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Hybrid-mixed ANS finite elements for stress analysis of laminated composite structures: Sampling surfaces plate formulation

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Abstract

A hybrid-mixed ANS four-node quadrilateral plate element through the use of the sampling surfaces (SaS) technique is developed. The SaS formulation is based on choosing inside the *n*th layer I_n not equally spaced SaS parallel to the middle surface, in order to introduce the displacements of these surfaces as basic plate variables. Such choice of unknowns with utilizing the Lagrange polynomials of degree $I_n - 1$ in the thickness direction for each layer leads to a very compact form of the governing equations. The SaS are located inside each layer at Chebyshev polynomial nodes that allows one to minimize uniformly the error due to the Lagrange interpolation. To avoid shear locking and have no spurious zero energy modes, the hybrid-mixed method and the ANS concept are employed. The developed four-node quadrilateral laminated plate element passes patch tests and exhibits a superior performance in the case of coarse distorted mesh configurations. It can be useful for the 3D stress analysis of thick and thin laminated composite plates because the SaS formulation gives the possibility to obtain the numerical solutions with a prescribed accuracy, which asymptotically approach the exact solutions of elasticity as the number of SaS tends to infinity.

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