Abstract

Functionally graded materials (FGMs) are advanced composite materials that have gained considerable attention due to their high strength, stiffness, and thermal resistance. Since the invention of FGM, variation of material property is considered in one direction only upto a certain time. This FGM is recently termed as uni-directional FGMs. In this type of FGM, material properties are assumed to vary in the thickness direction. To design advanced structures and components such as high-speed jet engines, space-shuttles, etc., the material properties of FGMs are required to be graded in two or more directions. These types FGMs are known as multi-directional FGMs. In the process of fabrication, FGM experiences different temperature gradients due to differences in the solidification temperature of metal and ceramic. This temperature difference leads to the formation of micro-voids or porosity. The existence of micro-voids or porosities in the materials reduces the mechanical strength of material, which may lead to the structural failure.

In this thesis, the uni-directional FGM plate is modeled considering power law to investigate the free vibration and buckling behavior under uni-axial and bi-axial compressive loads. The mathematical formulation has been presented for finite element solution using inverse trigonometric shear deformation theory (ITSDT). Uni-directional FGM sandwich plates are modeled using Voigt's micromechanical model considering the power and sigmoid law to investigate thermal buckling analysis afterward. Thermal loads are considered with respect to the rise in temperature following uniform, linear, nonlinear, and sinusoidal temperature profiles to obtain the critical buckling temperature of uni-directional FGM sandwich plates. Further porosity has been incorporated in the FGM sandwich plate to investigate the impact on critical buckling temperature. To incorporate the porosity in FGM sandwich plates, even, uneven, logarithmic uneven, linear uneven, and sinusoidal uneven porosity distribution models are considered.

A multi-directional FGM sandwich plate with porosity distribution is modeled to investigate the free vibration and buckling behavior. The effective material properties of multi-directional FGM sandwich plates are assumed to be continuously varying in the longitudinal and transverse directions. Bending analysis of multi-directional FGM sandwich plates under thermo-mechanical loading has been investigated afterward. The governing equations for free vibration, buckling and thermo-mechanical bending of multi-directional FGM sandwich plates are obtained using sinusoidal shear deformation theory (SSDT).

It is observed from the investigations that the direction of material gradation in uni-directional and multi-directional FGM plates has significant impact on its structural response. The results demonstrate that volume fraction index and material property gradation along longitudinal and transverse directions can be used as a significant parameter to design uni-directional and multi-directional FGM plates.

Keywords: Functionally graded material; Uni-directional FGM; Free vibration; Buckling; ITSDT, Thermal buckling; Power law; Sigmoid law; SSDT; Even and uneven porosity; Multi-directional FGM; Thermo-mechanical bending;