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# Quasi-static pore network modeling, revisited: a pore scale data-driven approach to investigate simulation correctness

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While quasi-static pore network models (PNM) have been used to investigate the relative permeability (Kr) behaviour of reservoir rocks since the seminal work by Bakke and Øren (1997), the capacity of these models to capture the appropriate physics and predict experimental data remains contentious (Sorbie and Skauge, 2011; Bondino et al., 2012; Berg et al., 2016). It is generally accepted that PNM have to be calibrated against relatively cheap experimental data in order to predict more complex experiments. However, even after matching the former, it is not clear when and why PNM fail to reproduce experimental trends in the latter. We propose that the main reason for this is that the information in the Pc and Kr-curves is extremely densely encoded: many aspects of the porous medium and the fluid behaviour are lumped into the same parameter. PNM are thus very likely overfitted, making it hard to assess whether model failure is due to inappropriately trained model parameters or due to a fundamentally lacking description of the pore scale flow physics.
To unravel this, there is a need for experimental data which probes the underlying properties that make up a Kr-curve. Thanks to recent innovations in micro-computed tomography (micro-CT), it is now possible to image a rock's pore scale fluid distribution during flow experiments. We propose that this data can be used to constrain the source of errors in a PNM, if the issue is addressed by investigating three questions in specific order (by decreasing fundamentality):
1. Does the model predict the correct pore scale fluid distributions? This relies on the accuracy of the pore and throat radii, on the assigned contact angles in each pore and throat, and on the physics implemented in the invasion algorithm.
2. Does the model predict the correct saturation for a certain fluid distribution? This depends on the volume partitioning between pores and throats and thus on pore/throat length partitioning, which is arbitrary; as well as on the description of wetting layers.
3. Does the model predict the correct flow rate for a certain fluid distribution? This is chiefly determined by calculation of the pore, throat and layer conductivity in the model.
In this work, we focus on the first question. We present a novel modeling/experimental methodology to compare the pore-by-pore fluid distributions in a PNM to micro-CT based steady-state flow experiments. Using this analysis, we assess the importance of errors in the filling state of pores and throats to the flow, while seeking to split off the influence of volume and conductivity assignment. The influence of the pore scale contact angle distribution is investigated by automatically measuring a large number of contact angles on an in-situ micro-CT image (AlRatrout et al., 2017). Each of these contact angles is assigned to the pore that corresponds with its location in the image. This allows to perform PNM simulations with directly measured contact angle distributions for the first time. We explore how this influences PNM simulation errors by comparison to simulations with contact angles drawn from random distributions.The correctness of an adaptated version of the PNM approach outlined in Dong (2007) and Valvatne and Blunt (2004) is investigated by applying the methodology to a water-wet Bentheimer sandstone. In drainage, the model is found to reproduce the main oil flow paths in the experiment, while however significantly overestimating the corresponding water saturation. In imbibition, tentative results show a higher level of snap-off in the experiment compared to the model.

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