Free vibration analysis of functionally graded porous sandwich plates with a complex shape

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Abstract. Free vibration analysis of geometrically nonlinear FGM sandwich porous plates of different shape and boundary conditions are studied. The face layers are composed of FGM (mixture of metal and ceramics) and the isotropic core is made of ceramics. The employed mathematical model is framed in the context of the first order shear deformation theory (FSDT). The power-law model is applied to determine the effective material properties of the structure. The R-functions theory combined with variational Ritz's method are used to carry out the free vibration analysis of porous sandwich plates. The natural frequencies of porous FGM sandwich plates are studied upon variation of the porosity to appreciate the underlying frequency linear shifts. New results for plates of complex shape with a hole are reported. The effects of the porosity volume fraction, the porosity models, the type of FGM, the layup of layers, boundary conditions on the linear and nonlinear frequencies are investigated.

Introduction

Functionally graded materials are new types of composite materials that have been extensively applied in many manufacturing processes in the last decades. These materials made of alloys of metal and ceramics do not typically suffer the stress discontinuity that is observed in multi-layered composites. Use of the FG sandwich structures allows to solve some mechanical problems since the gradual variation of material properties is attained at the interfaces between the core and face layers. Porosities and micro-voids are technical challenges rising out of the manufacturing process which lead to a reduced mechanical performance of FGM. That is why this issue has motivated wealth of theoretical and practical studies [1]. In this paper FSDT is used to investigate linear and geometrically nonlinear vibrations of porous FGM sandwich plates endowed with different shapes and boundary conditions.

Results and discussion

The proposed method consists of three steps. The linear vibration problem is solved in the first step. To solve this problem the R-functions theory [2] combined with the Ritz method are employed in a distinctively new approach. The main advantage of the R-functions theory is the possibility of constructing admissible functions in analytical form practically for an arbitrary domain. The eigenvalues and eigenfunctions found in analytical form are employed in the second step. Solution of the auxiliary inhomogeneous task of elasticity problem allows to reduce the initial system of PDEs to the following nonlinear second order ODE:

$$\ddot{y}_1(t) + \omega_L^2 y_1(t) + y_1^2(t)\beta + y_1^3(t)\gamma = 0. \qquad (1)$$

The solution of equation (1) is carried out in the third step, both numerically via the 4th order Runge-Kutta integration method and analytically by the method of multiple scales. The values of the coefficients in equation (1) are obtained in analytical form as integrals above given domain [2]. Figure 1 demonstrates effect of the porosity on frequency (linear and nonlinear) for Al/Al_2O_3 sandwich plate with different layup of layers.

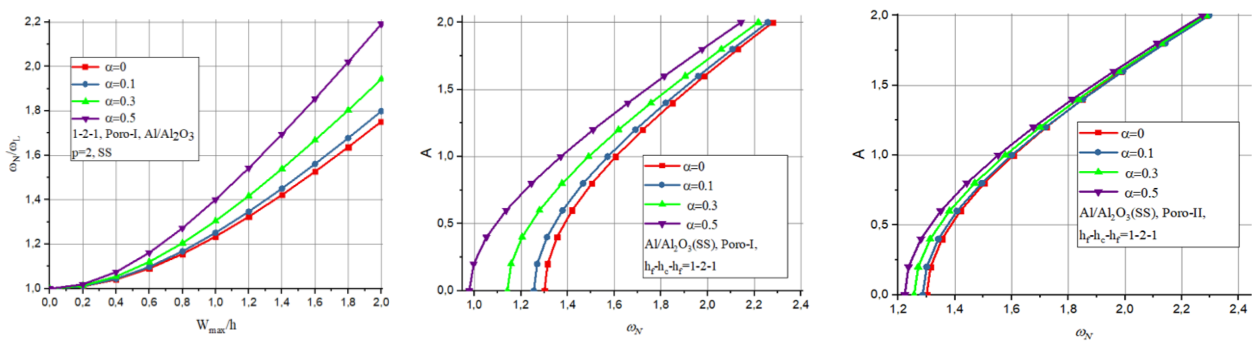

Figure 1: Linear and nonlinear frequencies of Al/Al_2O_3 sandwich plate with different layup of layers and type of porosity α

References

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[2] Awrejcewicz J., Kurpa L., Shmatko T. (2018) Linear and nonlinear free vibration analysis of laminated functionally graded shallow shells with complex plan form and different boundary conditions. *J. Non-linear Mechanics*. **107**: 161-169.