

Abstract

The present study deals with the development of new analytical and finite element models for the modeling and analysis of traditional multi-layered laminated composites and smart composite plate structures supported by elastic foundations. Layers of piezoelectric materials are stacked on the laminated composite plates along the thickness direction for sensing and actuation of the responses of the smart structures. The plate deformations are modeled with an inter-laminar transverse shear stress continuous plate theory. The plate theory consists of a global non-polynomial shear deformation field and a local segmented zigzag field with changes in slopes of displacement components at each interface of the plates. The non-polynomial shear deformation field is a refinement of the classical plate theory that incorporates a trigonometric shear strain function to accurately model the non-linear variation of the transverse shear strains across the thickness of the plates. The zigzag field consists of piecewise linear mathematical functions that are defined for each layer. Additionally, some auxiliary variables are also defined at the interfaces between adjacent layers of different material properties to incorporate the slope discontinuities of the displacement components. The number of field variables of the present plate model is equal to that of the global non-polynomial shear deformation theory as the auxiliary variables can be expressed in terms of the field variables with the help of inter-laminar continuity conditions of transverse shear stresses at all the interfaces of the plates. The deformation of the elastic foundations is modeled with Pasternak's foundation model, which takes into account the proportional interaction between the load intensity and deflection of any point on the surface of the elastic foundation and also accommodates the continuity of the adjacent displacements by considering shear interactions among the points on the elastic foundation. The governing equations of motion and the boundary conditions of the problem are derived using Hamilton's principle and variational calculus. Two solution methods namely, generalized closed-form analytical solutions of Navier-type and numerical solutions in the framework of finite element method are adopted for solving the governing set of equations. The solution involves a spatial solution and a temporal solution of the primary variables. The spatial solutions of the primary variables in the analytical and finite element method reduce the governing partial differential equations to ordinary differential equations in time. The temporal solutions of the ordinary differential equations are further obtained with Newmark's constant average acceleration method. A detailed investigation of the static and dynamic responses of both traditional laminated composite plates and smart composite plates is carried out by considering different geometrical and material features of the plate structure. The uncontrolled and controlled static responses in the form of deflection and stresses are derived under the action of purely mechanical and electromechanical loads. The free vibration response in the form of natural frequencies and forced vibration response in the form of displacement-time responses under the action of several forms of time-dependent mechanical and electromechanical excitations are obtained. The vibration control of the smart composite plates is also carried out by coupling the laminated composite plate and the piezoelectric materials with a feedback controller.

Additionally, the effects of the elastic foundations on the static and dynamic responses of traditional laminated composites and smart composites are also investigated in detail. It is concluded from the results that both analytical and finite element solutions are capable of accurately predicting the responses of laminated composite plates and smart composite supported on elastic foundations.

Keywords: Trigonometric zigzag theory; Analytical; Finite Element method; Laminated composites; Sandwich structure; Smart Composites; Elastic foundations; Static; Free vibration; Transient analysis; Navier's solution; Newmark's time integration.