RESPONSE OF SIMPLY SUPPORTED FGM PLATES SUBJECTED TO STATIC LOADING USING ANSYS

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ABSTRACT : *Functionally graded materials (FGM) are the class of advanced materials which are used in many applications. In FGM, two or more compatible materials are varied in composition along the thickness of plates or beams. Advantages of each constitutive material are combined in FGM to get superior mechanical properties. In the present study, rectangular FGM plates subjected to distributed loads are considered. The static deflections of plates under simply supported boundary conditions are presented. Numerical results are computed in non dimensional form. It is observed that as the value of number of layers n is increased, the central deflection of plate also increases.*

IndexTerms **– Functionally graded materials , plates, constitutive material.**

I. INTRODUCTION

Materials play a vital role in human life since the beginning of his life on Earth. Man has used several different materials or made composites for his protection and for numerous applications. Initially, bronze was frequently used which is actually an alloy of tin and copper. After that, a number of different alloys of metals and nonmetals were engineered for multiple purposes. Composite materials then attained great attention from researchers due to their wide range of application. Composite materials are lighter and stronger and can also provide design flexibility. They provide resistance to corrosion as well as wear. The disadvantage of composite materials is a sharp transition of properties at the junction of materials which leads to component failure by the process of delamination.

To overcome this disadvantage of conventional composite materials, a new class of materials called functionally graded materials (FGMs) are invented by Japanese researchers in 1984. The main application of their aerospace project [1] which required thermal barrier with the outside temperature of 2000 K and inside 1000 K within 10 mm thickness. A decade before, Shen and Bever [2] also worked on graded structure composite materials, but it was delayed due to unsophisticated fabrication equipment [3]. So far, it has been used almost in every field, for example, biomedical, chemical, nuclear, mining, and power plant. FGMs occur in nature as bones, teeth, bamboo trees, human skin, and so on to meet the specified requirement of human beings and environment.

In the recent years, the functionally graded materials (FGM) were the first proposed by Bever and Duwez [4] and have been applied in a variety of engineering industries because of their distinctive material properties, which vary continuously through the thickness. These are the special types with their characteristics can be tailored for many application and various working environments. In the typically plates, the smoothness and continuously changing in microstructure from the top to the bottom layer can made the materials displayed in distinct phases regarding to ceramic and metal. The combination by two phases is demonstrated that the ceramic with low thermal conductivity can well resist the harms of thermal stress and surface corrosion due to the high temperature effects [5].

Meanwhile the metal-rich surface is well capable of the highly impacted loading on the structures. In addition, matrix materials can reduce and not be prone to the initial cracks growing into the material sections and debonding of fiber composites at extremely thermal forces. Due to the advantages of mechanical behaviours of functional graded materials (FGM), the significant number of researches had been conducted to examine the mechanical responses of FG shells and plates [6]. Therefore, the analyses of displacement, stress, dynamic problems of natural frequencies and buckling responses are really necessary for FG material behaviours.

In the present study, the power law, is considered for the volume fraction distributions of the functionally graded plates. The work includes parametric studies performed by varying volume fraction distributions and aspect ratio. The FGM plate is subjected to transverse UDL (uniformly distributed load) and point load and the response is analysed. The finite element software ANSYS is used for the modeling and analysis purpose.

II. MATERIAL PROPERTIES ACROSS THE THICKNESS OF FGM

The effective material properties like Young's modulus and Poisson's ratio on the upper and lower surfaces of FG plate are different but are predefined. However, Young's modulus and Poisson's ratio of the plates vary continuously only in the thickness direction (z-axis).

Power Law Function (P-FGM)

The material properties of a P-FGM can be determined by the rule of mixture:

$$P(z) = (P_t - P_b)V_f + P_b \quad \text{………………(1)}$$

Where, P_t and P_b are the properties on top and bottom surfaces respectively ,V_f is the volume fraction.

$$V_f = \left(\frac{z}{h} + \frac{1}{2}\right)^n \quad \text{…………………………..(2)}$$

Where, n is the parameter which shows the variation of material property.

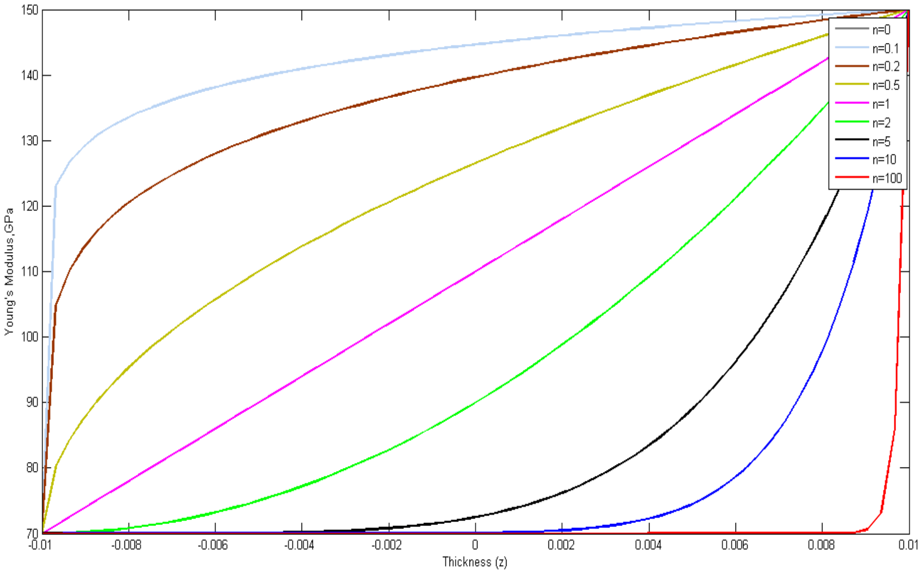

Fig. 1: Variation of Young's modulus along thickness with variation in n.

III. FINITE ELEMENT MODELLING

In finite element modeling, a rectangular FGM plate is considered with the in-plane dimensions a, b and thickness equal to h. The plate is simply supported on its four sides and is subjected to the transverse load, as shown in Fig. 2. The Poisson's ratio of the FGM plate is assumed to be 0.3 within the whole plate. The Young's moduli at the top and bottom surfaces of the FGM plate are assumed to be E_2 and E_1, respectively. However, the Young's modulus at any point on the FGM plate varies continuously in the thickness direction based on the volume fraction of the constituents. q is the magnitude of distributed load.

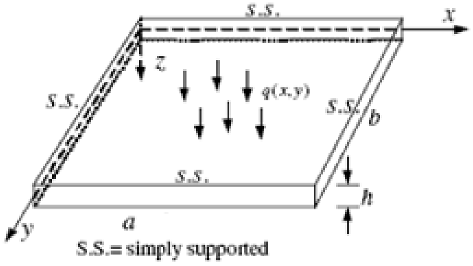

Fig. 2: Configuration of simply supported rectangular FGM plate

Young's modulus of constituents of FGM is listed in Table 1.

Table 1: Young's Modulus of constituent materials

Properties	E(GPa)
Metal (Al)	70
Ceramic(Al_2O_3)	380

In ANSYS, Shell 281 element is used to discretize the FG plate. Different layers can be formed by dividing the entire thickness of the plate into number of layers. The layers considered in the present work are shown in Fig.3. For each layer, one has to define the material properties.

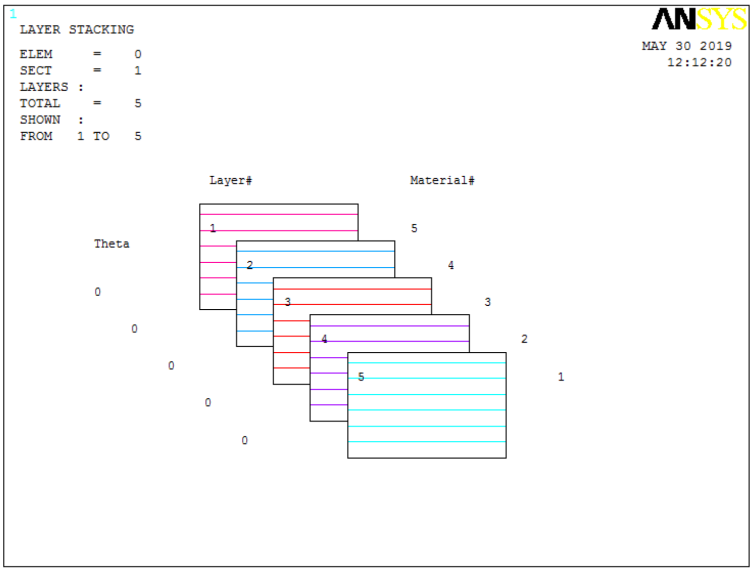

Fig. 3: Layer stacking in ANSYS

After discretization, simply supported boundary conditions are applied for all the edges of the plate and the distributed load q is applied.

IV RESULTS

The finite element analysis was carried out for two cases, case (i) for isotropic square and rectangular plates and for case (ii) for FG plates with different a/h and n values.

For case (i), the plate is considered to be made up of Ceramic. For a/b=1, 0.5 and h=0.04, 0.1, 0.2m, the non-dimensional deflection w' are tabulated in Table 2 against those obtained from Lee []. The results are in good agreement with the literature with acceptable error limits.

Table 2: Static deflection for isotropic square and rectangular plates

a	b	h	q0	w	w' (Present work)	w'(Lee et.al)
1	1	0.04	10000	1.83E-05	4.08E-03	4.10E-03
1	1	0.1	10000	1.21E-06	4.21E-03	4.27E-03
1	1	0.2	10000	1.69E-07	4.70E-03	4.90E-03
1	2	0.04	10000	4.56E-05	1.02E-02	1.02E-02
1	2	0.1	10000	2.97E-06	1.03E-02	1.05E-02
1	2	0.2	10000	3.98E-07	1.11E-02	1.14E-02

For n=0, the deflection contours are plotted as shown in Fig.4. It is evident from the plot that the deflection is maximum at the centre of the plate.

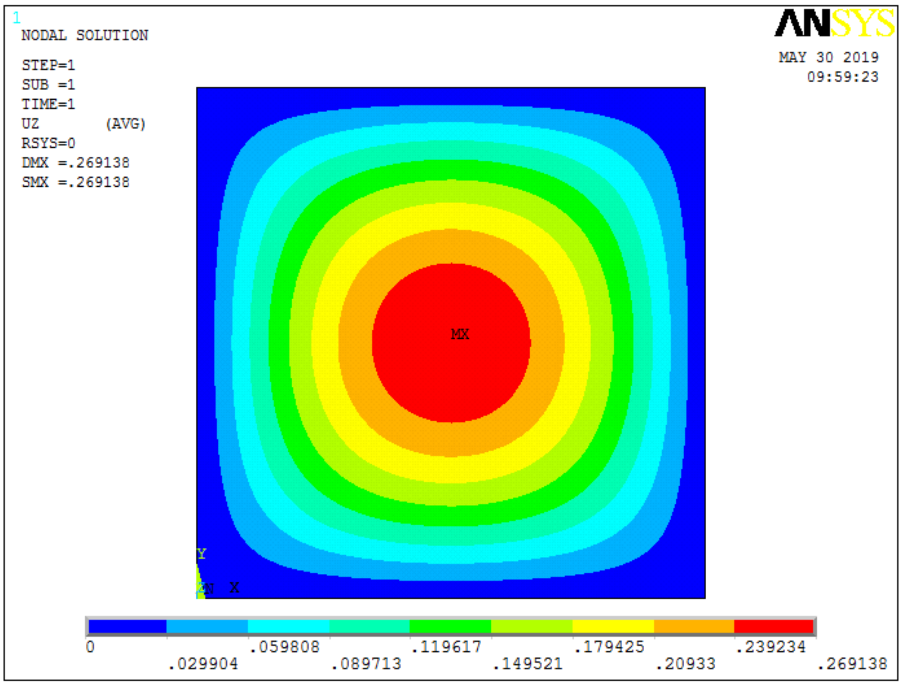

Fig. 4: Z-component of displacement for n=0

The Von-mises stress plot is shown in Fig.5.The maximum stresses are observed near the corners

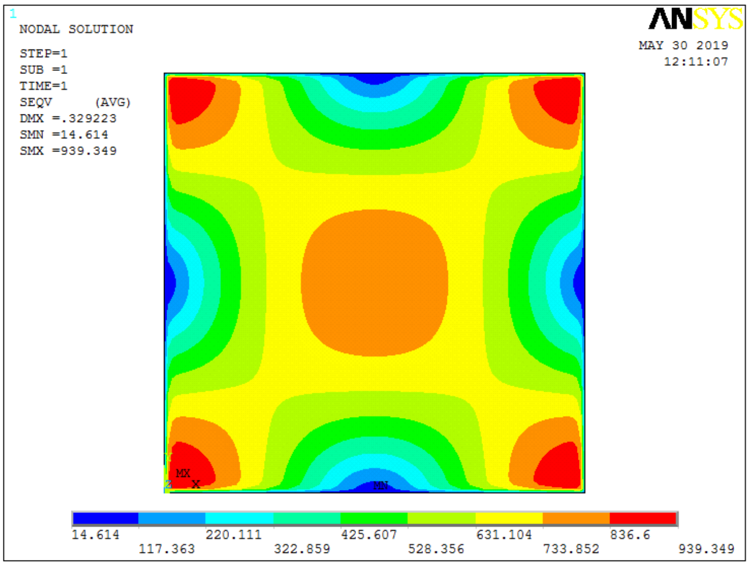

Fig. 5: Von-mises stress for n=0

For case (ii), the plate is considered to be functionally graded with different values of n. Each layer of the material is assigned with different Young's modulus which is found from equations (1) and (2). Poisson's ratio =0.3.The dimensionless out of plane deflection w' are calculated from equation (3).

$$w' = \frac{10 w E_c h'}{q a^4} \qquad \ldots\ldots\ldots.(3)$$

Where, Ec=Young's modulus of ceramic material

The results of finite element analysis of FG rectangular plates are tabulated in Table 2.The results are found to be in good agreement to those obtained from literature Long[].

Table 2: Central deflection for FG rectangular plates for different values of n

a/h	n	w' (present work)	w' (Long)
5	0	0.4458	0.4526
5	0.5	0.6805	0.6909
5	1	0.8777	0.8911
5	2	1.1291	1.1463
5	5	1.4049	1.4263
5	10	1.5713	1.5952
10	0	0.4324	0.439
10	0.5	0.6655	0.6756
10	1	0.8512	0.8642
10	2	1.0705	1.0868
10	5	1.2766	1.296
10	10	1.4186	1.4402
20	0	0.3936	0.3996
20	0.5	0.6082	0.6175
20	1	0.7826	0.7945
20	2	0.9879	1.0029
20	5	1.1632	1.1809
20	10	1.2789	1.2984
50	0	0.3860	0.3919
50	0.5	0.5971	0.6062
50	1	0.7693	0.781
50	2	0.9715	0.9863
50	5	1.1396	1.157
50	10	1.2500	1.269

IV. CONCLUSIONS

In the present work, FG plates subjected to distributed load are analysed using finite element package ANSYS. The results of central deflections for isotropic and FG plates with simply supported boundary conditions are in good agreement with the results obtained from literature. It can be noted that the deflections become higher with increasing value of n.

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