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A Refined Shell Finite Element with Thickness Stretch for Large Deformation Analysis of Composite Structures

J. N. Reddy, V. Vallala, G.S. Payette

Texas A&M University, College Station, Texas, 77843-3123; email: jnreddy@tamu.edu

In this paper we present a degenerate solid based shell finite element formulation obtained using a seven parameter expansion (with respect to the curvilinear thickness coordinate) of the displacement field [1-3]. The use of the 7-parameter formulation naturally circumvents the need for a rotation tensor in the kinematical description and allows for the use of general fully three-dimensional constitutive equations. Many of the developments in recent years in the area of locking-free shell element formulations have been in the context of low-order elements and mixed variational principles. In the present work, however, we utilize high-polynomial order quadrilateral finite elements to describe the mid-surface of a given shell element in a purely displacement based setting. The use of high-order spectral/hp interpolants in the numerical implementation naturally leads to a finite element model that is completely locking free. In the computer implementation, the Schur complement method is adopted at the element level to statically condense out all degrees of freedom interior to each element in the finite element discretization. This procedure vastly improves the computer memory requirements in the numerical implementation of the resulting shell element and allows for significant parallelization of the global solver. The use of high-order polynomial expansions in the parameterization of a given element geometry also allows for extremely accurate approximations of arbitrary shell geometries. This constitutes an important departure from the tensor based shell finite element formulation proposed previously in the work of Arciniega and Reddy [2, 3], where a chart was employed to insure exact parameterization of the shell mid-surface. The formulation requires as input the three-dimensional coordinates of the shell mid-surface as well as a set of directors (i.e., unit normal vectors to the mid-surface), for each node in the shell finite element model. As a result, the actual shell mid-surface as well as the unit normal to the shell mid-surface, are each approximated using the standard spectral/hp finite element interpolation functions within a given shell element.

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References

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