Introduction

CO₂ sequestration in underground formations is currently utilized as a means to mitigate CO₂ from indefinitely emitted to the atmosphere. The main concern in such a system is the possible occurrence of leakage to upper layers or to the earth surface. Computational modeling of leakage of a multiphase system in a heterogeneous multilayer system is rather challenging. It requires a discretization scheme capable of simulating the possible accumulation or suction at the boundary between layers of different hydraulic properties. Standard finite element discretization scheme is not able to model such a phenomenon. In this project, this phenomenon is modeled using a mixed discretization scheme.

Mixed Discretization

A discontinuous CO₂ saturation – continuous water pressure formulation is adopted. The partition of unity finite element method (PUM) is utilized to discretize the discontinuity in the CO₂ saturation field, and the standard Galerkin method (SG) is utilized to discretize the continuous water pressure:

\[ p_w(x,t) = N(x)p_w(t) \]

\[ S_{CO₂}(x,t) = N(x)S_{CO₂}(t) + N^{rh}(x)\tilde{S}_{CO₂}(t) \]

The leakage between two layers is described by a mass flux defined as:

\[ q_{CO₂} = \frac{\phi \Delta S_{CO₂} \rho_{CO₂} V}{A \Delta t} \]

Verification

The proposed PUM-SG model is verified by comparing its results to that obtained from a benchmark problem with a known semi-analytical solution. This problem involves a flow of a water phase from a high permeability domain to a low permeability domain occupied by a gas phase. This results to a jump in the saturation field at the boundary between the two layers. The computational results shows a very good agreement with the semi-analytical solution.

CO₂ Leakage

The proposed PUM-SG model is tested for the simulation of possible leakage of CO₂ from an underground aquifer. The computational results are compared for different mesh sizes and with that obtained from standard Galerkin FEM. The results clearly show that the proposed model is capable of modeling the accumulation at the boundary between layers, and it is effectively mesh independent. The standard Galerkin gave a false impression about the amount of leakage.

Supervision

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