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Analytical and Numerical Investigations of Locking in Transversely Isotropic Elasticity

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For isotropic materials the concept of volumetric locking in the context of low-order finite element approximations is well understood, and a variety of effective remedies exist: for example, the use of mixed methods, discontinuous Galerkin (DG) methods, or selective underintegration. Corresponding studies have been carried out, to a limited extent, to determine conditions under which locking related to inextensibility occurs, in small- and large-deformation contexts [1, 2]. The models treated in these works are of an isotropic material, with inextensibility imposed as a constraint. The present work is concerned with transversely isotropic linear elastic materials, which are characterized by 5 material parameters [3]. The behaviour under limiting conditions of near-incompressibility and near-inextensibility are investigated. It is shown both through numerical examples and an analysis of finite element approximations that locking behaviour for low-order elements depends critically on the degree of anisotropy of the material, that is, on the ratio of Youngs moduli and Poisson ratios for the directions parallel and transverse to the direction characterizing transverse isotropy. In addition to conforming finite element approximations, the use of DG approximations is also pursued: for these, it is shown that behaviour is locking-free.

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