PORE-NETWORK ANALYSIS OF EFFECTS OF TRAPPING ON HYSTERESIS IN TWO-PHASE FLOW IN POROUS MEDIA

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The constitutive relations of classical theory of two-phase flow in porous media (i.e. relative permeability-saturation and capillary pressure - saturation relationships) are strongly flow path dependent. Their values are not only a function of saturation, as the primary state variable, but also the drainage and imbibition history. Many models incorporate these hysteretic effects through ad-hoc adaptations based on fitting curves to experimental data. In addition, various physically-based models identify different pore-scale phenomena as crucial. There are other types of models, which identify new state variables, e.g. interfacial area or non-percolating fluid saturations, to resolve hysteresis.

Several models identify trapping and connectivity of fluids as an important contribution to macro-scale hysteresis. This is especially true for hysteresis in relative permeabilities. The trapping models propose trajectories from the initial saturation to the end saturation in various ways. However, experimental data or pore-scale model results are not available for the trajectories, i.e. the fate of the connectivity of the fluids while saturation changes.

Here, using a quasi-static pore-network model we study how the topology of the fluids changes during drainage and imbibition for different initial saturations. The pore-network has been developed for different polygonal geometries to permit different degrees of corner flow and residual saturations in the crevices. The effect of pore geometry and flow history on continuum-scale variables such as capillary pressure, phase relative permeabilities, and non-connected non-wetting phase saturation, have been studied as a function of total wetting phase saturation. We find a strong hysteretic behavior in the relationship between non-connected non-wetting fluid saturation and the wetting fluid saturation as well as relative permeability curves. This hysteretic behavior is pronounced in angular cross section domains, where the corner flow is important.