Miscible Viscous Fingering: Application in Chromatographic Columns and Aquifers

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Abstract

When a less viscous fluid displaces a more viscous one in a porous medium or Hele-Shaw cell, the interface between the two miscible fluids does not remain flat and deforms into fingers growing in time [1]. It occurs due to the faster movement of less viscous fluid than the more viscous one, for a given pressure gradient. Fingering affects in aquifers, in packed bed reactors, and detrimental to chromatographic separation and many other systems. Here, the classical model of miscible viscous fingering (VF) has been investigated, using the COMSOL Multiphysics CFD modules, based on Darcy's law for the evolution of the incompressible fluid velocity coupled to a diffusion-convection equation for the concentration of a solute in the porous medium or Hele-Shaw cell. We obtained the numerical solution in an Eulerian system using the initial condition at the interface by a random function. Numerical simulations are performed for a classical VF case similar to [1] and for finite rectangular and circular slices of viscous fluid case in the applications of chromatographic columns and dispersion of contaminant in aquifers. Numerical simulations (Figs. 1 and 2) obtained using COMSOL Multiphysics are compared with the results obtained by a Fourier-Spectral method [2,3] and other experimental results from the literature [4]. The fingering dynamics are analysed with the different relevant parameters of the problem, like log mobility ratios R and the Péclet number Pe.

Reference

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4. R. Maes, G. Rousseaux, B. Scheid, M. Mishra, P. Colinet and A. De Wit, Experimental study of dispersion and miscible viscous fingering of initially circular samples in Hele-Shaw cells, Phys. Fluids 22, 123104 (2010).

Figures used in the abstract

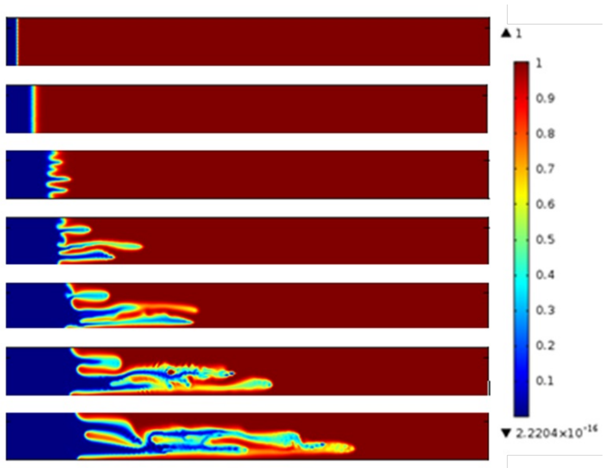

Figure 1: Fig.1: Density plots of concentration at successive times with U=6.78 × 10-4 m/s, Pe=512, R=4. From top to bottom t=0, 10, 20, 30, 40, 50, 60 seconds

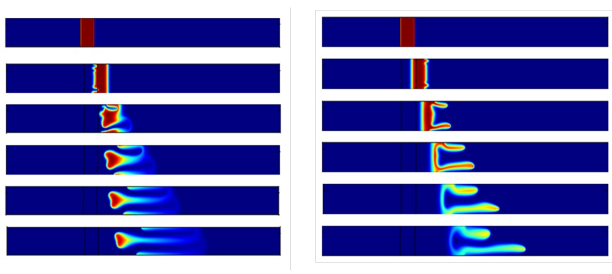

Figure 2: Fig.2: Density plots of concentration at successive times with U=3.14 × 10-4 m/s, Pe=512, (a) R=4, (b) R=-4. From top to bottom t=0, 20, 40, 60, 80, 100 seconds.