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Confinement, Flow, and Darcy's Law: Impact on Flame Hydrodynamic Instabilities

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The hydrodynamic instabilities of premixed flames in Hele-Shaw channels or porous media under the influence of an imposed flow and gravity are investigated within the framework of Darcy's law. The stability analysis accounts for the Darrieus-Landau, Saffman-Taylor, and Rayleigh-Taylor instabilities.

A theoretical study, treating the flame as a hydrodynamic discontinuity, provides a simple dispersion relation between the perturbation growth rate s and its wavenumber k in the form $s = (a\,k - b\,k^2) / (1 + c\,k)$, where a, b, and c are constants determined by the problem parameters [1]. The constant a characterises all three hydrodynamic instabilities, which are longwave in nature. In contrast, b and c, which characterise the influences of local curvature and flow strain [2] on the flame propagation speed, typically provide stabilization at short wavelengths comparable to the flame thickness.

The theoretical findings for Darcy's law are compared with a generalization of the classical work by Joulin & Sivashinsky [3], which is based on an Euler-Darcy model. The comparison provides a conceptual bridge between predictions based on Darcy's law and those on Euler's equation and offers valuable insights into the role of confinement on flame instabilities in Hele-Shaw channels.

Numerical simulations supporting and extending the theoretical study are carried out using a simplified chemistry model and Darcy's law. Special emphasis is given to the critical role played by the imposed flow in destabilizing or stabilizing the flame, depending on its direction relative to the flame propagation.

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[3] Joulin, G. and Sivashinsky, G. Influence of momentum and heat losses on the large-scale stability of quasi-2D premixed flames. Combustion Science and Technology, *98*(1-3), pp.11-23, 1994.