Experimental results on gravity driven fully condensing flows in vertical tubes, their agreement with theory, and their differences with shear driven flows' boundary-condition sensitivities

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1. Introduction and background

This paper presents a fundamental experimental investigation for gravity driven internal condensing flows inside a vertical tube. Only the pure vapor case (with FC-72 as a working fluid) is considered.

There are quite a few existing experimental papers with condensation in vertical tubes and passages ([1–4], etc.) which involve a number of pure fluids. Also there are several heat transfer correlations ([5–11], etc.) which have been developed to cover various different realms of internal condensing flow physics (including those involving horizontal and vertical tubes). The experiments as well as the correlations in the literature [1–11] cover a rather large set of internal condensing flow regimes and associated flow physics. For example, condensing flows in the literature involve: shear driven to gravity driven condensate motion (inside horizontal to vertical tubes and channels), laminar to turbulent nature of the flows in the vapor phase, and laminar (with or without waves) to turbulent (wavy) nature of condensate flows, and annular to various non-annular (plug/slug, bubbly, etc.) liquid/vapor interface-configuration patterns (also termed liquid/vapor morphologies). One of the goals of these types of investigations has been to synthesize analyses and experiments to provide reliable order of magnitude estimates for average heat transfer coefficients over the large set of flow physics conditions associated with condensing flows. In addition to the above, there are also modern condensing flow experiments for flows in μm–mm scale ducts [12–14]. These newer experiments typically involve shear driven and laminar condensate motion and exhibit even a greater variety of liquid–vapor morphologies (injection annular, plug/slug, etc.) for different steady/quasi-steady and oscillatory realizations of these flows.

In the above context, the goal of the reported experiments is to use a reliable synthesis of experiments with computational/theoretical results obtained for a specific flow physics category and to develop a reliable heat transfer correlation(s) for the chosen category. In this paper, gravity driven flows with laminar wavy and annular condensate flows are investigated. The theoretical/computational results [16] and its synthesis with experimental results reported here is, to begin with, for the flow physics category of laminar condensate and laminar vapor (in the near interface region) flows which are annular with small to moderate waviness. The theoretical/computational results in [16] do not employ any ad hoc models (as in [7,8,15]) for interfacial shear stress, pressure gradient, condensate turbulence, etc. Results from this approach, in conjunction with experimental result, is used to define flow physics boundaries. This is done by considering experimental data that agree with the theory in [16] as well as data that systematically deviates from the flow physics assumptions underlying the theory. Therefore this approach identifies nearby flow physics categories for which the agreement is not good and one needs to properly

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