Abstract

The non-linear analysis of shell type structures is a problem of considerable relevance, particularly for the researchers in this field. The requirements for higher strength-to-weight ratios, better corrosion resistance, longer fatigue life as well as several other positive features have resulted in increasing demand for laminated composite structures in many challenging applications. Shells made of laminated composites are being extensively used in aerospace, mechanical and marine industries.

Over a couple of decades extensive research has been carried out on the computational treatment of stress resultant based nonlinear shell models. But still there is a thrust on developing more sophisticated shell models that have the ability to handle displacements and rotations regardless of their magnitude and the capability of predicting reasonably accurate results when applied to various kind of engineering problems. In the present thesis the main attention has been focussed on the development of a procedure for the non-linear analysis of geometrically exact laminated composite shells with appropriate finite element analysis schemes which can be applicable also for the analysis of hyper elastic shell problems.

The field equations for general piezo-elastic laminated composite shells in a stress resultant format incorporating the thermal effects have been derived. The formulation has been applied for the finite element analysis of geometrically exact laminated composite shells, where the enhanced assumed strain (EAS) for the membrane part, the assumed natural strain (ANS) or MITC scheme for the transverse shear part are assumed to make the element completely free from various locking effects. In the theoretical development a simple local rotation definition has been derived and implemented for handling finite rotations without any singularity. To make some of the

computational part straight forward, a unique procedure to extract the composition of two finite rotations numerically has also been developed by exploiting the Lie-group structure.

A consistent way of interpolating the rotation tensor is prescribed by making the use of local rotation for getting reliable behavior of shells under different loading conditions.

The consideration of through-the-thickness stretch ensures the direct use of three dimensional constitutive equations in the present study. Thus, this formulation has been applied for the analysis of shells made of hyper-elastic materials without any major change. The effect of temperature is included in the formulation to check whether the present formulation can be easily applied to the thermal post-buckling problems.

The iterative methods are applied to solve the non-linear equations arising from such kind of shell formulations. The arc-length method is usually applied for handling those equations. To make this kind of continuation or path-following methods more automatic, a simple path-direction choice scheme has been proposed and used for the solution of almost all the relevant problems studied in this thesis.

Several of problems have been solved to establish the accuracy and the performance of the present analysis method in both linear and non-linear (including snapping, finite deformation, finite rotation and finite strain) problems. New results are also presented for different types of problems.