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Condensation of ethylene glycol on pin-fin tubes: Effect of circumferential pin spacing and thickness

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ABSTRACT

New experimental data are reported for condensation of ethylene glycol at atmospheric pressure and low velocity on five three-dimensional pin-fin tubes. The only geometric parameters varied were circumferential pin spacing and thickness, since these have been shown to have a strong effect on condensate retention on pin-fin tubes. Heat-transfer enhancement was found to be strongly dependent on the 'unflooded' area enhancement i.e. on the parts of the tube and pin surface not covered by condensate retained by surface tension. For all the tubes, vapour-side, heat-transfer enhancements were found to be approximately 2.5–3 times the corresponding unflooded area enhancements. An increase in the vapour-side, heat-transfer enhancement is noticed with decreasing values of pin spacing. The best performing pin-fin tube gave a heat-transfer enhancement of 4.9; equal to those obtained from an 'optimised' two-dimensional fin-tube reported in the literature and about 20% higher than the 'equivalent' two-dimensional integral-fin tube (i.e. with same fin-root diameter, longitudinal fin spacing and thickness and fin height).

1. Introduction

The mechanism of condensation heat transfer on rectangular and trapezoidal cross-section integral-fin tubes (hereafter referred to as 'integral-fin tubes') is relatively well understood (see for instance, Marto [1], Briggs and Rose [2]). Condensate is drained from the tips and flanks of the fins by surface tension induced pressure gradients, causing localised thinning of the condensate film and enhancing the local heat-transfer coefficient. Condensate retention or flooding between the fins at the bottom of the tube, however, leads to a decrease in available surface area and hence reductions in the heat transfer to that part of the tube. Fin spacing and the ratio of surface tension to density of the condensate have been identified as critical variables effecting condensate flow and retention and hence heat transfer. For steam, the highest heat-transfer enhancement ratio[1] reported in the literature is thought to be just over 4 by Wanniarachchi et al. [3]. For refrigerants, where low surface tension leads to reduced condensate flooding, the highest reported enhancement ratio was 10.2, by Honda et al. [4] for R-113. Finally, for ethylene glycol, which has a surface tension to density ratio between the two extremes of water and most refrigerants, Briggs et al. [5] reported a maximum enhancement of 4.8.

Attention is now focusing on tubes with more complex '3-dimensional' fin profiles. Honda et al. [4], Belghazi et al. [6] and Briggs et al. [7] presented data for various fluids condensing on commercially available tubes which had complex 3-dimensional profiles, as well as on integral-fin tubes with 2-dimensional rectangular and trapezoidal cross-section fins. Their results showed that the best of the 3-dimensional tubes gave similar heat-transfer performance to the best of the simpler 2-dimensional tubes. The tubes tested in the investigation were commercially available, and their geometries were presumably dictated by the need for mass production. Moreover, the tube geometries appear to have been chosen with a view to maximising surface area, while work on integral-fin tubes has demonstrated that this is not the only criteria for optimising heat transfer during condensation.

A simpler 3-dimensional geometry is illustrated in Fig. 1. These tubes, hereafter referred to as pin or pin-fin tubes, have rectangular cross-section pins, and can be characterised by 6 dimensions, namely pin-root diameter, pin height, longitudinal pin spacing and thickness and circumferential pin spacing and thickness. Sukhatme et al. [8] and Kumar et al. [9] reported data for R-11, R-134a and steam condensing on pin-fin tubes. For steam heat-transfer enhancement ratios only slightly higher than the increase in

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[1] Throughout this paper enhancement ratio is defined as heat-transfer coefficient of the enhanced tube, based on the fin or pin-root diameter, divided by that of a plain tube with diameter equal to the root diameter of the enhanced tube and at the same vapour-side temperature difference.

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