Non-polynomial zigzag theory for the static and buckling analysis of laminated composite and sandwich plates

Rosalin Sahoo[1*], Bhrigu Nath Singh[2], Neeraj Grover[3]

[1]*Civil Engineering Department, Malaviya National Institute of Technology Jaipur-302017, India*
[2]*Department of Aerospace Engineering, Indian Institute of Technology Kharagpur, Kharagpur 721302, India*
[3]*Department of Mechanical Engineering, Thapar University, Patiala 147004, India*

***Corresponding Author:** sahoorosalin7@gmail.com

Presently, a non-polynomial zigzag theory is proposed for the static and buckling analysis of laminated composite and sandwich plates. This theory considers an inverse hyperbolic function as the shear strain shape function, which gives non-linear distribution of transverse shear stresses. This model satisfies the traction free boundary conditions on the surfaces of the plate and inter-laminar continuity conditions at the layer interfaces obviating the need of shear correction factor. The in-plane displacement fields of this theory are assumed to be the combination of an inverse hyperbolic shear strain shape function and a linear zigzag function with different slopes at each layer. The transverse displacement is preferred to be constant throughout the thickness. An efficient C^0 continuous isoparametric serendipity element with seven degrees of freedom is employed for the usual discretization. Numerical examples covering different features of laminated composite and sandwich plates such as loading and boundary conditions, core-to-face thickness ratios, aspect ratios, span-thickness ratios, modular ratios, stacking sequence, higher modes of buckling and corresponding mode shapes are studied in MATLAB environment. The evaluated results are compared with the exact results and with some existing results based on various theories. The minimum percentage error compared to the exact solution among other deformation theories ascertains its accuracy and efficiency. Fig.1 and 2 show the variation of transverse shear stress, $\bar{\tau}_{yz}$ and in-plane stress, $\bar{\sigma}_{xx}$ across thickness coordinate, z/h of [0/90/90/0] laminated plate. Fig. 3 and 4 explain the convergence study of buckling load and effect of boundary conditions on bi-axial buckling loads of [0/90/0] laminate. The effect of loading conditions for un-symmetric five layered sandwich plate and the higher mode shapes for symmetric [0/90/90/0] plate are denoted by Fig. 5 and 6. It can be observed that the increasing in-plane axial force ratio reduces the buckling load values irrespective of the boundary conditions.

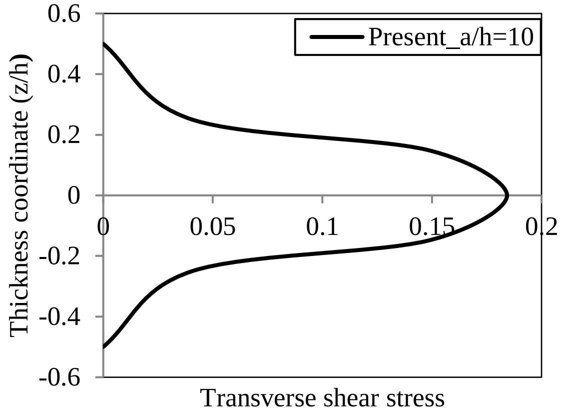

Fig.1. Variation of transverse shear stress, $\overline{\tau}_{yz}$ across thickness for [0/90/90/0] laminated plate

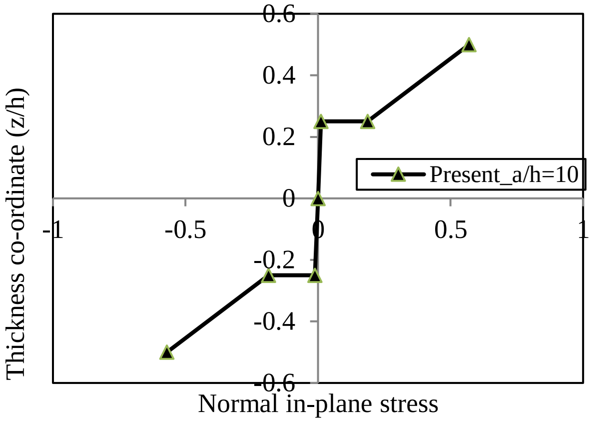

Fig.2. Variation of normal stress, $\overline{\sigma}_{xx}$ across thickness for [0/90/90/0] laminated plate

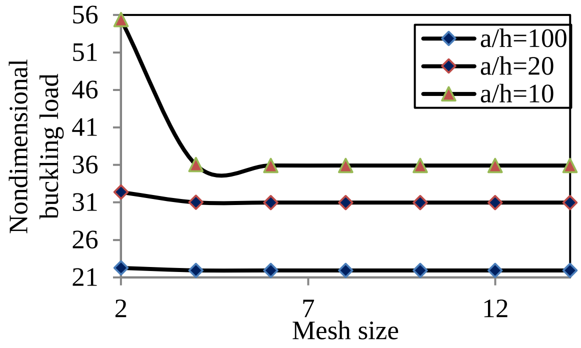

Fig.3. Convergence of buckling load parameter for laminated composite plate [0/90/0]

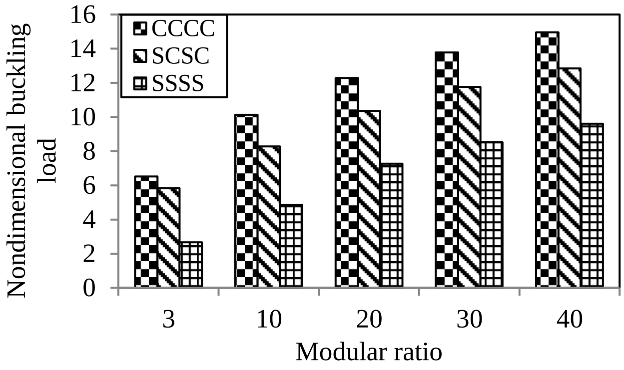

Fig.4. Effect of boundary conditions on bi-axial buckling loads of square laminate [0/90/0]

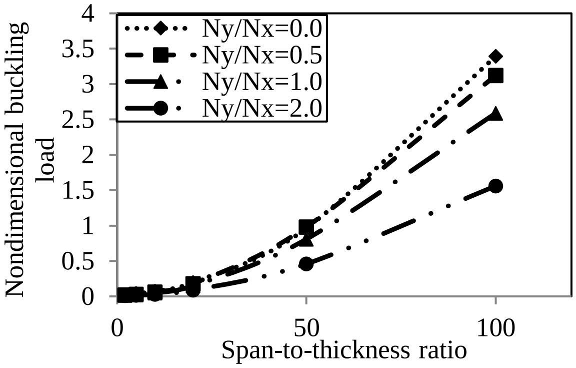

Fig. 5. Effect of loading conditions on an un-symmetric sandwich plate [0/90/C/0/90] under clamped boundaries

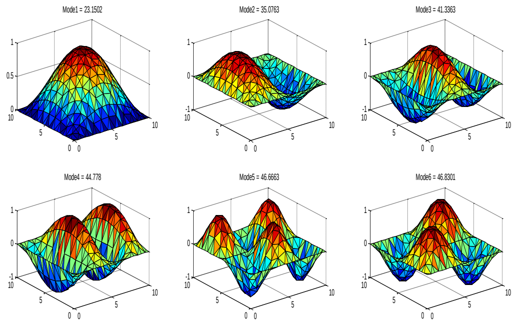

Fig. 6. First six buckling mode shapes of simply supported laminated composite plate [0/90/90/0]