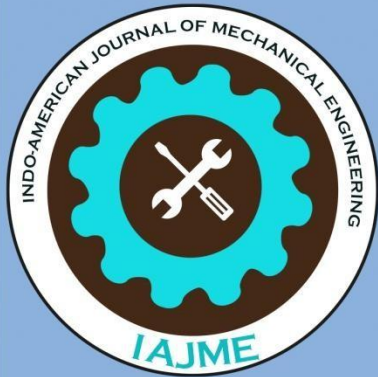


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Investigation of R744/R134a Heat Transfer Properties in a Smooth Horizontal Tube

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ABSTRACT

This study details the heat transfer properties of a refrigerant combination running via a horizontal smooth tube, namely R744/R134a. We test the refrigerant combination under a variety of intake temperature, heat flux, and mass circumstances. Here are the experimental findings for a horizontal smooth tube with an inner diameter of 4 mm, a mass flux ranging from 40 to 80 kg/m² s, and the heat transfer coefficient, inner wall temperature, and exergy of mass flow. The most efficient heat transfer is achieved with a mixture of R744 and R134a in a ratio of 25:75 with a mass flow of 80 kg/m² s.

Keywords: heat flux, mass flux, refrigerant mixture

1. INTRODUCTION

The usage of conventional refrigerants is being reduced due to their possible environmental hazards. These refrigerants include CFCs and their substitutes, HFCs. According to Lorentzen and Pettersen (1993) and Riffat et al. (1997), carbon dioxide (CO₂) is being used in low temperature refrigeration systems, heat pumps, and automobile air conditioners because it is non-flammable, nontoxic, and has zero ozone depletion potential (ODP) and a very small global warming potential (GWP) compared to other conventional refrigerants like R134a.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1. Experimental apparatus

A method comparable to that described by Cho et al. was used to study the heat transmission of R744/R134a in a horizontal tube during evaporation, as shown in Figure 1. (1). A pump, test



section, pre-heater, condenser, and Coirolis-type mass flow meter make up the refrigerant loop. A pump is used to transfer the liquid refrigerant. A Coirolis-type mass flow meter is the next stop before the refrigerant reaches the pre-heater. The intake vapor quality to the test section may be controlled with the help of the pre-heater. In a two-phase condition, the refrigerant first enters the test section. The test section is a 1.44-meter-long copper tube with an outside diameter of 5 millimeters and a thickness of

0.25 millimeters. The surface-mounted type-T thermocouples are used to gauge the wall temperature. Once the test segment is completed, the refrigerant is either in a two-phase or superheated condition. Subcooling occurs in a counter-current condenser before the fluid reaches the pump. The test section's inlet and outlets are used to monitor pressure. After that, we tried various mass flows, heat fluxes, and input temperatures in our flow boiling experiments.

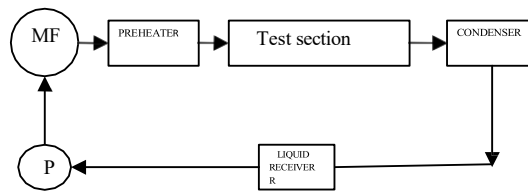


Fig.1. Schematic experimental set up

2.2 Data reduction

By measuring the temperature and pressure, the thermo physical characteristics may be computed. The equation $h = q / (T_w - T_{sat})$ is used to get the local heat transfer coefficient at each thermocouple. Assuming a constant fluid pressure, the saturated temperature of the refrigerant (T_{sat}) and the inner wall surface temperature (T_w) are defined in this context. The test section's fluctuations in the refrigerant's thermo-physical characteristics were computed using REFPROP 8.0.

3. RESULTS AND DISCUSSIONS

A number of factors, including heat flow, decreased pressure, vapor quality, mass velocity, surface roughness, and channel shape, are

discovered to influence heat transfer coefficients (HTCs). Evaporation heat transfer via thin liquid layer surrounding vapor plugs in slug flow, nucleate boiling, and forced convection evaporation are all factors that Miyata et al. (2011) consider when predicting heat transfer coefficients with vaporization. Despite several suggested equations, none of them have gained widespread acceptance.

3.1 Behaviour of R744/R134a mixture at different mass flux conditions

The variation of heat transfer coefficient, inner wall temperature and exergy on the quality of refrigerant mixture flowing through the horizontal tube at different mass flux conditions of the refrigerant mixture of R744/R134a in combinations of 25/75, 50/50 and 75/25 is shown in fig. 2-4(a-d).

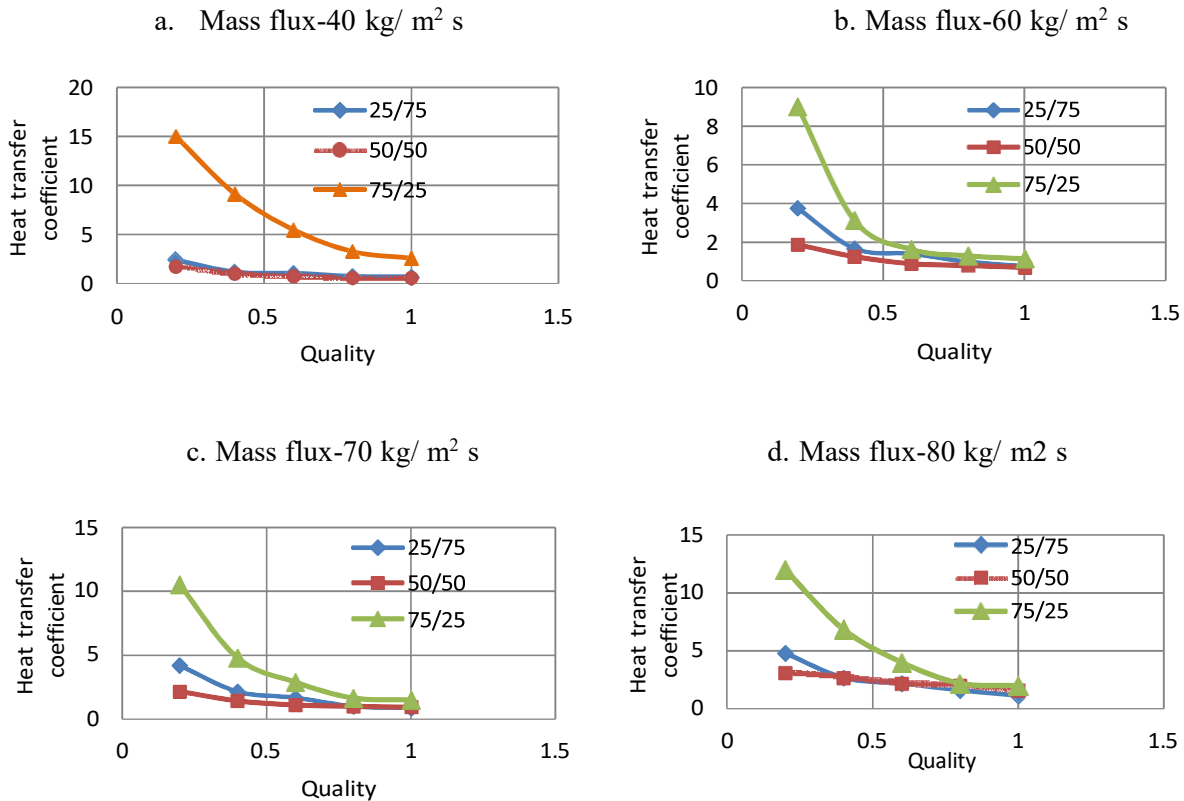


Fig.2 Variation of heat transfer coefficient at different mass fluxes

The heat transfer coefficient of refrigerant mixture in three combination at the mass fluxes of 40, 60, 70 and 80 kg/ m² s is shown in the above figure2 (a-d). In all the cases the heat transfer coefficient of mixture of 25/75 is higher than the mixture of 50/50 at the same time the highest value is for the mixture combination 75/25. The heat transfer coefficient at the mass flux 40, the mixture of 25/75 and 50/50 combination is almost same but for the mixture of 75/25 is well above and reduces drastically.

The heat transfer coefficient for the mass fluxes 60, 70 and 80 follows the similar pattern in the flow. In all the cases the heat transfer coefficient is maximum for the refrigerant mixture of 75/25.

The inner wall temperature along the test section at different mass flux conditions of 40, 60, 70 and 80 are shown in the following figure 3(a-d).

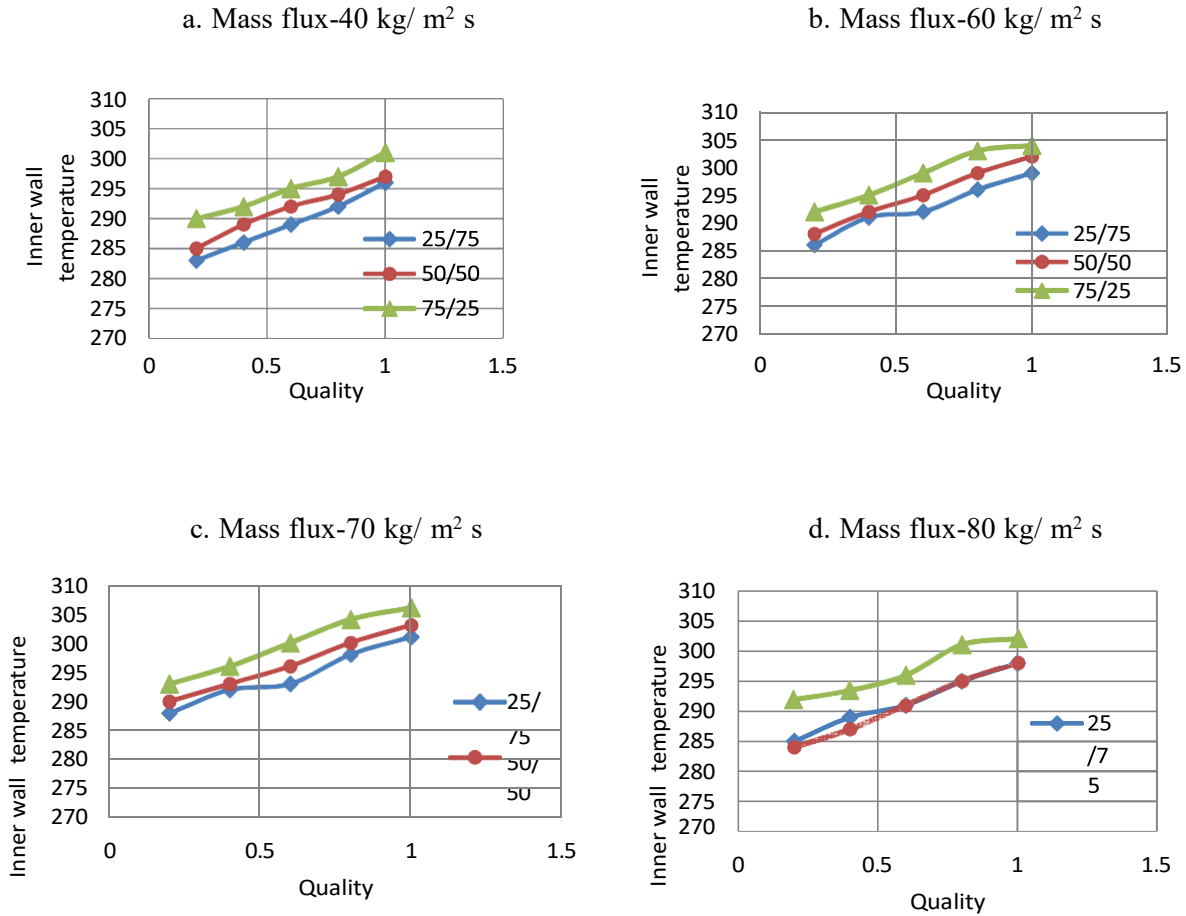


Fig.3 Variation of inner wall temperature vs quality at different mass fluxes

Inner wall temperature of the test section for three refrigerant mixtures namely 25/75, 50/50 and 75/25 is following same pattern for all the mass flux conditions. The inner wall temperature increases along the test section, lower value for 25/75 mixture followed by 50/50 mixture with the maximum value is for 75/25 mixture as evident from the above figure.

The exergy of the refrigerant mixture flowing through the test section for three combinations at different mass fluxes is shown in the fig4(a-d).

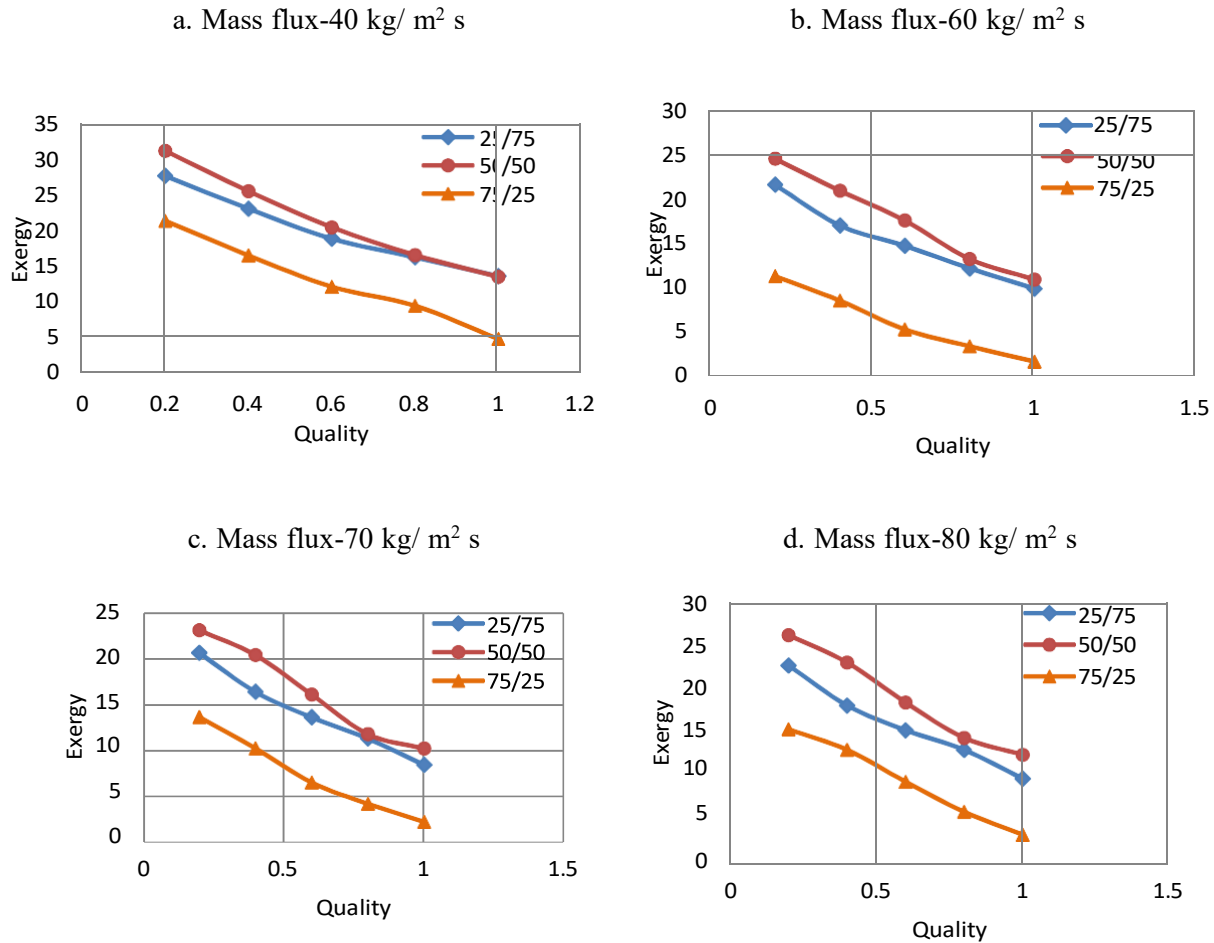


Fig.4 Variation of exergy vs quality at different mass fluxes

Exergy variation of mixtures in all the three combinations at four different mass fluxes 4, 60, 70 and 80 are following the same pattern in general. The exergy of fluid decreases towards the end of tube. The exergy value of 25/75 mixture refrigerant lies in between the higher value of 50/50 and lower value of 75/25 mixtures. The exergy of the mixture approaches close value before end point of the tube for the mass fluxes 40,60 and 70 kg/ m² s.

3.2 Behaviour of R744/R134a mixture at different heat flux conditions

The variation of heat transfer coefficient, inner wall temperature and exergy on the quality of refrigerant mixture flowing through the horizontal tube at different heat flux conditions is shown in fig. 5-7.

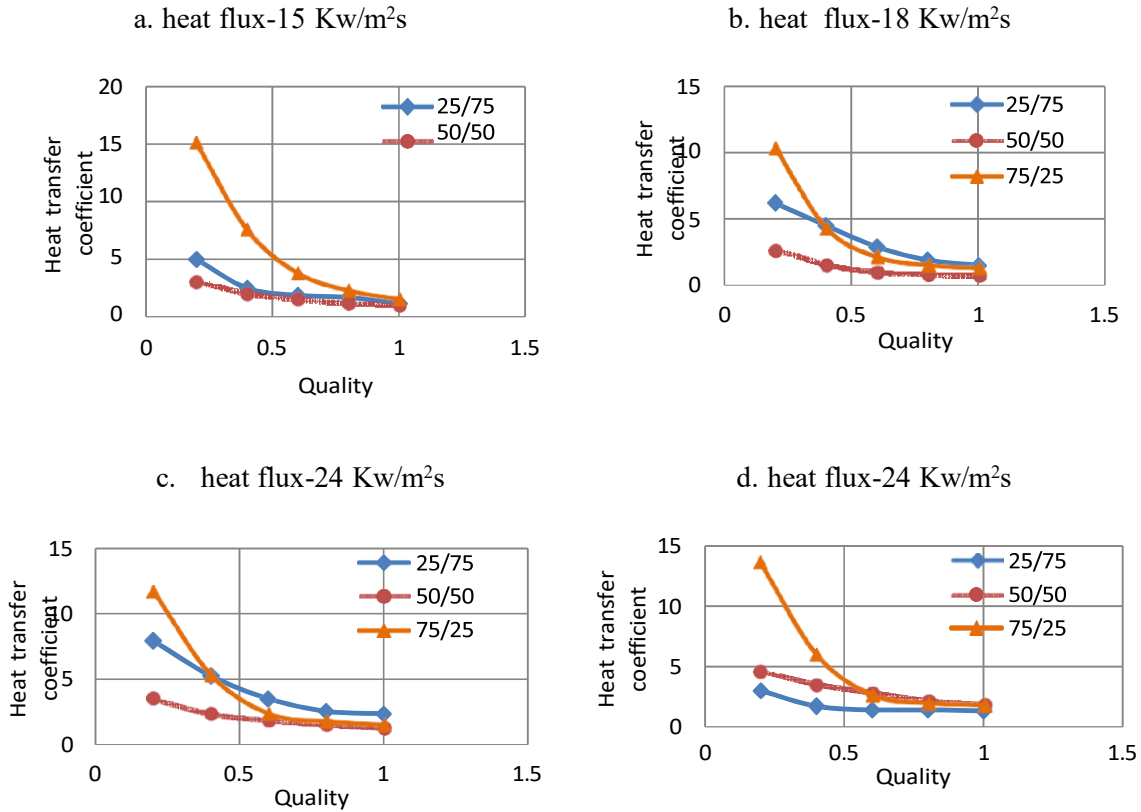


Fig.5 Variation of heat transfer coefficient vs quality at different heat flux

As the combination moves down the tube, its heat transfer coefficient drops precipitously from its initial high value. Mixtures of 50/50 and 25/75 have the lowest and somewhat greater heat transfer coefficients, respectively. For the 75/25 combination, the largest value is at the beginning of the section, and it continues to decrease towards the end of the tube, reaching a low point at the conclusion. At a heat flux condition of 24 Kw/m²s, however, the heat transfer coefficient is lowest for a 25/75 combination, then 50/50, and finally highest for a 75/25 blend; in other words, the blend acts differently at this mass flux. As shown in figure 6 (a-d) below, the temperature of the test section's inner wall rises continuously from the start for all heat flow circumstances and mixes.

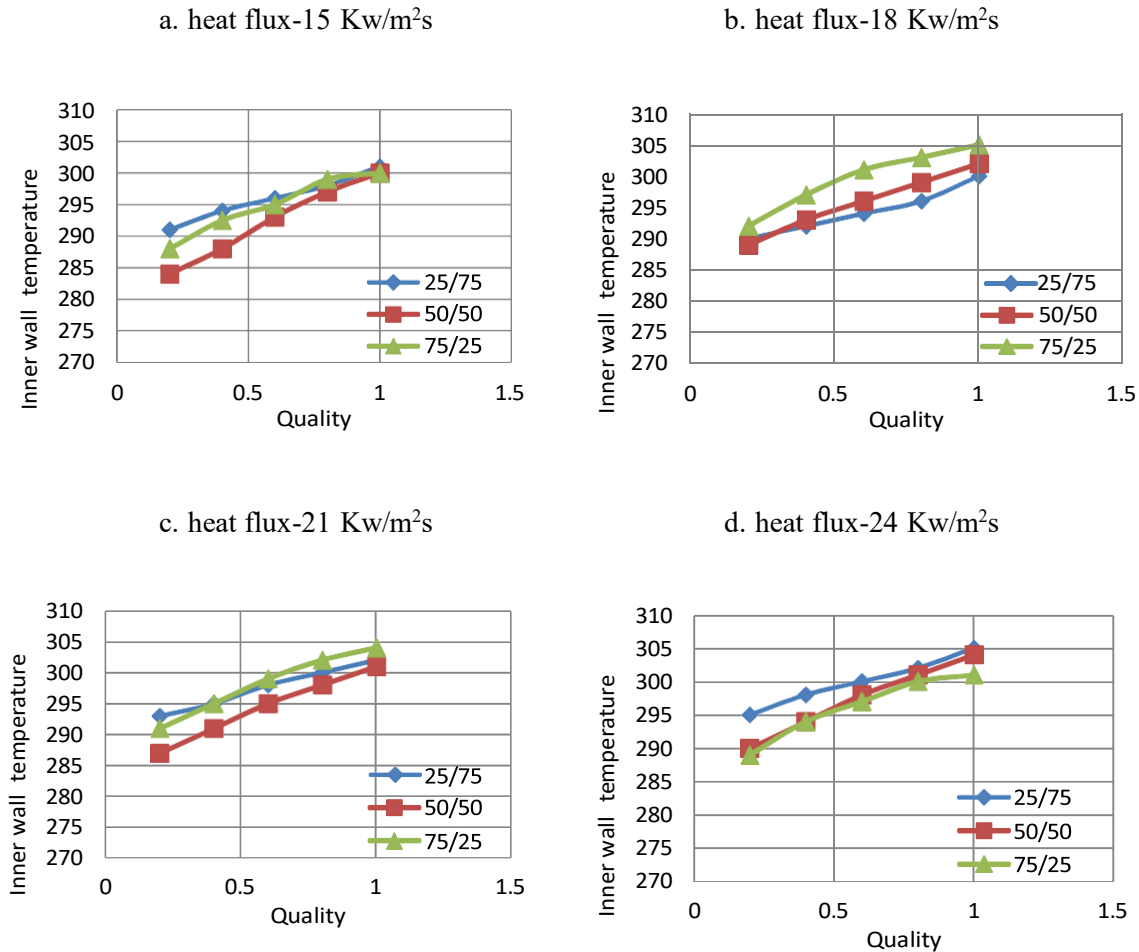


Fig. 6 Variation of inner wall temperature vs quality at different heat flux

Variation of inner wall temperature of the test section for all the heat flux conditions are behaves in different way. At 15Kw/m²s the inner wall temperature is maximum for 25/75mixture and lower value is for 50/50 mixture between these two 75/25 mixture lies as the temperature increases towards the end of the tube as in fig a above.

At 18Kw/m²s the inner wall temperature is maximum for 75/25mixture and lower value is for 25/75 mixture between these two 50/50 mixture lies as the temperature increases towards the end of the tube as in fig b above.

At 21Kw/m²s the inner wall temperature is maximum for 75/25mixture and lower value is for 50/50 mixture between these two 25/75 mixture lies after first quarter of the tube as the temperature increases towards the end of the tube as in fig c above.

At 24Kw/m²s the inner wall temperature is maximum for 25/75mixture and lower value is for 75/25 mixture between these two 50/50 mixture lies as close as to 75/25 as in fig d above.

The variation of exergy of the mixture on the quality along the tube at different heat fluxes for three blends is shown in fig7(a-d).

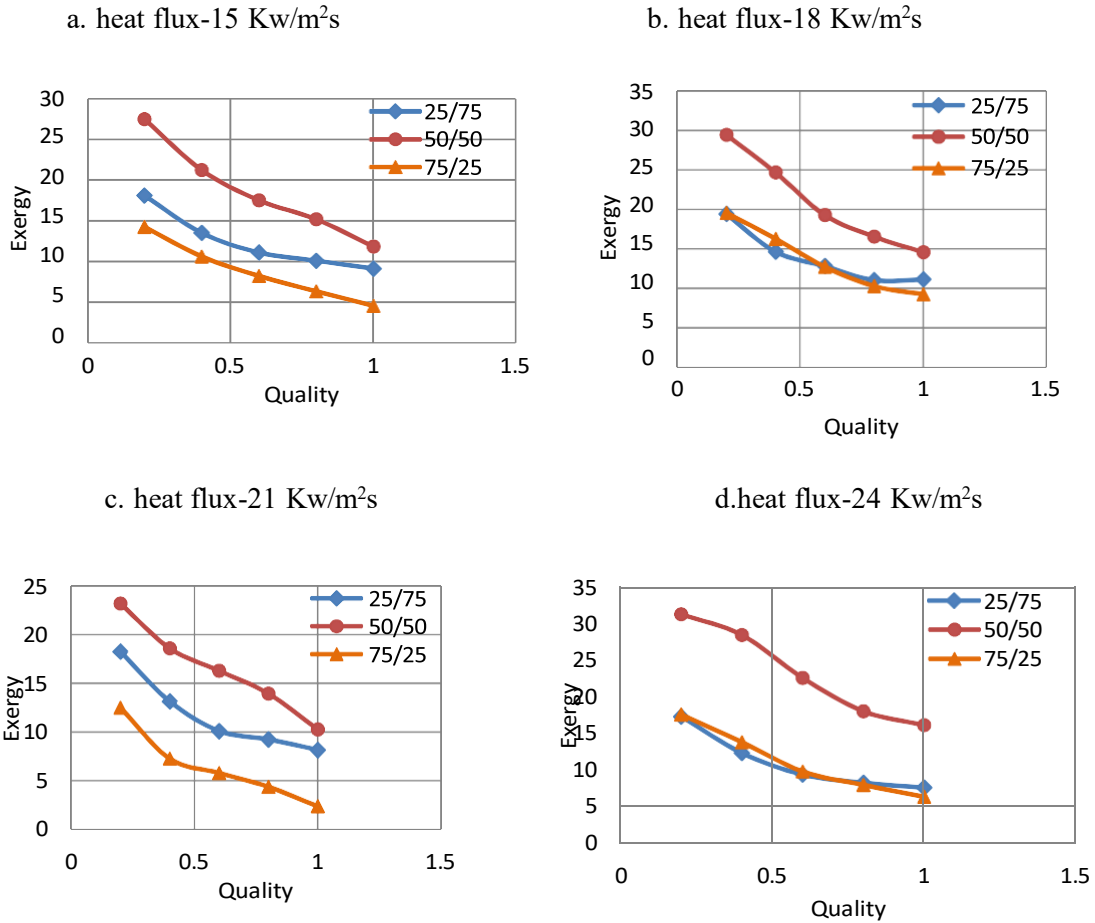


Fig.7 Variation of exergy vs quality at different heat flux

Exergy of blends at 15 and 24 Kw/m²s vary in similar way as it decreases from beginning to end of tube. The maximum value is for 50/50 blend and approaches to close values for 25/75 and 75/25 blends, lower than equal refrigerant blend.

At 18 and 21Kw/m²s the exergy is maximum for 50/50mixture and lower value is for 75/25 mixture between these two lies 25/75 mixture as above.

3.3 Behaviour of R744/R134amixture at different inlet temperature conditions

The heat transfer coefficient at different inlet temperatures of the test section decreases from the beginning for all the blends as depicted in figure8 (a-d) below.

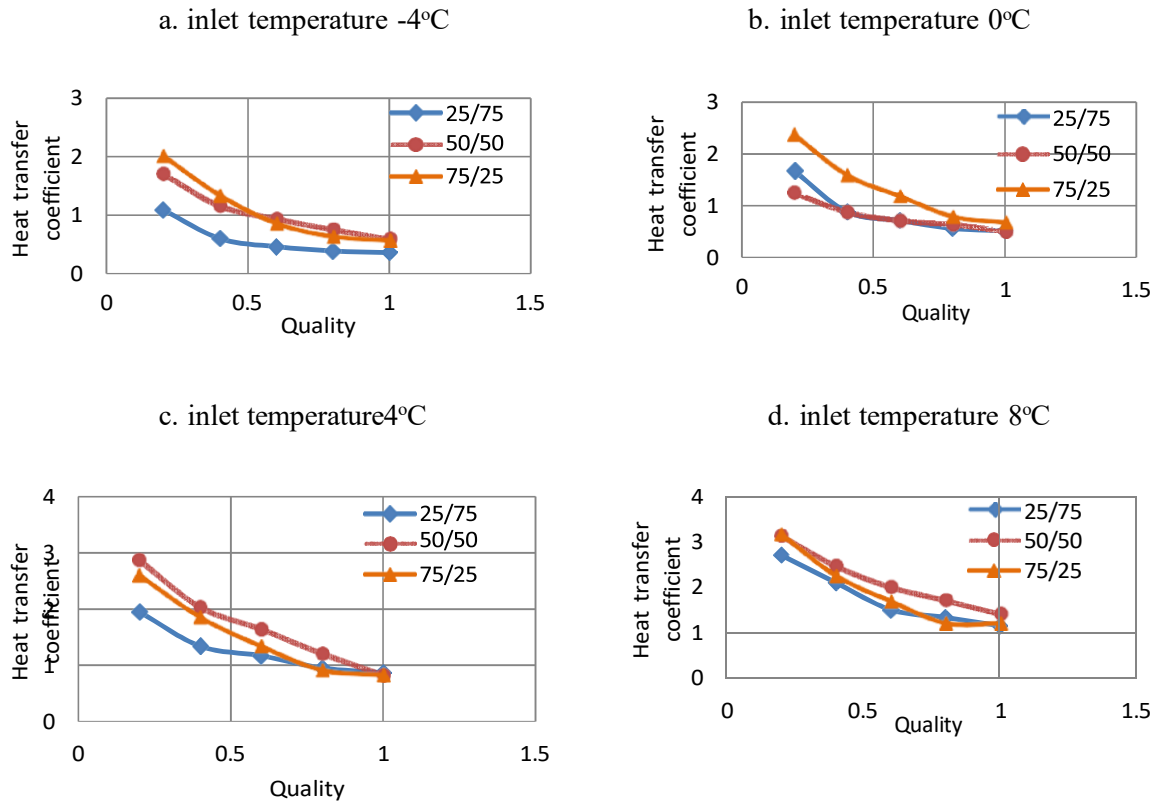


Fig.8 Variation of heat transfer vs quality at different inlet temperature conditions

The heat transfer co efficient of the refrigerant mixture is initially high and start decreasing towards the end of the test section .The heat transfer coefficient is high for 75/25 mixture and lower value is for 25/75 for the inlet temperatures of -4°C and 0°C . In case of 4°C and 8°C the higher heat transfer coefficient is for 50/50 mixture and low for 25/75 mixture.

Inner wall temperature of the test section increases steadily from the beginning for all the inlet temperatures and for all blends as depicted in figure9 (a-d) below.

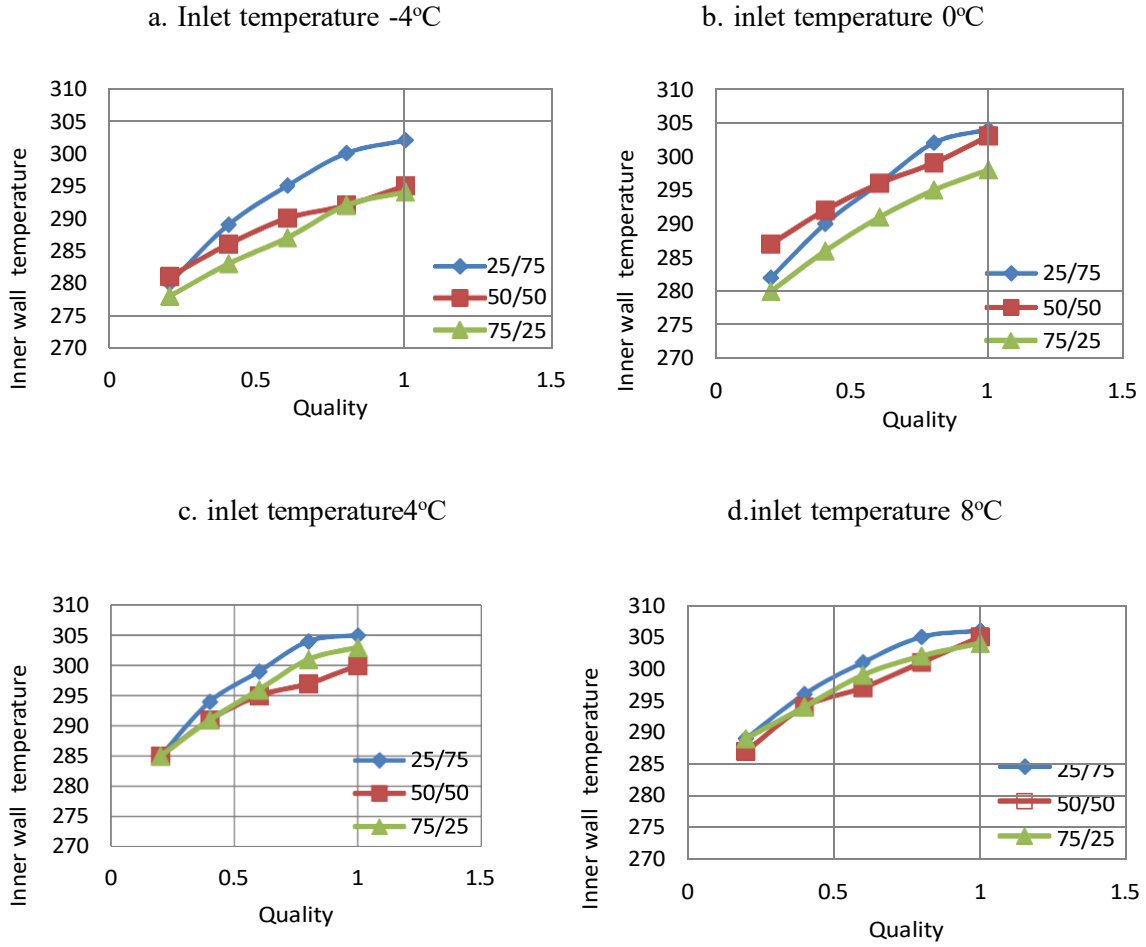


Fig.9 Variation of inner wall temperature vs quality at different inlet temperature conditions As the tube nears its terminus, the temperature of its inner wall rises gradually. At an intake temperature of -4oC, the inner wall temperature is highest for a 25/75 combination, then drops to 50/50, and finally reaches a low point for a 75/25 mixture. When the outside temperature is zero degrees Celsius, the interior wall temperature is lowest for a 75/25 combination, highest for a 50/50 blend in the upper half of the section, and lowest for a 25/75 blend in the lower half. The inner wall temperature is lowest for a 50/50 combination at 4oC and highest for a 25/75 mixture at 8oC; 35/25 is in the middle. Figure 10 (a-d) below shows that for all input temperatures and mixes, the exergy of the test section declines from the beginning.

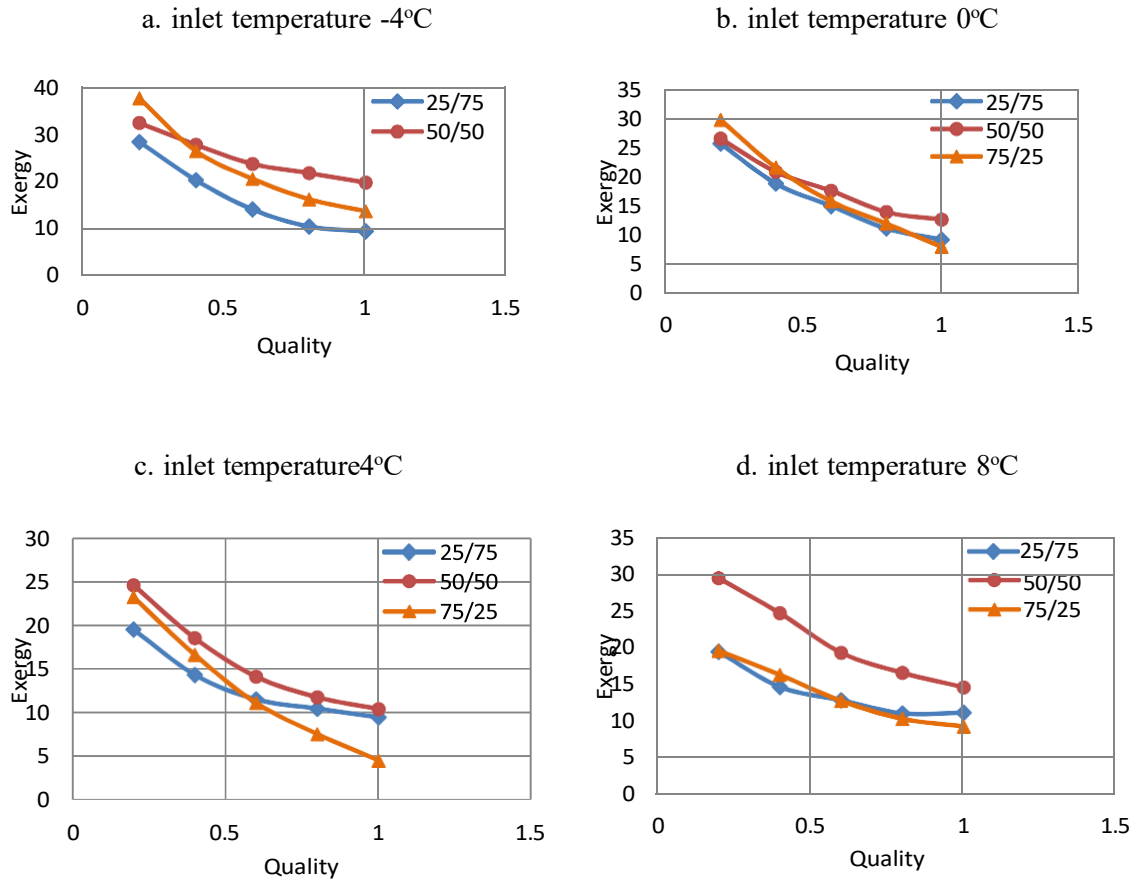


Fig.10 Variation of exergy vs quality at different inlet temperature conditions

The 50/50 mix shows the greatest exergy in all intake temperatures. At -4 and 0 degrees Celsius for the intake, the lower exergy is for a 25/75 mix. For an input temperature of 4°C , the low exergy scenario is a 25/75 mixture in the first part of the section and a 75/25 mixture in the second part. The low exergy occurs for a 25/75 combination in the first half of the segment when the input temperature is 8°C , and for a 75/25 mixture in the second half of the section, but the values are rather similar.

4. CONCLUSIONS

The results of the experimental boiling of R744/R134a in a horizontal tube as a mixture of 25/75, 50/50, and 75/25 were given, with the input temperature, mass flux, and heat flux varied. The following findings were derived from the investigation of the behaviors of various blends with respect to the local heat transfer coefficient, inner wall temperature, and exergy:

In most experiments, the heat transfer coefficient is large at the outset but gradually drops as the experiment progresses. As can be seen from the

graphs, the heat transmission coefficient is affected by the mix fluctuation. - Even under low heat flux circumstances, the heat transfer coefficient was shown to be significantly affected by heat flux. Under circumstances of significant heat flow, this effect was less pronounced.

Regardless of the circumstances, the exergy drops as the tube nears its end due to the blend's impact, and the inner wall temperature rises for all blends as the tube nears its end due to changes in the mix.

An expansion in study into this area is very desired, since current general prediction processes are not up to scratch when it comes to taking full use of the potential of natural refrigerants.

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