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Upscaled model for two-phase flow in porous media

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The formal derivation of the macroscopic mass and momentum balance equations for two-phase, creeping incompressible and Newtonian flow in rigid and homogeneous porous media is proposed in this work, assuming separation of length-scales and the existence of a (periodic) representative elementary volume, both classical for upscaling. The development is performed by making use of elements of the volume averaging method, combined with the adjoint technique and a Green's integral formulation [1, 2]. The macroscopic mass balance equation in each phase is identical to that already reported in the literature [3, 4]. The macroscopic momentum balance equation expresses the seepage velocity in each phase under the form of a pair of Darcy-like terms, involving a dominant and coupling permeability tensor, respectively related to viscous effects in the phase under concern and viscous coupling through the interfaces. Importantly, it includes an additional term resulting from capillary effects. The latter has not been obtained so far as a result of a priori assumptions that

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this term should be negligible, in particular for small capillary numbers [4, 5, 6]. The effective coefficients present in this macroscopic model are all obtained from the solution of two coupled closure problems that coincide with those already reported in the literature [4, 5, 6, 7]. The performance of the model is illustrated with numerical simulations carried out in a model two-dimensional configuration using a boundary element method. Average velocities, resulting from direct numerical simulation, are compared to the predictions of the macroscopic model obtained from the closure problems solution, showing excellent agreement over extended ranges of the capillary number, viscosity ratio and wetting-phase saturation. The additional capillary term present in the average momentum equation is shown to have a very important contribution in some situations. Extensions to other flow situations are briefly discussed.

Participation:

In-Person

References:

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