Dynamic Pore Network Modeling of Two-Phase Flow Through Fractured Porous Media: 
Direct Pore-to-Core Up-scaling of Displacement Processes

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Abstract

Pore networks provide practical descriptions for porous media to model multiphase flow by incorporating physically-based displacement mechanisms at the pore scale\cite{1, 2}. To do so, generated networks should retain important features of the pore space topologies affecting fluid flow behavior, such as the location, size, shape, and connectivity of each pore and throat. With the advent of high-resolution imaging technologies such as X-ray computed micro-tomography (micro-CT), direct three dimensional (3-D) pore-scale images of the porous media can be obtained and utilized to extract representative pore networks of the actual rock samples\cite{3, 4, 5, 6}. In this work, to study two-phase flow in a fractured rock, we generate a hybrid pore network that represents the fracture, the surrounding matrix, and their corresponding connectivity.

A dynamic pore network modeling (DPNM) approach\cite{7} is then utilized to simulate various displacement processes in the generated hybrid network by incorporating pore-scale displacement mechanisms that are relevant to transport of fluids through fractured systems. In such systems, due to the high velocity of fluid flow through the fracture domain, the absence of viscous forces is no longer an appropriate assumption. Hence, we combine capillary, viscous and gravity forces to determine the total pressure drop associated with pore-scale displacement events. The algorithm presented in this model is optimized computationally to handle simulations in large-scale networks. In this way, we are able to predict macroscopic multiphase flow behavior of core-size samples through direct up-scaling of pore-level displacement physics.

The presented network model is validated against experimental results of a two-phase flow study on a fractured Berea sandstone core used to generate the final hybrid network\cite{8}. Predicted saturation profiles in the fracture and the neighboring matrix are compared with their experimental counterparts during multi-sequence drainage and imbibition flow conditions. A 3-D computerized visualization is also used to create an overlay of geometrical

Figure 1: The 3-D overlay of Matrix(Left) and Fracture-Matrix(Right) pore network representation on the segmented micro-CT images. At each pore and throat, various properties such as volume, surface area, inscribed and effective radii, shape-factor, sphericity, aspect ratio, coordination number, and mineralogies are stored.
characteristics and fluid configurations on the micro-CT images to perform comparison on a pore-by-pore basis (Figure 1).

Using the validated DPNM, we conduct simulations of two-phase flow with various fluid properties and flow conditions. This in turn enables us to efficiently study flow behavior of fractured porous systems under a wide range of enhanced oil recovery applications.

References


