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Performance evaluation of triangular and quadrilateral flat shell elements based on Refined Zigzag Theory for static and modal analysis of multi-layered and curved composite and sandwich structures

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ABSTRACT

The paper investigates the modelling and the analysis of curved and warped multilayered-composite and sandwich structures by means of finite elements based on the Refined Zigzag theory (RZT). RTZ, originated from the First-Order Shear Deformation Theory (FSDT), is adopted to provide accurate and computationally affordable predictions of the global responses for thick laminates with high transverse flexibility and heterogeneity.

The kinematic formulation considers zigzag rotations around the in-plane axes, the anisoparametric interpolation method eliminates the shear locking phenomenon and introduces a coarse drilling degree of freedom, two stabilization matrices are used to add a fine drilling rotation and to remove spurious modes, introduced with the coarse drilling rotation, and the Rigid Link Correction is adopted to consider warped geometries.

A three-node triangular and a four-node quadrilateral RZT-based flat shell elements are developed for the static and modal analysis.

The obtained results are displacements in the nodes and in the elements centroid, natural frequencies and corresponding modal shapes, strain and stress tensor along the thickness in the centroid.

This article focuses on showing the broad range of applicability of the proposed finite elements. A wide number of analysis cases, that differ for geometrical complexity and for transversal heterogeneity, are presented to assess the performance, in terms of accuracy and convergence. Comparisons are made with analytic RZT solutions, 3D finite element models and FSDT-based flat shell elements.

The study highlights the reliability of the elements and their performance superiority, compared to the finite elements used in the commercially available software.

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