Buckling of Laminated Plates Considering Pre-Buckled Stress State

Alfia Bano[†], **P.M.Mohite**[‡], **Ashwini Kumar**[†]

[†] Department of Civil Engineering, Indian Institute of Technology
Kanpur, Uttar Pradesh, 208016, India
alfia@iitk.ac.in, ashwini@iitgn.ac.in

[‡]Department of Aerospace Engineering, Indian Institute of Technology
Kanpur, Uttar Pradesh, 208016, India
mohite@iitk.ac.in

ABSTRACT

Laminated composite structures have found increased application as critical structural members due to their high specific strength, stiffness and lightweight properties. In many practical situations these structures are subjected to various types of in-plane loadings necessitating the clear understanding of their behaviour under these loadings.With few exceptions, most of the existing results on buckling load are based on assumed in-plane (pre-buckled) stress distribution. Reddy *et al.*, see [3], presented the analytical solution for buckling of laminated plates using different plate theories and ignored the effect of prebuckled state of stress. In general, the stability analysis of composite plates is based on the assumptions that the plate is free to move laterally (in-plane) and the state of stress within the plate is equal to the applied traction at the boundary. However, in more realistic situations, the plate is laterally restrained and the internal in-plane stress distribution is significantly different from the edge traction. As a result, the buckling load of the plate may be different for varying in-plane boundary conditions. Bert and Devarakonda, see [2], found that all the three in-plane stress components need to be accounted to obtain the correct critical load.

The aim of the present work is to address this problem by taking care of the actual stress distribution, for more realistic in-plane restraints. To achieve this goal a finite element model using generalized higher order theory is developed using approach given by Actis *et al.*, see [1]. Here the problem is formulated in two steps, first solving the linear elasticity problem for the reference load and constraints to obtain the accurate stress distribution within the plate. Subsequently, using these stresses, the geometric stiffness matrix and then minimum buckling load factor is evaluated. The unique feature of this formulation is that it is not restricted to particular type of plate theory or dimensionally reduced model but rather can be used in conjunction with the available plate theories for both thin and thick plates and even for fully three-dimensional models. One more advantage of this formulation is that we can have higher-order variation of transverse normal strains which is generally ignored. Figure 1 shows the stress intensity (value of pre-buckled stress divided by the applied traction) distribution of σ_{xx} under uniform compressive load and Fig. 2 shows its effect on the critical buckling load for [0/90] laminate with simply supported boundary condition. Although all the six stress components exist in the plate, stress distribution is shown for σ_{xx} only.

The final paper would contain the detailed description of the model developed for the analysis. Study of actual stress distribution pattern under the combination of in-plane and shear loading

and its effect on the critical load factor will be addressed in detail. Further, the effect of higher-order terms for transverse displacement on stress distribution, critical load for different aspect ratio, ply orientation and boundary conditions will be studied.

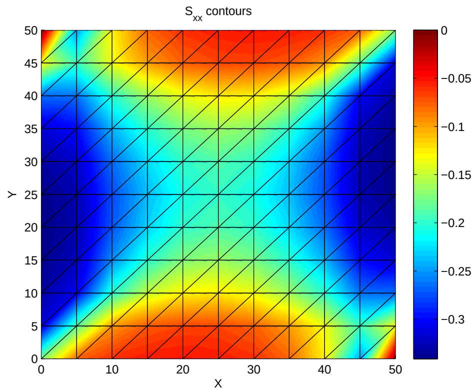

Figure 1: Stress intensity for [0/90] laminate with simply supported boundary conditions.

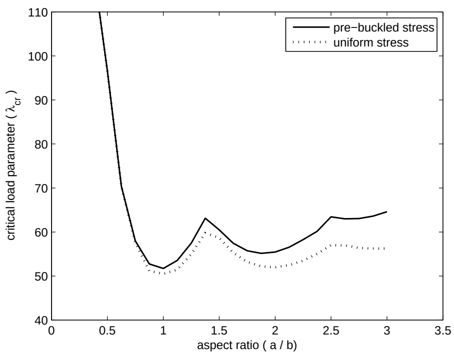

Figure 2: Influence of pre-buckled stress on critical load factor for [0/90] laminate.

References

[1] R.L. Actis, B.A. Szabo and C. Schwab, Hierarchic models for laminated plates and shells. *Comput. Methods Appl. Mech. Eng.* 172:79-107, 1999.

[2] C.W. Bert and K.K. Devarakonda, Buckling of rectangular plates subjected to nonlinearly distributed in-plane loading. *Int. J. Solids Struct.* 40:4097-4106, 2003.

[3] J.N. Reddy and A.A. Khedir, Buckling and vibration of laminated composite plates using various plate theories. *AIAA J.* 27:1808-1817, 1989.