Study on Vibration Analysis of a Multistory Building for Twisted Plates

Parul Jaiswal[1] Prof. Thakur Ramji Ram[2]
[2]Professor & Head of Department
[1,2]Department of Civil Engineering
[1,2]NRI Institute of Research & Technology, India

Abstract— materials find applications in space antennae, aerospace structures and ship structures. For high temperature applications, the functionally graded material gives good performance compared to the laminated composite materials. The twisted plates have various applications in the power generation field such as generator and turbine blades. Due to light weight and high stifiness properties, the Functionally Graded Materials are economical as they require less power. Many of these plates are subjected to high temperature environment in these applications; hence functionally graded material is a good alternative to metal plates. The present paper will explore the free vibration behavior of thin twisted functionally graded material (FGM) plates. The vibration analysis is done using finite element method. An 8 noded shell element is used for finite element calculations. To model the FGM section, continuous variation in the material property along the thickness is approximated to a laminated composite section consisting of a number of layers and each layer is considered as isotropic. The material property in each layer is determined using power law. Material density, Young's modulus and Poisson's ratio change along the thickness based on power law. The first order shear deformation theory is used in the analysis of pretwisted FGM plate.

Keywords: Vibration, Multistory Building, Twisted Plates

I. INTRODUCTION

Composite materials are a class of advanced materials made by combining one or more materials in the solid state with distinct chemical and physical properties. These composite materials ofier superior properties compared to their parent materials and are also light in weight. FGMs are an advanced class of composite materials with varying material property over the change in dimension. Due to the gradual change in material property from one surface to another, it can eliminate inter laminar stress due to sudden change in material property. The materials and their composition are selected based on the function the material has to perform. Metal ceramic FGMs are commonly used as a thermal barrier material, where the ceramic surface will resist the temperature and the metal matrix will provide the strength.

II. LITERATURE REVIEW

The literature review for the graded materials. In this, some studies related to characterization of other vibration properties of initially twisted composite plates is discussed, in order to pave the methodology for the characterization of the thermo-mechanical eflects.

A. [Wetherhold et al. (2016)]

studied the use of functionally graded materials in controlling thermal deformation. By changing the fiber material content within a laminated composite beam and a gradual change in material property, temperature deections were reduced.

B. [Reddy and Chin (2014)]

presented the vibration of graded cylinder and plate. Finite element formulation developed takes in to account the thermo-mechanical efiects. Thermo-mechanical efiects have a more dominant efiect on the radial stress, compared to the hoop stress in the case of cylinder.

C. [Nabi and Ganesan (2010)]

studied vibration properties of initially twisted composite plates considering plate and beam theory. For the analysis of twisted composite beams, torsion exure, shear exure and exure are considered. Triangular plate element was used to represent the beam to an equivalent plate element. Parametric studies are conducted using plate and beam theories. The parameters considered in the analysis were layer sequence, twisting angle, orientations of the fibers and tapering ratio.

D. [Noda (2006)]

studied temperature induced stresses in FGMs. He observed that when functionally graded materials were exposed to extreme temperature loads, the cracks initiated in the ceramic face and propagated in the functionally graded material. The temperature stress concentration in the fgms with varying type of cracks was examined by using analytical and numerical methods. The crack propagation path due to thermal shock was studied.

III. APPLIED METHODOLOGY

The material composition changes gradually along the thickness. The rate of material property change along the thickness is indicated by a variable n (material gradient index). The plate is considered to be completely ceramic if n = 0 and the plate is completely metal if n = infinity.

The material properties vary in accordance with the power-law.

$$Pz = (Pt - Pb)Vf + Pb \quad (2.1)$$

$$Vf = \left(\frac{Z}{h} + \frac{1}{2}\right)^n \quad (2.2)$$

Where 'P' is the material property, 'z' is the distance from the center of layer under consideration to the center of plate, Pt and Pb are the property at the upper surface and lower surface respectively, Vf represents volume content of ceramic, 'n' is the gradient index. Young's modulus (E), Material density (fi) and Poisson's ratio (fi) values change according to equation 2.1. Vf varies over the thickness.

To calculate the material property in each layer power law variation is assumed. The laminated structure represents the step wise change in properties, by using a high number of layers the gradation can be approximated.

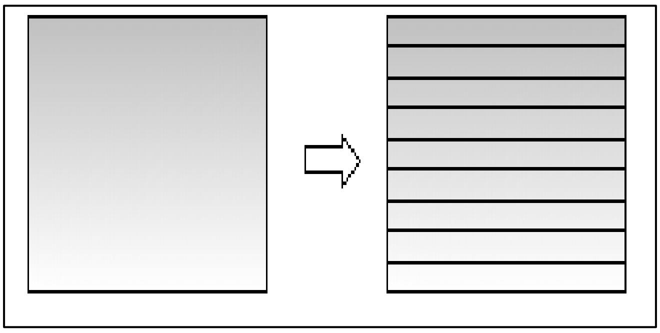
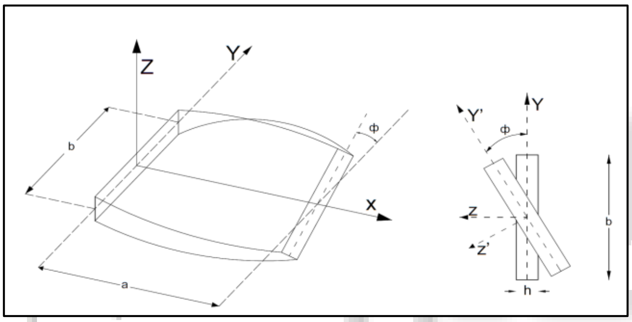


Fig. 1: FGM section and equivalent laminated composite section

A MATLAB code based on finite element method is prepared for the computation. The MATLAB code is checked by comparing the results of at FGM plates with published results. Shell element is used to model the thin twisted plate.

IV. FREE VIBRATION ANALYSIS

The materials used to design the mix for M25 grade of concrete are cement, sand, coarse aggregate, water and Fly-Ash SiO2. The properties of these materials are presented below.



Ø= angle of twist. a and b are length and width of the plate respectively. h is the thickness of plate.

V. FINITE ELEMENT FORMULATION

Finite element method can be used for complex shape and boundary conditions were analytical methods are not so easily applicable. Using the First order shear deformation theory the finite element formulation was developed for the structural analysis of FGM pretwisted shell elements. The plate is assumed to be consisting of a number layers, where each layer is considered to be homogenous and isotropic. An eight noded isoparametric quadratic shell element is used in analysis. The shell element consists of midsurface nodes. Each node has five degrees of freedom u,v,w,fix and fiy. The Jacobian matrix transfers the isoparametric element in natural coordinate system into Cartesian coordinate system. The Figure 3.2 shows 8 noded isoparametric element with node numbers. The shape function for 8 noded shell element is given by,

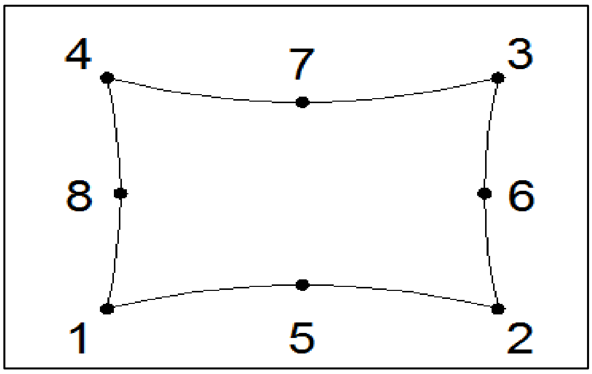


Fig. 2: Isoperimetric quadratic shell element

Convergence study for number of mesh divisions is done first. The convergence studies are conducted on a simply supported isotropic plate (n=0). The first four frequencies are observed with increase in number of mesh divisions. The Table 4.1 shows the observations. The results show good convergence for mesh division 10 fi 10. The mesh division 10 fi 10 is used for further study.

Mesh division	Non-dimensional frequency (ω*)		
	1st frequency	2nd and 3rd frequency	4th frequency
4 x 4	116.80	306.25	631.86
6 x 6	115.94	290.80	473.02
8 x 8	115.90	289.86	464.33
10 x 10	115.90	289.68	463.39
12 x 12	115.89	289.62	463.19
Ref [30]	115.89	289.58	463.07

Table 1: Convergence of Non-dimensional frequency (ω*) with varying mesh size n = 0

The FGM section is considered as an equivalent laminate section for the finite element modeling. Convergence study is conducted for determining the number of layers required to represent the FGM property accurately. The further analysis is conducted using 50 numbers of layers.

Mesh division	Non-dimensional frequency (ω*)		
	1st frequency	2nd and 3rd frequency	4th frequency
4	89.24	223.58	357.17
6	88.70	222.22	355.01
12	88.42	221.51	353.87
36	88.44	221.08	353.69
50	88.44	221.06	353.66
80	88.43	221.05	353.65
Ref [30]	88.43	220.97	353.38

Table 2: Convergence of Non-dimensional frequency (!fi) with number of layers (n = 1)

VI. CONCLUSION

From the free vibration analysis of cantilever twisted FGM plates following conclusions are made in this study.

- With the increase in the angle of pretwist, the fundamental frequency of vibration decreases.
- As the gradient index increases, the fundamental frequency of vibration decreases.
- The fundamental frequency of vibration decreases as the aspect ratio (a/b) increases.

– The fundamental frequency of vibration decreases as the length to thickness ratio (a/h) increases.
– The natural frequencies of vibration of FGM plate decreases with increase in temperature gradient due to reduction of stifiness.
– The reduction in natural frequency due to temperature need not be linear, it depends upon side to thickness ratio and gradient index.

VII. References

[1] Aboudi, J., Pindera, M. J., Arnold, S. M. \Higher order theory for functionally graded materials,"Composites: Part B, 30, (1999): 777- 832.
[2] Alibakhshi, R. and Khavvaji, A. \Free vibration analysis of thick functionally graded rectangular plates using variable refined pl
[3] Baferani, A. H., Saidi, A. R., and Jomehzadeh, E. \An exact solution for free vibration of thin functionally graded rectangular plates"Journal of Mechanical Engineering Science, 225, Part C (2010):
[4] Baferani, A. H., Saidi, A. R., and Jomehzadeh, E. \Exact analytical solution for free vibration of functionally graded thin annular sector plates resting on elastic foundation,"Journal of Vibration and Control,18, no. 2 (2011): 246-267.
[5] Biner, S. B. \Thermo-elastic analysis of functionally graded materials using Voronoi elements," Materials Science and Engineering, A315, (2001): 136-146.
[6] Chandrashekhara, K. \Free vibrations of anisotropic laminated doubly curved shells,"Computers and Structures,33, no.2 (1989): 435-440.
[7] Cho, J. R. and Ha, D. Y. \Averaging and finite element discretization approaches in the numerical analysis of functionally graded materials, "Materials Science and Engineering, A302, (2001): 187-196.
[8] Dong, C. Y. \Three-dimensional free vibration analysis of functionally graded annular plates using the ChebyshevRitz method,"Materials and Design,29 (2008): 1518-1525.
[9] Fallah, A., Aghdam, M. M. and Kargarnovin, M. H. \Free vibration analysis of moderately thick functionally graded plates on elastic foundation using the extended Kantorovich method,"Arch Appl Mech,83, (2013): 177-191.
[10] Huang, X. L. and Shen, H. S. \Nonliear vibration and dynamic response of functionally graded plates in thermal environments,"International Journal of Solids and Structures, 41, (2004): 2403-2427.
[11] Kee, Y.J. and Kim, J.H. \Vibration characteristics of initially twisted rotating shell type composite blades,"Composite Structures, 64, no. 2 (2004): 151-159.
[12] Kiani, Y., Eslami, M. R. \An exact solution for thermal buckling of annular FGM plates on an elastic medium,"Composites: Part B, 45, (2013): 101-110.
[13] Malekzadeh, P., Shahpari, S. A., Ziaee, H. R. \Three-dimensional free vibration of thick functionally graded annular plates in thermal environment," Journal of Sound and Vibration, 329, (2010): 425-442.
[14] Nabi, Y.J. and Ganesan, N. \Comparison of beam and plate theories for free vibrations of metal matrix composite pretwisted blades,"Journal of Sound and Vibration, 189, no. 2 (1996): 149-160.
[15] Noda, N. \Thermal stresses in functionally graded materials," Journal of Thermal Stresses, 22, (1999): 477-512.
[16] Rath, M. K. and Sahu, S. K. \Vibration of woven fiber laminated composite plates in hygrothermal environment,"Journal of Vibration and Control, 18, no. 2, (2011): 1957-1970.
[17] Reddy, J. N. \Analysis of functionally graded plates,"International Journal for Numerical Methods in Engineering, 47, (2000): 663-684.

