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Numerical Modeling of Fluid Flow through a Borehole-Porous Medium System: Comparison between Brinkman and Darcy Equations

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Subsurface petroleum storage in excavated caverns sealed using a hydraulic containment system offers many advantages over traditional surface storage tanks. The challenge of accurately simulating a complex subsurface system includes accounting for the viscous shear forces within free-flow regions such as the boreholes, fractures, voids, and storage tanks. The Brinkman extended Darcy's equation is one solution which accounts for viscous shear forces along the free-flow boundaries and momentum transfer across the porous media interface.

This study aims to demonstrate the significance of fluid viscosity forces in the subsurface flow regime, and show the suitability of the Brinkman equation by using numerical modeling in COMSOL to create lab-scale simulations of a borehole coupled with porous media. It analyzes and compares the simulated velocity gradients and head gradients, calculated using the Brinkman equation and the classic Darcy equation. This study shows simulation cases at various inlet pressures, inlet velocities, porosities, and permeabilities, such as those used for subsurface storage to evaluate the influence of these parameters.

The preliminary results show that the Brinkman equation predicts a non-uniform velocity profile within the borehole due to friction along the borehole interface. The two equations also predict different velocity distributions across the borehole interface and in the porous media near the borehole. These differences are more significant at higher inlet velocities/pressures. These models could be validated by laboratory experiments, enhanced to include fractures, and enlarged to field scales. This study will have implications for numerous injection and well production activities, such as subsurface energy storage, hydraulic fracturing, and contaminant transport studies.