Selection Mechanism in Non-Newtonian Saffman-Taylor Fingers

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***Abstract*—** We present an analytical approach to the problem of predicting the finger width of a simple fluid driving a non-Newtonian (power-law) fluid. Our analysis is based on the Wentzel- Kramers-Brillouin (WKB) technique, by representing the deviation from the Newtonian viscosity as a singular perturbation in a parameter, leading to a solvability condition at the fingertip, which selects a unique finger width from the family of solutions. We find that the relation between the dimensionless finger width, Λ and the dimensionless group of parameters containing the viscosity and surface tension, ν, has the form: $\Lambda \sim \frac{1}{2} - O(\nu^{-1/2})$ for shear thinning case, and $\Lambda \sim 1/2 + O(\nu^{2/(4-n)})$ for shear thickening case, in the limit of small ν. This theoretical estimate is compared with the existing experimental, finger width data as well as the one computed with the linearized model and a good agreement is found near the power-law exponent, $n = 1$.

***Keywords*—** Fingering instability; Pattern formation; Power-law rheology; Viscoelastic solution; WKB approximation