

Abstract

The advantage of continual gradation of ceramic and metal in functionally graded (FG) materials and the ability of these constituents to withstand large thermal and mechanical loads have widespread the applications of FG structures in industries employing high-temperature applications. Shell structures as well as structures of various other forms are extensively employed in these industries where they are required to perform very efficiently and safely under such severe loading conditions. The current study in the dissertation investigates the thermal and mechanical responses of the ceramic-metal composed FG shell structures and plane strain media as an effect of exposure to rapidly applied thermal loads on their boundaries.

The effect of thermal shock on the FG shell structures is studied based on the uncoupled theory of thermoelasticity. The effect of functional gradation is brought into the thickness of the shells by varying the volume fraction of the constituent materials along that direction using a recently proposed four-parameter power law. The thermal and mechanical properties of the constituents are considered to be temperature-dependent. The present uncoupled thermoelastic problem is solved by importing the temporally varying temperature distribution into the finite element (FE) code for structures written in the MATLAB environment. Since this analysis is done on thin and moderately thick shell panels and shells of revolution, the FE formulation is developed in the regime of higher-order shear deformation theory (HSDT) of shells. Furthermore, the non-linearity in the structural responses due to the von Karman strain-displacement relationship has also been included in the formulation. Numerical results of the uncoupled thermoelastic analysis are presented for geometric non-linearity, temperature dependency of the properties, variation in volume fraction of the constituents, etc.

The lack of control over the manufacturing processes and also during the determination of the properties of the constituents may cause material uncertainty to creep into the structure to a certain degree within a range from their mean values. Therefore, later the uncoupled thermoelastic study of thermal shock analysis is extended to study the stochastic transient thermal stresses in the FG shells due to uncertainty in the properties of the constituents

using the Monte Carlo Simulation (MCS) and Response Surface Methodology (RSM) based Perturbation Technique. The effect of uncertainty of the properties is cumulatively studied with their volume fraction variation across the thickness of the shell.

Certain fabrication processes like welding and cutting require localized heating of the workpiece using a high-intensity laser beam. Aviation and energy sectors have recently started to employ large-scale FGM plates which are required to be fabricated to very close tolerances. This can be achieved using laser cutting technology. The final study in the thesis is based on investigating the effect of locally applied thermal shock on a 2-dimensional FG domain using nonlinear Lord-Shulman (LS) generalized thermoelastic theory. The solutions to coupled equations of thermal and structural analysis are obtained using the FE code where the gradation in the domain is accounted using graded finite elements. The effects of volume fraction index and orientation of the material gradation are investigated.

Keywords: Functionally graded materials, Uncoupled thermoelasticity, Shell structures, Temperature dependency, Geometric non-linearity, Material uncertainty, Monte Carlo simulation, Perturbation technique, Generalized thermoelasticity, Localized thermal shock, Graded finite elements, Finite element analysis.