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

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ABSTRACT

In recent years, algorithms to extract pore network models (a network of idealized pores and pore throats) directly from micro-computed tomography (μCT) scans of porous rocks have been developed. These networks can be used to simulate capillary pressure curves, (relative) permeabilities and electrical properties in drainage/imbibition cycles. However, extracting and performing simulations on pore network models from rocks with very broad pore-size distributions as exhibited in certain carbonates remains a topic in need of further research.

Even though micropores with pore sizes below the resolution cannot be resolved in μCT scans, microporous zones can often be distinguished. This allows segmenting a μCT scan into microporous, solid and air phases [1]. In order to build a new type of two-scale network model which incorporates microporosity information without taking every individual micropore into account, the microporous phase was first clustered into connected regions. Then, a "classical" macroporous network model was extracted from the air phase by applying the maximal ball method [2]. Macropores touching a microporous cluster were identified, and the area of the associated contact surface was calculated for each of these macropores individually (by applying a marching cube algorithm). Every two pores bordering the same cluster were then connected by a microporous link. A maximal pore-to-pore distance for these connections was imposed, in order to exclude spurious links when large microporous clusters were present. Drainage simulations were run on two-scale networks extracted from Estaillades, a French porous limestone, using an adaptation of the PoreFlow invasion-percolation code developed at Imperial College [3]. Microporous links were assigned a capillary pressure curve, an absolute permeability and relative permeability curves. At each applied capillary pressure, the saturation of the microporous volume in the network was determined based on the microporous capillary pressure curve. Macropores were allowed to be invaded by the non-wetting phase through microporous links if the capillary pressure exceeded a break-through pressure [4]. The code assigns (non-)wetting phase hydraulic/electric conductances to microporous links based on the volumes of the clustered microporous regions in the μCT scan, the pore-micropore contact surface areas and the distance between the two pores connected by the link. Conductances are also proportional to the microporous absolute permeability/formation factor and relative permeability/resistivity index at the applied capillary pressure, and contain a fitting parameter related to the pore-micropore contact. We show preliminary results to investigate the validity of this new approach to multi-scale network generation and simulation.

REFERENCES

[1] D. Bauer, S. Youssef, M. Fleury, S. Bekri, E. Rosenberg, and O. Vizika, "Improving the Estimations of Petrophysical Transport Behavior of Carbonate Rocks Using a Dual Pore Network Approach Combined with Computed Microtomography," *Transp Porous Med*, vol. 94, no. 2, p. pp 505–524, 2012.

[2] H. Dong and M. J. Blunt, "Pore-network extraction from micro-computerized-tomography images," *Phys. Rev. E*, vol. 80, no. 036307, 2009.

[3] P. H. Valvatne and M. J. Blunt, "Predictive pore-scale modeling of two-phase flow in mixed wet media," *Water Resour. Res.*, vol. 40, no. 7, 2004.

[4] S. Békri, C. Laroche, and O. Vizika, "Pore network models to calculate transport and electrical properties of single or dual- porosity rocks," in *Proc. Int. Symp. Soc. Core Analysts*, 2005.