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Modeling fluid flow in deformation bands with stabilized localization mixed finite elements

WaiChing Sun[1*], Jakob T. Ostien[1*], James W. Foulk[1*], Fadi Abdeljawad[2*]
[1] *Mechanics of Material, Sandia National Laboratories, Livermore, CA94551*
[2] *Department of Mechanical and Aerospace Engineering, Princeton University, Princeton NJ08544*

Deformation bands in geological materials refer to narrow zones of inhomogeneous strain. Their onset and propagation may cause significant changes in microstructures and therefore profoundly enhance or suppress fluid flow and induce anisotropy. These changes in hydraulic properties have strong implications in geotechnical engineering, carbon dioxide sequestration and nuclear waste storage. The difficulty in modeling such multiphysics phenomena is threefold. 1. Monolithically coupled promechanics formulation may lead to non-physical oscillation in pore pressure near the undrained limit if identical mesh and basis functions are used for pore pressure and displacement. 2. Onsets of deformation bands may lead to non-converging mesh-dependent results if no length scale is introduced to the finite element formulation. 3. Modeling anisotropy induced by the deformation band may require a very fine mesh to capture the sharp pore pressure gradient and results in a computational intensive system.

In this study, we introduce a projection-based technique to stabilize a large deformation finite element model that eliminates the non-physical oscillation in pore pressure. Using a 1D analytical solution as guideline, we introduce a simple scheme that can adaptively update the optimal value for the stabilization parameter that can restore stability without over-diffusing the system. This stabilized model is coupled with a localization element technique used to introduce proper length scale to regularize the governing equations and resolve the fluid flow jumps across the deformation bands. Numerical examples are presented to demonstrate the properties and performance of the proposed localized models.

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