GENERALIZED SAFFMAN-TAYLOR FORMULA FOR MULTI-LAYER HELE-SHAW AND POROUS MEDIA FLOWS

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Abstract: Stability theory plays a major role from fundamental science to applied sciences. It is useful in the design of many processes and engineering instruments as well as in explaining many phenomena. In this talk, we review some of the author's and his collaborators' recent works on the extension of Saffman-Taylor instability which occurs at an interface between two immiscible fluids in porous media and Hele-Shaw cells when displacing fluid is less viscous than the displaced one. The growth rate of interfacial disturbances is given by a formula called Saffman-Taylor formula which plays a very important role in many areas including flows in porous media and oil recovery among several others. We summarize our results on generalization of this formula to many interfaces in multi-layer flows. The generalization is in the form of upper bounds on the growth rates of interfacial disturbances. This is discussed in cases of constant viscosity layers and variable viscosity layers. The upper bound provides a way to assess cumulative effects of many layers and many interfaces on the growth rates of unstable waves. As an application of the generalized Saffman-Taylor formula, we present necessary conditions for suppressing instability of two-layer flows by introducing arbitrary number of constant viscosity fluid layers in between. The important role that this condition plays in stabilization of hydrodynamic instabilities and enhanced oil recovery is discussed. Moreover, many other results relevant for stabilization of multi-layer Hele-Shaw flows are reviewed from our recent publications listed below.

[1] P. Daripa and G. Pasa, An optimal viscosity profile in enhanced oil recovery by polymer flooding, Int. J. Engg. Sci. 42(19-20) (2004), 2029-2039.

[2] P. Daripa and G. Pasa, New bounds for stabilizing Hele-Shaw flows, Appl. Math. Lett. 18(11) (2005), 1293-1303.

[3] P. Daripa and G. Pasa, On the growth rate for three-layer Hele-Shaw flows: variable and constant viscosity cases, Int. J. Engg. Sci. 43(11-12) (2005), 877-884.

[4] P. Daripa and G. Pasa, A simple derivation of an upper bound in the presence of viscosity gradient in three-layer Hele-Shaw flows, J. Stat. Mech.: Theory and Experiment, No. P01014, January 2006.

[5] P. Daripa and G. Pasa, Stabilizing effect of diffusion in enhanced oil recovery and three-layer Hele-Shaw flows with viscosity gradient, Transport in Porous Media 70 (2007), 11-23.

[6] P. Daripa and H. J. Hwang, Nonlinear Saffman-Taylor instability for Hele-Shaw flows, J. Differential Equations 245(7) (2008), 1819-1837.

[7] P. Daripa, Studies on stability in three-layer Hele-Shaw flows, Phys. Fluids 20 (2008), Article #112101.

[8] P. Daripa, Hydrodynamic stability of multi-layer Hele-Shaw flows, J. Stat. Mech. (2008), Article #P12005.

[9] P. Daripa and G. Pasa, On diffusive slowdown in three-layer Hele-Shaw flows, Quart. Appl. Math. LXVIII (3) (2010), 591-606.