Abstract

Thermal stresses often constitute a predominant factor affecting the behavior of structures operating at high temperatures. Laminated composite shells are being extensively used in the design applications of launch vehicles, aircraft, turbines, etc. due to high specific strength and stiffness properties apart from other important features. With the advent of advanced composite materials such as metal matrix, ceramic matrix and carbon carbon composites for high temperature applications, many conventional thermal and structural problems have to be examined and new problems have to be addressed as well. They essentially cover the problem domains of static, quasi-static, and dynamic thermal structural analysis. In each case the knowledge of temperature as a function of space and time is needed for the entire structure. Therefore the transfer of data between the thermal and structural analysis plays a critical role, and an integrated analysis approach using the same geometry for both thermal and structural analysis is desirable.

The present investigation deals with an integrated analysis method for the static, quasi-static, dynamic and coupled thermostructural analysis of laminated composite shells subjected to various thermal loadings. Two types of formulations namely, a general 2-D shell and an axisymmetric shell, are considered for the analysis. The governing finite element equations for heat conduction and structural analysis are derived from energy and equilibrium condition of the panel using the Galerkin procedure. The heat transfer boundary conditions of heat flux, convection and radiation are taken into consideration in the conduction analysis. The strain-displacement relations of the panel are based on the Donnell's shallow shell theory. The transverse shear flexibility of composite laminate is considered in the structural formulation. Two elements namely, six and nine noded isoparametric elements, are used for the doubly curved shell analysis. Axisymmetric analysis also uses two finite elements of two noded and three noded isoparametric elements. The present finite element modeling is validated after carrying out suitable convergence study and verification of results with those in the open literature.

The numerical results for temperature, displacements and stresses are presented to examine the thermostructural behavior of composite shell panels made up of MMC, CMC and CCC materials to the applied uniform, non-uniform, through-the-thickness and time dependent thermal loads. The effect of temperature dependent material properties on temperature distribution and displacement response is studied. The effect of cutout on the shell due to the heat flux loading is also investigated. Thermostructural behavior of closed circular cylindrical shells subjected to an asymmetric heat flux is studied in both static and quasi-static analysis domains. Both dynamic and coupled responses of laminated composite shells are studied for the applied heat flux and mechanical load pulses. In all the above cases parametric studies are carried to study the effect of radius to span ratio of the shell, lamination scheme, type of composites and structural boundary conditions, apart from others. The results are discussed in detail and conclusions highlighting the important findings are made. The scope for further research in the area is also identified.