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Theory and Numerics of Layered Shells with Variationally Embedded Interlaminar Stresses

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Highlights

- An interface to 3D material models is available.
- For linear elasticity there is automatically continuity of the interlaminar shear stresses.
- Use of standard nodal degrees of freedom allows computation of shell intersection problems.
- Present model requires only a fractional amount of computing time in comparison with fully 3D computations.

Abstract

Present paper deals with layered shells subjected to static loading. The basic equations include besides the global equilibrium formulated in terms of stress resultants, the local equilibrium in terms of stresses, the geometric field equations, the constitutive equations, a constraint which enforces the correct shape of the superposed displacement field through the thickness and the boundary conditions. Thereby an interface to three-dimensional material laws is created. The weak form of the boundary value problem is derived and a finite element formulation for quadrilaterals is specified. The mixed hybrid shell element possesses the usual 5 or 6 nodal degrees of freedom. This allows standard geometrical boundary conditions and the elements are applicable also to shell intersection problems. For linear elasticity the computed transverse shear stresses are automatically continuous at layer boundaries and zero at the outer surfaces. In comparison to fully 3D computations present element formulation needs only a fractional amount of computing time.

Key words: Layered plates and shells, interlaminar stresses, mixed hybrid shell element, standard nodal degrees of freedom

1 Introduction

Shell elements which account for the layer sequence of a laminated structure are able to accurately predict the deformation behavior of the reference surface, a sufficiently refined mesh presupposed. This holds also for the shape of the in–plane stresses, if the shell is not too thick. In contrast to that only averaged transverse shear strains through the thickness are obtained within the Reissner-Mindlin theory. As a consequence only the average of the transverse shear stresses is accurate. Neither the shape of the stresses is correct nor the boundary conditions at the outer surfaces are fulfilled. Within the Kirchhoff theory the