Miscible Viscous Fingering of Pushed Versus Pulled Interface

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Abstract

Introduction:

During the displacement of a more viscous fluid by a less viscous one in a porous medium or Hele-Shaw cell the interface separating the two fluids becomes unstable and finger like projections are observed [1]. For a given pressure gradient the less viscous fluid travels faster than the high viscous fluid through the medium. Hence the less viscous fluid tries to invade the more viscous one and penetrate through the latter. Fingering can appear in various industrial and environmental processes such as recovery of crude oil from oil fields, channeling in packed columns, fixed-bed chemical processing, filtration and hydrology, chromatographic columns, medical applications and in aquifers. Viscous fingering (VF) instability has been extensively studied for miscible and immiscible fluids a with step-like interface [2-3]. Successful modeling of such classical miscible VF instability for two semi-infinite domains and finite sample cases [4] have been performed in COMSOL Multiphysics®. However, in reality the displaced fluid can be localized in a circular region, hence separating it from the displacing fluid by an interface other than flat. We study the miscible VF instability at such a pushed or pulled interface.

Use of COMSOL Multiphysics®:

Modeling of the evolution of the incompressible fluid velocity coupled to a convection-diffusion equation for the saturation of the two fluids in the porous medium or Hele-Shaw cell has been done using the two-phase Darcy's law model in the COMSOL CFD Module. Numerical simulation has been performed in a Eulerian system for different flow parameters of the problem, like log-mobility ratio R and the Péclet number Pe. We investigate the instability patterns for both more and less viscous localized fluid displacements.

Results:

When the less viscous fluid penetrates through the high viscous fluid across a pushed interface, more fingers are formed than in the case of a pulled interface. In the case of the pushed interface, fingers appear immediately after the flow starts (see Fig. 1). On the other hand, finger formation is delayed for a pulled interface (see Fig. 2). In the case of the former, more fingers

are formed and they also propagate faster.

Conclusion:

It has been observed that the interfacial geometry has a great influence on the miscible VF instability. Pushed interfaces lead to instability quickly, as compared to the case of the flat interface. Detail study should be done to understand the effect of the nature of the interface on the VF instability to control the dynamics according to the requirement of channeling or mixing of viscous fluids under different circumstances.

Reference

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3. M. Mishra, M. Martin, A. De Wit, "Differences in miscible viscous fingering of finite width slices with positive or negative log-mobility ratio", Phys. Review E 78, 066306- (2008).
4. S. Pramanik, G. Kulukuru, M. Mishra, "Miscible viscous fingering: Application in chromatographic columns and aquifers", COMSOL Conference, Bangalore (2012).

Figures used in the abstract

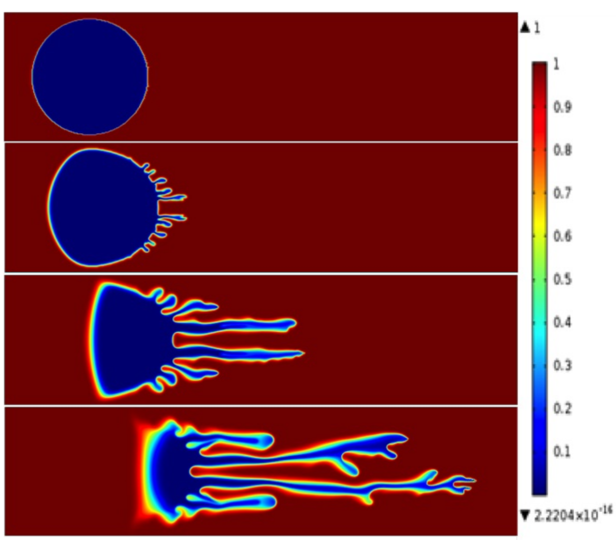

Figure 1: Density plots of concentration at successive times with U = 1 mm/s, Pe = 2000, R = -3. From top to bottom t = 0, 5, 20, 40 seconds.

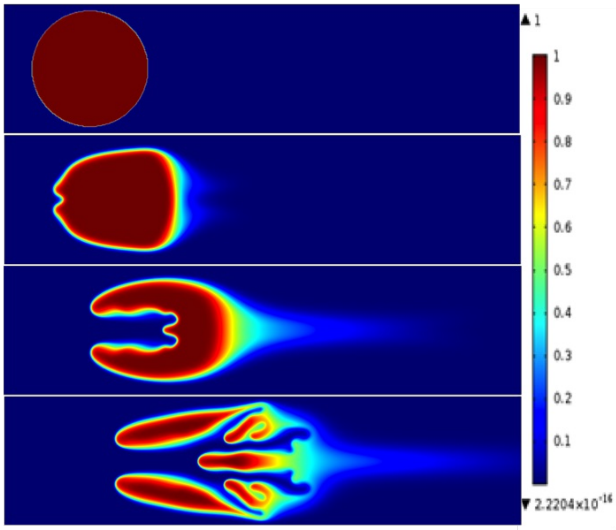

Figure 2: Density plots of concentration at successive times with U = 1 mm/s, Pe = 2000, R = 3. From top to bottom t = 0, 50, 150, 200 seconds.