Abstract

The present work comprises of development and implementation of new tangential non-polynomial quasi-3D theory (TNPQT) to analyse functionally graded plates by displacement formulation and mixed formulation approaches. For a functionally graded plate the properties vary across the thickness which makes modelling of these plates a very challenging task. The two dimensional shear deformation theories cannot predict variation of transverse displacements across the thickness and may lead to inaccurate structural response. Hence, present work focuses on the development of a shear deformation theory which can predict accurate structural responses of functionally graded plates. The shear strain function is represented by trigonometric-tangential function in the developed quasi-3D theory and it consists of six field variables. The theory inherently satisfies the condition of zero transverse shear strains at top and bottom surfaces and do not require a shear correction factor. Unlike two dimensional theories, the present theory is able to predict the transverse normal stress and strain. Also, according to TNPQT the transverse displacement of plate is not constant across the thickness hence the present theory has capacity of predicting accurate structural responses. The accuracy of the present theory is ascertained by implementing Navier-type analytical solution for the structural responses which include bending, buckling and free vibration analysis. The analytical solution is based on the displacement formulation approach. In the displacement based approach the stresses are derived quantities and possess more error than displacements; also, evaluation of continuous transverse shear stresses is very complex in the displacement based formulation. Because of these reasons mixed formulation approach has also been adopted in the present study. In the mixed formulation approach the transverse stresses are also included in the primary variables along with the generalised displacements, which leads to the accurate evaluation of transverse stresses in very simpler way. Generalized displacements are modelled according to the TNPQT whereas transverse stresses are modelled according to the Legendre Polynomials. The governing equations for mixed formulation approach are derived by employing Reissner's Mixed Variational Theorem which satisfies the condition of equality of strains due to geometric relations and constitutive relations. To address more practical problems, efficient C^0 finite elements in the framework of displacement formulation and mixed formulation approaches are developed. Bi-quadrilateral iso-parametric eight noded serendipity finite element has been employed to derive the governing equations. The results are generated with displacement based analytical solution (DFA-Analytical), finite element method based on displacement formulation approach (DFA-FEM), and finite element method based on mixed formulation approach (MFA-FEM). The generated results are compared with the elasticity solution and other various methodologies to assess the accuracy of present displacement model and solution methodologies. The effect of various physical parameters and boundary conditions have also been studied in details for exponentially graded as well as for power law gradation of plate.

Overall, the versatility of the present displacement model is demonstrated by obtaining various structural responses for various plate conditions using displacement formulation and mixed formulation approaches.

Keywords: Functionally Graded Materials, Functionally Graded Plates, Quasi-3D Shear Deformation Theory, Non-polynomial shear strain function, Mixed Formulation Approach, Reissner's Mixes Variational Theorem, Bending Analysis, Buckling Analysis, Free Vibration Analysis, Finite Element Method, Legendre's Polynomials, Navier Solution