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GEOMETRICALLY NONLINEAR ANALYSIS OF COMPOSITE PLATES USING LAYERWISE DISPLACEMENT MODEL

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Summary. The low mass density and the high tensile strength, usually expressed through the specific modulus of elasticity and the specific strength, have made composite materials lighter and stronger compared with most traditional materials (such as steel, concrete, wood, etc.) and have increased their application not only for secondary, but during the last two decades also for primarily structural members in aerospace and automotive industry, ship building industry and bridge design. Although weight saving has eliminated constrain of slenderness and thickness and has made possible use of very thin plate elements, they have become susceptible to large deflections. In such cases, the geometry of structures is continually changing during the deformation and geometrically nonlinear analysis should be adopted. In this paper the geometrically nonlinear continuum plate finite element model, hitherto not reported in the literature, is developed using the total Lagrange formulation. With the layerwise displacement field of Reddy [Reddy JN, Barbero EJ, Teply JL. A plate bending element based on a generalized laminated plate theory. International Journal for Numerical Methods in Engineering 1989; 28: 2275-2292], nonlinear Green-Lagrange small strain large displacements relations (in the von Karman sense) and linear elastic orthotropic material properties for each lamina, the 3D elasticity equations are reduced to 2D problem and the nonlinear equilibrium integral form is obtained. By performing the linearization on nonlinear integral form and then the discretization on linearized integral form, tangent stiffness matrix is obtained with less manipulations and in more consistent form, compared to the one obtained using laminated element approach of Reddy [E. J. Barbero, J. N. Reddy, Nonlinear Analysis of Composite Laminates Using a Generalized Laminated Plate Theory, AIAAL Journal, Vol. 28(11), 1990, 1987-1994]. Symmetric tangent stiffness matrixes, together with internal force vector are then utilized in Newton Raphson's method for the numerical solution of nonlinear incremental finite element equilibrium equations. Despite of its complex layer dependent numerical nature, the present model has no shear locking problems, compared to ESL (EquivalenSingleLayer) models, or aspect ratio problems, as the 3D finite element may have when analyzing thin plate behavior. The originally coded MATLAB computer program for the finite element solution is used to verify the accuracy of the numerical model, by calculating nonlinear response of plates with different mechanical properties, which are isotropic, orthotropic and anisotropic (cross ply and angle ply), different plate thickness, *different boundary conditions and different load direction (unloading/loading). The obtained results are compared with available results from the literature and the linear solutions from the previous paper [Ćetković M, Vuksanović Dj, Bending, Free Vibrations and Buckling of Laminated Composite and Sandwich Plates Using a Layerwise Displacement Model. Composite Structures 2009; 88(2): 219-227].*