

# Intrinsically locking-free formulations for isogeometric beam, plate and shell analysis

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Isogeometric Analysis (IGA) [1] opened up a broad field of new concepts and applications in computational mechanics. Some key properties are smooth function spaces (e.g. B-splines, NURBS) and higher inter-element continuity. In earlier contributions within the group of authors [2, 3], transverse shear locking has been successfully removed for isogeometric beam, plate and shell elements by means of hierarchic concepts, which benefit from the higher inter-element continuity of NURBS. We want to emphasize that these finite elements rely on a primal (purely displacement based) formulation, whereas transverse shear locking is avoided intrinsically, i.e. on the level of theory rather than discretization.

Recent investigations [4] concern the construction of a novel mixed concept utilizing displacement-like variables only, thus called Mixed Displacement (MD) concept. It is a unified concept to treat all geometrical locking effects. Strong relations between hierarchic displacements, strain gaps from the DSG method [5] and the novel mixed displacement variables can be identified.

In this contribution we will present a class of formulations for beams, plates and shells avoiding locking, independent of the utilized discretization scheme. In particular, we will confirm this statement by several numerical tests using different smooth ansatz spaces, e.g. NURBS or meshless maximum entropy approximants. Furthermore, some applications to different solution schemes will be studied, i.e. weak form Galerkin-type solution and collocation based on the corresponding Euler-Lagrange equations of the boundary value problem. In all numerical studies the quality of both stress resultants and displacements will be investigated.

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