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Evaporation heat transfer of R-134a inside a microfin tube with different tube inclinations

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ABSTRACT

An experimental investigation has been carried out to study the heat transfer characteristics during evaporation of R-134a inside a single helical microfin tube. The microfin tube has been provided with different tube inclination angles of the direction of fluid flow from horizontal, α. The experiments were performed for seven different tube inclinations, α, in a range of $-90°$ to $+90°$ and four mass velocities of 53, 80, 107 and 136 kg/m^2 s for each tube inclination angle during evaporation of R-134a. The results demonstrate that the tube inclination angle, α, affects the boiling heat-transfer coefficient in a significant manner. For all refrigerant mass velocities, the best performing tube is that having inclination angle of $\alpha = +90°$. The effect of tube inclination angle, α, on heat-transfer coefficient, h, is more prominent at low vapor quality and mass velocity. An empirical correlation has also been developed to predict the heat-transfer coefficient during flow boiling inside a microfin tube with different tube inclinations.

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1. Introduction

Evaporator is an integral part of refrigeration and air-conditioning systems which determines the performance of the whole system. Therefore, the design of efficient evaporators has always been significant to equipment designers. In this regard, the use of augmentative techniques, either active or passive, to increase the convective heat transfer rates on tube side has been studied for quite some time [1,2]. One of the passive techniques to enhance heat-transfer coefficient is the application of microfin tubes. Microfin tubes represent a technology that is able to beneficially enhance the heat transfer without causing a large increase in the pressure drop and have been widely used in refrigeration and air-conditioning systems [3].

Many experimental studies reporting on the effects of fin geometry [4], presence of lubricating oil in refrigerant [5] and different refrigerants flows [6] on the performance of microfin tubes have been published. A review of the existing literature reveals that, although vast studies have been done on heat transfer enhancement in these tubes, yet the focus of almost all of the studies is on two-phase refrigerant flow in horizontal tubes. Infact, apparently only one test has been done for evaporation in the vertical orientation. Kattan et al. [7] ran tests for R-134a and R-123 in a microfin tube with an 11.9 mm maximum internal diameter. They ran tests for the same test-section for vertical upflow and horizontal flow under identical operating conditions to determine the possible benefit of using microfins in vertical thermosyphon reboilers. The experiments showed a significant effect of flow direction on heat transfer and it was found that the heat-transfer coefficient for horizontal flow is more than that for vertical upward flow.

It is obvious that the flow pattern in an evaporator tube plays an important role on the characteristics of heat transfer. The heat-transfer coefficient generally keeps changing as the flow pattern changes along an evaporator tube. On the other hand, the flow regime is influenced by interfacial shear stress, surface tension and gravitational force. Thus, there is a great necessity to consider and study the effect of gravitational force on heat transfer rate during evaporation of refrigerants inside a tube. Therefore, an experimental investigation has been carried out to study the evaporation of R-134a inside a microfin tube with different inclinations of the tube. In our previous paper [8], condensation of R-134a vapor inside inclined microfin tubes has been studied. The experimental results indicate that the tube inclination affects the condensation heat transfer in a significant manner.

2. Test apparatus and procedure

The schematic diagram of the test apparatus has been shown in Fig. 1. Infact, the experimental set-up was a well instrumented vapor compression refrigeration system. The test apparatus consisted of a test-evaporator having a test-section length of 1100 mm. The test-section was a copper tube having internal microfins with triangular fin cross-section. The geometrical parameters of microfin are the same as that used in our previous work [8]. This tube

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