Multi-scale, image-based pore network models to simulate two-phase flow in heterogeneous rocks

Tom Bultreys, Wesley De Boever, Luc Van Hoorebeke* and Veerle Cnudde

PProGRess / *Radiation Physics research team
Centre for X-ray Tomography (UGCT), Ghent University, Ghent (Belgium)
Tom.Bultreys@UGent.be

Problem

- **Rocks** with a wide range of pore length scales often do not adhere to classical transport relations (e.g. Archie’s law, Brooks-Corey relationship).
- **Microporosity** influences their behaviour.
- **Coupling** of the microporosity and the macroporosity is crucial.
- Trying to capture this coupling in a model is computationally difficult.

Approach

1. Start from micro-CT scan:
   - Macropores | Microporous regions

2. Perform segmentation into 3 phases:
   - Pore voxels | Microporous voxels | Solid voxels

3. Extract maximal ball pore network model (PNM) from pore space (Dong & Blunt, 2009)

4. Cluster microporous voxels into connected regions and add the appropriate connectivity between neighbouring macropores in the PNM

5. Approximate microporous pathways geometrically as truncated cones by measuring contact surface areas and lengths locally on the micro-CT

6. Compute two-phase flow properties of the coupled system (Pc-curve, K, Kr-curve, FF, RI-curve)
   - Solver is extension on Valvatne & Blunt (2004)
   - Also includes non-wetting phase percolation through microporosity

Results

1. Artificial network
   - Can the model replicate the behaviour of a PNM where microporosity is taken into account as individual small pores, instead of as a continuous porous medium?

   - Mehrani & Prodanovic (2014): artificial network in which 50% of macropores were “clogged” and replaced with microporosity
   - Generate equivalent network with our method and compare results:
   - Challenge: user-defined cut-off length for microporous connections needed, can this parameter be eliminated?

2. Micro-CT-based network of Estaillades limestone

   - Input parameters for microporosity from MIP experiment and literature
   - Radii in the PNM were adjusted to fit MIP experiment / permeability

Conclusions

- Our image-based DPNM takes microporosity into account in drainage simulations, allows simulations where macroporosity does not percolate
- Theoretically, behaviour of a network with individual micropores can be replicated
- Multiphase flow behaviour of Estaillades can be replicated, but:
  - Microporosity input parameters are hard to assess
  - Remaking user-defined cut-off length parameter
  - Further development necessary for predictive modeling


Acknowledgments & references


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