Pore-scale hydro-mechanical modeling of gas transport in coal matrix

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ABSTRACT
Coal beds are dual permeability systems characterized by a porous matrix enclosed within sets of orthogonal fractures known as cleats. Production of coalbed methane (CBM) consists in desorbing methane from the low permeable coal matrix to the high permeable cleat system. Unlike in conventional reservoirs exploitation, sorption mechanisms cause shrinkage and swelling of the matrix which increase the complexity of the phenomena at stake, leading to complex reservoir behaviors in terms of production.

A 3D discrete element method (DEM) coupled to a pore scale finite volume method (PFVM) is used here to better understand the different mechanisms at stake. The model, implemented in the open source software Yade Open DEM (Smilauer et al., 2015), is an offspring of the hydro-mechanical model proposed by Catalano et al. (2014). The coal matrix is treated as an assembly of bonded particles interacting one with another through elastic-brittle contact laws. The pore space is discretized into tetrahedra, generated from a regular triangulation of the particle assembly. Both Knudsen and surface diffusion as well as sorption processes are modeled considering the coal matrix as a microporous material. The method is hydro-mechanically coupled in the sense that changes in pore pressure produce hydrostatic forces that deform the solid skeleton, while deformation of the pore space induces pore pressure changes that promote interporal flow. In addition, sorption induced deformations are taken into account by considering an additional pressure term related to the concentration of gas within the medium (the so-called solvation pressure).

In this work, we first present the model and its constitutive equations. We assess its capabilities by comparing its predictions to well established solutions describing diffusive flow in porous media as well as to classic poroelasticity concepts. In particular, we focus on the influence of sorption induced deformations on the Biot coefficient estimation. Finally, we compare the model predictions to swelling test data from the literature to illustrate its consistency.

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