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On the paradox of thermocapillary flow about a stationary bubble

EHUD YARIV, MICHAEL SHUSSER, Faculty of Mechanical Engineering, Technion, Haifa 32000, Israel — When a stationary bubble is exposed to an external temperature gradient, Marangoni stresses at the bubble surface result in fluid motion. A straight-forward attempt to calculate the influence of this thermocapillary flow upon the temperature distribution fails to provide well-behaved solution [Balasubramaniam & Subramanian, *Phys. Fluids* **16**, 3131 (2004)]. This paradox is resolved here using regularization procedure which exploits the qualitative disparity in the long-range flow fields generated by stationary bubble and moving one. The regularization parameter is an (exponentially small) artificial bubble velocity U, which reflects the inability of any asymptotic expansion to satisfy the condition of exact bubble equilibrium. The solution is obtained using asymptotic matching of two separate Reynolds-number expansions: an inner expansion, valid at the bubble neighborhood, and remote outer expansion, valid far beyond the familiar Oseen region. This procedure provides well-behaved solution, which is subsequently used to evaluate the convection-induced correction to the hydrodynamic force exerted on the bubble. The independence of that correction upon U confirms the adequacy of the regularization procdure to descibe the stationary-bubble case. The ratio of the calculated force to that pertaining to the classical pure-conduction limit [Young, Goldstein Block, *J. Fluid Mech.* **6**, 350 (1959)] is given by $1-Ma/8+o(Ma)$, where Ma is radius-based Marangoni number.

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