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Evaporation heat transfer and friction characteristics of R-134a flowing downward in a vertical corrugated tube

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ABSTRACT

Differently from most previous studies, the heat transfer and friction characteristics of the pure refrigerant HFC-134a during evaporation inside a vertical corrugated tube are experimentally investigated. The double tube test sections are 0.5 m long with refrigerant flowing in the inner tube and heating water flowing in the annulus. The inner tubes are one smooth tube and two corrugated tubes, which are constructed from smooth copper tube of 8.7 mm inner diameter. The test runs are performed at evaporating temperatures of 10, 15, and 20 °C, heat fluxes of 20, 25, and 30 kW/m^2, and mass fluxes of 200, 300, and 400 kg/m^2 s. The quality of the refrigerant in the test section is calculated using the temperature and pressure obtained from the experiment. The pressure drop across the test section is measured directly by a differential pressure transducer. The effects of heat flux, mass flux, and evaporation temperature on the heat transfer coefficient and two-phase friction factor are also discussed. It is found that the percentage increases of the heat transfer coefficient and the two-phase friction factor of the corrugated tubes compared with those of the smooth tube are approximately 0–10% and 70–140%, respectively.

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1. Introduction

Since the depletion of the ozone layer and global warming have been discovered, many conventional refrigerants are being phased out from industries. Consequently, the refrigeration industry has switched over to "ozone-friendly" refrigerants such as R-134a. Therefore, improving the performance of heat transfer equipment which uses R-134a is necessary. The thermal performance of heat transfer equipment can be improved by using heat transfer enhancement techniques. In general, heat transfer enhancement techniques are classified into two groups: active methods and passive methods. Active methods are those that use the addition of external power essentially to facilitate the desired flow modification and concomitant improvement in the rate of heat transfer such as mechanical vibration, injection, and electric field. The second group is passive methods which do not require direct input of external power such as surface modification.

The rough surface technique is a passive method that usually involves surface modification to promote turbulent flow and increases the heat transfer surface area. Normally, smooth tubes are replaced by corrugated tubes in many heat exchangers to increase the heat transfer rate by mixing and also limiting the fluid boundary layers close to the heat transfer surfaces. Moreover, they can promote two-phase heat transfer enhancement.

Over the years, the heat transfer and flow characteristics of refrigerants have been studied by a large number of researchers, both experimentally and analytically, mostly in horizontal straight tubes (Goldstein et al. [1]). Study of the heat transfer and pressure drop of refrigerant in vertical tubes has received comparatively little attention in the literature. Publications on the heat transfer and flow characteristics of refrigerant flow in vertical tubes are summarized as follows.

Ma et al. [2] experimentally studied the heat transfer and pressure drop characteristics for condensation of downward flow of R113 in vertical smooth and micro-fin tubes. Lee and Chang [3] investigated the heat transfer characteristics in the post-dryout region for the boiling of up-flow of R-134a in vertical smooth tubes and rifled tubes. Cheung et al. [4] studied the EHD-assisted external condensation of R-134a in vertical and horizontal smooth tubes. Experimental results demonstrated a remarkable potential in utilizing EHD to enhance external condensation heat transfer. Among all these studies, extensive studies concerning the condensation of R-134a in vertical smooth tubes have been continually performed by Dalkilic et al. [5]. The two-phase pressure drop during condensation of R-134a was studied. A new correlation for the two-phase friction factor was presented by means of the equivalent Reynolds number. In a series of studies, Dalkilic et al. [6,7] presented the effect of void fraction models on the two-phase friction

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