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Condensation heat transfer characteristics of CO_2 in a horizontal smooth- and microfin-tube at high saturation temperatures

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ABSTRACT

The condensation heat transfer characteristics for CO_2 at high saturation temperatures in a horizontal smooth- and microfin-tube were investigated by experiment with respect to condensation temperature and mass flux. The test sections consist of 2400 mm length with a horizontal copper tube of 4.6 mm (smooth) and 4.95 mm (microfin) inner diameter. The experiments were conducted at refrigerant mass flux of 400–800 kg/(m^{2}s), and saturation temperature of 20–30 °C. The main experimental results showed that annular flow almost dominated the major of condensation flow in the horizontal smooth- and microfin-tube. The condensation heat transfer coefficients for the smooth- and microfin-tube increase with the decreasing saturation temperature and increasing mass flux. The average heat transfer enhancement factor (EF) for the microfin tube is approximately from 1.006 to 1.48, and penalty factor (PF) varies from 1.14 to 1.23. The experimental data in the smooth- and microfin-tube were compared against previous heat transfer correlations. Most of correlations failed to predict the experimental data. However, the correlations by Kondou and Hrnjak [1] and Cavallini et al. [4] showed relatively good agreement with experimental data in the smooth- and microfin-tube, respectively. But it is necessary to develop accurate and reliable correlation to predict condensation heat transfer coefficient at high saturation temperatures in the horizontal smooth- and microfin- tube.

1. Introduction

During summer season, commercial refrigeration systems using CO_2 spend most operating hours in a transcritical cycle, while these systems at autumn and spring season are operated as a subcritical cycle. [1] The operation conditions of the subcritical cycle are quite different from those of the transcritical one.

In the summer season, the heat rejection temperatures of the transcritical system of CO_2 are usually above the critical temperature of CO_2 (31.1 °C), the systems using CO_2 will have to operate in the transcritical cycle. As such, the heat rejection takes place above the critical pressure in a so-called gas cooler (corresponding to the condenser in the subcritical systems), while the heat rejection process at autumn and spring season remains below the subcritical region. Consequently, the CO_2 heat transfer characteristics of the heat rejection process in the subcritical cycle are considerably different from those in the transcritical cycle. Thus, it is necessary to understand the characteristics of the subcritical cycle to ensure reliable system performance and to evaluate the annual performance.

Heat transfer enhancement has been a substantial factor to obtain high energy efficiency in refrigeration and air-conditioning applications. Microfin tubes represent a technology that has been able to beneficially enhance condensation heat transfer without causing similar increases in pressure drop and refrigerant charge, both in single-phase and two-phase application. Condensation heat transfer in microfin tubes is increased of (i) the larger surface area (A), (ii) the thinning of the condensate film (δ) by a redistribution of the liquid due to spiraling and surface tension forces, and (iii) the presence of film disturbances caused by the presence of the fins, all of which results in an increase of the thermal capacity performance of the heat exchanger [2,3].

For conventional refrigerants, flow condensation in smooth and microfin tubes was investigated by several researchers [4–14]. But, as shown in Table 1, the characteristics of CO_2 flow condensation heat transfer in horizontal smooth and microfin tubes are not well known. However, in recent years, some researchers [15–18] have studied for CO_2 condensation heat transfer inside smooth and microfin tubes.

As shown in Table 1, most of the previous studies about flow condensation in tubes were performed at low temperatures below

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