Transfer of Rate-thinning and Rate-thickening Liquids Between Separating Plates and Cavities

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One promising technology for fabricating low-cost printed electronics on a large scale is roll-to-roll gravure, which involves transfer of inks from microscale cavities to a second surface. Although printing inks containing functional additives usually exhibit non-Newtonian rheological behavior, the influence of ink rheology on liquid transfer is not yet well understood. To address this issue, an axisymmetric model is used to develop fundamental understanding of how ink rheology affects liquid transfer between vertically separating surfaces. Liquids whose rheological behavior is described by Carreau-type models are considered, inertial and gravitational forces are neglected, and the nonlinear governing equations are solved with the Galerkin finite-element method. For liquid transfer between two flat plates, the results reveal that rate-thinning (rate-thickening) rheology leads to reduced (enhanced) viscosities near the less-wettable surface where stronger pressure gradients arise. The reduced (enhanced) viscous forces further assist (hinder) the slip of the moving contact line, allowing more (less) liquid to be transferred from the less-wettable surface to the more-wettable one. For liquid transfer between a flat plate and a trapezoidal cavity, the effect of cavity angle on liquid transfer is investigated first. The amount of liquid transferred to the flat plate is found to increase with a larger cavity angle and this phenomenon is observed for both Newtonian and rate-dependent liquids. In addition, the influence of rate-dependent rheology is found to pri- marily occur near the flat plate. This behavior is attributed to the presence of the cavity wall, which reduces the interface deformation, the associated capillary pressure gradients, and thus the effect of rate-dependent rheology. As a consequence, rate-thickening (rate-thinning) tends to increase (decrease) the amount of liquid transferred from the cavity.