Contribution ID: **82** Type: **Oral 20 Minutes**

Accurate Modelling of Counter-current Spontaneous Imbibition in 2D and 3D Geometries

Tuesday, 15 May 2018 14:37 (15 minutes)

Counter-current spontaneous imbibition (SI) is an important transfer mechanism that exchanges fluids between the mobile fractures and immobile rock matrix in naturally fractured reservoirs. The current state of the art of modelling SI involves the use of quasi-analytic solutions for symmetric imbibition along a 1D axis. Unlike contemporary simulators which use first order transfer functions based on saturation potentials, the analytical solutions can capture both the early and late time behaviour of SI.

Our research focuses on the accurate modelling of SI in 2D and 3D. No general analytical solutions exist for SI with arbitrary initial and boundary conditions, so an empirical approach was followed. However, analytical solutions exist for SI where the capillary diffusion coefficient (DC) is linear. Hence we investigated how non-linearizing DC impacts the scaling of the recovery during SI. This analysis revealed that, similar to the 1D case, the behaviour in 2D and 3D can be characterized accurately by an early time regime which scales with tn where n varies from 0.4 to 0.5, and a late time regime which scales exponentially.
These temporal regimes were identified from a derivative analysis of the numerically simulated recovery curves during SI. The numerical error was assessed against the analytical solution for linearized SI problems as the simulation of non-linear SI requires highly resolved grids to correctly capture the recovery and determine the scaling of the temporal regimes. The parametrisation of the temporal regimes was achieved by a numerical sensitivity study involving the effect on recovery due to the shape of DC and the aspect ratio (AR) of the matrix blocks.

The parametrisation of the temporal regimes reveal that they are directly proportional to properties of DC such as the maximum of DC, the saturation at which the maximum occurs, the area under the DC curve and the AR of the blocks. The comparison to contemporary first order model shows that our model captures the fluid exchange during SI over the entire time more accurately.

References

March, R., F. Doster, and S. Geiger (2016), Accurate early-time and late-time modeling of countercurrent spontaneous imbibition, Water Resour. Res., 52, 6263–6276,

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Session Classification: Parallel 5-C

Track Classification: MS 4.11: Multiphase flow through fractured/fractured karst carbonate reservoirs