Marangoni Flow Induced in a Thin Liquid Film by the Presence of a Volatile Solvent

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Abstract : When studying the evolution of a thin liquid film over a solid substrate under the presence of a volatile solvent source with its interfacial surface tension gradient approximated by $\boldsymbol{t}.\nabla\gamma=\partial_x\gamma+\partial_x h\partial_y\gamma$ instead of the hitherto adopted approximation $\boldsymbol{t}.\nabla\gamma\approx\partial_x\gamma$ and a constant pressure-gradient-driven flow generated into the vapor phase, their effects were found to disturb the results. The impact of these effects on the dynamics of a thin liquid film is examined in this paper. Using the long-wave approximation of the coupled Navier-Stokes and advection-difusion equations, we show that the generic motion of the thin liquid film in such a complex situation can be translated mathematically into a degenerate fourth order nonlinear parabolic h -evolution equation. When the constant pressure-gradient-driven flow is disregarded, the thinning process produced by the presence of the volatile source is much increased by the inclusion of the hitherto neglected term $\partial_x h\partial_y\gamma$. Otherwise, the liquid film thins less rapidly but undergoes translational movement in the direction of the pressure-gradient-driven flow so as to deviate the diffusive fluxes from hitting the free surface of the liquid film horizontally — a phenomenon suggesting a new route for regulating the Marangoni effect. A series of numerical experiments are carried out to graph the leading features resulting from these mechanisms and the overall results are analysed parametrically to explain their characteristics. In the context of practical applications, the studies show that the hitherto neglected term weakens the Marangoni flow and the constant pressure-gradient-driven flow might be substituted for air blow to regulate the Marangoni flow.

Key Words : Thin liquid film, Long Wave Approximation (LWA), Volatile source, Constant pressure-gradient-driven flow, Chemical interfacial phenomenon