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Non-Linear geometrically exact solid-shell elements with seven displacement degrees of freedom

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Summary

This paper presents the robust non-linear geometrically exact four-node solid-shell elements based on the first-order seven-parameter equivalent single-layer theory, which permits us to utilize the 3D constitutive equations. The term "geometrically exact" reflects the fact that geometry of the reference surface is described by analytically given functions and displacement vectors are resolved in the reference surface frame. As fundamental shell unknowns six displacements of the outer surfaces and a transverse displacement of the midsurface are chosen. Such choice of displacements gives the possibility to derive strain-displacement relationships, which are invariant under arbitrarily large rigid-body shell motions in a convected curvilinear coordinate system.

To avoid shear and membrane locking and have no spurious zero energy modes, the assumed strain and stress resultant fields are invoked. To improve a geometrically non-linear shell response, the modified ANS method is applied. Additionally, analytical integration throughout the element is employed to evaluate the tangent stiffness matrix. As a result, the present finite rotation solid-shell element formulation allows using coarse meshes and very large load increments and is suitable for large-scale computations.

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