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Correlations for evaporation heat transfer coefficient and two-phase friction factor for R-134a flowing through horizontal corrugated tubes ☆

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ABSTRACT

Correlations for the evaporation heat transfer coefficient and two-phase friction factor of R-134a flowing through horizontal corrugated tubes are proposed. In the present study, the test section is a horizontal counter-flow concentric tube-in-tube heat exchanger with R-134a flowing in the inner tube and hot water flowing in the annulus. Smooth tube and corrugated tubes with inner diameters of 8.7 mm and lengths of 2000 mm are used as the inner tube. The corrugation pitches are 5.08, 6.35, and 8.46 mm and the corrugation depths are 1, 1.25, and 1.5 mm, respectively. The outer tube is made from smooth copper tube with an inner diameter of 21.2 mm. The correlations presented are formed by using approximately 200 data points for five different corrugated tube geometries and are then proposed in terms of Nusselt number, equivalent Reynolds number, Prandtl number, corrugation pitch and depth, and inside diameter.

1. Introduction

Heat transfer enhancement techniques can produce superior heat exchanger performance. One such technique is the use of corrugated tube instead of smooth tube. Corrugated tubes can enhance the heat transfer coefficient on both the outer and inner heat transfer surface area without a significant increase in pressure drop. Typically, corrugated tubes can improve the heat transfer performance of the heat exchanger by increasing fluid mixing, unsteadiness, turbulence flow or by limiting the growth of fluid boundary layers close to the heat transfer surface. Corrugated tubes are sometimes chosen for the design of industrial shell-and-tube heat exchangers in order to reduce the size of the heat exchangers. However, use of corrugated tubes to replace conventional smooth tubes has only been reported over the past two decades. It is still a new method for improving the heat transfer performance of heat transfer equipment. So far, the heat transfer and flow characteristics of corrugated tube have been reviewed as described in the following subsections and in Table 1.

Nozu et al. [1,2] investigated local heat transfer and pressure gradients of pure R-114, R-113 and a zeotropic refrigerant mixture during condensation in the annulus of a double-tube coil consisting of three U-bends and four straight lengths. A corrugated copper tube with an ID of 17.2 mm was used as the test section. Mass fluxes were tested in the range of 80 to 240 kg/sm^2. The results showed that the local heat transfer coefficient decreased along the tube length and that the U-bends showed higher heat transfer coefficients than straight lengths.

Dong et al. [3] experimentally determined the turbulent friction and heat transfer characteristics for four spirally corrugated tubes with various geometrical parameters. Water and oil were used as the working fluid. The experimental conditions were tested at Reynolds numbers ranging between 6000 and 93,000 for water, and from 3200 to 19,000 for oil. Compared with a smooth tube, their results showed that the heat transfer coefficient enhancement varied from 30% to 120%, while the friction factor increased from 60% to 160%.

Barba et al. [4] experimentally studied single-phase heat transfer and flow behaviour of corrugated tube used in the chemical and food industry. The tested conditions were done at moderate Reynolds numbers ranging from 100 to 800. In this study, ethylene glycol was used as the working fluid. The results offered a heat transfer enhancement ranging from 4.27 to 16.79, while the friction factor increased by up to 1.83–2.45 times compared to the smooth tube. Based on the experimental data, Nusselt number and friction factor correlations were proposed.

Rainieri and Pagliarini [5] experimentally investigated the thermal performance of corrugated tubes. Helical and transverse corrugated tubes with different pitches were used as the test section. Ethylene glycol was employed as the working fluid. The experimental conditions were conducted at Reynolds numbers ranging from 90 to 800.

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