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F-bar projection method for incompressible finite deformation elasticity and plasticity using NURBS based Isogeometric Analysis

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ABSTRACT

Nonlinear finite element structural analysis is dominated by the use of low-order "displacement" elements that are specially designed to avoid volumetric or incompressible locking. Deformations that involve very small volume changes occur for rubber-like materials, and the elastic-plastic response of metals and undrained soils.

For volumetric locking, Galerkin mixed finite element formulation fulfilling the LBB condition as well as stabilization techniques, such as SUPG and GLS, are often employed to circumvent this problem. However, an approach of engineering interest would rather be to preserve a simple purely displacement-based formulation, such as the classical B-bar method, see Hughes [1], in the infinitesimal theory. Some attempts have been made to extend the B-bar method to the large strain theory, but most of them are only valid for linear elements. In this paper we present a strategy for the small and large strain theory that is valid for linear and higher order elements in both elasticity and plasticity. In the infinitesimal theory, this strategy consists in the extension of the usual B-bar one to higher order elements. In the large strain theory, it is based on a multiplicative split of the deformation gradient into a deviatoric and a dilatational part. The new definition of a dilatational deformation gradient results in constraint relaxation that overcomes volumetric locking with no assumption on the order of the discretization.

The formulation is introduced in a quasi-static framework with a full Newton-Raphson iterative scheme for which the consistent tangent operator is derived. The method is developed in the context of the Isogeometric Analysis, a new computational method that makes use of NURBS functions to represent the geometry and the solution fields, see Hughes *et al.* [2]. A new higher-order approach has emerged from isogeometric analysis, namely k-refinement, in which discretizations of order p achieve $\mathcal{C}^{p-1}$ continuity [2,3]. The proposed method makes use of this strategy to obtain efficient locking-free high order elements. Two and three dimensional examples in the small and finite deformation elastic and plastic case are shown to validate the method.

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