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Rising or Sinking — An Elongated Bubble in a Vertical Capillary Tube Under External Flow[1] YINGXIAN ESTELLA YU, Princeton University, MIRCO MAGNINI, The University of Nottingham, SUIN SHIM, HOWARD A. STONE, Princeton University — When a confined bubble translates steadily in a vertical capillary tube under co-current fluid flow, the motion of the bubble depends on both the buoyancy and the mean fluid velocity. Although a wide variety of studies have been carried out analyzing the motion of the elongated confined bubble, most of them focus on the dynamics in one of two distinct limits — either when buoyancy effects are negligible (Bo <<1) or when Bo >>1. In this work, we systematically investigate the motion of an elongated bubble and its film thickness profile with Bo ˜1 under external downward flow. In a stagnant fluid, a bubble spontaneously rises only when Bo >0.842 (Bretherton 1961), and intuitively, external downward flow can slow down the bubble motion or even reverse the translation direction. By varying the capillary number of the external downward flow, different film profile regimes are observed. A theoretical model based on the extended lubrication theory is developed in order to predict the bubble velocity and steady state solutions of the film profiles in different regimes. The critical external flow conditions are further characterized and validated by combining with the results from experiments and direct numerical simulations.

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