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Flow Boiling Heat Transfer at Low Mass and Heat Fluxes: Heat Transfer Coefficient, Flow Pattern Analysis and Correlation Assessment

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Abstract : Flow boiling heat transfer remains an important area of research due to its relevance in thermal management systems and other applications. Despite the enormous work done in the field of flow boiling heat transfer over the years to understand how flow parameters such as mass flux, heat flux, saturation conditions and tube geometries influence the characteristics of flow boiling heat transfer, there are still many contradictions and lack of agreement on the actual mechanisms controlling heat transfer and how flow parameters impact the heat transfer. This work thus seeks to experimentally investigate the heat transfer characteristics and flow patterns at low mass fluxes, low heat fluxes and low saturation pressure conditions which are of less attention in literature but prevalent in refrigeration, air-conditioning and heat pump applications. In this study, flow boiling experiment was conducted for R134a working fluid in a 5 mm internal diameter stainless steel horizontal smooth tube with mass flux ranging from 80- 100 kg/m2 s, heat fluxes ranging from 3.55kW/m2 - 25.23 kW/m2 and saturation pressure of 460 kPa. Vapor quality ranged from 0 to 1. A well-known flow pattern map created by Wojtan et al. was used to predict the flow patterns noticed during the study. The experimental results were correlated with well-known flow boiling heat transfer correlations in literature. The findings show that, heat transfer coefficient was influenced by both mass flux and heat fluxes. However, for an increasing heat flux, nucleate boiling was observed to be the dominant mechanism controlling the heat transfer especially at low vapor quality region. For an increasing mass flux, convective boiling was the dominant mechanism controlling the heat transfer especially in the high vapor quality region. Also, the study observed an unusual high heat transfer coefficient at low vapor qualities which could be due to periodic wetting of the walls of the tube due to slug flow pattern and stratified wavy flow patterns. The flow patterns predicted by Wojtan et al. flow pattern map were mixture of slug and stratified wavy, purely stratified wavy and dry out. Statistical assessment of the experimental data with various well-known correlations from literature showed that, none of the correlations reported in literature could predicted the experimental data with enough accuracy.

Keywords : flow boiling, heat transfer coefficient, mass flux, heat flux.
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