Contribution ID: **945** Type: **Poster**

Direct simulation of permeability including Klinkenberg effect

Tuesday, 15 May 2018 17:15 (1h 30m)

Core analysis for characterization of rock properties such as permeability involves laboratory flow experiments often performed at lower temperature and pressure than the conditions typically present in subsurface hydrocarbon reservoirs. For gas permeability in particular, slippage flow can occur at reservoir conditions, resulting in higher apparent permeabilities than would occur for Darcy flow. Known as the Klinkenberg effect, the impact on permeability can be significant, and depends on the gas type and characteristic pore sizes that govern the fluid flow; the pore sizes in turn depend on the formation rock matrix and may also be influenced by effective stress and clay content.
Digital rock physics has emerged over the last decade as a complimentary or alternative technique to laboratory testing for rock property characterization. In this study, we perform direct numerical simulation of gas flow in porous media over a wide range of Knudsen number regimes, where the dimensionless Knudsen number is given by the fluid particle mean free path divided by a characteristic channel width for the porous medium. As Knudsen number increases, the ratio of apparent permeability to Darcy permeability (S) increases as the system moves from Darcy flow to slip, transition, and finally the Knudsen flow regime, as seen in the included Figure.
This study uses a flow simulator based on the Lattice Boltzmann Method (LBM) technology. First the simulator is benchmarked by comparing predicted results to existing experimental data over the full range of Knudsen number flow regimes ranging from 0.001 to 10 for flow in rectangular channels (Ewart et al. and Colin et al.) and 3D micro-tubes (Perrier et al.). Resolution studies show that the flow simulations retain good accuracy at low grid resolutions which are typically required for digital rock based analyses. Next, simulations are performed to demonstrate the Klinkenberg effect in tight sandstones and unconventional shale rocks. It is shown that the apparent permeability of tight rocks can be up to 2 orders of magnitude higher than would occur for Darcy flow, which corresponds to the unexpectedly high permeabilities sometimes observed in the field.

References

Chen, H., Orszag, S.A., Staroselsky, I. 2007 Macroscopic description of arbitrary Knudsen number flow using Boltzmann-BGK kinetic theory. Journal of Fluid Mechanics, vol. 574, pp. 495-505
Colin, S., Lalonde, P., Caen, R. 2004 Validation of a second-order slip flow model in rectangular microchannels. Heat Transfer Engineering, vol. 25, no. 3, pp. 23-30
Ewart, T., Perrier, P., Graur, I., Meolans, J.G. 2007 Mass flow rate measurements in a microchannel, from hydrodynamic to near free molecular regimes. Journal of Fluid Mechanics, vol. 584, pp. 337-356
Perrier, P., Graur, I.A., Ewart, T., Meolans, J.G. 2011 Mass flow rate measurements in microtubes: From hydrodynamic to near free molecular regime. Physics of Fluids, vol. 23, 042004

Acceptance of Terms and Conditions

Click here to agree

Primary authors: BALASUBRAMANIAN, Ganapathi (Exa); GHODKE, Chaitrali (Exa); FREED, David M. (Exa); CROUSE, Bernd (Exa Corporation)

Presenter: CROUSE, Bernd (Exa Corporation)

Session Classification: Poster 2

Track Classification: MS 1.12: Fluids in Nanoporous Media