A homogenization framework for inelastic layered porous materials

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Abstract:

Many applications involving geomaterials, such as reservoir engineering, geothermal energy, and waste storage, entail tight coupling between multiphase fluid flow, transport, as well as thermo-mechanical and poromechanical deformations. Natural rocks are often highly heterogeneous and consist of fractures, solid and fluid phases that form complex structures at multiple scales. Explicit incorporation of multiple scales of fractures and heterogeneities into large-scale tightly coupled models is impractical and would cause tremendous computational costs. Therefore, efficient multi-scale strategies are necessary for capturing sub-grid-scale processes and their impacts on macroscopic behavior.

In this work, we present a homogenization framework for inelastic layered media. The proposed approach allows for separate micro-constitutive laws and properties for each layer, explicit representation of layers with different properties and their distribution, as well as incorporation of imperfect bonding between the adjacent layers. Subsequently, we demonstrate extension of the framework to coupled hydro-mechanical problems. We describe a homogenization strategy for computing both the mechanical and fluid flow constitutive behavior of fractured rock. Contrary to continuum-scale constitutive models, the present framework accounts for the coupling between planes of weakness and the matrix. Simulation results show that important features such as strength and permeability anisotropy arise naturally from the small-scale description of the phase and fracture distribution. We show how the resulting material models may be readily incorporated into continuum or discrete-fracture-network simulations of reservoir systems, providing an efficient way of capturing both large- and small-scale processes.