Experimental Investigation of Local Heat Transfer Coefficients of a Minichannel Evaporator with Propane as the Refrigerant

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Accurate heat transfer coefficients are fundamental to the design and optimization of refrigeration systems. This study investigates the local heat transfer coefficients of a minichannel heat exchanger used as an evaporator in a heat pump with propane (R290) as the refrigerant. The growing demand for sustainable refrigeration systems is driving the adoption of natural refrigerants with negligible ozone depletion and low global warming potential. Propane offers excellent thermodynamic performance, but its flammability requires charge minimization, highlighting the importance of compact heat exchangers with small internal volumes and high efficiency. The experimental data were obtained from a previously developed minichannel aluminum evaporator operating in a controlled system. Previous studies by one of the authors focused on determining average heat transfer coefficients of the evaporator. In contrast, the present study utilizes the same experimental dataset to investigate the local heat transfer characteristics of propane in the minichannel evaporator through a detailed segment-wise analysis of heat transfer behavior. The evaporator was divided into 12 sections to calculate local shell-side heat transfer coefficients. To evaluate the applicability of existing predictive models, the experimentally obtained heat transfer coefficients were compared with several widely used empirical and semi-empirical correlations from the literature. Where necessary, constants were adjusted while preserving the original mathematical formulation of each correlation. These included correlations proposed by Lazarek and Black, Malek and Colin, Pierre, Cooper, Kandlikar, which have been extensively applied in the analysis of boiling heat transfer in conventional and microscale channels. Among the evaluated correlations, the Kandlikar model exhibited the best agreement with experimental data across all flow regimes, demonstrating adaptability to minichannel conditions. The Malek and Colin correlation performed well in the saturated boiling region after modification, indicating its suitability for predicting nucleate flow boiling under certain conditions. In contrast, Lazarek and Black and Pierre correlations showed moderate agreement, with limitations in accurately capturing superheated or transitional regions. These findings demonstrate that section-wise analysis provides a more accurate representation of boiling heat transfer than average-value methods and offers improved predictive capability for the design and optimization of compact, low-charge propane heat exchangers used in sustainable refrigeration and heat pump applications.

Keywords: heat pump, minichannel evaporator, Propane (R290), local heat transfer coefficients, boiling heat transfer correlations