A linear shell model regarding initial curvature as a finite deformation: a meshless implementation

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In the last few years a considerable effort has been directed to the development of consistent geometrically exact formulations of beams [1, 2] and shells [3, 4] structural theories. Here no limitations on the magnitude of the rotation of the cross section or the shell director were imposed.

Implementation of these theories are usually undertaken using the Finite Element Method (FEM) discretization [5, 6]. Alternatives were also developed, using a meshless approximation based on the Multiple Fixed Least Squares (MFLS), both for beam [7] and shell [8] problems.

The generalization to initially curved configurations has also been successfully considered [9, 10]. Based on the alternative approach for the analysis of arbitrarily curved shells thus developed, a linear kinematic model is accomplished in the present work. By alternative we mean that neither differential geometry nor the concept of degeneration is invoked here to describe the shell surface. We begin with a flat reference configuration for the shell midsurface, after which the initial (curved) geometry is mapped as a stress-free deformation from the plane position. The actual motion of the shell takes place only after this initial mapping. In contrast to classical works in the literature, this strategy enables the use of only orthogonal frames within the theory and therefore objects such as Christoffel symbols, the second fundamental form or 3-D degenerated solids do not enter the formulation. Furthermore, the issue of physical components of tensors does not appear. Other important aspect (but not exclusive of our scheme) is the possibility to describe exactly the initial geometry. The model is linear kinematic in the sense that encompasses infinitesimal strains in a totally consistent manner.

The resulting model inherits the same features of [4, 6] in the sense that (i) cross-sectional stresses and strains are defined in a totally consistent way, rendering a complete stress-resultant theory, (ii) first-order shear deformations are accounted for, as Reissner-Mindlin kinematics is assumed based on an inextensible director (no thickness changes) and (iii) both the first Piola-Kirchhoff stress tensor and the deformation gradient appear as primary variables, what makes possible the enforcement of the plane-stress condition over the actual (nominal) midsurface normal stress. Remarkably, the resulting equations have the same general structure as in [4, 6]. We believe these three aspects combined with the above-mentioned use of only orthogonal frames lead to a neat, consistent formulation for the analysis of initially curved shells.

A variational statement of the shell model is presented, where the domain displacements and kinematic boundary reactions are independently approximated, hence falling in the category of the hybrid-displacement formulations.

The discretization of this variational form is made using the MFLS approximation on the domain and simple quadratic Lagrange polynomials on the boundary.
The implementation resources a general pre- and post-processor software, in order to generate the particle distribution, the background integration mesh and to visualize the results. Assessment is made by means of several numerical simulations.

References