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Condensation pressure drop of HFC-134a and R-404A in a smooth and micro-fin U-tube

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ABSTRACT

The frictional pressure drop during condensation of HFC-134a and R-404A in a smooth (8.56 mm ID) and micro-fin U-tubes (8.96 mm ID) are experimentally investigated. Different from previous studies, the present experiments are performed for various condensing temperatures. The test runs are done at average saturated condensing temperatures ranging from 35 °C to 60 °C. The mass fluxes are between 90 and 800 kg/m^{2}s. The experimental results indicate that the average frictional pressure drop increases with mass flux but decreases with increasing condensing temperature for both smooth and micro-fin-tubes. The average frictional pressure drops of HFC-134a and R-404A for the micro-fin-tubes were 1–1.7 and 1–2.1 times larger than that in smooth tube respectively. New correlations based on the data gathered during the experimentation for predicting frictional pressure drop are proposed for wide range of operating conditions.

1. Introduction

In design practice, accurate predictions of the heat transfer and pressure drop are of great importance. The pressure drop in condenser affects not only pumping power consumption but also significantly the heat transfer performance due to the dependence between the local condensing temperature and pressure of refrigerant, especially in the case of condensation in micro-fin-tubes where the vapour-to-surface temperature difference is smaller [1].

U-type wavy tubes (hairpin) with consecutive 180° return bends are widely employed in the condenser and evaporator of the refrigerating systems. The presence of curved tubes will induce secondary flow due to the contribution of the centrifugal force. The centrifugal force drives the more rapid fluid in the concave part of the curved channel while the fluid in the convex part is slowing down. The magnitude of secondary flow increases with a decrease in bend radius and with an increase of fluid velocity. In the two-phase flow application, the flow pattern in the return bend is dramatically affected by the vortices of the secondary flow. Since flow patterns are intimately interrelated to both two-phase heat transfer and pressure drop, the higher pressure drop would increase the pumping power and also affect the performance of refrigerating systems. As a consequence, the refrigerant two-phase pressure drop in a consecutive U-type wavy tube is very important for the design of air-cooled heat exchanger [2].

Condensation of flowing vapour inside a tube has become a topic of investigation with the advent of modern refrigerating systems. Unlike the case of condensation of pure stagnant vapour on a surface as solved by Nusselt [3], the phenomenon of condensation of vapors flowing in a tube is more complex because of several hydrodynamic flow patterns that may arise all along the length of the tube. The survey reveals that some of the correlations are obtained purely by dimensional analysis, while other investigators worked out the problem employing a theoretical and semi-theoretical approach using two-phase flow characteristics. By and large the annular two-phase flow regime is considered in modeling with the interfacial shear stress, void fraction etc. Hence, its accurate estimation depends upon the correctness of the two-phase friction coefficient value chosen in computations.

Most of the frequently used correlations to predict the two-phase frictional pressure gradient take the form of two-phase frictional multipliers. The concept for using the multipliers was first introduced by Lockhart and Martinelli [4]. A work published by Ould-Didi et al. [5] showed a comparison between some leading predictive methods and experimental data obtained for five different refrigerants segregating the experimental data by flow regimes. Overall, they found that the Grönnerud [6] and the Müller-Steinhagen and Heck [7] methods to be equally the best, while the Friedel [8] method was the third best in a comparison of seven leading predictive methods. Segregating the data by flow regimes using the flow pattern map by Kattan et al. [9], the authors found

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