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A Layerwise Finite Element for Geometrically Nonlinear Analysis of Composite Shells

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Abstract

This work aims to develop a nonlinear layerwise shell element formulation for shear-deformable laminated composite plate and shell structures. The element is formulated based on a zigzag theory in presence of individual local coordinates in the thickness direction for separate layers. In order to properly employ the zigzag theory, the considered local coordinates have different ranges of variation for middle, upper and lower layers. Using Mindlin-Reissner theory a convenient displacement field is derived for each layer and an ordered algorithm is adapted to calculate increments in the director vector of each layer due to relative finite rotations of its adjacent layers. Employing this shear deformable displacement field in the principle of virtual displacement leads to integral governing equations with various through-the-thickness parameter ranges. To overcome this challenge, the stress and strain tensors are rewritten in terms of through-the-thickness parameters and an explicit integration is performed in thickness direction. In this way, the nonlinear formulation is derived using the updated Lagrangian approach in accompany with a particular linearization scheme. To assess the performance of the present finite element formulation, a proprietary nonlinear finite element program is developed. Some illustrative problems are solved and comparisons with available solutions are presented.

Keywords: Layerwise theory; Shear deformable; Large deformation; Shell element; Laminated composites; Plate and shell structures

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