## SYNOPSIS

The goal of the present study is to give a reliable three dimensional computational approach for layered medium for local quantity of interest, like stress state at a point. The study focusses on laminated composites in which each lamina may have different properties at macro level. The laminated structures are generally thin (length to thickness ratio is high). The system of partial differential equations of three dimensional elasticity is generally intractable analytically, especially for a layered medium. The development of classical theories was motivated to alleviate these problems by reducing the dimension for analysis. Families of plate models are available in the literature. In this study, the pointwise accuracy of a popular shear deformable theory, a hierarchic plate model and a layerwise model has been evaluated. These models are compared with the three dimensional elasticity solution due to Pagano. Further, a general layerwise model has been proposed in this study. The model has capability of having different transverse approximation of the displacement components in the layers. The sequences of transverse approximation of displacement components are based on separating membrane and bending actions, as suggested by Schwab.

The attractive feature of shear deformable and hierarchic model is that the cost of computation is independent of number of layers in the laminate. But these models fail to accurately predict the three dimensional state of stress at the cut-out boundaries, re-entrant corners, edge singularities, free edges, near delaminated and damaged zones and boundary layers. Away from these details the stress state is accurately predicted when the equilibrium based postprocessing approach is used to extract the transverse stress components. The three dimensional state of stresses at these details is accurately predicted by the layerwise model even without the postprocessing but the cost of computation increases significantly and can become almost intractable for large number of layers. To circumvent this situation a novel 'region-by-region modeling approach' is proposed. With this approach, a layerwise model can be put in the regions where the three dimensional effects are predominant and at other places an equivalent single layer or intermediate model can be used. The approach is a three dimensional generalization of the constrained approximation of Demkowicz et al and dimensional adaptivity of Stein et al. The region-by-region approach is as accurate locally as layerwise model and computationally very economical compared to layerwise model.

Another goal of this study is to estimate and control the error in the in-plane approximation and transverse approximation with respect to three dimensional elasticity solution. The former part, the error in the three dimensional exact solution ($u_{3d}$), and the exact solution of a plate model ($u_M$) constitutes the modeling error ($e_M = u_{3d} - u_M$) while the later part, the error between exact solution of a plate model and its finite element solution $\left(u_M^{fe}\right)$ constitutes the discretization error $\left(e_h = u_M - u_M^{fe}\right)$. Thus, for the finite element solution of a given plate model the total error with respect to three dimensional solution is the sum of modeling error and discretization error ($e = e_M + e_h$). The residuum type of error estimators available in literature are very reliable and have the additional property of being an upper or lower bound of the exact error. The computational cost of these estimators is significant in the current three dimensional setting. The extrapolation type estimators are also reliable but cannot be shown to be an upper or lower bound of the exact error. In this study, a class of extrapolation based estimators for strain and displacement components are proposed for laminated plates. This is the first known reliable extension of the extrapolation based estimators to laminated plates. Further, an a-posteriori estimator for the error in the quantity of interest (e.g. stress, displacement component or any desired quantity) using influence function approach has been done. A new procedure for control of the error in the quantity of interest is achieved by multiple mesh refinements in 'one shot', has been proposed and implemented. With this strategy of controlling the discretization error, a new explicit modeling error indicator for estimation of modeling error for the laminate has been proposed following the theoretical developments of Schwab for a single layered plate. The proposed modeling error estimator is novel because it measures the error in the postprocessed stresses for a given plate model. The major advantage of this approach is that it leads to very small modeling error for symmetric laminates, thin laminates for which the postprocessed transverse stresses are very close to the exact one. Hence, this estimator truly reflects the accuracy of the chosen plate model.

The plate models proposed in this study, along with discretization and modeling error estimation and control, are used to address the problem of onset and growth of damage in laminates. The first-ply failure load is used as a damage initiation criterion. Following the seminal work done by 'World Wide Failure Exercise', 'Tsai-Wu' failure criterion is used. When the discretization error control is used along with equilibrium based post-processing, the first-ply failure load is dramatically lower than the one reported in the literature. Further, the continuum based damage mechanics approach for laminated composites made of unidirectional fibrous composites proposed by Ladevèze is implemented with minor modifications. This model is capable of both predicting onset and growth of damage. The developed plate modeling strategy, along with the proposed adaptive analysis, is used to study the effect of damage on response quantities. Specifically, the surface signatures are obtained for different ply and interfacial damage modes. The damage in fibres affects the surface signature significantly while the damage in interface (delamination) do not have much effect. The results obtained for the growth of damage with the present approach are similar to one obtained using refined 3D finite element analysis reported in literature. The current work has led to the development of a reliable and economical tool for the analysis of composite laminates.