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Condensation heat transfer characteristics of zeotropic refrigerant mixture R407C on single, three-row petal-shaped finned tubes and helically baffled condenser

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ABSTRACT

Condensation heat transfer coefficients (HTCs) of zeotropic refrigerant mixture R407C on single horizontal petal-shaped finned (PF) tube and three rows of PF tubes with an in-line arrangement were experimentally measured. All measurements were taken at the vapour temperature 39 °C with the wall subcooling of 2–8 °C. The results showed that the average enhancement factor provided by the PF tube was about 5.02, and the effect of condensate inundation was significant for the PF tube. Furthermore, the experiments also were performed to compare the shell-side condensation HTCs of an integrally helical baffle condenser with PF tubes to those of that with low fin (LF) tubes at vapour temperature of 39 °C, the condensation HTCs of helically baffled condenser with PF tubes were about 1.56 times as large as that of helically baffled condenser with LF tubes at the same heat flux. Correlations have been suggested for both the shell-side condensation HTCs for the two condensers with different tube types and give very good agreement with experimental results. It is a promising route to use PF tubes instead of LF tubes for improving the performance of an integrally helical baffle condenser.

1. Introduction

Condensation of zeotropic mixtures is important in various industrial fields such as refrigeration, heat pumps, and chemical process industries [1–5]. One of the most common condenser technologies for heat pumps or refrigerant machines consists of a shell and tube heat exchanger in which the vapour condenses on the outer surface of the tube banks while the coolant flows through the inner passages of the tube banks. In order to apply zeotropic mixtures successfully in the condensers, their condensation heat transfer coefficients (HTCs) on the outside tubes need to be measured with their heat transfer characteristics analysed subsequently. Condensation of a zeotropic mixture differs from that of a pure fluid in only two ways [6,7]: Firstly, the effects of gliding temperature difference (GTD) can become apparent, and secondly the effects of mass transfer resistance are introduced. As the less volatile component is more liable to condense first the remaining mixture has a lower dewpoint temperature, thus causing the equilibrium temperature to fall. The practical significance of such a temperature fall, called “glide”, will be a reduction in temperature difference between the condensate and the coolant with a corresponding reduction in local heat transfer. Furthermore, the preferential condensation of the less volatile component causes a depletion of the less volatile component close to the interface. This means that the less volatile component must be transported through a film enriched by the more volatile component. A vapour diffusion layer appears between the bulk vapour and the condensate surface. This vapour film creates an additional mass transfer resistance to the condensation process.

In the last few decades, various types of enhanced surface tubes have been used to enhance the shell-side condensation of zeotropic mixtures. These enhanced tubes can be classified according to two types: two dimensional (2D) fin enhanced tubes with transverse plain fins and three-dimensional (3D) fin enhanced tubes with interrupted fins, spines (Turbo-C, Gewa C, Gewa SC, Tred-D and Thermoexcel C tubes, etc) [8–12]. When assessing the effectiveness of enhanced surfaces during heat transfer it is useful to define an enhancement factor (EF) which indicates the ratio of the condensation HTC of the enhanced tube over that of a smooth tube at the same wall subcooling $\Delta T = (T_{sat} - T_w)$. Jung et al. [8] measured the condensation HTCs of zeotropic mixtures of R32/R134a, R134a/R123 and R407C (R32/R125/R134a = 23/25/52 mass %) on a low fin (LF) tube and a Turbo-C tube. The results showed that, for all mixtures tested, the difference of EF between the Turbo-C tube and the LF tube was small. For R407C, EF was between 3 and 5 in the Turbo-C tube. Belghazi et al. [9] carried out experiments to

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