have temperature – dependent and vary according to the power law distribution through the thickness, i.e. in the z direction.

$$E(z,T) = [E_m(T) - E_c(T)]\left(\frac{z+0.5h}{h}\right)^{g} + E_c(T) \qquad (2)$$

Here, E_m and E_c are the Young`s modulus of metal and ceramic respectively. g is power index and T is the temperature. z is the thickness coordinate and h is the thickness of the plate. Here power index value varies from 0 to infinity. At g = 0, the FGM plate is behaves similar to the pure ceramic plate and at g is tends to infinite, the FGM plate behaves as pure metallic plate.

III. PARAMETRIC STUDY

In this study, three dimensional FGM annular plate with inner radius R_i = 0.5m, outer radius R_o = 2m, and thickness h = 0.1m, is using to obtain the modal analysis under thermal effect clamped – free boundary condition.

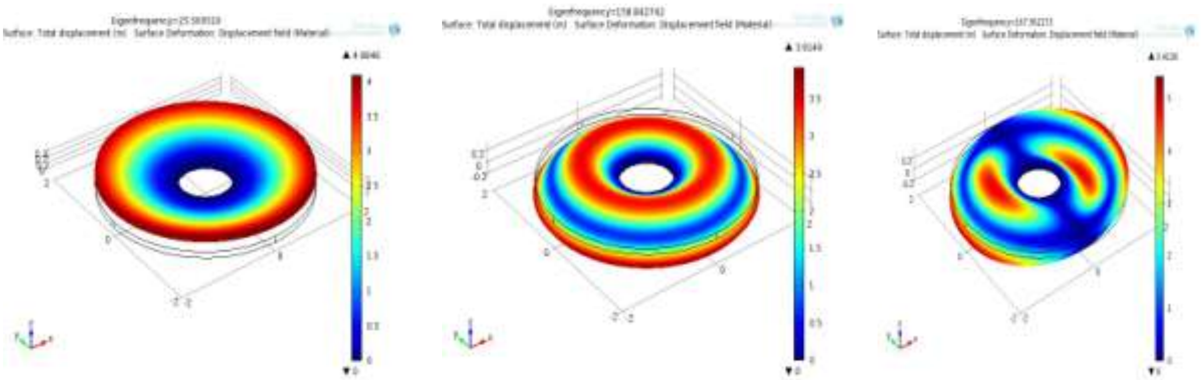
Free vibration analysis of FGM annular plate using free clamped boundary condition under thermal effect is presented. Material constants are dependent on temperature and vary in the thickness direction 100% Zro_2 at upper surface and 100% TI - 6Al - 4V at lower surface according to the power-law distribution.

Natural frequencies of FGM annular plate C – F boundary conditon under thermal effect

Table 1 Natural frequencies (Hz) for an FGM annular plate for clamped - free boundary condition under thermal effect at power index g = 1

T_{upper} (K)	(0,0) Mode Frequency (Hz)	(0,1) Mode Frequency (Hz)	(1,0) Mode Frequency (Hz)
300	28.889	180.541	203.147
400	26.746	165.905	175.931
500	25.509	158.842	167.362
600	24.322	151.450	159.573

Table 1 shows the variation of natural frequency (Hz) with different temperature under clamped - free boundary condition. Results are obtained for modes (0,0), (1,0) and (0,1). It can be seen that the natural frequencies are decrease with increase in temperature for modes (0,0), (0,1) and (1,0). Some of the mode shapes of FGM annular plate are shown in Figure.



Eigenfrequency = 25.5095 (0,0) Mode

Eigenfrequency = 158.842 (0,1) Mode

Eigenfrequency = 159.573 (1,0)

Figure 2 Mode shapes of FGM annular plate under clamped - free boundary condition under thermal effect (g = 1, T_{upper} = 500 K)

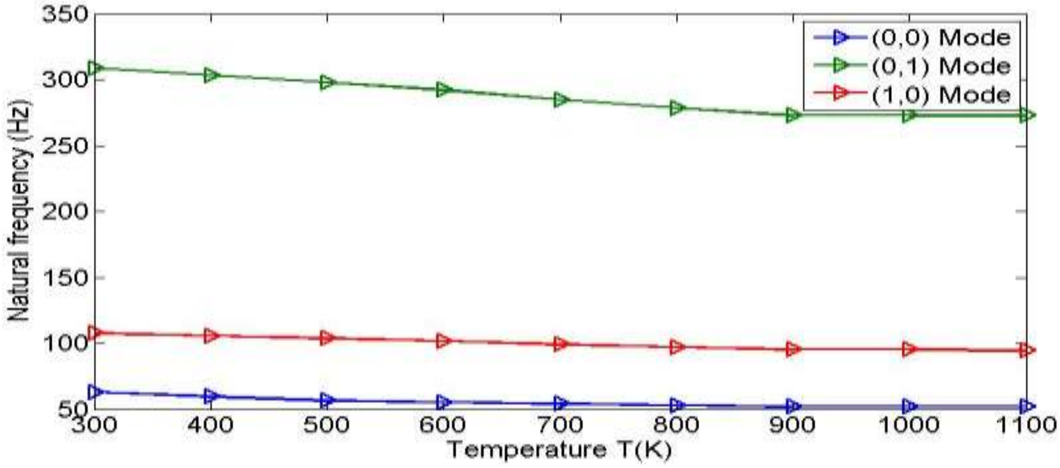


Figure 3 Effect of temperature on the natural frequencies (Hz) of an FGM annular plate for clamped - free boundary conditions under power law (g = 1)

Figure 3 Shows the characteristics of natural frequency varying with temperature. It may be seen that the natural frequencies are decrease with increase in temperature for modes (0,0), (0,1), (1,0).

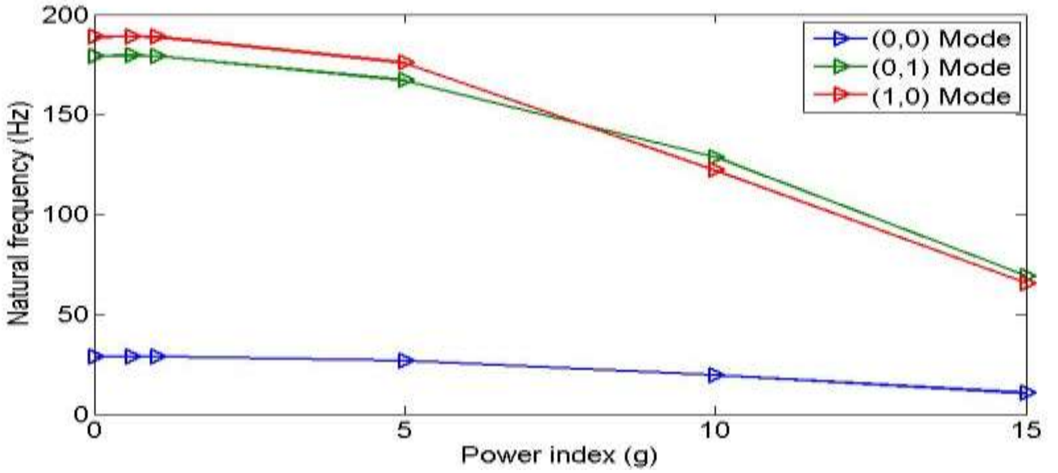


Figure 4 Effect of power index on the natural frequencies of FGM annular plate for clamped - free boundary conditions under thermal effect (T_{upper} = 400 K) at different power index (g)

Figure 5shows the effect of gradient index on natural frequencies of FGM annular plate. It can be seen that, with the increase in power index (g), the natural frequencies decreases for modes (0,0) and (0,1), (1,0).

IV. CONCLUSION

Free vibration analysis of FGMs annular plate under thermal effect is reported. Material properties are temperature dependent and vary according to the power law distribution in the thickness direction. The thermal effect on FGMs annular plate is done by imposing different temperature on upper surface and keep constant temperature (ambient) at lower surface.

The conclusions of this study can be summarized are as follows:

1. With the increase in temperature of upper surface of plate, the natural frequencies decreases for modes (0,0) (0,1) and (1,0).
2. With the increase in power index, the natural frequency decreases for modes (0,0) (0,1) and (1,0).

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