Steering pattern formation of viscous flows

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Viscous liquid layers on hydrophobic surfaces are susceptible to hydrodynamic instabilities. These instabilities trigger a complex dynamics that evolves an initially flat layer into a characteristic pattern of stationary droplets. By representing the boundary with functions $u(t)$, one can recast the hydrodynamic free boundary problem as a gradient flow $\partial_t u = -\mathbb{K}(u)\mathrm{D}\mathcal{E}(u)$, where the operator $\mathbb{K}$ describes the friction/dissipation of the flow and $\mathcal{E}$ measures the interfacial area of the boundary. In practice, modifications of surface properties change the dissipation $\mathbb{K}$, which in turn switches between various observed droplet patterns. This mechanism is demonstrated using a finite dimensional example and then extended to a free boundary problem for a viscous fluid. Numerical simulations are used to show the impact of the metric induced by the dissipation. The presentation covers mathematical and numerical aspects of free boundary problems for viscous flows and highlights the underlying gradient flow structure. The focus is the intruiging interplay of bulk-interface properties encoded in $\mathbb{K}$ and $\mathcal{E}$.

References

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