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A complete evaluation method for the experimental data of flow boiling in smooth tubes

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ABSTRACT

A complete solution for boiling phenomena in smooth tubes has been giving as a procedure regarding with the calculation of convective heat transfer coefficient and pressure drop using accurate experimental data validated by flow regime maps and sight glasses on the experimental facility. The experimental study is conducted in order to investigate the effect of operating parameters on flow boiling convective heat transfer coefficient and pressure drop of R134a. The smooth tube having 8.62 mm inner diameter and 1100 mm length is used in the experiments. The effect of mass flux, saturation temperature and heat flux is researched in the range of 290–381 kg/m^2 s, 15–22 °C and 10–15 kW/m^2, respectively. The experiments revealed that the heat transfer coefficient and pressure drop are significantly affected by mass flux for all tested conditions. Moreover, the experimental results are compared with well-known heat transfer coefficient and frictional pressure drop correlations given in the literature. In addition, 122 number of heat transfer and pressure drop raw experimental data is given for researchers to validate their theoretical models.

1. Introduction

Determination of flow boiling heat transfer coefficient and frictional pressure drop are very important issue for design of evaporator used in the air conditioning and refrigeration applications. The evaporator having high heat transfer rate and low pressure drop is always desired. The experiments are conducted by many researchers in order to determine boiling heat transfer coefficient and frictional pressure drop and some of them can be summarized as follows:

Jabardo et al. [1] performed an experimental study in order to determine convective boiling performance of R134a, R22 and R404a flowing in horizontal tube. They researched effect of mass flux, heat flux, saturation temperature and refrigerant type on heat transfer coefficient. They observed that R134a has the maximum heat transfer coefficient value compared to other tested refrigerants for tested conditions. As another result of the study, they stated that nucleate boiling effect can be observed high heat flux and vapor quality conditions.

Wongwises et al. [2] conducted evaporation experiments by using R134/lubricant flowing in horizontal tube. The experiments revealed that heat transfer coefficient increases with increasing mass flux, heat flux as expected. They compared experimental results with the correlations given literature and developed correlation for prediction of heat transfer coefficient. They stated that developed correlation can predict experimental results in the range of ± 30.

Choi et al. [3] investigated the evaporation heat transfer of refrigerants flowing in horizontal smooth tube. They observed similar results for effect of parameters on heat transfer coefficient and developed a new correlation for evaporation heat transfer coefficient by means of superposition method. It was observed that the developed correlation can predict experimental results with absolute average deviation of 13.2%.

Sripattrapan and Wongwises [4] developed an annular flow model in order to determine axial heat transfer coefficient and pressure drop variations of refrigerants. In the model, a horizontal tube under constant heat flux is considered and two-phase separated flow model is used. The model showed that heat transfer coefficient of vapor, tube wall temperature, liquid and vapor refrigerant temperature decreases along the tube while transfer coefficient of liquid increases.

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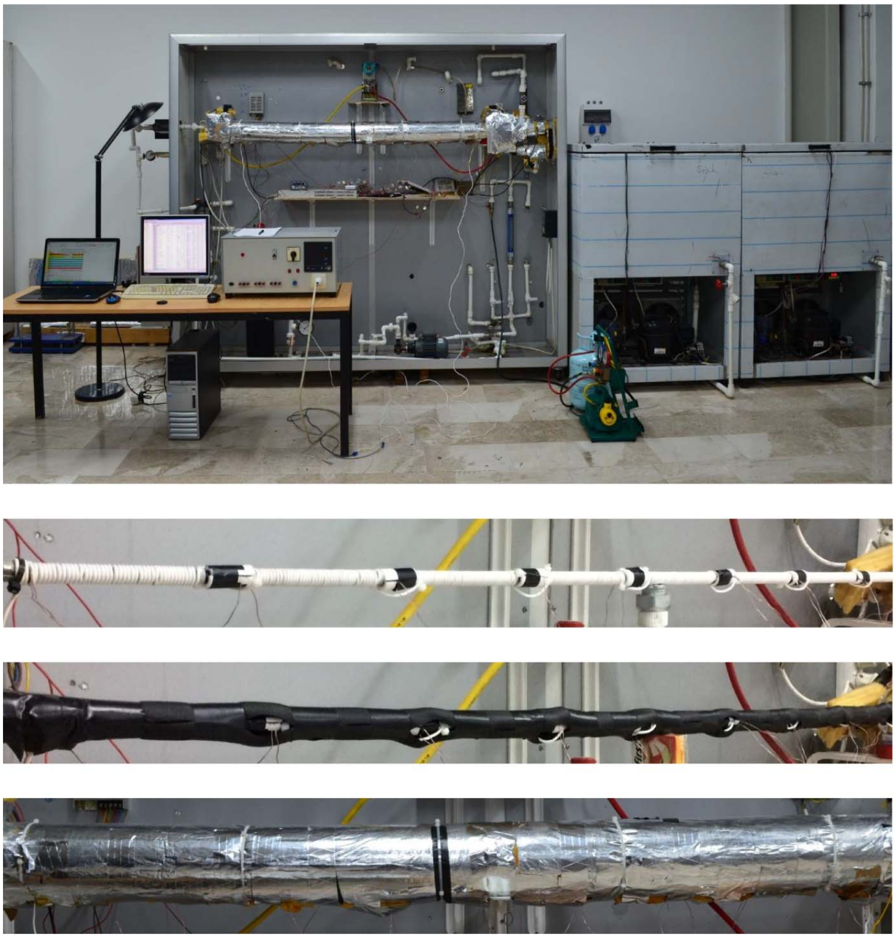

a) b) c) d)

Fig. 1. Photography of a) test facility, b) resistance wrapped test tube, c) first layer insulation d) test section.

Greco [5] researched the main parameters affecting convective boiling heat transfer by using different refrigerants and wide range of operation conditions. Experiments showed that heat transfer coefficient increase with increasing mass flux, heat flux and saturation temperature and R134a performed the highest heat transfer performance among the tested refrigerants. They also proposed a criterion for transition from nucleate boiling to convective boiling.

Lima et al. [6] investigated boiling heat transfer prediction performance of correlations having different types such as strictly empirical, strictly convective, superposition and flow pattern based. They conducted experiments for different operation conditions by using R134a as refrigerant to evaluate prediction performance of these correlations. They concluded that the prediction of superposition and flow pattern based methods are better than the other for all experimental results. Moreover, they also pointed out that strictly empirical method has high prediction performance for slug pattern.

Del Col [7] experimentally investigated flow boiling heat transfer of refrigerants at such high temperatures. They stated that the nucleate boiling regime has serious effect at high saturation temperatures. Moreover, they observed that the heat transfer coefficient decreases with increasing vapor quality for R410A and mentioned about the similar results given in the literature for carbon dioxide. As another results of the study, they compared experimental results with flow boiling well-known correlations.

Padilla et al. [8] visualized two-phase flow regime of R134a and HFO-1234yf by using glass tube and they observed similar flow patterns for both refrigerants for the same operating conditions. They also pointed out that Wojttan et al. map [9] can be used for determination of flow pattern in two-phase flows since experimental visualization result are in the good agreement with it. Moreover, they experimentally compared frictional pressure drop of R134a, HFO-1234yf and R410a and it was seen that R134a has the highest pressure drop among them because of highest density ratio and viscosity ratio.

Grauso et al. [10] presented an experimental study to compare heat transfer and pressure drop performances of R134a and R1234ze(E). The experiments showed that local heat transfer results of both refrigerants are so similar but earlier dryout occurs in R1234ze(E) flow compared to R134a. In addition, it was seen that the adiabatic frictional pressure drop of R134a is lower than R1234ze(E) and it increases with decreasing saturation temperature of refrigerant.

Mohseni and Akhavan-Behabadi [11] experimentally investigated the influence of inclination angle on heat transfer and flow pattern of R134a evaporating in smooth tube. They observed that tube inclination has serious effect on heat transfer coefficient especially in low mass and vapor qualities. The highest heat transfer coefficient is obtained for vertical upward flow for seven different inclinations. Moreover, they proposed an equation for determination of flow boiling heat transfer coefficient of R134a flowing in inclined tubes.

Chiapero et al. [12] researched influence of mass and heat fluxes on heat transfer coefficient, pressure drop and flow pattern during flow boiling. They observed that both heat transfer coefficient and dryout