Muti-physics numerical model for the analysis of CO2 injection in carbonate rocks and its influence on hydraulic conductivity properties of porous media

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ABSTRACT

In recent years, it was noticed an increased interest on the development of multi-physics constitutive models to provide reactive chemical analysis of the impacts of CO2 injection in oil reservoirs. The movement was led by research groups interested in modelling Carbon Capture and Storage (CCS) and Enhanced Oil Recovery (EOR). Different solutions for carbon sequestration from the atmosphere were developed to fulfil target reductions on carbon emissions. The most promisor long-term solution is the injection of carbon dioxide in underground rocks or carbonate oil reservoirs. The injection of CO2 in carbonates promotes acidification of underground water making it more prone to react and dissolve the rock porous matrix. With dissolution, the pore structure of the rock changes, modifying the permeability and hydraulic conductivity of the medium.

In order to quantify the long-term impacts of carbon capture by CO2 injection in reservoirs, it is necessary to understand and quantify the chemical effects of dissolution in porous media, its impacts on rock structure and consequent change in underground flow. It is necessary to account for the study of transport of chemical species and its contribution to the reaction. Continuous models were proposed taking into consideration the effect of reaction kinetics, diffusive effects, and both effects in two scales (Panga et al, 2005). The model proposed by Panga is similar to the model of heterogeneous catalytic reactors, but considers flow coupling, reaction/dissolution rates, and effects of mass transfer in pore scale. Indeed, the major part of reactive modeling consider the diffusive-convective transport with source/sink term to represent chemical reaction with hydraulic coupling (Van der Lee et al, 2003).

This work presents a straightforward implementation of a numerical model fully coupled capable to evaluate the impacts of CO2 transport in porous media, recovering the dissolution and the change in porosity using the Finite Element Method. To model reactive chemistry, we chose continuous model approach, describing the phenomena in Darcy scale and adaptation of the kinetic model from Chou (Chout et al, 1989), incorporating a term to describe the change on the porous superficial area (Noiriel et al, 2004). The Finite Element method (FEM) was chosen to the domain discretization and to compute the transport equations and chemical reactions. To evaluate the change in porosity, the formulation proposed by Hao was implemented (Hao et al, 2013) with porosity change derived directly from the reaction rate of calcite dissolution.

The model was implemented in the commercial software COMSOL Multiphysics and considers coupling of Darcy and Reactive Transport of Species physics with the Chemistry Module. Results obtained in the numerical analysis follow closely experimental data of carbonate rock dissolution given CO2 injection described in the literature (Noiriel et al, 2009).

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