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STUDY OF HEAT TRANSFER AND PRESSURE DROP CHARACTERISTICS OF R134A IN MICROTUBE CONDENSER

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ABSTRACT

The condensation heat transfer coefficient and pressure drop were investigated numerically in a microtube condenser using R134a. The microtube condenser comprises of trapezoidal oblique finned microchannel at the top and rectangular fins at the bottom of the tube. Water and air are used as cooling fluids on the top and bottom side of the microtube condenser. The simulations procedure validated initially with the existing work of shah. The condensations effect included the vapour quality and mass flux ranging from 0.25 to 0.9, 99 kg/m2s to 468 kg/m2s respectively. The results indicate that the condensation heat transfer coefficient and pressure drop increase with the mass flux and vapour quality. The microtube condenser enhances the heat transfer coefficient to 24.4% and a pressure drop of 18.6% more than the existing model.

Keywords: *Microtube Condenser, Trapezoidal microchannel, R134a, Heat transfer coefficient, Pressure drop.*

I. INTRODUCTION

The drift towards the miniaturization and advancement in micro-technology led to the development of micro tube condenser. Also, an increasing demand for the compact refrigeration system has been increased, which accelerates the manufacturers to improve the design of condenser that explores approaches, opportunities, and solutions already having an impact. Moreover, the strategies focus on increasing the effectiveness of the condenser by decreasing the vapor quality from 1 to 0.65 over the length of the tube. The effects of a decrease in the pressure drop on the air side and increases in the heat transfer coefficient on the refrigerant side. The refrigerant used here is R134a which is eco-friendly and safe to use. The impact of miniaturization of the condenser is, by decreasing the tube diameter in the condenser, that led increases the heat transfer coefficient and the desired condensation effect is achieved. The various applications of the micro tube condensers include the compact refrigeration system, compact heat exchangers in the electronics industry. Several types of research have investigated the condensation effect in micro tube condenser with micro channel by experimentally and numerically. Goss et al. [1] conductedan experiment on condensation heat transfer using R134a in an eight parallel microchannel. The mass velocity and heat flux ranging from 17 to 53 kW/m^2 and 230 to 445 kg/m^{2}s respectively. The results show a heat transfer coefficient increase with mass velocity for the vapour quality less than 0.95. Also, they conductedan experiment on pressure drop during convective condensation of R134a in eight circular micro tube condensers. The result shows that the pressures drop increase with an increase in mass velocity. The maximum pressure drop was obtained in a microtube condenser is 10kpa at 445 kg/m^{2}s.Melanie Derby et al. [2]proceeds the study on the Condensation heat transfer in the semi-circular, triangular and square, mini-channelsto determine the mass flux and vapour quality which have significant effects on the condensation process. The experimental and numerical study involves predicting the effect of mass flux and vapourquality on the condensation heat transfer coefficient even at lower mass fluxes, during saturation pressure, heat flux, anddifferent channel geometry. The condensation heat transfer coefficients, evaluated from measured temperature with help of thermocouples attached to the tube. Cavallini et al. [3] they studied condensation heat transfer coefficients in multiple channels with1.4 mm diameter tube. The vapour quality and pressure drop were strongly dependent on mass flux but not on heat flux. Condensation heat transfer effectof rectangular minichannels with multiport tube has been investigated by DaisukeJige et al., [4] stating the study on the refrigerants R134a, R32, R1234ze (E), and R410A in a horizontal multiport tube with rectangular minichannels.

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Thehydraulic diameter decrease with increasing frictional pressure drop for the reason thatthe shear stress increase in the same vapour quality and mass flux condition. The mass flux of refrigerants was extremely low with flow pattern transition disappeared, showing an inoculation shape annular flow with an unbroken ligament. Oliveiraet al.[5].They perform an experiment on inside parallel microchannels for accounting pressure drop during condensation with R-134a The results be evidence for that the pressure drop improved with decreasing saturation temperature and increasing mass velocity, while it is not considerablyaffected by the heat flux. The adiabatic two-phase flows within bore pipes reasonably predict by accounting the pressure drop with correlations. The average vapour quality is 0.55 for condensing micro channel.

Above literature review shows that there are several possible ways of changing tube dimensions and cooling technology. In the present study, the microtube condenser design was modified by adding the microchannel heat sink at the top and rectangular fins bottom of the tube respectively. Water and air are used as cooling fluids on the top and bottom side of the microtube condenser. The performance of the microtube condenser is evaluated by keeping constant inlet pressure with varying mass flux of the working fluid. The numerical resultiscompared with existing experimental work.

II. MATERIAL AND METHOD

The complete setup was designed for a particular dimension considering the application of portable cooler. The dimension of the microtube condenser as a major influence on its performance. An optimum dimensional range is selected based on a literature survey. The specifications F of microtube condenser shown in table 1.

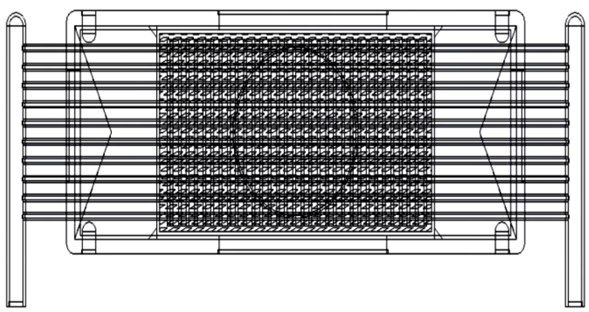

Fig. 1 Microtube condenser

The modeling of the microtube condenser was done in SOLIDWORKS package. This design was done by the readings in the above calculations. The Fig. 1 the top view of the full micro tube condenser and microchannel setup in the two dimensional.

Table 1 Specifications of micro tube condenser

DESIGN PARAMETERS	**DESCRIPTION**
Condenser Material	Copper
Working fluid	R134a
Tube	copper
Tube Diameter	
Outer Diameter	1mm
Inner Diameter	0.8mm
Length	
Length of tube	100mm
Fin Dimensions	
Length	40 mm
Width	30 mm
Thickness	1 mm
Number of fins	11

Assembled model of Microtube condenser

The fig. 2 shows the assembled view of the microtube, microchannel,and fins. This assembly was done by the SOLIDWORKS package. The solid part was made by the part file and then the assembly was done.

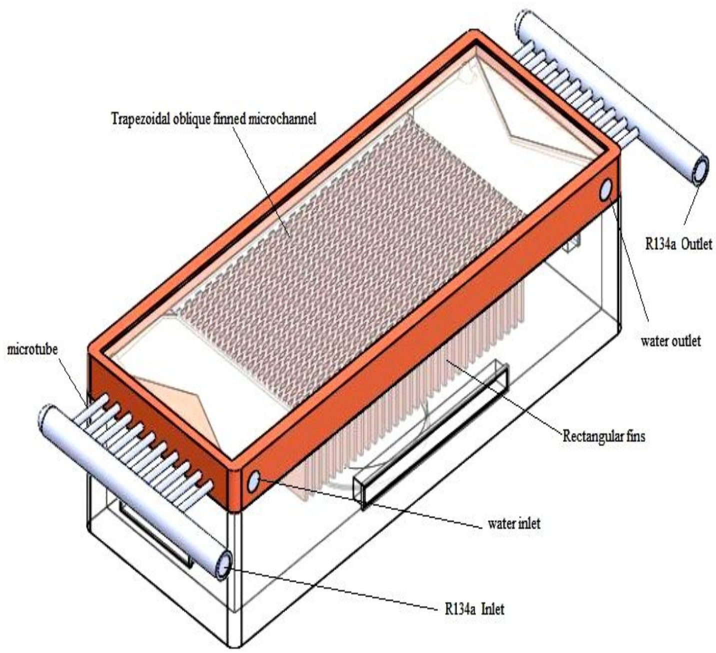

Fig. 2 Assembled view of microtube condenser

Data Reduction

The heat transfer coefficient was obtained fromMelanie Derby et al. [2].

$$h=\frac{q_i}{(T_w-T_f)} \quad (1)$$

The pressure drop was obtained fromOliveira et al. [5]

$$\Delta P = \Delta P_a + \Delta P_f + \Delta P_g (2) \quad (2)$$

The vapour quality was correlated with the work of Kuo-Wei Lin et al. [6]

$$\chi = \frac{Q_{in} - m^{\circ}Cp\Delta T sub}{m^{\circ} i^{\circ} fg} \quad (3)$$

III. NUMERICAL STUDY

The microtube condenser is covered by a material which is thermally insulated, and also the boundary is assumed to be adiabatic. Supporting the symmetry conditions, the central surface of the wall and the microchannel is considered as adiabatic. The Uniform velocity and temperature were applied at the inlet of the condenser. The simulations are performed using the SOLIDWORKS flow simulation. The boundary condition for numerical analysis is taken based on data collected for various studies are given below (1) Water and air flowing over a microtube condenserare one-dimensional. (2) Refrigerant flow in a segment is one-dimensional and uniform. (3) The flow of refrigerant in each port of a segment is same through inlet and outlet. (4) The wall temperature distributed uniformly within a tube.The temperature of the refrigerant R134a entering, pressure, mass flow rate, material selection, and surface goals are provided.

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Temperature and Pressure distribution

In this study, the Solidworks Flow Simulation is used to simulate the characteristics of the parallel tube microcondenser. Initially,the modeling was done in SolidWorks and then loaded with the preliminary conditions necessary to begin the simulation in the SOLIDWORKS.

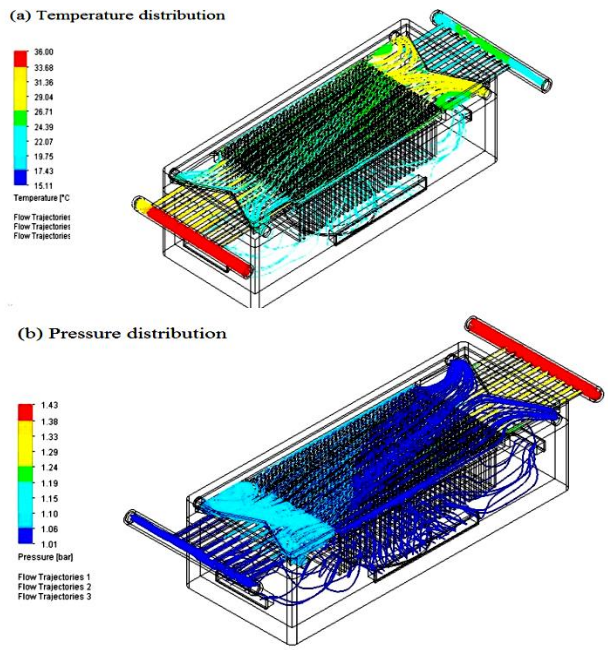

Fig.3Temperatures (a) and pressure (b)distribution

The fig.3 (a) shows temperature distribution inside the test. The mass flux was applied as 99 kg/m^2s at the inlet of the microtube condenser. The condensing temperature obtained by applying the above boundary condition is 24^0C.Similarly, by varying the mass flux such as 99 kg/m^2s, 198 kg/m^2s, 275 kg/m^2s, 370 kg/m^2s, 468 kg/m^2s corresponding condensing temperature are evaluated. The pressure distributions for microtube condenser are shown in the fig. 3(b). The refrigerant R134a leaves from the condenser outlet 101.34 kPa. The condensing temperature obtained by applying the above boundary condition is 24℃. The corresponding condensing temperature can be evaluated. The amount of pressure drop 32.53 kPa and temperature rise is 14℃ the pressure drop is low due to the absence of bends and the temperature variance is due to the increase in the overall heat transfer coefficient.

IV. RESULTS AND DISCUSSIONS

Validation

The numerical procedure was validatedby comparing with the existing experimental work of Shah. The analysis was performed in the microtube condenser by varying the mass flux. The variation of nusselt number with mass flux for the numerical results shown in fig.4.The same dimensions used for microtube condenser as per existing experimentalwork and the nusselt number are calculated using the correlation. Thus the nusselt number values were compared with the previous work of Shah. From the figure, it is obvious that the Nusselt's number enhance with an increase of the mass flux. The experimental values show 12% higher value of the Nusseltnumber as compared to the numerical value for each mass flux. The Nusseltnumber results are closer to that of previous work. So that present numerical procedure can be used for further study.

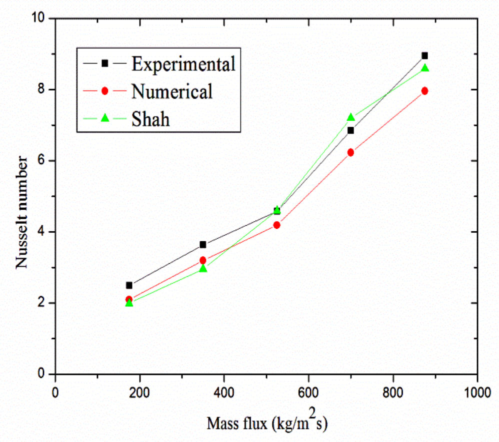

Fig.4 Variations of the nusselt number with mass flux

Temperature Variation

The vapour quality is the important factor for evaluating the condensation heat transfer coefficient. Fig. 5 represents the variation of Temperature distribution with length for both experimental and numerical results. The mass velocity as follows 99 kg/m^{2}s, 198 kg/m^{2}s, 275 kg/m^{2}s, 370 kg/m^{2}s, 468 kg/m^{2}s. It is clear that the temperature decreases with the increasein length also with an increase in mass flux the temperature variation decrease. The best result is achieved by using the mass velocity of 468 kg/m^{2}s.

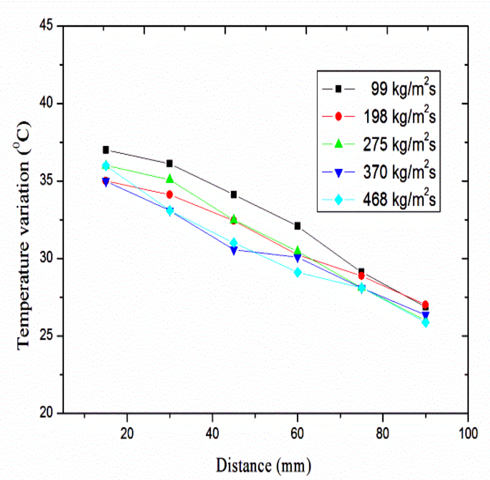

Fig.5 Variation of Temperature distribution with length

Heat transfer coefficient characterizes

The numerical analysis was carried out for microtube condenser by flowing R134a with various mass velocities. The effect of the condensation heat transfer coefficientsuggested that the contribution of mass velocities and vapour quality. Fig. 6 represents the variation of Heat transfer coefficient with Vapour quality for both experimental and numerical results. It is clear that the heat transfer coefficient increases with the increase with Vapour quality. The graph shows the variation of 24.2 % as compared to shah's. The experimental and numerical result of heat transfer coefficient shows the variation of about 30% at a higher vapour quality value. The experimental result at 0.9 vapour quality shows the maximum heat transfer of 8200 W/m^{2}K. The fig. 7 shows that the heat transfer coefficient decreases linearly with an increase in mass velocity. The experimental and numerical result shows less deviation of

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the heat transfer coefficient of about 8.38% at higher mass velocities. The experimental result shows better value than both the numerical and shah's result.

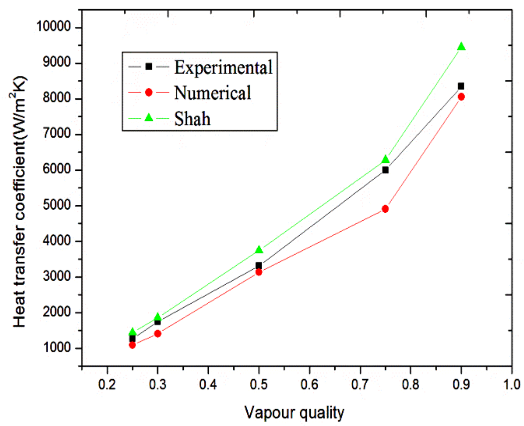

Fig. 6 Heat transfer coefficient vs Vapourquality

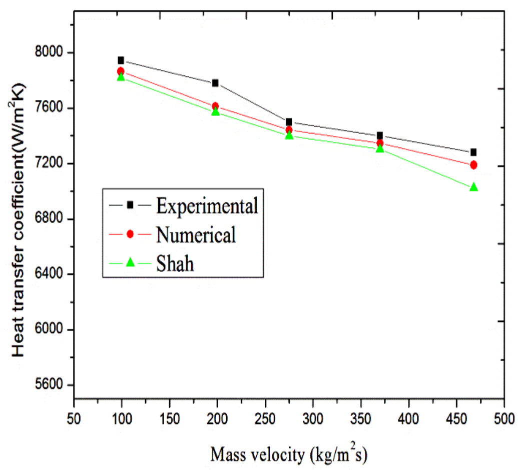

Fig.7 Heat transfer coefficient vs Mass velocity

Pressure drop characteristics

The pressure drop is one of the most important factors for enhancing the condensation in a microtube. Fig. 8 shows that as a result of an increase in mass velocity there is an increase in pressure drop. The massflux of 468 kg/m^{2}s there is a small variation of 20% with the shah's experimental value. Thisstudy shows that the average pressure drop is higher than 18.6% compare to Shah Work.

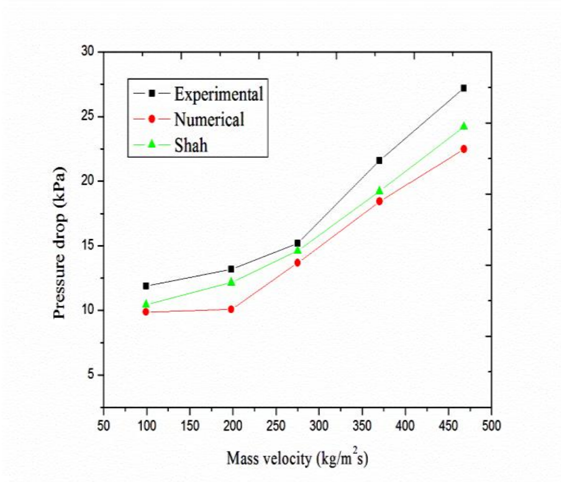

Fig. 8 Variation of pressure drop with mass velocity

V. CONCLUSION

In this paper, the heat and flow characteristics of R134a flowing in microtube of diameter 0.8mm are studied numerically. The influences of heat transfer coefficient and pressure drop are discussed and the following conclusions are achieved as follows,

- Vapour quality was varied and found that the heat transfer coefficient increases when it is increased.
- The mass flux also influenced the heat transfer coefficient, When it is increased the heat transfer coefficient also increased.
- The heat transfer coefficient was increased by 24.4% when compared with the existing work of shah.
- The pressure drop increase by 18.6% with existing work an increase in mass flow rate.

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NOMENCLATURE

A	Area, m^2
C_p	Constant pressure specific heat, J/kg-K
d	tube diameter, m
G	mass velocity, kg/m^2-s
h	heat transfer coefficient, W/m^2K
k	Thermal conductivity
l	length, m
m°	Mass flow rate, kg/s
Re	Reynolds number = ρud/μ
Nu	Nusselt number = hd/k
p	Pressure, N/m^2
Q	Heat transfer, W
q	Heat flux, W/m^2
T	temperature, °C, K
u	velocity, m/s
x	vapour quality
μ	dynamic viscosity, Pa-s
v	kinematic viscosity = μ/ρ, m^2/s
ρ	density, kg/m^3
f	liquid
g	gas phase
l	liquid phase