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Inertia, non-equilibrium, and momentum conservation in porous media

Theoretical and computational models of flow through porous media typically ignore inertial effects and use Darcy's law (and extensions thereof) to approximate momentum balance. This contrasts with experimental observations of rapid fluid movement in the pore space, such as Haines jumps that occur in presence of multiple flowing phases. Also, neglecting acceleration may lead to contradictions analogous to those encountered when Fourier's law is used as constitutive equation in the heat equation.

We review the role of local inertial effects in shaping the morphology of invading fluid fronts, paying particular attention to the effects of surface energy instabilities, spontaneous reconfiguration of the interface, collective pore filling, and hysteresis. Then, we discuss how a macroscopic momentum-balance equation can be introduced to model multiphase flow in porous media and describe salient flow features that are observed in the experiments but cannot be captured if Darcy's law is used.

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