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Relations between seepage velocities in immiscible two-phase flow in porous media

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Based on the volumetric flow rate in immiscible two-phase flow in porous media under steady-state conditions* being an Euler homogeneous function of order one, we have earlier derived a set of relations between velocities that descibe the flow of the two immiscible fluids. These velocities we call thermodynamic velocities and they are distinct from the seepage velocity of each fluid. However, the two sets of velocities, the thermodynamic velocities and the seepage velocities, are related through a linear transformation. This transformation encodes the effect of the porous medium on the mixing of the immiscible fluids.

We use the theory on four analytically solvable variants of the parallel capillary tube model: 1) The capillaries are completely filled with either immisicble fluid; 2) the capillaries are filled with a mixture of each fluid; 3) a subset of the capillaries are so narrow that only the wetting fluid may enter whereas the rest of the capillaries are filled with either fluid, and 4) a subset of the capillaries are so narrow that only the wetting fluid may enter whereas the rest of the capillaries are filled with a mixure of the two immisicible fluids.

Lastly we analyze numerically a network model using our theory.

In all cases, we demonstrate the consistency of the models with the theory.

*By steady-state flow we mean that the macroscopic flow parameters fluctuate around well-defined averages in constrast to stationary flow where the microscopic interfaces remain fixed.

References

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