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EXPERIMENTAL STUDY OF HEAT TRANSFER CHARACTERISTICS OF R744/R1270 IN A SMOOTH HORIZONTAL TUBE

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ABSTRACT

This paper presents the heat transfer and pressure drop characteristics of the refrigerant mixture of R744/R1270 flowing through the horizontal smooth tube. The refrigerant mixture is studied in different mass and heat flux conditions. Experimental results on the heat transfer coefficient, inner wall temperature and Nusslet number of mass flux from 40 to 80 kg/ m^2 *s in a horizontal smooth tube of 4 mm inner diameter are provided and compared with correlations. It is found that the mixture combination of R744/R1270 in 25/75 at a mass flux of 80 kg/* m^2 *s gives maximum heat transfer.*

Keywords: heat flux, mass flux, refrigerant mixture

1. INTRODUCTION

Conventional refrigerants, such as the CFCs and their alternatives the HFCs, have potential environmental problems, so their use is being curtailed. CO2 is non-flammable and nontoxic with a zero ozone depletion potential (ODP), and a global warming potential (GWP) that is very small compared with other conventional refrigerants such as R134a; therefore, CO2 is a promising refrigerant for environmental, economical and safety reasons, and is being applied in automobile air-conditioning, heat pump or other low temperature refrigeration systems, as suggested by Lorentzen and Pettersen (1993) and Riffat et al. (1997).

2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1. Experimental apparatus

The experimental system used to investigate the heat transfer of R744/R1270 in a horizontal tube during evaporation is shown schematically in Fig. 1 and it was used similar to the set up and working as mentioned by Cho et al (1). The refrigerant loop consists of a pump, test section, a Coirolis-type mass flow meter, a pre-heater and a condenser. The liquid refrigerant is pumped via pump. Then the refrigerant passes through a Coirolis-type mass flow meter before entering the pre-heater. The pre-heater is used to control the vapor quality at the test section inlet. A direct-current heating is applied on the test section. The refrigerant enters the test section in two-phase state. The test section consists of

5 mm outer diameter with 0.25 mm thick copper tube having length of 1.44 m. The wall temperature is measured using type-T, thermocouples, positioned on the Surface. The applied heat flux is measured by power meters. The refrigerant leaves the test section in two-phase or superheated state. It enters then a counter-current condenser where it is sub-cooled before entering the pump. Pressure is measured at the test section inlet and outlets. Flow boiling tests were then performed at different mass fluxes and heat fluxes.

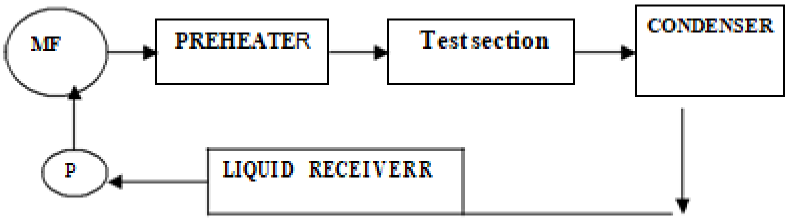

Figure.1. Schematic experimental set up

2.2. Data reduction

The thermo physical properties are calculated based on the measured temperature and pressure. The local heat transfer coefficient at each thermocouple is calculated based on the following equation

$$h = q / (T_w - T_{sat})$$

Where, q- heat flux, Tw is the inner wall surface temperature and Tsat is the saturated temperature of the refrigerant deduced from the fluid pressure. The variations of the refrigerant thermo-physical properties in the test section were calculated with REFPROP 8.0.

3. RESULTS AND DISCUSSIONS

Despite the recent intense activity carried out in order to investigate flow boiling heat transfer, there is still a lack of information and reliable data, particularly for natural refrigerants and mixtures, if compared to the wide range of engineering applications. Heat transfer coefficients (HTCs) are found to depend on some or all of the following parameters: heat flux, reduced pressure, vapor quality and often mass velocity; furthermore they might depend on surface roughness and channel geometry. Most authors have suggested equations based on nucleate boiling and two-phase forced convection components, some of which developed for macro channels. Only Miyata et al. (2011) present a correlation to predict heat transfer coefficients with vaporization which takes into account nucleate boiling, forced convection evaporation and evaporation heat transfer through thin liquid film around vapor plugs in slug flow. Several equations have been proposed, but none is widely accepted.

3.1. Behaviour of R744/R1270 mixture at different heat flux conditions

The variation of heat transfer co efficient, inner wall temperature of the test section and Nusslet number on the quality of refrigerant mixture flowing through the horizontal tube at different heat flux conditions is shown in fig. 2-4.

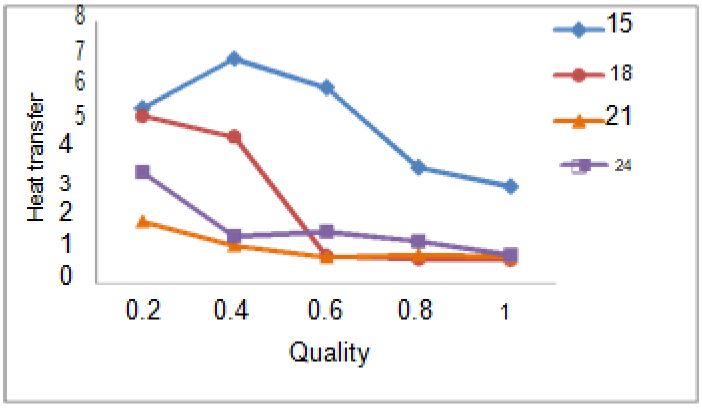

Figure.2 Variation of heat transfer Vs quality at different heat flux

The heat transfer co efficient of the mixture at 15 and 18 Kw/m^{2}s is high at the beginning and then starts decreasing sharply towards the length of the tube. But at the heat flux of 21 and 24 Kw/m^{2}s it decreases gradually as it is evident from fig 2. Inner wall temperature of the test section increases steadily from the beginning for all the heat flux conditions with slight variation for the heat flux of 21 Kw/m^{2}s at the end of the tube as in fig 3.The higher inner wall temperature occurs for the high heat flux of 24 Kw/m^{2}s.

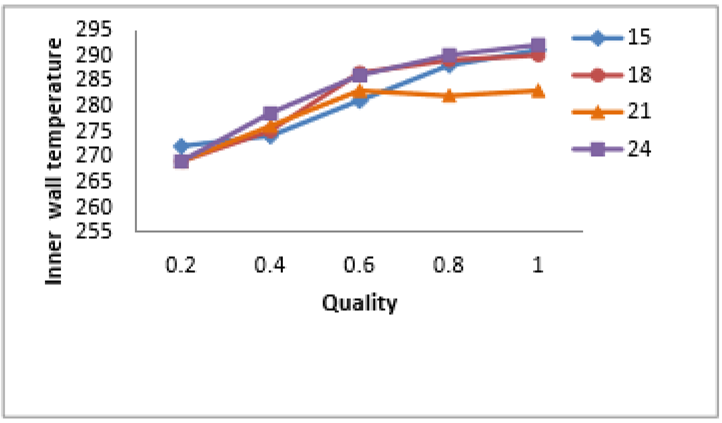

Figure 3 Variation of inner wall temperature vs quality at different heat flux

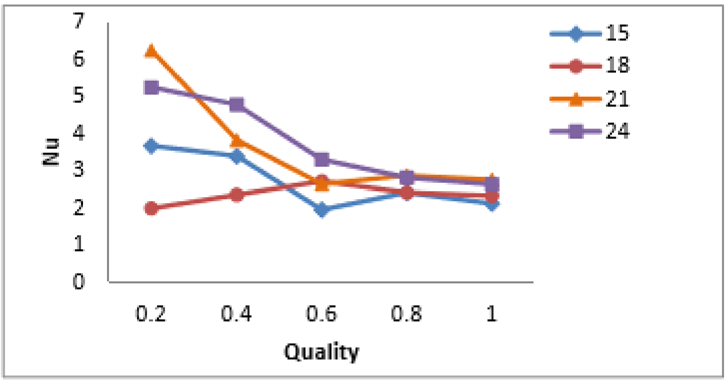

Figure 4 Variation of Nusselt number vs quality at different heat flux

The Nusselt number initially has high value for the mixture but decreases along the test section as in fig 4. The value is highest at the heat flux of 24 Kw/m^2s as compared with other heat fluxes and is low for the heat flux of 18 Kw/m^2s.The variation of the Nussle number almost follows similar pattern except for 18 Kw/m^2s heat flux condition. 3.2 Behaviour of R744/R1270 mixture at different mass flux conditions

The variation of heat transfer co efficient, inner wall temperature of the test section and Nusslet number on the quality of refrigerant mixture flowing through the horizontal tube at different mass flux conditions is shown in fig. 5-7.

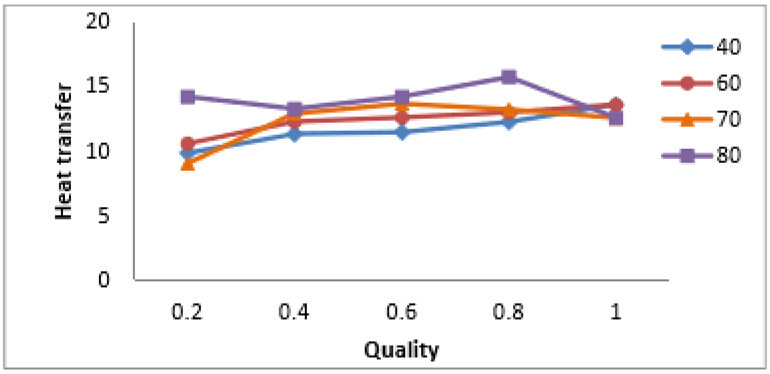

Figure 5 Variation of heat transfer vs quality at different mass flux

The heat transfer co efficient of the refrigerant mixture varies steadily in the range of 40-80 Kg/m^2s with a deviation for the mass flux of 70 Kg/m^2s.The higher heat transfer takes place at higher mass flux and lower value at mass flux as expected. At higher mass flux the heat transfer co efficient initially starts decreasing and the slowly increases and again decreases. For all mass fluxes the heat transfer coefficient almost in the middle of the test section seems stable.

The inner wall temperature of the tube initially increases and slightly decreases at the end. The inner wall temperature steadily increases at a mass flux of 80 Kg/m^2s.Heat transfer coefficient at low mass fluxes decreases in the last portion of the tube as in fig .6.

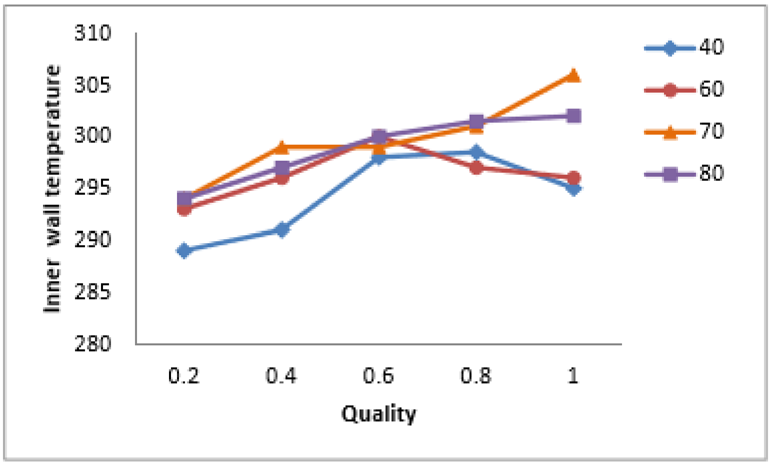

Figure 6 Variation of inner wall temperature vs quality at different mass flux

The variation of Nusslet number of the mixture on the quality along the tube is shown in fig7. Higher value Nusslet number is evident at a mass flux of 40 and low value is for the mass flux at 80 .The value of Nusslet number for the other mass fluxes lies in between these range and it appears that an unstable.

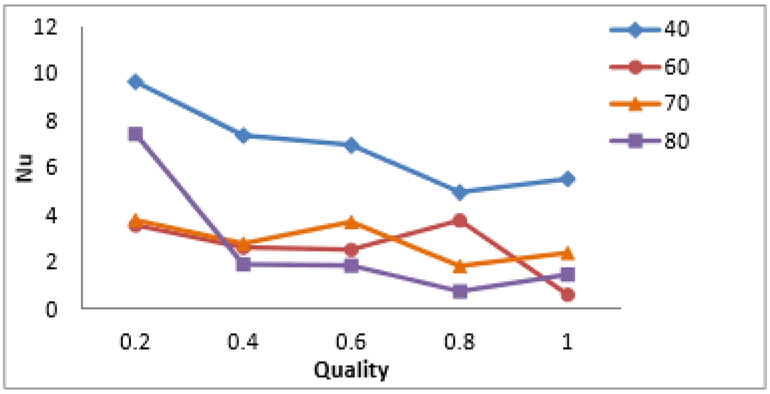

Figure 7 Variation of Nusseltt number vs quality at different mass flux

4. CONCLUSIONS

Experimental results for the flow boiling of R744/R1270 as 25/75 mixture combination in a horizontal tube under variations in the mass flux and heat flux were presented. The behaviours of the local heat transfer coefficient, inner wall temperature and Nusselt number were investigated and the following conclusions could be drawn from this study:

- In the low heat flux conditions, it was possible to observe a significant influence of heat flux on the heat transfer coefficient. In the high heat flux conditions, this influence tended to disappear and the coefficient decreased;
- The influence of mass velocity on the heat transfer coefficient was detected which became higher as the mass flux increased. To fully exploit the opportunity with natural refrigerants, it is necessary to rely on trustworthy tools for predicting heat transfer coefficients and associated frictional pressure drops. Particularly with in tube boiling of natural refrigerants in mini-geometries, accepted general predicting procedures are still far from satisfactory, and an increased research effort on this matter definitely desirable

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