Numerical modeling of a capillary pressure as a discontinuity applied on the interface of a bi-fluid flow through porous media

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ABSTRACT

Capillary forces are rarely taken into account in the simulation of flow through porous media at a macroscopic level, while they can have significant impacts on the flow. Capillary forces can be modeled by a capillary pressure considered mathematically, as a pressure discontinuity applied on the fluid front or interface for bi-fluid flows.

At macroscopic scale, flows in porous media are generally governed by Darcy's or Brinkman's equations which are solved in this paper, by the finite element method using a mixed linear approximation for both velocity and pressure (P1/P1). In order to ensure the numerical scheme consistency [3], this formulation is stabilized through a Variational Multi-Scale Method called Algebraic SugGrid Scale. This technique is based on the decomposition of the unknowns into a resolvable scale - the finite element solution - and a finer scale the effects of which on the resolvable scale are included [1]. An enrichment of the pressure space [2] is also needed to accomodate the jump in the pressure field. Firstly, elements crossed by the fluid interface are split into subelements. Secondly, two degrees of freedom with discontinuous shape functions are added at this interface and then eliminated by static condensation prior to the assembly of the system.

The models are implemented in the Zset [4] software. A comparison between Darcy and Brinkman models highlitghs the drawbacks of the Darcy model such as spurious velocities at the interface. Afterwards, a Brinkman system has been compared with an analytical model and experimental data from [5]. The latter expressed the time dependent height and mass of water, impregnating fibrous carbon reinforcement during capillary wicking. Simulation results are found to be in very good agreement with both analytical and experimental studies.

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