ABSTRACT

The applications of laminated composite shells have increased manifold in the aerospace and other engineering applications due to several attributes of composites such as lightweight, high specific strength, high specific stiffness as well as excellent fatigue and corrosion resistance properties. Shallow shells are used in structural applications either as main structures or as structural components. Most structures are subjected to hygrothermal exposure during the service life. The increase of temperature and moisture levels affects the elastic moduli and degrades the strength of the laminated material. As a result, a careful evaluation of the effects of moisture and temperature is required to find the nature and extent of their deleterious effects upon performance.

In particular, the aerospace structures made of thin shells undergo large deformation of the higher order of the shell thickness when subjected to static/dynamic loading. In many situations, the composite structures are likely to encounter impact due to accidents or foreign objects. It is well known that one of the weakness of advanced fiber-reinforced composites is their relatively poor resistance to impact loading. Impact in most cases cause large deformation of the target structure. Nonlinear analysis methods are required to predict the large deformation behaviour. Among the nonlinear analysis methods, the finite element method has been widely used in solving nonlinear problems because of easy implementation with any boundary condition and arbitrary geometry.

The present investigation is aimed to developing the geometrically nonlinear finite element analysis procedure using eight noded isoparametric composite shell elements to study the static and dynamic response of laminated composite shells in hygrothermal environments. The present finite element formulation considers doubly curved shells, and the Green-Lagrange type nonlinear strains are incorporated into the first-order shear deformation theory. The material behaviour is assumed to be linear and elastic.

The governing equilibrium equations for the finite element analysis are formulated employing virtual work principle based on total Lagrangian approach. The nonlinear bending problem is solved using the incremental modified Newton-Raphson scheme. The subspace iteration technique along with the nonlinear iterative method is used for computing the nonlinear fundamental frequencies. The nonlinear time dependent equation is solved by using the Newmark average acceleration method in conjunction

with an incremental modified Newton-Raphson scheme. A modified Hertzian contact law is incorporated into the finite element program to evaluate the impact force.

The finite element codes are accordingly developed in C++ language. The validity of the present finite element code is demonstrated by comparing the present results with the solutions available in the literature. The analysis accounts for the reduced material properties at elevated temperature and moisture concentration. A parametric study is carried out varying the curvature and side-to-thickness ratios of laminated composite cylindrical, spherical and hyperbolic paraboloid shell panels.

Numerical results are generated on the bending behaviour of simply supported and clamped laminated composite shallow shells subjected to uniform rise in moisture concentration and temperature. The nonlinear fundamental frequency results are generated for simply supported laminated composite shells subjected to various moisture concentrations and temperatures. The results are also presented for the transient vibration response and impact response of simply supported laminated composite shells subjected to mechanical load or impact in hygrothermal environments. Based on the critical discussion of numerical results, major conclusions are drawn and the scope for future research is also identified.