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Impact of Surface Roughness on Capillary Trapping Using 2D-Micromodel Visualization Experiments

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According to experimental observations, capillary trapping is strongly dependent on the roughness of the pore-solid interface. We performed imbibition experiments in the range of capillary numbers (Ca) from 10^{-6} to $5x10^{-5}$ using 2D-micromodels, which exhibit a rough surface. The microstructure comprises a double-porosity structure with pronounced macropores. The dynamics of precursor thin-film flow and its importance for capillary trapping is studied. For the first time Thin-Film Dynamics and the Complex Interplay of Thin Film- and Corner Flow for Snap-off Trapping is visualized using fluorescence microscopy. The experimental data for thin-film flow advancement show a square-root time dependence. Contrary to smooth surfaces, we prove by strict thermodynamical arguments that complete wetting is possible in a broad range of contact angles (0 – 90°). We develop a pore-scale model, which describes the front dynamics of thin-film flow on rough surfaces. Furthermore, contact angle hysteresis is considered for rough surfaces.

We conduct a comprehensive cluster analysis, studying the influence of viscous forces (capillary number) and buoyancy forces (bond number) on cluster size distribution and comparing the results with predictions from percolation theory. We found that our experimental results agree with theoretical results of percolation theory for Ca = 10^{-6}: (i) a universal power-like cluster size distribution, (ii) the linear surface-volume relationship of trapped clusters, and (iii) the existence of the cut-off correlation length for the maximal cluster height. The good agreement is a strong argument that the experimental cluster size distribution is caused by a percolation-like trapping process (Ordinary Percolation).

[1] H. Geistlinger, I. Ataei-Dadavi, S. Mohammadian, and H.-J. Vogel (2015) The Impact of Pore structure and Surface Roughness on Capillary Trapping for 2D- and 3D-porous media: Comparison with Percolation theory. Special issue: Applications of Percolation theory, Water Resour Res, 51, doi:10.1002/2015WR017852.

[2] H. Geistlinger, I. Ataei-Dadavi, and H.-J. Vogel (2016) Impact of Surface Roughness on Capillary Trapping Using 2D-Micromodel Visualization Experiments. Transport in Porous Med., in press.