Stretching liquid bridges with moving contact lines: Comparison of model predictions and experiments

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Printing processes are being explored for the large-scale manufacture of electronic devices. Transfer of liquid from one surface to another plays a key role in most printing processes. Incomplete liquid transfer can produce defects that can be detrimental to device operation. One important printing process is gravure, which involves transfer of liquid from micron-scale cavities at high speeds. However, its underlying physical mechanisms remain a mystery. During liquid transfer, a liquid bridge—a mass of liquid connecting two solid surfaces—is formed. The liquid bridge then undergoes significant extensional (stretching) motion and the contact lines (where air, liquid, and solid meet) move on the bounding surfaces. This research focuses on the fundamental problem of a stretching liquid bridge with moving contact lines. To begin to understand this problem, two hydrodynamic models have been developed. The first is a slender-jet model, which assumes that the liquid bridge is long and thin. Predictions of liquid transfer from this model agree well with previously published experimental data. The second is a two-dimensional axisymmetric model based on the Galerkin finite-element method. The two-dimensional model is more computationally intensive, but provides better predictions. Results from parametric studies examining the influence of the initial bridge shape, surface wettability (contact angles), and capillary number (ratio of viscous to surface tension forces) will be presented. The results from the fundamental studies described in this research will aid the optimization of gravure and other printing processes, and thus help advance the production of printed electronic devices.

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