A New Two-Scale Computational Model for Hydromechanical Coupling in Jointed Rocks

Josue S. Barroso[a,*], Marcio A. Murad[a], Patricia A. Pereira[a]

[a]*COMOHR Group, Laboratório Nacional de Computação Científica (LNCC), Petrópolis, RJ, Brazil*

Abstract

We develop a new computational model to describe hydro-mechanical coupling in fractured rocks composed of a linear poroelastic Biot medium and nonlinear elastic joints with constitutive response governed by the Barton-Bandis (BB) law. The model aims at capturing increase in stiffness induced by fracture closure during fluid withdrawal. The nonlinear hydro-mechanical formulation is constructed within the framework of the Discrete Fracture Model with flow and geomechanical sub-systems coupled through a sequential iterative algorithm. The internal contact constraint arising from non-overlapping between opposite fracture faces is enforced through the weak fulfillment of the BB-law. Such a constraint is captured within the framework of the Augmented Lagrangian formulation, where the nonlinear mechanical interaction is enforced adopting successive approximations of the Lagrange multiplier, interpreted as the contact pressure in the joint, supplemented by a penalty component associated with the rock stiffness. Furthermore, adopting a traditional flow based upscaling method, macroscopic permeabilities are numerically reconstructed with magnitude strongly dependent on the local stress state. Such a mechanical dependence of the homogenized properties is represented in a discrete manner through pseudo-coupling tables, with enormous potential to be explored within a preprocessing stage in reservoir simulators to compute multipliers relative to a chosen pre-stressed reference state, where input data is available. Numerical simulations are performed for some fracture arrangements illustrating the potential of the formulation proposed herein in bridging hydromechanical coupling at different scales in jointed rocks.

Keywords: Hydro-mechanical coupling, Jointed rocks, Barton-Bandis model, Augmented Lagrangian, Upscaling, Pseudo-coupling tables, Nonlinear elasticity
2010 MSC: 00-01, 99-00

1. Introduction

The study of hydro-mechanical coupling in fractured porous media is becoming increasingly important in the field of rock mechanics (Berge et al.; Garipov et al., 2016; Ganis et al.,

*Corresponding author.
Email addresses: jsantos@lncc.br (Josue S. Barroso), murad@lncc.br (Marcio A. Murad), patricia@lncc.br (Patricia A. Pereira)

Preprint submitted to Computers & Mathematics with Applications, on Robust and Reliable Finite Element Methods in Poron