Steady-state fluid front morphologies in gap-modulated narrow channels

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The study of controlled spatio-temporal modulations in problems of pattern formation is a very useful conceptual tool to ellucidate dynamic aspects which are not easily accessible in realistic situations. This strategy has been found useful in many contexts [1]. In the present problem, in contrast with most other cases, the interfacial dynamics is strongly nonlocal, and this leads to a particular phenomenology.

The specific system that we study is a stable imbibition displacement, in which a viscous and wetting fluid (oil) displaces a nearly inviscid and less wetting fluid (air), in a rectangular Hele-Shaw cell with spatially-variable gap thickness [2]. The external perturbations considered here are generated by a topographic relief of the bottom plate of the cell that gives rise to spatial variations of the gap thickness in the direction transverse to the direction of front advancement.

The local variability of the gap thickness gives rise to two distinct physical effects: variations in the local capillary pressure at the interface and variations in the local permeability of the medium. Both control the morphology and dynamics of the fluid front. In spite of having a common geometrical origin, these two effects are very different and often counteracting.

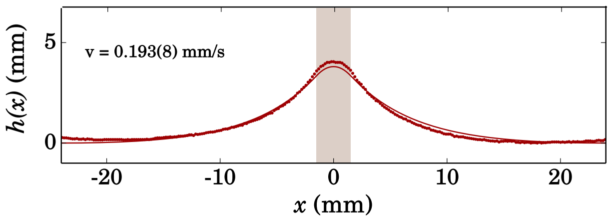

Figure 1: Steady state morphology of the front for an experiment with a gap space of 0.46 mm and an injection velocity of 0.193(8) mm/s around the heterogeneity. The continuous line correspond to the analytical solution and dots to experimental data.

In the present communication we focus our attention on the steady state. In this regime the front morphologies observed experimentally are in excellent agreement with the predictions of a linear theory without adjustable parameters, particularly for low intensities of the gap modulation. Figure 1 shows an example of this agreement for an experiment at given gap space and injection velocity.

[1] M. Cross and P. Hohenberg, Rev. Mod. Phys. **65**, 851-1112 (1993).

[2] J. Soriano, J. Ramasco, M. Rodríguez, A. Hernández-Machado and J. Ortín, Phys. Rev. Lett. **89**, 026102 (2002).