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Dynamical study of the three dimensional Saffman-Taylor problem MATTEO NICOLI, HERVÉ HENRY, MATHIS PLAPP, Ecole Polytechnique - CNRS — The mathematical generalization of the Saffman-Taylor problem to three spatial dimensions is straightforward but, nevertheless, it has not been widely studied. Recently, Levine and Tu [Phys. Rev. A **45**, 1044 (1992)] solved numerically the problem in the axisymmetric tube geometry finding several solution branches which merge for positive values of the rescaled surface tension parameter $\bar{\gamma}$ (of the order of 10^{-3}). Unlike the two dimensional case, it seems that for this geometry does not exists any axisymmetric solution below this threshold. We have developed a phase-field model of two viscous flows to investigate the dynamics of the 3D Saffman-Taylor problem in the regime of small $\bar{\gamma}$. Full three dimensional simulations in a channel with square section and two dimensional axisymmetric simulations in the tube geometry show that the growing finger undergoes a Plateau-Rayleigh instability leading to pinch-off at the finger tail. Through the linear stability analysis of the tube solution in the axisymmetric geometry, we show that the solutions found by Levine and Tu are unstable for any value of $\bar{\gamma}$. Our phase-field model reproduces accurately this linear prediction and allows to study the influence of the finger tip on the pinch-off velocity. Moreover, we observe that the interface between the two fluids undergoes a tip splitting instability for $\bar{\gamma} < 6.5 \times 10^{-3}$, spoiling the stability of the Saffman-Taylor finger.

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