



Macro-to-microchannel transition in two-phase flow: Part 1 – Two-phase flow patterns and film thickness measurements

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ABSTRACT

The classification of macroscale, mesoscale and microscale channels with respect to two-phase processes is still an open question. The main objective of this study focuses on investigating the macro-to-microscale transition during flow boiling in small scale channels of three different sizes with three different refrigerants over a range of saturation conditions to investigate the effects of channel confinement on two-phase flow patterns and liquid film stratification in a single circular horizontal channel (Part 2 covers the flow boiling heat transfer and critical heat flux). This paper presents the experimental two-phase flow pattern transition data together with a top/bottom liquid film thickness comparison for refrigerants R134a, R236fa and R245fa during flow boiling in small channels of 1.03, 2.20 and 3.04 mm diameter. Based on this work, an improved flow pattern map has been proposed by determining the flow patterns transitions existing under different conditions including the transition to macroscale slug/plug flow at a confinement number of $Co \approx 0.3$ – 0.4 . From the top/bottom liquid film thickness comparison results, it was observed that the gravity forces are fully suppressed and overcome by the surface tension and shear forces when the confinement number approaches 1, $Co \approx 1$. Thus, as a new approximate rule, the lower threshold of macroscale flow is $Co = 0.3$ – 0.4 while the upper threshold of symmetric microscale flow is $Co \approx 1$ with a transition (or mesoscale) region in-between.

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1. Introduction

The type of two-phase flow pattern observed in a channel depends on the respective distribution of the different phases which take on a particular configuration. Due to differences in macroscale (macrochannels) and microscale (microchannels) phase change phenomena, it has been conclusively shown that applying or extrapolating two-phase macroscale flow pattern maps to microscale two-phase flows is unrealistic. This is because the distinguishing criteria, such as the relative importance of the various hydrodynamic forces, e.g. inertia, viscosity, buoyancy and surface tension effects, all play an important role concerning the motion of the liquid and vapor phases flowing in the conduit. These two-phase flow pattern transitions when passing from macroscale-to-microscale do not occur abruptly but in a gradual manner due to the diminishing influence of the gravity forces when channel confinement increases. While gravity plays an important role in macroscale flows, it has less impact in the microscale due to the increasingly stronger effect of surface tension.

The main objective of this study is to investigate the effect of channel confinement, with the aim to define the lower threshold

of the macro-to-microscale transition and the upper threshold of symmetric microchannel two-phase flow. Evidently, the gradual suppression of stratified flow (a macroscale flow regime) and the convergence of the intermittent flow regime (slug, plug and stratified-wavy) into the isolated and coalescing bubble regime in microscale channels supports the idea of a macro-microscale transition region in-between these two thresholds (which has been referred to as a mesoscale and minichannels in literature). This article presents experimental two-phase flow pattern observations for channels of internal diameters of 1.03, 2.20 and 3.04 mm for the three refrigerants combined with the earlier flow pattern observations of Revellin and Thome [1] for 0.50 and 0.80 mm channels with two of these refrigerants (R134a and R245fa). A new updated macro-microscale flow pattern map is proposed here, that is capable to predict both the macro and microscale flow patterns based on the current experimental flow pattern observations and that of Revellin and Thome [1]. In combination, the effect of channel confinement on the liquid film stratification was also investigated by comparing the liquid film thickness at the top to the bottom of the channel through high speed image processing of flow visualization videos to help define the macro-to-microscale transition in two-phase flow.

In the second part of this study (Part 2 – flow boiling heat transfer and critical heat flux), the results for flow boiling heat transfer

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