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Intrinsically Locking-Free Shell Formulations

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The present contribution addresses different concepts for intrinsically locking-free formulations using equal-order interpolation for all involved displacement fields, independent of the kind of discretization. In a hierarchic formulation the Kirchhoff-Love (KL) model is taken as basic building block for other higher order models. For a Reissner-Mindlin extension, the transverse shear part is superimposed in an incremental way; since the function spaces of these extra parts are separated from the KL basis, the formulation is completely free from transverse shear locking. In a first concept [1] both transverse shear components are introduced as hierarchic (incremental) rotations. Since it turned out that the shear stress resultants still show a tendency to oscillate due to unbalanced function spaces, a second concept [2] is proposed, in which the two displacement fractions responsible for the transverse shear are superimposed as hierarchic displacement parameters leading to a shear-deformable rotation-free shell formulation. Both formulations have been extended into the geometrically non-linear regime [3]. A corresponding primal formulation to avoid membrane locking is still a challenge. Therefore, this defect was remedied by applying either mixed formulations, or the Discrete Strain Gap (DSG) method is utilized.

In order to overcome also this obstacle a related alternative formulation has been introduced recently [4]. Inspired by the DSG method a novel variational method is proposed avoiding any kind of geometrical locking effects, being in particular efficient to remedy membrane locking in an elegant way. Again the formulation is independent of the kind of discretization scheme. In this mixed method additional degrees of freedom are introduced which are in most cases extra displacements and can be interpreted as the strain gaps from the DSG method. Also here these variables are discretized by equal-order interpolation and do not require specific strain or stress function spaces as in conventional mixed variational methods. So in conclusion it can be stated that this formulation is automatically locking-free and does not show any spurious oscillations.

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