Abstract

The analysis of smart shells is a problem of considerable relevance and has drawn the attention of the researchers in recent years. Though the mechanics of multifunctional materials are understood reasonably well, rigorous modelling using these materials in a composite structural system under different loading conditions is still a challenging task. Therefore, there is a thrust on the development of the theory and the modelling of the multi-field (piezo-elastic) coupled interaction in laminated smart shells. In the present thesis the main attention has been focussed on the development of an improved higher order electro-elastic shell formulation that accounts for the continuous inter-laminar transverse shear stresses and the transverse electric displacement. A suitable mixed functional of modified Hellinger-Reissner type that involve only the first derivatives of all the independent fields via considering the moment stress-resultants as primary unknowns have been constructed. Polynomial multi-scaling for the electro-elastic shell kinematics (i.e., different polynomial degree for the mechanical and the electric potential parts) have been employed to capture accurately the electric influence since it is significantly weaker than those of the mechanical counterpart. The resulting finite element equations have then been developed using the derived mixed variational principle. The developed C^0 finite element formulation are found to be free from shear and membrane locking and also free from any spurious modes. Unlike other theories where cross-section rotations are considered, in the present development the average cross-section shearing strains are treated as the independent field. A simple least-square finite element in the thickness direction for the accurate estimation of the transverse stresses is made. The developed finite elements based on the higher order shear deformable equivalent shell theory is coupled with a simple post-processing stage for the accurate estimation of the transverse stresses and are found to be a better alternative for engineering applications. An efficient algorithm is developed for solving the general symmetric

eigenvalue problem involving the null diagonal block in mass/geometric stiffness. Unlike the static condensation technique which renders the system matrix dense, the present algorithm does not affect the sparse/band nature of the system. The range of applicability of the proposed model is demonstrated by successfully solving shell problems having different lamination schemes with varied location of the integrated piezoelectric layers, different thickness ratios, aspect ratios, mechanical and electrical boundary conditions, loading pattern and other relevant parameters. Numerical results are generated for the bending and free vibration of coupled electro-elastic shells and are discussed. The numerical study shows that the analysis of smart laminated shells, which involves a complex electromechanical coupled field problem, by the proposed model, is computationally as efficient as the analysis of a displacement type resultant-based shell model. The numerical results show that the performance of the proposed finite element model is excellent in predicting the structural behaviour of composite and sandwich doubly curved shells with surface bonded as well as embedded piezoelectric layers accurately.