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Heat pump performance enhancement by using a nanofluids (experimental study)

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ABSTRACT

Nowadays, heat pumps are widely used for air conditioning, cooling, and heating. It is well known that nano-particles can enhance conduction and convection coefficients, raising the transfer of heat and thus. Heat pump was filled with R600a during the experimental work, then copper oxide CuO and Aluminum oxide AL_2O_3 were used in different amounts and combined with pure water to obtain a nanoscale solution that we use for heat pump condenser cooling. Three proportions were used from CuO and AL2O3 (0.1%, 0.3%,0.5%) in the current study. The study results revealed that the efficiency coefficient increased by 22 %, but the energy consumption decreased by 31 % when using 0.5 % CUO instead of the traditional pure water used to cool the heat pump condenser. Finally, we infer from the results that as a result of the use of copper oxide with a ratio of 0.5 %, the cooling effect will be increased and the compressor work will be decreased.

KEYWORDS

AL2O3, Heat pump, CUO, Nano fluid.

INTRODUCTION

In many applications, heat pumps have recently been used, Such as air conditioning, cooling and ventilation, warm water processing, hotels, large estates, etc. Nanofluid is a liquid that contains Particles that are sized (1-100 nm). It's been well founded that nano-particles, can raise rates of convection and conduction and thus improve heat transfer[1]. For nanofluids, there are also several possible uses, one of which is to be used as a working fluid in cooling, air conditioning and heat pump cycles. Efficiency ratio and energy conservation, for example, were performed in many works. The efficiency of nanoparticles suspension with refrigeration systems and lubricating oils in cooling systems has also been reviewed by Saidur et al.[1], indicating that categories (I) and (II) have obtained the top interest. Undoubtedly, understanding of property, heat transfer and material compatibility provides the basis for the development of heat pumps that use nanofluids as base fluid. It is clear that a lot of work, but not the heat pump, has been done with respect to the cooling system. The heat pump, though is an electricity alternative to waste heat recovery.

Even more research on the efficiency of a heat pump utilizing nanofluids as working fluids must be studied on the basis that about one third of the world's power consumption is consumed by the construction industry. In addition, Research into nanofluids as working fluids is also important. The machine efficiency of the heat pump using water and the nano particles AL2O3 and CUOO3 was systematically analysed in this work. Experiments were carried out at various cooling and heating loads. Researchers Yimin and Qiang[2] conducted a study of the conductivity coefficient of nanoscale fluids. They relied on that on some nanoscale fluid samples that were prepared by mixing nanoparticles in the base fluid. They found that the nanoscale fluid consisted of copper particles mixed with the conductivity coefficient affected by the shape or size and the concentration of the nanoparticles, where they found the percentage of change in the conductivity coefficient of the nanoparticle changed from (1.24) to (1.78) when the concentration of the nanoparticles in the liquid base changed from 2.5% to 7.5%. Kakac and pramuanjaroenkijb [3] conducted a review of previous research and theoretical and experimental articles in which the heat transfer properties of nanofluids were the focus of their study.

The two researchers focused their study on measuring the thermal conductivity and viscosity of the nanofluid and the effect of this on enhancing heat transfer using suspensions of nanometer-sized solid molecular materials (metallic or non-metallic). Has different conductive properties than the base liquid. Khedkar et al. [4] An experimental research was conducted on a double-tube heat exchanger using alumina nanoparticles (AL2O3) mixed in water as a base liquid at different concentrations. The study focused on calculating the thermal conductivity factor and the total heat transfer coefficient of the nanofluid. The results showed that there is an improvement in the overall heat transfer coefficient when using nanofluid instead of water, and that there is an improvement in the thermal conductivity coefficient when adding nanoparticles to water by 16% at a concentration of 3% for nanofluid. As for Chavda and his colleagues [5], they conducted an experimental study to find out the influence of the nanoparticle concentration (Al2O3) blended in water as a base liquid on the performance for 2 ways of flow and a double pipe heat exchanger (parallel and opposite). The researchers used different volume concentrations ranging from (0.001% - 0.01%) and they concluded from the study that the total heat transfer coefficient increases with increasing the volumetric concentration of nanoparticles in water, and this increase continues until the volumetric concentration reaches 0.008%. The study aims to improve the efficiency of the heat pump by using the nanofluid to cool the condenser in this article.

METHODOLOGY

Test rig setup

Figure (1) indicates the main feature of the test rig consisting of the compressor (hermetic compressor), the water-cooled copper condenser, the reverse valves and the capillary tube, the coil evaporator was fully immersed in water, made of copper. Pressure gauges were used to measure pressure in the cycle. The temperatures of the various points in the experimental setup were calculated using K-type thermocouples. To measure the temperature, six thermocouples were used for precise measurements. Using a mercury thermometer, calibration of the thermocouples was performed. A digital wattmeter was used to measure the electricity consumed by the device. The experimental rig was positioned on a flat stage.

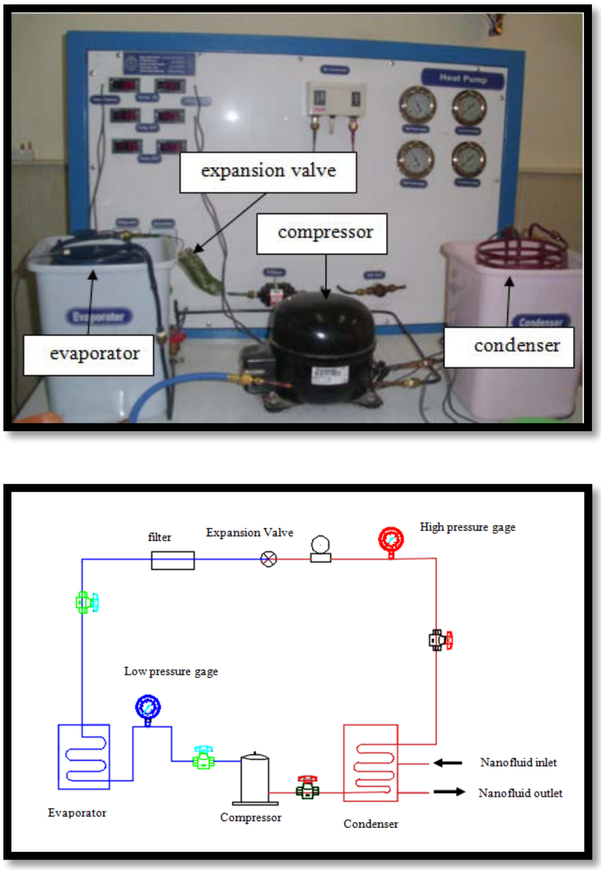

Figure 1. Photograph and schematic of the experimental system.

Preparation of nanofluids

In the present study, the first-step method has been used for nanofluid preparation. This method involves using nanoparticles and adding a sufficient amount of water to the bottle, then using the ultrasonic vibration homogenizer system to mix the water with the nanoparticles (Al2O3) and (CUO). The ultrasonic unit was filled with water to ensure no damage to the device, as suggested by the supplier 's instructions, and then the basket was placed inside the bath for 30 to 45 minutes [6]. For preparing the nanofluids in all volume fractions, water is used. As shown in Figure (2), three volume fractions (0.1%, 0.3%, and 0.5 %) of Al2O3-water & CUO-water nanofluid have been prepared.

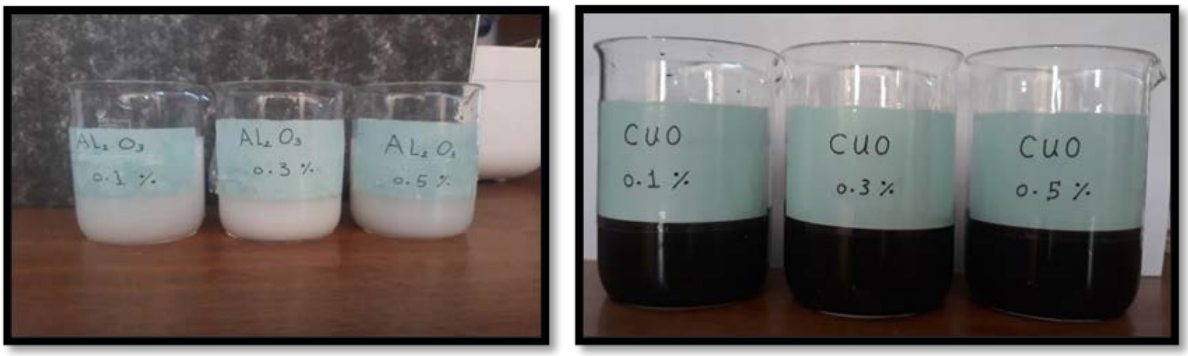

Figure 2. The volume concentrations of Al2O3 & CUO Nanofluid.

Analyzing Data

The enthalpy values were plotted at different points on the refrigerant Pressure -enthalpy diagram (Refrigerant 600a) to calculate the rate of transfer of heat from the evaporator and the condenser, as shown in figure (4), Depending on the combination of temperature and pressure, the enthalpy values can be determined using the ROFPRO program. The performance coefficient , the heat-rejection ratio and energy consumption are the essential variables of the heat pump efficiency[7].

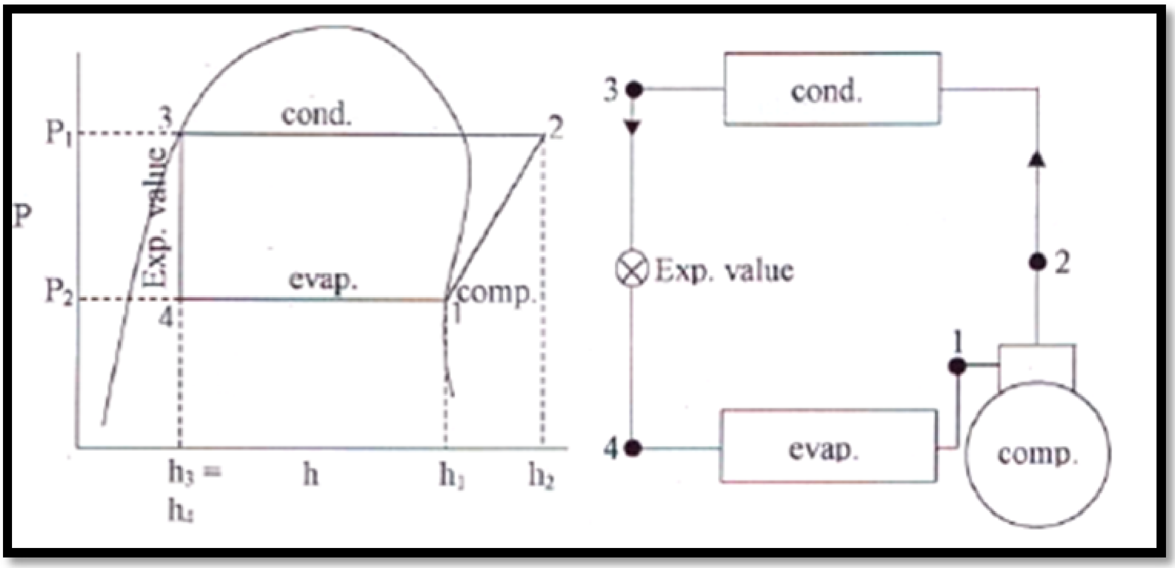

Figure 4. Pressure-enthalpy diagram of heat pump cycle.

1) COP

$$COP = \frac{\text{Heat removal}}{\text{Work}}$$

$$COP_{exp} = \frac{h_1 - h_4}{h_2 - h_1} \quad (1)$$

2) (H.R.R)

(H.R.R) = rate of rejected at condenser/rate of absorbed at evaporator

$$HRR_{\text{exp}} = \frac{\text{rate of heat rejection at the condenser}}{\text{rate of heat absorbion at the evaporator}}$$

$$HRR_{\text{exp}} = \frac{h_2 - h_3}{h_1 - h_4} \;) \quad (2)$$

3) Power consumption by the compressor

$$W_{exp} = \dot{m} * (h_2 - h_1) \quad (3)$$

Where-:
h_1– Refrigerant enthalpy in the compressor inlet (kJ/kg)
h_2 – The enthalpy of the refrigerant at the compressor outlet (kJ/kg)
h_3– Refrigerant enthalpy inlet at the evaporator inlet (kJ/kg)
h_4 – The enthalpy of the refrigerant at the evaporator outlet (kJ/kg)
$\dot{m}$:- mass flow rate of refrigerant (kg/s)

RESULTS AND DISCUSSION

Coefficient of Performance (COP)

The COP values that were determined from equation (1) are shown in Fig. (4). This means that when applying CuO to pure water, the COP values have been strengthened. Used this power supply values and cooling ability, the actual coefficient performance was obtained. We also conclude from Figure (4) that the value of COP increases when we increase the concentration of nanoparticles in the fluid. The highest value is obtained when using copper oxide with water, with a mixture ratio 0.5%. As the amount of increase in performance when using copper oxide is by 22% in comparison with pure water. This finding can be explained by adding the tiny size of the nanoparticles of CuO to the distilled water[8]. The compressor's energy consumption will be reduced and a sub-cooling of the nano-refrigerant in the condenser will be observed, resulting in an increase in coefficient performance of cycle.

Impact of CuO & AL_2O_3 volume fractions on consumed of energy by a compressor

A comparative of compressor energy consumption is given in Fig. (5). Among seven cases under analysis, which, when minimizing volume fractions, shows a substantial reduction in power consumption. The reduction in power consumption was about 31 percent when using 0.5 percent CuO, but when using AL_2O_3 at the same volume fractions, the reduction was about 12 percent when using AL_2O_3-water and CuO-water instead of pure water. This behaviour is meeting with the results data behaviour of Hussein et al., [9].

Effect of volume fractions of nanoparticles on heat rejection ratio

It is a concept that is used most to refer to that of evaporator to heat flow rate at the condenser. Fig. (6) shows that if nanofluid is used to cool the condenser in the cycle, (H.R.R) decreases. The figure shows that using the mixtures (CuO-water 0.1%, CuO-water 0.3%, CuO-water 0.5%, AL_2O_3- water 0.1%, AL_2O_3- water 0.3%, and AL_2O_3-water 0.5%) the value (H.R.R) decrease about (1.3%, 1.5%, 1.8%, 0.8%, 0.9%, 1.1%) consecutively in compared with distilled water. Reducing heat rejection ratio values implies that the cooling effect will increase and compressor operations will decrease.

Effect of volume fractions of nanoparticles on refrigeration effect

Figure (7) indicates the changes in the cooling effect over time. It was found that the 0.5 per cent CuO-water mixing does have a greater cooling the impact of using nanoparticles to cool the condenser than in other cases. It is also evident from the figure that with an increase in the volume fraction of CuO nanoparticles due to sub-cooling in the condenser, the cooling effect increases. Because as heat transfer rate has improved and the refrigerant mass flow rate has enhanced, the compressor work reduces and the energy has decreased..

Effect of nanoparticles volume fraction on work compressor

Fig. (8) demonstrates the variance of compressor work with compressor discharge temperature. The figure indicates that compression work decreases as the temperature of the discharge of the compressor raises. From the figure, it is also shown that the 0.5% CuO-water mixture mixing have higher compressor work than other instances. This is based on the assumption that as the compressor discharge temperature rises, the compressor suction temperature also raises due to the incidence of subheat in the suction line, which improves the mass of the refrigerant flowing through compressor every unit of time, thus reducing the compressor's work by reducing the consumption of energy [10].

Impact of the size of nanoparticles on outlet temperatures of the condenser

Figure (9) the relation between the evaporator's temperature and the temperature of the condenser outlet suggests that the temperature of the evaporator and the temperature of the outlet condenser decreases when the CuO-water is used to cool the condenser in the cycle. It is also noticed that when the CuO-water 0.5 percent mixture is used, the decrease in The temperature of the evaporator and outlet condenser is higher than in other mixing cases. However, the addition of nanoparticles in water and used for condenser cooling, which increases the heat transfer rate of the condenser, improves the efficiency of the heat pump.

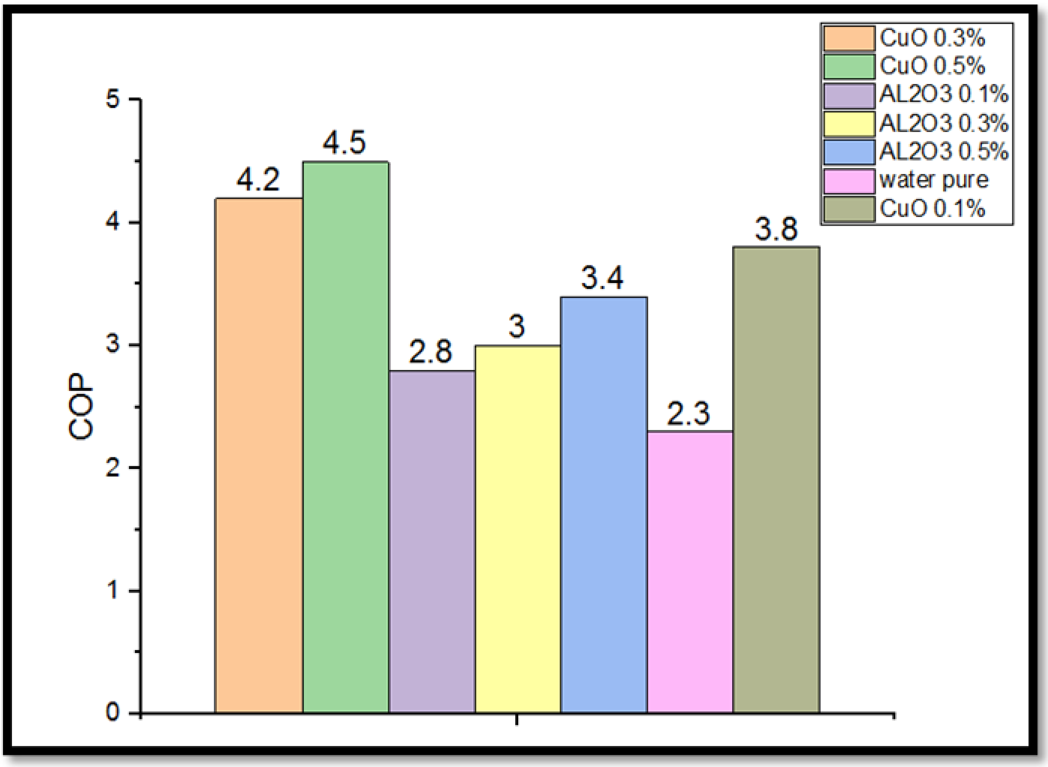

Figure 4. Experimental of COP at different mixture

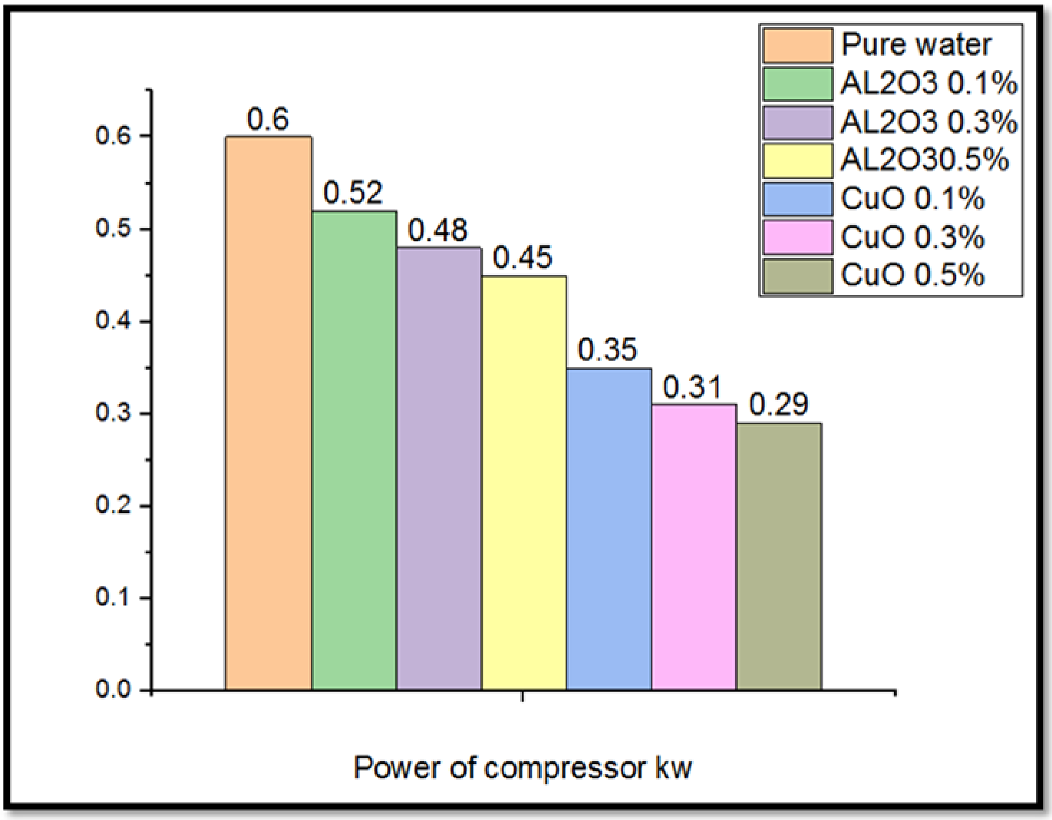

Figure 5. Experimental comparison of the use of compressor power

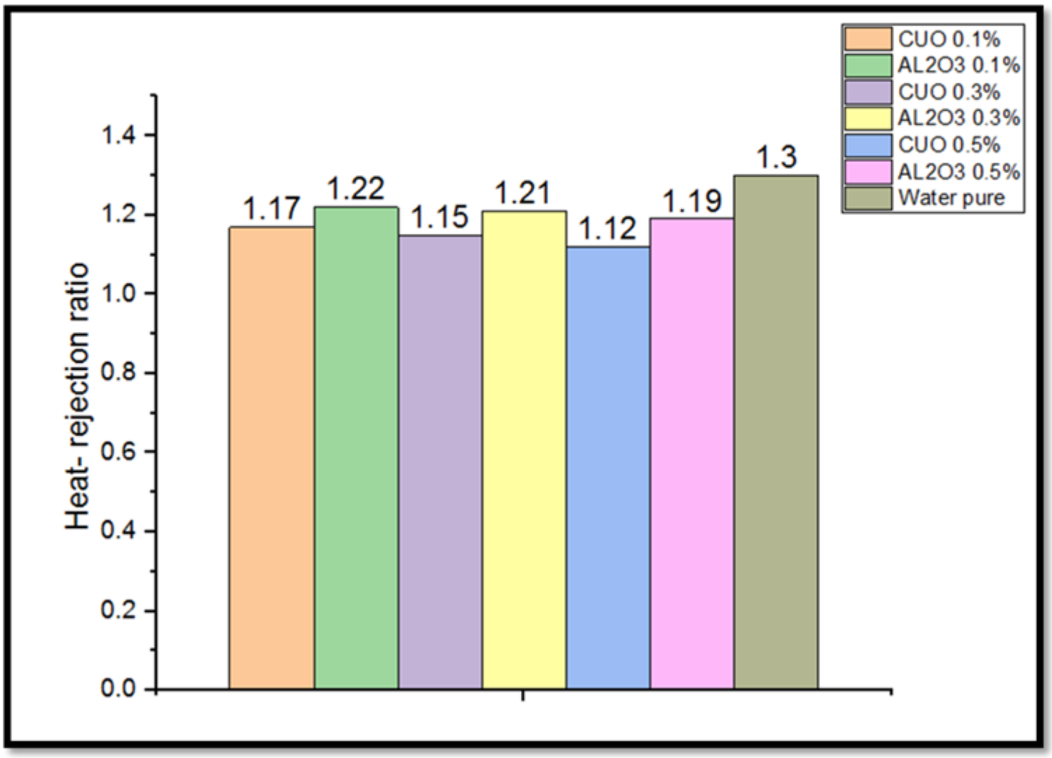

Figure 6. Experimental relation of H.R.R.

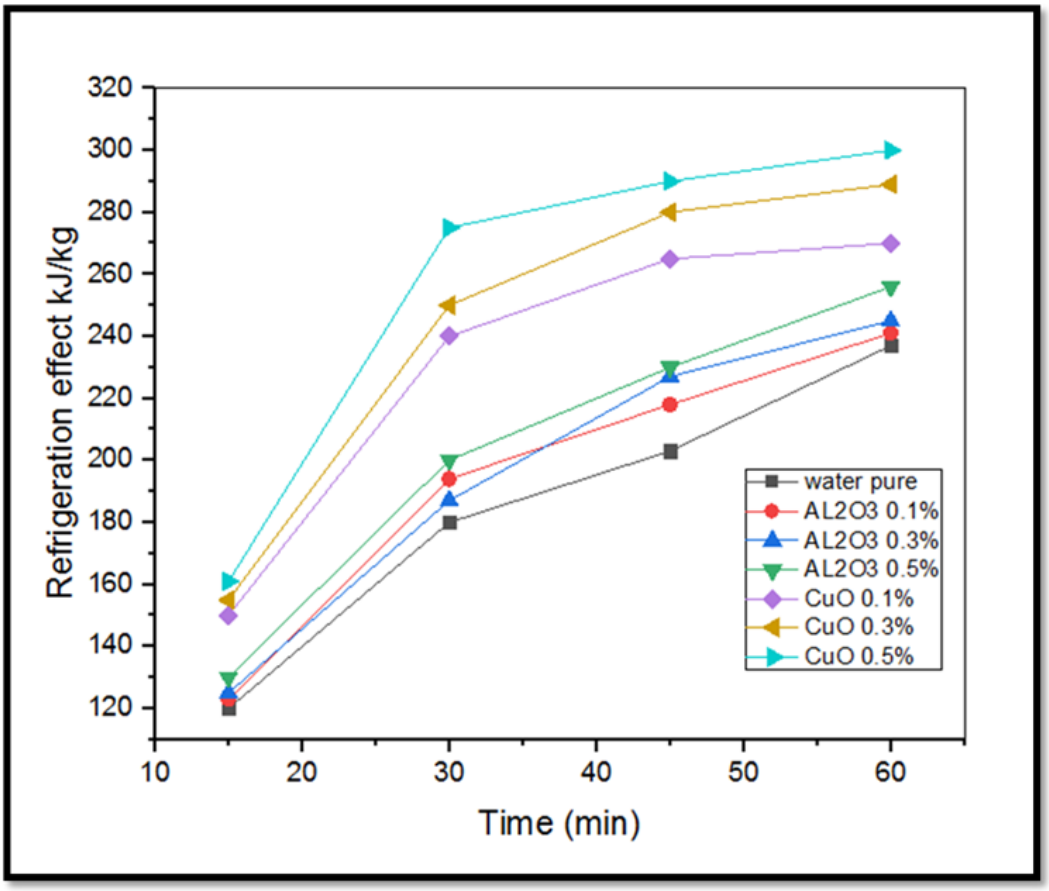

Figure 7. The effect of volume fraction on refrigerating effect.

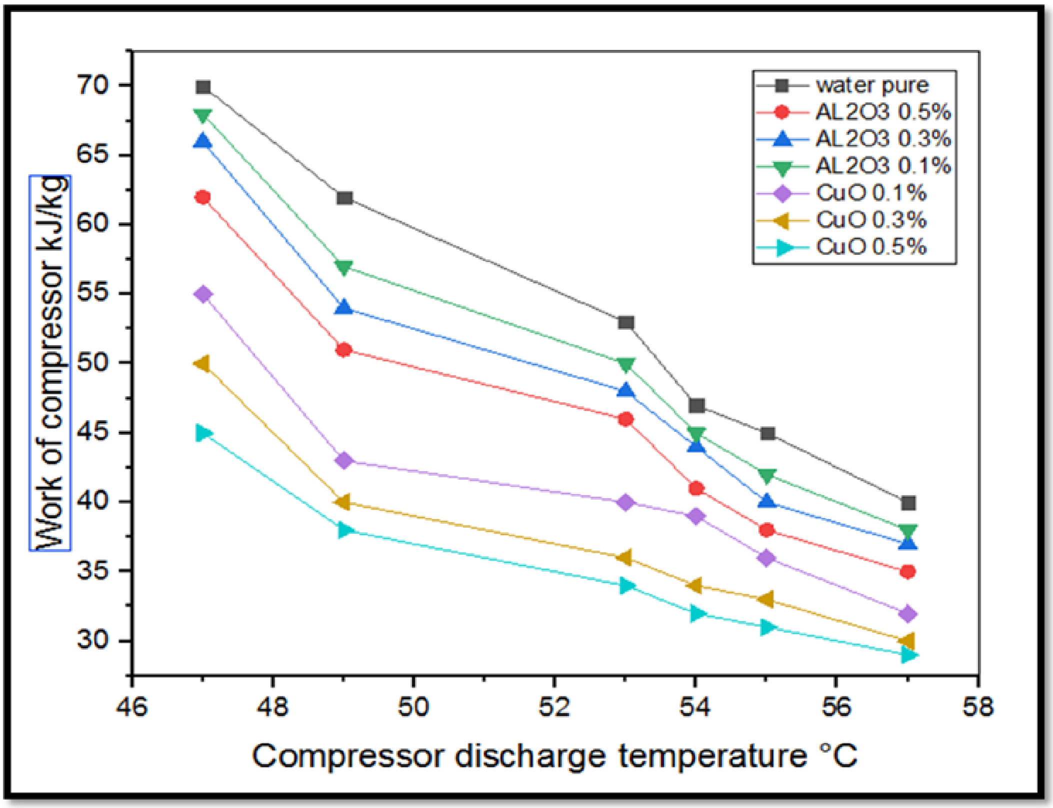

Figure 8. The effects of volume fractions on compressor work.

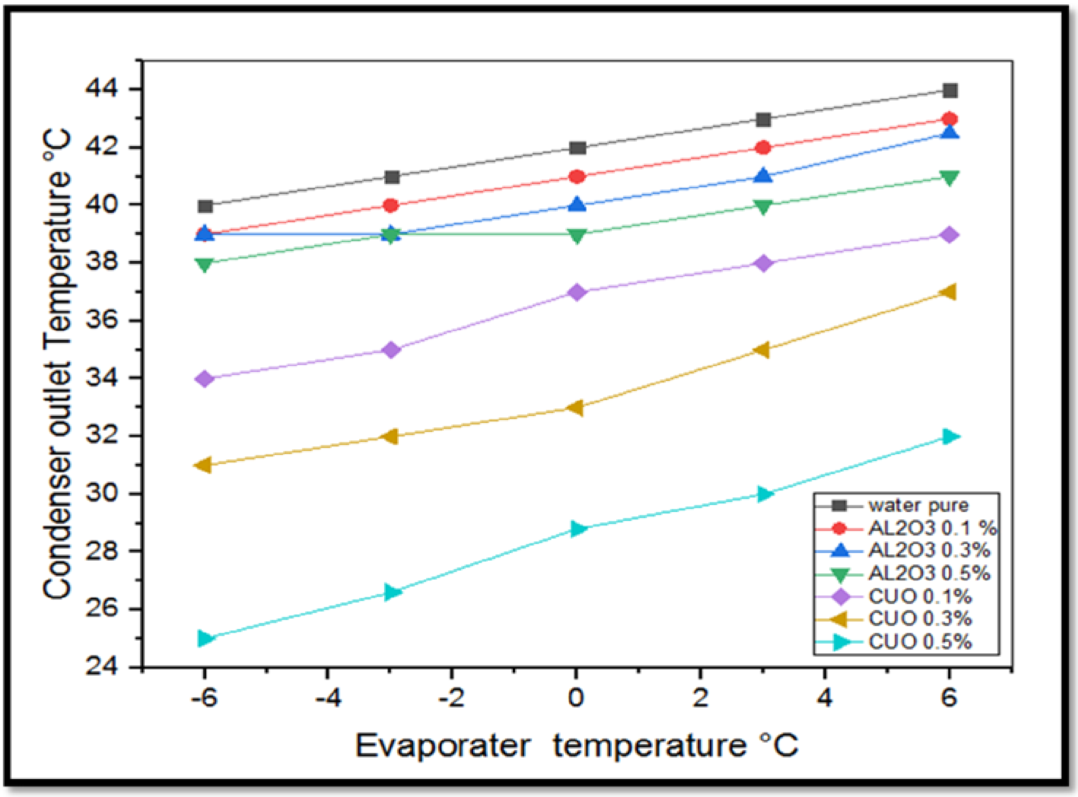

Figure 9. The temperature of outlet condenser and temperature of a evaporator.

CONCLUSION

In order to provide an indication of improved heat pump efficiency, this study focused on the impact of nanofluids on heat pump performance. The key results of this research were that the refrigerating effect was as the volume fraction of nanofluid (CuO-water) increases, it increases. Among the six cases considered for this experimental research, using (CuO-water) with a volume fraction of 0.5 percent has been found to increase COP by 22 percent and minimize compressor power consumption by approximately 31 percent, also decreasing heat rejection by approximately 0.8 percent. In addition, the temperatures of the condenser outlet and evaporator would decrease further.

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