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A Simple Correlation for Horizontal Micro-Fin Tube Convective Boiling with Example Calculation

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INTRODUCTION[1]

The first micro-fin tube was probably developed around 1938 to solve the problem of dryout in water tube steam boilers (Bailey, 1942). Bailey's patent describes an invention for a tube with 53 internal fins approximately 0.38 mm tall rifling down the tube axis at a helix angle of 60º with the purpose of inducing circumferential flow to maintain the liquid film on the upper portions of the tube wall. Because of the difficulty of mass production in copper, the commercial application of micro-fin tubes to refrigeration and air-conditioning did not occur until the early 1990's (Bogart, 2021). Since its commercial availability, the micro-fin tube has become the most popular internal enhancement for evaporators and condensers of new unitary refrigeration and air-conditioning equipment, primarily as a result of its highest heat transfer with the lowest pressure drop as compared to other enhancements (Webb and Kim, 2005). Consequently, flow boiling heat transfer measurements and prediction models for the micro-fin tube with refrigerants are essential for the evaluation of their use for unitary applications.

As Lin et al. (2022) have shown, despite the fairly long history of the micro-fin tube, a simple and accurate prediction model is still needed. For the last few decades, pressure from the policies set by the Montreal Protocol (1987) and the Kigali Amendment (2016), the Kyoto Protocol (1997) and the European Mobile Directive (2006) have caused a shift to refrigerants with both zero Ozone Depletion Potential (ODP) and low Global Warming Potential (GWP). Consequently, a concerted effort has been made to develop new replacement refrigerants. However, many of the databases that were used to develop popular prediction models contain mainly hydrofluorocarbon (HFC) refrigerants and include only a few of the most recent replacement refrigerants. For example, the Thome et al. (1997) model predicts micro-fin test data for R134a and R123. Cavallini et al. (2006) developed a flow boiling heat transfer model for R22, R134a, R407C, R410A, R507A, and CO_2. Tang and Li (2018) developed a micro-fin flow boiling model using the following seven refrigerants: R22, R134a, R407C, R410A, R1234yf, R1234ze(E), R1234ze(Z) and CO_2. The micro-fin flow boiling correlation by Mehendale (2018) was developed with the following refrigerants: R12, R22, R 32, R134a, R404A, R410A, R1234yf, R1234ze(E), and CO_2. Although extensive, the database used for the Hamilton et al. (2008) model was for the following older refrigerants: R22, R32, R125, R410B, R32/R134a (27/73% and 30/70% mass), and R407C. More recent models from the National Institute of Standards and Technology (NIST) included refrigerants R134a, R1234yf/R134a, and R1234ze(E) (Kedzierski and Park, 2013) and refrigerants R448A, R449A, and R452B (Kedzierski and Kang, 2016). In addition, the databases for correlation development were limited to a single tube diameter for the following models: Thome et al. (1997), Hamilton et al. (2008), Kedzierski and Kang (2016), and Kedzierski and Park (2013). The databases used for the Cavallini et al. (2006), Tang and Li (2018), and Mehendale (2018) correlation had tube diameter of limiting ranges that differed between the studies. Being that the industry is rapidly switching to low-GWP refrigerants, a general model is needed that encompasses most all of the available data for micro-fin tubes so that a wide range of refrigerants and tube diameters can be used to produce an accurate representative predictive model for the HTC of new refrigerants in micro-fin tubes. This endeavor will ensure an accurate

[1] Certain trade names and company products are mentioned in the text or identified in an illustration in order to adequately specify the experimental procedure and equipment used. In no case does such an identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products are necessarily the best available for the purpose.