Heat Transfer Analysis of Vapor Compression System Using Nano Cuo-R134a

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Abstract. Improving heat transfer characteristics in refrigeration and air conditioning systems has been intensively studied by many investigators. In the present work the effect of using nano CuO-R134a in the vapour compression system on the evaporating heat transfer coefficient is experimentally investigated. An experimental test rig is designed and constructed here for this purpose. The test section is a horizontal tube in tube heat exchanger made from copper. The refrigerant is evaporated inside an inner copper tube and the heat load is provided from hot water that passing in an annulus surrounding the inner tube. Measurements were performed for heat flux ranged from 10 to 40 kW/m2, using nano CuO concentrations ranged from 0.05 to 1% and particle size from 15 to 70 nm. The measurements indicated that for a certain nano concentration as heat flux or mass flux increases the evaporating heat transfer coefficient increases. The measurements indicated also that the evaporating heat transfer coefficient increases with increasing nano CuO concentrations up to certain value then decreases. Comparison with the available published data shows good agreement.

Keywords: Evaporating Heat Transfer Coefficient, Heat Flux, Mass Flux, Nano CuO Concentration, R134a.

1. Introduction

With the progress of thermoscience and thermal engineering applications, many efforts have been devoted to increase heat transfer enhancement. Among these techniques is the use of additives to liquids. Since the flow media themselves may be the controlling factor of limiting heat transfer performance, solid additives are suspended in the base liquids in order to change transport propertiesof flow and heat transfer features of the liquids [1,2]. Nanoparticles can be used to improve the working fluid properties due to their special properties which have attracted attention worldwide [3,4]. Besides describing chronological development in this field. HFC 134a is the most widely used alternative refrigerant in refrigeration equipment such as domestic refrigerator and automobile air-conditioners [5]. First proposed creating "nanofluids" by suspending high thermal conductivity nanoscale metallic or non-metallic particles in base fluid. These nanofluids have been shown to have superior heat transfer capabilities [6,7]. The application of nanoparticles in refrigerator oil is also studied [8,9]. The heat transfer characteristics of nano fluids inside horizontal tubes are investigated [10].

2. Experimental Test Rig

The objectives of the present study are investigating the effects of adding nano CuO on R134a for various values of heat flux, nonoparticles size and concentration on the evaporating heat transfer coefficient. An experimental test rig is constructed to fulfill these objectives where the experimental measurements are performed. Fig.1 shows a schematic diagram for the experimental test rig. The experimental test rig consists of two different loops; the refrigerant loop and the water loop. In the refrigeration loop, the refrigerant vapor is taken form the evaporator (7) and goes to the compressor (10) then condensed in a water cooled condenser

(1). The refrigerant flows over an oil separator (12) before entering the condenser to ensure that the refrigerant is not contaminated by the lubricating oil used in the compressor. At the inlet of the condenser a specific amount of oil is mixed with the desired amount of CuO and introduced into the refrigerant line by gravity, and mixes with the refrigerant then this mixture flows through the condenser to the expansion valve (6), in which the mixture is throttled to the evaporator where it evaporates using hot water. The hot water flows around the refrigerant tube in counter direction and represents the load on the evaporator. The hot water loop consists of hot water tank (15) which includes electric heater (14) and pump (16). The compressor used in the present test rig is sealed hermetic reciprocating type of 1 HP, 220 Volts and 50 Hz. The test section, evaporator is a straight horizontal tube in tube heat exchanger as shown in Fig. 1 which has a length of 1400 mm with inner tube made of copper having an outer diameter of 9.52 mm and inner diameter 7.72 mm. The refrigerant flows through the inner tube and the hot water used to evaporate the refrigerant flows through the annulus. The outer tube is made of copper having an outer diameter of 19.05 mm and inner diameter of 17 mm.
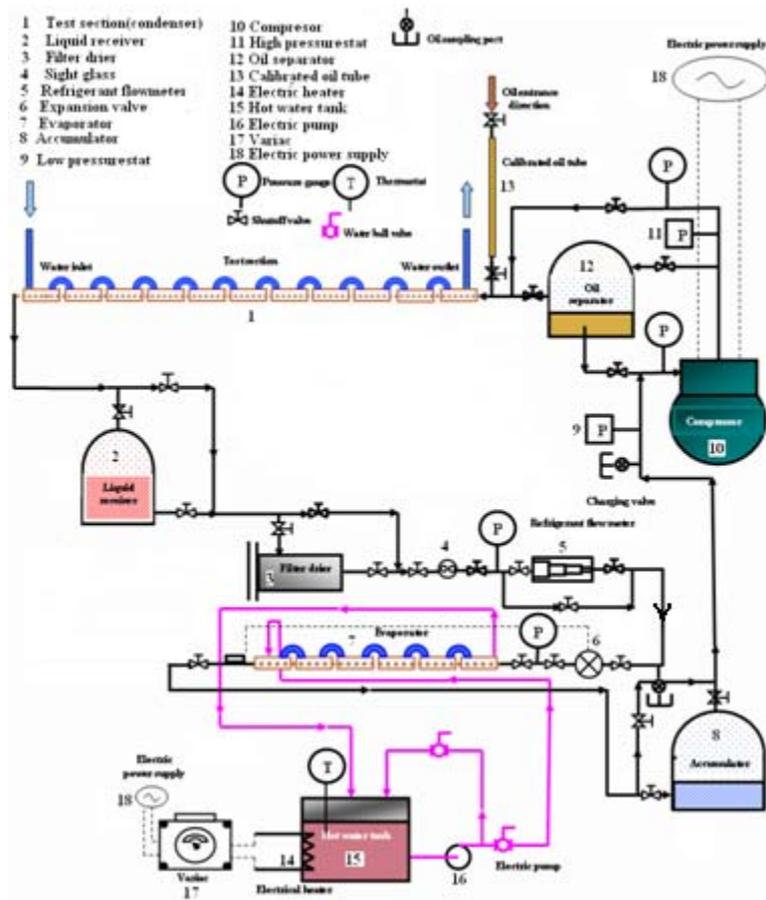

Fig. 1: A schematic diagram for the experimental test rig

3. Experimental Measurements and Instrumentation

The temperatures are measured in the different parts of the experimental test rig using thermocouples type "T", which are connected to a digital indicator which is provided with selector switch to record the temperature at the desired locations. An interface is provided to record the thermocouples readings within temperature range of 1.3 to 35 oC with a resolution of 0.1 oC. Thirteen thermocouples are used to measure the temperatures at different locations along the test rig. Nine of these thermocouples are distributed on the test section (evaporator). Refrigerant pressure is measured in the test rig by four pressure gauges, two of them are connected to the high pressure side of the refrigeration cycle. The first one is connected to the discharge tube of the compressor, and the other of the flow-meter inlet. These two gauges have a pressure range from 0 to 1 bar. The other two gauges are connected to the low pressure side of the refrigeration cycle;

one of them is connected to the suction tube of the compressor, while the other is fixed at the exit of the expansion valve. These two gauges have a pressure range from 0 to 9.28 bar. The heat flux applied to the evaporator in any experimental run is adjusted to the prescribed value. This can be done by adjusting the amount of hot water flowing through the evaporator. Evaporating pressure is adjusted by choosing a specific value of the refrigerant mass flux passing through the expansion device. For each run, the refrigeration cycle is left running for about 0.5 hour to achieve steady state conditions before adding CuO nanoparticles.

4. Data Reduction

The average heat transfer coefficient is calculated as follows:

$$\frac{1}{h} = \frac{\pi di\, L(Tref.,av - T\,wall)}{Qtot} - \frac{di}{2k}\ln\frac{do}{di} \tag{1}$$

Where,

$$Qtot = mw\, Cw\, (Tw,o - Tw,i) \tag{2}$$

m_w :	cooling water mass flow rate	kg/s ,	*Cw:* specific heat of water K
Tw,i:	inlet temperature of water	K,	*Tw,o* outlet temperature of water K
Tref, av :	average temperature of refrigerant	K,	*Twall:* average temperature of tube wall K
di:	inner diameter of refrigerant tube	m,	*do* outer diameter of refrigerant tube m
L:	evaporator length	m,	*k,* evaporator tube thermal conductivity kW/m K

5. Results and Discussion

The results presented here are based on the experimental measurements which performed under different operating conditions and parameters that affect the evaporating heat transfer coefficient. The measurements are performed for heat flux ranged from 10 to 40 kW/m2, CuO nanoparticles concentrations of 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.55, 0.6, 0.8 and 1% in addition to nanoparticles size ranged from 15 to 70 nm are studied.

5.1. Effect of Heat Flux on the Evaporating Heat Transfer Coefficient

Figures 2 shows the variation of the evaporating heat transfer coefficient with heat flux for different values of nanoparticles concentrations. It is noticed that the variation of the evaporating heat transfer coefficient is linear on the logarithmic scale where the heat transfer coefficient increases with the increase of heat flux. Also the heat transfer coefficient increases up to 0.55% CuO nanoparticles concentration and then decreases. The heat transfer coefficient for nanoparticles free refrigerant, 0 % concentration shows the lowest value and then increases with almost constant rate up to 0.55% CuO nano particles concentration.

5.2. Effect of CuO Nanoparticles Concentrations on the Evaporating Heat Transfer Coefficient

Figure 3 indicates the variation of the evaporating heat transfer coefficient with the CuO nanoparticles concentrations for different values of heat flux It is noticed that the evaporating heat transfer coefficient with the increase in CuO concentration up to 0.55% then decreases> At 0.55% concentration the evaporating heat transfer coefficient has its highest value for all values of heat flux.

5.3. Effect of CuO Nanoparticles Size on the Evaporating Heat Transfer Coefficient

Figure 4 shows the variation of the evaporating heat transfer coefficient with CuO particle size for different values of heat flux. It is indicated that the heat transfer coefficient increases with CuO nanoparticle size up to 25 nm and then decreases with the increase of nanoparticles size. It is obvious that the heat transfer coefficient have the same trend for all values of heat flux.

The present results are compared with the published data given by Hao, et al. [7],

$$hr,n = \exp\left\{\varnothing\left[0.8\frac{kn}{kn,L} - 39.94\frac{(\rho Cp)n}{(\rho Cp)n,L} - 0.028G - 733.26x(1-x)\right]\right\}hr \tag{3}$$

Where,
hr,n: heat transfer coefficient (W/m^{2}K)
φ:volume fraction of nanoparticles

k: thermal conductivity (W/Mk)
Cp: isobaric specific heat (J/kg K)
ρ:density (kg/m^3)
G:mass flux(kg/m^{2}s)
x:vapor quality (kg/kg)
r: refer to refrigerant
n: refer to nanoparticles
L:refer to liquid
This equation is used for CuO nanoparticles and Refrigerant R- 113. Comparison shows reasonable agreement with maximum deviation of 16%.]
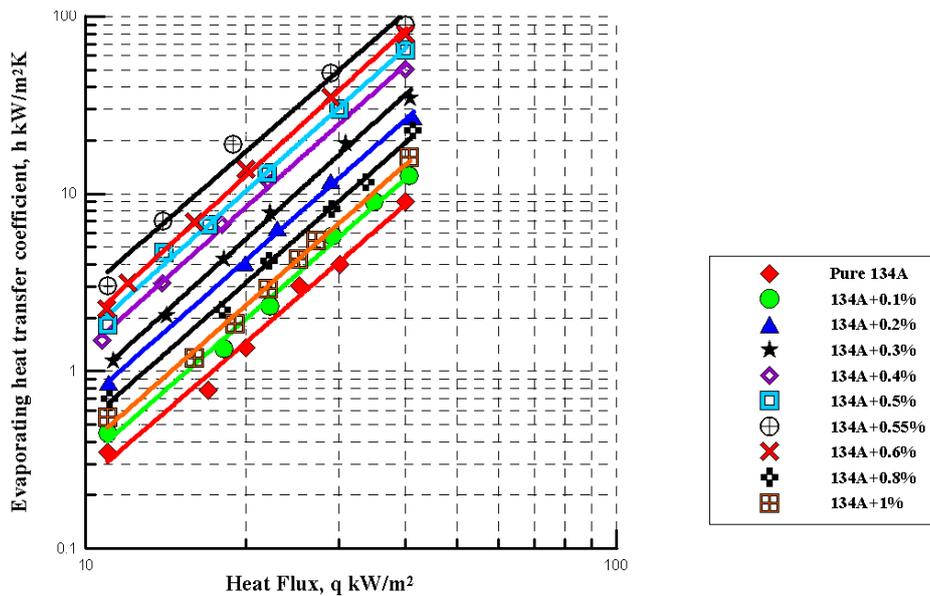

Fig. 2: Variation of evaporating heat transfer coefficeient with heat flux for different CuO concentrations (G = 100 kg/m2s, particlel size 25 nm)
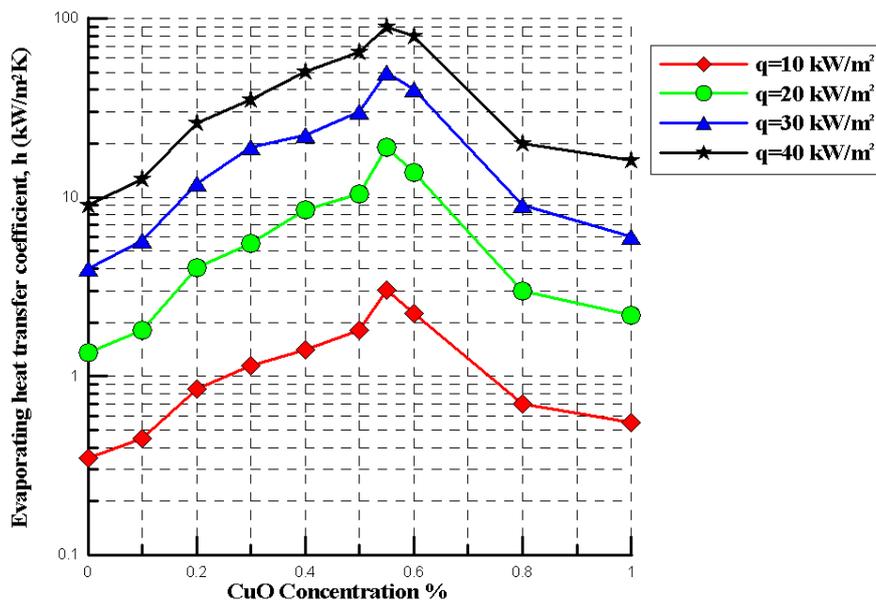

Fig. 3: Variation of the evaporating heat transfer coefficient with CuO concentration for different values of heat flux (G = 100 kW/m^2, Particle size 25 nm)

6. Conclusions

From the experimental measurement obtained here the following conclusions are drawn:

The evaporating heat transfer coefficient increases with the increase of:

1- Heat flux within the range used here

2- CuO nanoparticles concentration ranged from 0.1 to 0.55 % then decreases for all values of heat flux

3- CuO nanoparticles size ranged from 15 to 25 nm then decreases for all values of heat flux.

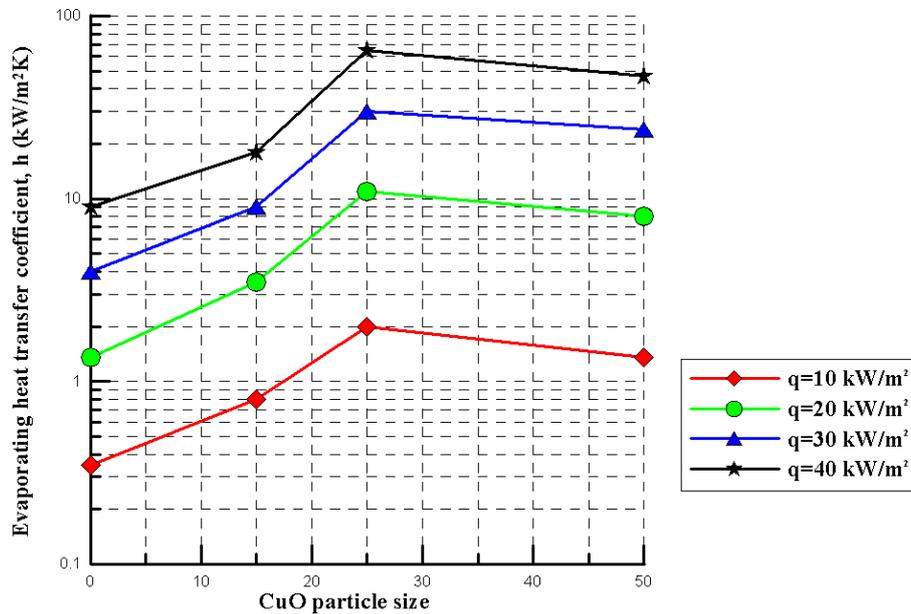Comparison of the present results with the published data shows reasonable agreement.

Fig. 4: Variation of the evaporating heat transfer coefficient with nanoparticle size
(G = 100 kW/m^2, concentration 0.55 %)

7. References

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