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A QUADRATIC TRIANGULAR FINITE ELEMENT FOR THE NONLINEAR ANALYSIS OF THIN SHELLS

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ABSTRACT

This work presents a fully nonlinear Kirchhoff-Love shell formulation together with a quadratic triangular shell finite element for the solution of the resultant static boundary value problem. In contrast with [2] and [3], our approach is based on the Kirchhoff-Love model for thin shells, so that transversal shear deformation is not accounted for. We define energetically conjugated cross sectional stresses and strains. Appealing is also the fact that both the first Piola-Kirchhoff stress tensor and the deformation gradient appear as primary variables.

Following the ideas of [2] and [3], elastic constitutive equations are consistently derived from fully three-dimensional finite strain constitutive models. A genuine plane-stress condition is enforced by the vanishing of the true (first Piola-Kirchhoff) mid-surface normal stress, yet rendering a symmetric linearized weak form. This idea is general and can be easily extended to inelastic shells, once a 3-D stress integration scheme within a time step is at hand.

A plane reference configuration is assumed for the shell mid-surface, but in the same way as in [1] and [4], initially curved shells can also be considered if regarded as a stress-free deformed state from the plane position. As a consequence the use of convective non-Cartesian coordinate systems is not necessary, and only components on orthogonal frames are employed.

A quadratic 6-node triangular shell element is in addition developed. The element is C_0, with the C_1 condition partially imposed as a penalty condition at midside nodes. An augmented Lagrangian version is also under preparation. Thus, this element can be regarded as the Kirchhoff-Love version of the triangular element of [2] and [3]. Our approach can be regarded as an alternative to that one from [5] and [6]

As already stated in [2] and [3], we believe that the combination of reliable triangular shell elements with powerful mesh generators is an excellent tool for the nonlinear analysis of thin-walled structures.

REFERENCES

[1] Pimenta P. M., “Geometrically-Exact Analysis of Initially Curved Rods”, in: Advances in Computational Techniques for Structural Engineering, Edinburgh, U.K., v.1, 99-108, Civil-Comp Press, Edinburgh,1996.

[2] E.M.B. Campello, P.M. Pimenta and P. Wriggers, “A triangular finite shell element based on a fully nonlinear shell formulation”, Comput. Mech., 31 (6), 505-518, 2003.

[3] Pimenta P. M., Campello E. M. B. and Wriggers P., “A fully nonlinear multi-parameter shell model with thickness variation and a triangular shell finite element”, Comput. Mech., 34 (3), 181-193, 2004.

[4] P. M. Pimenta, E. M. B. Campello, P. Wriggers, “Shell curvature as an initial deformation: geometrically exact finite element approach”, submitted to Int. J. Num. Meth. Engng. 2007.

[5] Oñate, E. and F. G. Flores (2005). "Advances in the formulation of the rotation-free basic shell triangle." Computer Methods in Applied Mechanics and Engineering 194: 2406-2443.

[6] Flores F.G. and Oñate, E. (2007) "A rotation-free shell triangle for the analysis of kinked and branching shells." International Journal for Numerical Methods in Engineering 69: 1521-1551.