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Stability results on radial porous media and Hele-Shaw flows with variable viscosity between two moving interfaces. (English) [Zbl 07383814]

Summary: We perform a linear stability analysis of three-layer radial porous media and Hele-Shaw flows with variable viscosity in the middle layer. A nonlinear change of variables results in an eigenvalue problem that has time-dependent coefficients and eigenvalue-dependent boundary conditions. We study this eigenvalue problem and find upper bounds on the spectrum. We also give a characterization of the eigenvalues and prescribe a measure for which the eigenfunctions form an orthonormal basis of the corresponding $L^2$ space. This allows for any initial perturbation of the interfaces and viscosity profile to be easily expanded in terms of the eigenfunctions by using the inner product of the $L^2$ space, thus providing an efficient method for simulating the growth of the perturbations via the linear theory. The limit as the viscosity gradient goes to zero is compared with previous results on multi-layer radial flows. We then numerically compute the eigenvalues and obtain, among other results, optimal profiles within certain classes of functions.

MSC:
76E17 Interfacial stability and instability in hydrodynamic stability
76S05 Flows in porous media; filtration; seepage
76D27 Other free boundary flows; Hele-Shaw flows
76M22 Spectral methods applied to problems in fluid mechanics

Keywords:
linear stability analysis; Saffman-Taylor instability; eigenvalue problem; spectrum upper bound; Chebyshev pseudo-spectral method

Full Text: DOI