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Evaluation of a Refrigeration System Based on Nano-Refrigerants and Nano-Lubricants

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Abstract: Most of studies reported that disperse nanoparticles into refrigerants and lubricating oils lead to improve a coefficient of performance, due to improvement of thermal physics properties of a pure fluid, which leads to reduced energy consumption. Using nanoparticles in a refrigeration system is associated with many difficulties such as the cost of preparing and obtaining a stable and homogeneous mixture for a longer time with less agglomeration and sedimentation. In this research, nanoparticles were prepared as a mixture in an inexpensive and easy way consisting of copper and cerium oxides for the first time, with suitable average diameter to verify the possibility of overcoming the problem of stability of nanoparticles for a longer time with refrigerant. As most studies focus on improving the thermal properties of a refrigerant by using high thermal conductivity nanoparticles, while this study focuses on improving both of thermal conductivity of refrigerant and stability of nanoparticles with a refrigerant. Some studies have reported on the use of copper oxide and its effect on improving the performance of refrigeration system, but cerium oxide has not been used in refrigeration systems and this research will open the door to cerium oxide as a single material and as a mixture with copper oxide to verify the possibility of this oxide to create greater stability of nanoparticles and improve thermal properties.

Keywords: Vapor Compression Refrigeration System, Thermophysics properties, Coefficient of Performance COP, Nano-refrigerants, Nano-lubricant

Introduction

The world today is facing a major challenge in the energy sector, due to its diminishing sources and a large increase in energy consumption especially in refrigeration, heat pumps and air conditioners Varieties of research have improved the efficiency of thermal systems. This can be performed in two ways, firstly by improving a design of the heat exchanger to include shell and tube type, plate type, micro channel and so on and secondly by using new kinds of a working fluid (Bhattad *et al*., 2018). In 1873 Maxwell dispersed particles ranging in diameters from millimeter to micrometer into a pure fluid for the first time to enhance its heat transfer characteristics, however, this attempt encountered several problems, for example, stability, clogging and erosion. Recently a new concept of working fluids was advanced; known as nanofluid where a nanoparticle is dispersing into a pure fluid, was done by to enhance its heat transfer characteristics (Nair *et al*., 2016). The nanofluid is divided into three categories depending on the composition of nano-particles (i) Mono-nanofluids which consist of similar nanoparticles, (ii) Hybrid nanofluids which consist of dissimilar, (iii) Hybrid nanofluids which consist of composite nanoparticles (Bhattad *et al*., 2018). Four conditions are required for successful preparation of the nanofluid (i) Dispersability of nanoparticles (ii) Stability of nano-particles (iii) Chemical compatibility of nanoparticles and (iv) Thermal stability of nanofluids. These conditions will create a nanofluid that has the best heat transfer properties between solid particles and fluids (Kotu and Kumar, 2013). Nanofluids have many applications for example microelectronics, heat exchangers, hybrid powered engines, fuel cells, pharmaceutical process, electronic cooling systems, nuclear reactors, surface engineering, bio-reactors, automotive HVAC, space cooling, cryogenics and so-on. Most of studies in the field of nanofluids showed that adding nanoparticles with different concentration to the base fluid improves Thermophysics properties of the base fluids. Recently the addition of nanoparticles to refrigerants bagan to take a lot of attention as a result of improving the performance of refrigeration system based on nano refrigerant and nano lubricant. Studies have also proven the chemical and physical properties of nanoparticles such as, shape, concentration, method of dispersion, method of preparation and the type of nanoparticle effect on the Thermophysics properties of the nano refrigerant (Bharathwaj *et al*., 2021; Pinni *et al*., 2020). Practically there are two methods to prepare the nano-refrigerants, a one-step method and a two-step method. A two-step method is commonly used for preparing of nano-refrigerants, where the nanoparticles are manufactured as a powder, then is put into the base fluid, followed by several types of dispersion methods such as agitation either by ultrasonic or magnetic force, homogenizing and high shear mixing to disperse nanoparticles inside a mixture. A one-step method is based on condensing a vapor nano-phase powders to liquid by reducing a pressure and then dissolving them inside a liquid immediately (Celen *et al*., 2014; Sharif *et al*., 2018). Improving the refrigeration system can be accomplished in two ways, first way, by increasing the amount of heat absorbed inside the evaporator and second way, by reducing compressor work. By adding nanoparticles into a refrigeration system will improve heat transfer in and thus the performance of refrigeration system will be enhanced. Two methods to add nanoparticles into a refrigeration system either add to the refrigerant or add to the lubricant oil of compressor (Kumar *et al*., 2021; Vamshi *et al*., 2021). Mixing of nanoparticles with lubricant oil enhance heat transfer coefficient also reduce the friction between walls of piston and cylinder of the compressor, which increases heat transporting ability, while using of nano refrigerants will make the refrigeration systems efficient by improving the heat transfer characteristics of base fluids and thus reduce the power consumption and also reduces the environmental risks associated with the use conventional refrigerants (Vijaya Kumar *et al*., 2021).

Literature Review

Reviewed literature is classified in two sections. The first one evaluates the performance of vapor compression refrigeration system based on nano-refrigerant and nano-lubricant and the second one evaluates basic properties of nano-refrigerant and nano-lubricant such as thermal conductivity, viscosity, specific heat and density. Vijaya Kumar *et al*. (2021) evaluated the performance of refrigerator based on nano-lubricants consisting of an Aluminum di oxide an average diameter 205 nm to 40 nm added to polyolester oil, 60 g of R602a was used as a refrigerant. The results showed that the refrigerating effect increased by 6.09%, the compressor work reduced by 15.78% and the COP increased by 20.09% as compared to the conventional system without nanoparticles (Vijaya Kumar *et al*., 2021). Choi *et al*. (2021) evaluated the performance of refrigerator based on nano-lubricants consisting of 0.1 wt.% MWCNTs were dispersed into the POE, R134a was charged as a refrigerant. The results showed that the power consumption of the compressor consisting of nano lubricant reduced by 17% (Choi *et al*., 2021). Senthil Kumar *et al*. (2021d) evaluated the performance of refrigeration system based on nano-lubricants consisting of hybrid nanoparticles prepared by mixing Al_2o_3 and Sio_2 at two different concentrations of 0.4 and 0.6 g/L, 40 and 60 g of R600a were charged as a refrigerant. The result indicated that COP and refrigerating effect increased by. 30 and 25% respectively, while the power consumption reduced by 80W (Senthil Kumar *et al* 2021a). Senthil Kumar *et al*. (2021b) evaluated the performance of vapor compression refrigeration system based on hybrid nano-lubricants consisting of two different nano-particles such as CuO and Sio_2 at 0.2 and 0.4 g/L concentrations, 40 and 60 g of R600a were charged as a refrigerant. The results indicated that hybrid nano-lubricants improves COP by 35% and refrigeration effects by 18% while reduced the power consumption by 75 W as compared to the system without nanoparticles (Senthil Kumar *et al*. (2021b). Senthil Kumar *et al*. (2021a) evaluated the performance of refrigeration system based on nano-lubricants consisting of 0, 0.2, 0.4 and 0.6 g/L of Sio_2 mixed with POE oil, 30, 40, 50, 60 and 70 g of R410A were used as a refrigerant. The results indicated that 0.4 g/L Sio_2 nano-lubricant and 40 g refrigerant achieved a high refrigeration effect as compared with system without. The using of nano lubricants reduced compressor work by 80 W with 0.4 g/L and 40 g of refrigerant. Disperse of Sio_2 into the lubricants enhanced COP by 1.7 for 0.4 g/L nano lubricants as compared to base oil (Senthil Kumar and Anderson, 2021a). Evaluated the performance of refrigeration system based on hybrid nano-lubricants consisting of 0.4 g/L of ZnO/Sio_2 with 40 g of R600a refrigerant and 0.6 g/L ZnO/Sio_2 with 60 g of R600a refrigerant. The results indicated that 0.6 g/L ZnO/Sio_2 hybrid nano lubricants achieved a high refrigeration effects by 180 W as compared to the base oil, enhanced COP by1.7, while the lower compressor work was 78 W achieved at 0.6g/L and 60 g of R600a as compared to the system without nanoparticles (Senthil Kumar *et al*., 2021c) evaluated of performance of VCRs based on hybrid nano-lubricants consisting of 0.2, 0.4 and 0.6 g/L of CuO/Al_2O_3, 70 g of R600a was used as a refrigerant. The results showed that the adding of CuO/Al_2O_3 hybrid nanoparticles into a compressor oil enhanced COP by 27% and increase the refrigeration capacity by 20% while reduction the power consumption by 24% as compared to the base system (Senthil Kumar and Anderson, 2021b). Sarrafzadeh and Saidur (2021) evaluated the performance of refrigerator based on nano-lubricants consisting of 0.1 wt.% Al_2O_3. The results indicated that 0.1 wt.% of Al_2O_3 reduced the power consumption by 2.69 % of the refrigeration system as compared to lubricant oil without nanoparticles (Gill *et al*., 2019). Gill *et al*. (2019) evaluated the performance of domestic refrigerator based on nano-lubricants consisting of 0.2, 0.4 and 0.6 g /L of TiO_2 added to (Capella D) oil as an alternative to R134a Various charges of LPG from 40 to 70 g were used as refrigerant. The results indicated that refrigeration effect and COP were higher than R134a by 18.74-32.72 and 10.15-61.49%, respectively. In addition, the compressor power input was lower than R134a about 3.20-18.1, respectively. Also reported that 40 g of LPG refrigerant with 0.4 g/L of TiO_2 achieved the best energy performance of the refrigerator (Gill *et al*., 2019). Karthick *et al*. (2020) evaluated the performance of VCRs based on four samples of nano-lubricant: Sample 1 (MO + 0.02 vol% Al_2O_3 + 0.01 vol% TiO_2), sample 2 (MO + 0.01 vol% Al_2O_3 + 0.005 vol% TiO_2), sample 3(MO + 0.05 vol% Al_2O_3) and sample 4 (MO + 0.02 vol% Al_2O_3 + 0.02 vol% ZnO). R600a was charged as a refrigerant. The results indicated that COP improved by 14.61%. Nano-lubricant exhibited higher COP which reduces the power consumption of the system (Karthick *et al*., 2020). Adelekan *et al*. (2019a) studied the performance of a refrigerator based on nano-lubricants consisting of 0.2 g/L, 0.4 g/L and 0.6 g/L of TiO_2 concentrations, the safe mass charge of LPG was charged as refrigerant. The results showed that all various concentrations of nano-lubricant achieved a reduction of power consumption by 14%, 9 % and 8% respectively. MO achieved the highest power consumption whereas 0.2 g/L of TiO_2 achieved the lowest one. The refrigeration effects based on 0.4 g/L and 0.6 g/L were higher, while based on 0.2 g/L was lower as compared to pure oil (Adelekan *et al*., 2019b). Subhedar *et al* (2020) evaluated the performance of VCRs based on nano-lubricants consisting of 0.05vol %, 0.075vol %, 0.1vol % and 0.2vol % of Al_2O_3 mixed with MO, R134a was charged as a refrigerant. The results indicated that 0.075vol % achieved the maximum enhancement in COP around 85% and the use of nano-lubricant saves approximately 27% compressor power. Also reported that 0.075vol % was the best concentration of vapor compression refrigeration system (Subhedar *et al*., 2020). Babarinde *et al*. (2019) investigated the performance of a domestic refrigerator based on nano-lubricants consisting of 0.4 and 0.6 g/L of TiO_2 mixed with MO and R600a was used as a refrigerant as an alternative to R134a. The results indicated that 0.4 g/L of TiO_2 achieved the highest COP and lowest power consumption as compared to R134a (Babarinde *et al*., 2019). Selimefendigil (2019) investigated the performance of VCRs based on nano-lubricants consisting of 0.5 vol%, 0.7 vol%, 0.8 vol% and 1 vol% of TiO_2 mixed with PAG oil and R134a was used as a refrigerant. The results indicated that 0.5 vol%, 0.8 vol% and 1 vol% achieved an improvement of COP around 1.43, 15.72% and 21.42 %, respectively; 1 vol% reducing energy consumption by 15% as compare to the base oil (Selimefendigil, 2019) Sundararaj *et al*. (2020) investigated the performance of VCRs based on nano-lubricants consisting of 0.1 vol% Au, 0.2 vol% Au, 0.1vol% HAuCl4, 0.2 vol% HAuCl4, 0.1 vol% Au and 0.05 vol% CNT, 0.2 vol% Au and 0.02 vol% of CNT added to PAG oil and R134a was used as a indicated that 0.2 vol% Au and 0.02vol% CNT achieved the lowest power input as compared to another compositions of nanoparticle, greatest cooling capacity ,and maximum value of COP Therefore it is preferred to run the system using 0.2vol % Au and 0.02vol % of CNT as volume fraction (Sundararaj and Manivannan, 2020). Peyyala (2020) investigated the performance of VCRs based on nano-lubricants consist of 0.1vol % to 0.2 vol % of Al_2O_3 nano powder mixed with MO, R410a was used as a refrigerant. The results indicated that an increase in COP value with increasing the nanoparticle concentrations and the maximum value was observed to be at 0.2 vol % of Al_2O_3 (Peyyala, 2020). Babarinde *et al*. (2019) investigated the performance of VCRs based on nano-lubricants consisting of 0.2, 0.4 and 0.6 g/L graphene added to MO, 50g-70 g of R600a were used as a refrigerant. The results indicated that nano-lubricant based on 60 g of R600a and 0.2 g/L graphene exhibited the lowest power consumption, the highest COP was 3.2 achieved at 0.2 g/L graphene nano-lubricant (Babarinde *et al*., 2020). Adelekan *et al*. (2019a) evaluated the performance of refrigerator based on nano-lubricants consisting of 0.1 g/L, 0.3 g/L, 0.5 g/L of TiO_2 concentrations, mixed with MO. 40 g, 60 g, 80 g of R600a were used as a refrigerant. The results showed that the highest COP and refrigerating effects were 4.99 and 290.83 kJ/kg based on 40 g-0.1g/L nano-lubricant (Adelekan *et al*., 2019b). Ajayi *et al*. (2019) evaluated the performance of VCRs based on 0.5 g/l Al_2O_3 nanoparticles concentrations mixed with (Capella D) oil and 100g of R134a was used as refrigerant. The results showed that nano-lubricant achieved a higher refrigeration effect, better performance and improves energy consumption as compare to the base oil (Ajayi *et al*., 2019). Senthil Kumar and Anderson (2020c) evaluated the performance of VCRs, based on nano-lubricants consisting of 0.2 g/L, 0.4 g/L and 0.6 g/L of Sio_2, added to POE oil, 30, 40, 50, 60 and 70 g of R410A were used as a refrigerant. The results indicated that nano-lubricant based on 40 g of R410A and 0.4 g/L of Sio_2 achieved better refrigerating effects and reduction of power consumption. This leads to an enhanced COP as compare to pure lubricant (Senthil Kumar and Anderson, 2021a). Pawale *et al*. (2017) evaluated the performance of VCRs based on nano-refrigerant consisting of 0.5wt % and 0.1wt % of Al_2O_3, particle size diameter 50nm was dispersed into R134a. The results showed that the nano-refrigerant based on 0.5wt% achieved improvement of the performance. However, increasing of nanoparticles concentration will lead to reduce a performance of a system (Pawale *et al*., 2017). Kumar *et al*. (2018a) evaluated the performance of vapor compression refrigeration system based on nano-refrigerant consisting of (1gr of ZnO/1gr SiO_2), (1.5gr of ZnO/0.5gr of SiO_2) and (0.5gr of ZnO /1.5gr of SiO_2) were dispersed into 0.5 kg of R134a.The results showed that COP increased around 26%. Furthermore, the different proportions of nanoparticle exhibited different influences on a performance of a system (Kumar *et al*., 2018b) Manikanden and Avinash (2019) investigated the performance of domestic refrigerators based on nano-refrigerants consisting of CuO, pure nano-CuO and Ag - doped nano-CuO are dispersed into R290. The results indicated that Ag-doped nano-CuO achieved the best performance of a system as compared to pure nano-CuO. The COP of Ag-doped nano-CuO increased up to 29%, while the power consumption of a system reduced up to 28%, (Manikanden and Avinash, 2019). Kundan and Singh (2021) evaluated the performance of VCRs based on nano-refrigerant consisting of 0.5 to 1 wt.% of Al_2O_3 are dispersed into R134a, particle size diameter 20 nm. The results based on volume flow rates of refrigerants showed that 6.5 L/h and 11 L/h achieved improvements of COP from7.20 % to 16.34% respectively at 0.5 wt.% of Al_2O_3. However, applied 1 wt.% of Al_2O_3 caused reduction of COP at the same volume flow rates (Kundan and Singh, 2021). Nagaraju and Reddy (2018) evaluated the performance of VCRs based on nano-refrigerants consisting of 0.05 to 0.8 wt.% of CuO particle size range 10 to 70 nm is dispersed into R134a. The results showed that 0.8 wt.% of CuO was the optimal concentration which achieved the highest heat transfer enhancement, enhanced COP and reduction of power consumption, but the cost of nano-refrigerant was expensive (Nagaraju and Reddy, 2018). Kumar and Tiwari (2019) evaluated the performance of VCRs based on R134a/PAG oil, R600a/PAG oil and Cu nanoparticles is dispersed into R600a. The results showed that R600a achieved a higher COP and refrigeration effect around 27.12% and 25% respectively as compare to R134a, while the reduction of power consumption was 1.69 % which was less than that of R134a. Moreover dispersing 0.5 wt. %, 1wt % and 1.5 wt.% of Cu into R600a improved COP, refrigeration effect and reduced the power consumption as compared to pure R600a (Kumar and Tiwari, 2019). Kumar *et al*. (2016) investigated the performance of VCRs based on 0.01 vol% and 0.06 vol % of ZrO_2, particle size diameter 20 nm is dispersed into both R134a and R152a. The results indicated that the improvement of COP was 33.45% based on (0.06 vol % of ZrO_2 - R152a) nano-refrigerant. The application of R152a as a refrigerant was environmentally beneficial due to its properties such as zero ozone depletion potential and very low global worming potential (Kumar *et al*., 2016). Mahdi *et al*. (2017) evaluated the performance of VCRs based on nano-refrigerant consisting of 0.01vol % and 0.02 vol% of Al_2O_3, diameter size of 20-30 nm was dispersed into R134a. The results showed that a rising nanoparticle concentration caused improvement of COP by 3.33% to 12%, respectively and reduction of power consumption by 1.6% and 3.3%, respectively (Mahdi *et al*., 2017). Pandey (2017) evaluated the performance of VCRs based on 0.2, 0.4 and 0.6 vol % of TiO_2 and particle size diameter 30-50 nm was dispersed into R134a.The results showed that nano-refrigerant based on 0.4 vol % of TiO_2 achieved an improvement of COP around 11.1% at 20°C, 25°C and 30°C evaporator temperatures. Also, it has not been observed an increase or decrease in power consumption, which shows that nanoparticle was completely dissolved in the refrigerant (Pandey, 2017). Kumar *et al*. (2021) evaluated the performance of VCRs based on nano refrigerants consisting of R600a + 0.20 g Al_2O_3, R600a + 0.30 g Al_2O_3 and R600a + 0.40 g Al_2O_3, with average size of Al_2O_3 was 20 t0 30 nm. The results showed that Al_2O_3 improved COP by 3.68% to 11.05% and reduced the power consumption by 13.6 to 30.4% (Kumar *et al*., 2021). Thermal conductivity is the most important among of Thermophysics properties of nano-refrigerants due to its effects on the boiling and convective heat transfer coefficients. This explains why most researchers are focusing on studying thermal conductivity. Recently interest in the study of viscosity has begun to appear to extend to the other Thermophysics properties to form a clear idea of the heat transfer properties (Kumar *et al*., 2021). Kedzierski *et al*. (2017) evaluated of Thermophysics properties of nano-lubricants based on nanoparticle size diameter 127 nm and 135 nm of Al_2O_3 and ZnO respectively mixed with POE oil at atmospheric pressure with temperature ranging from 288 to 318 K and various mass fractions of Al_2O_3, ZnO were used such as 15 wt.%, 20 wt.%, 25 wt.%, 30 wt.%, 35 wt.%, 38 wt.% and 5.6 wt.%, 15 wt.%, 24.4 wt.%. 25 wt.%. 28 wt.% respectively. The results showed increasing of nanoparticle concentrations leads to increase of viscosity, density and thermal conductivity but a viscosity and density decreased with increasing of temperature (Kedzierski *et al*., 2017). Sanukrishna and Prakash (2018) studied thermal conductivity and viscosity of nano-lubricant based on 0.07 to 0.8 vol%

of TiO_2 added to PAG at temperatures ranging from 20°C to 90°C. The results indicated that increasing of nanoparticle concentration leads to increase these parameters, while these parameters decreased with increasing a temperature (Sanukrishna and Prakash, 2018). Zawawi *et al*. (2018) evaluated thermal conductivity and dynamic viscosity of nano-lubricants based on 0.02 to 0.1 vol% of Al_2O_3/SiO_2, Al_2O_3/TiO_2 and TiO_2/SiO_2 mixed with PAG oil at temperatures ranging from 303 to 353 K. The results showed that nano-lubricant based on 0.1 vol% of Al_2O_3/TiO_2/PAG enhanced the viscosity of 20.50% at 303 K. While nano-lubricant based on 0.1 vol% of Al_2O_3/SiO_2/PAG improved the thermal conductivity by 2.41% at 303 K (Zawawi *et al*., 2018). Harichandran *et al*. (2019) measured the density and the kinematic viscosity of nano-lubricants based on 0.1 to 0.4 vol% of h-BN nanoparticle. The results indicated that increasing nanoparticle concentration leads to increase density, related to a kinematic viscosity of pure POE and nano-lubricants at various temperatures. The results reported that decreasing these values with increase of temperatures and kinematic viscosity of 0.4 vol% nano-lubricants was 14% higher than pure oil at room temperature (Harichandran *et al*., 2019). Karthick *et al*. (2020) investigated thermal conductivity of four samples such as, sample1 (MO+ 0.02 vol% Al_2O_3 + 0.01 vol% TiO_2), sample 2 (MO+0.01 vol% Al_2O_3+ 0.005 vol% TiO_2), sample 3 (MO + 0.05 vol% Al_2O_3) and sample 4 (MO+ 0.02 vol% Al_2O_3 + 0.02 vol% ZnO). The results showed that MO based on 0.05 vol% of Al_2O_3 produced a higher increase of thermal conductivity and MO containing 0.01vol% Al_2O_3 and 0.005 vol% of TiO_2 produced the least increase in thermal conductivity. It was observed that sample 1 was given the highest value of kinematic viscosity than the other three samples. On the other hand, samples 3 and 4 were chosen as the best samples (Karthick *et al*., 2019). Kumar *et al* (2018a) investigated a viscosity of nano-lubricants based on 0.2 to 1.0 wt.% of CuO. The results showed that 0.2-1.0 wt.% of CuO leads to improve viscosity around 17%. In addition, viscosity decreases with increasing temperature (Kumar *et al*., 2018b; Jatinder *et al*., 2019) evaluated thermal conductivity and viscosity of nano-lubricants based on 0.1 to 0.6 g/L of TiO_2.The results showed that thermal conductivities of nano-lubricants were higher than pure lubricant nearly 14.37-41.25%, while a viscosity of nano-lubricants was lower than pure lubricant nearly 2-6%. Moreover, a viscosity of nano lubricants decreases with increasing the nanoparticle concentrations until 0.2 g/L and then increases with increasing concentrations to reach the peak value at 0.6 g/L of TiO_2 nanoparticle concentrations (Peyyala, 2020).

Materials and Methods

The nanoparticles were prepared by the author of this study based on the use of nitrates, distilled water and ammonia. The preparation process was briefed as the following steps:

1. Heating until 80°C for 1 hour with constant mixing speed equal to 375 rpm
2. Adding ammonia at constant temperature 60°C and constant mixing speed equal to 375 rpm to reach PH = 10 ± 1
3. Raising the temperature to 90°C until copper oxide is deposited
4. Cooling the solution to room temperature
5. Filtration
6. Drying in electric oven at 110°C for 1hour
7. Milling
8. Screening; and
9. Packing

According to the following equations. A mixture of copper oxide and cerium oxide were prepared as indicated clearly in Table 1

$$M = \frac{W}{M_w} \quad (1)$$

$$C = \frac{n}{v} \quad (2)$$

Where:

M:	Mole	g/mol
W:	Weight	g
M_w:	Molecular weight	mol
C:	Mole concentration	mol/L
n:	Number of moles	
v:	Volume	L

Prepareing of Nanorefrigerant

In this part of the study, mixing vessels were made from a laboratory bottle is made from Pyrex in the OSTIM area in Ankara Turkey. This vessel consists of the following parts:

1. A laboratory bottle is made from Pyrex, one bottle costs 4 $
2. Copper cover with inner diameter 4 cm cost 4 $
3. Copper tube L shaped, its length 6.5 cm inside the container is welded with a cap and its length outside the container 2.5 cm with an additional

length up to 4 cm to place the valve of transfer the gas at a cost of 2 $ This vessel was tested in terms of its resistance to leaks as well as in terms of its tolerance for the pressure required for the liquefaction process. Figure 1 shows the mixing vessel of this study

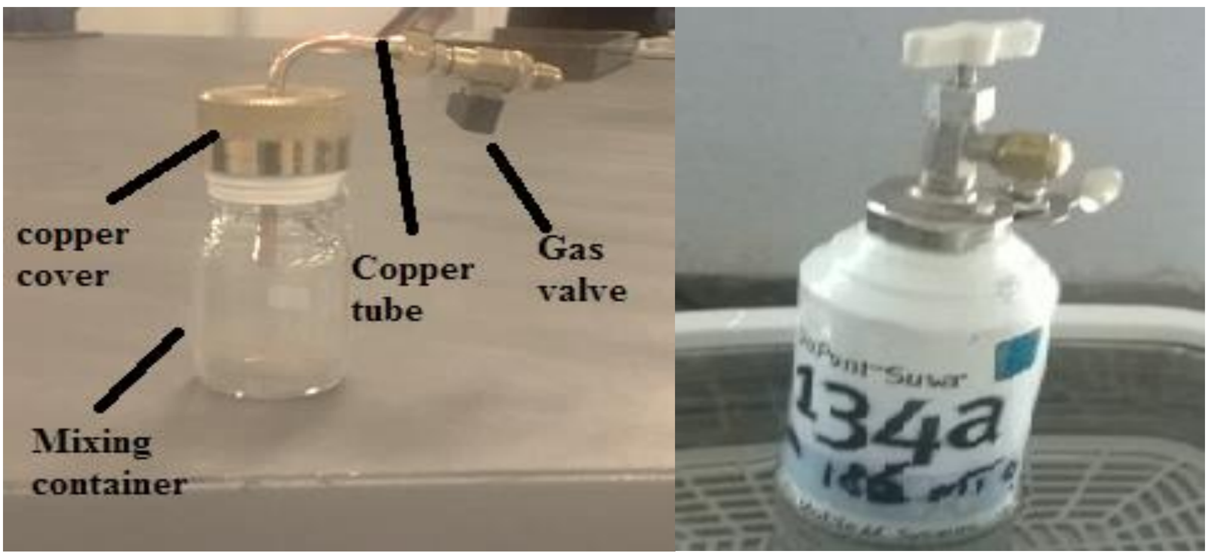
As shown in Eq. (3) a specific amount of nanoparticles as a mixture from 0.5% copper oxide and 0.5% cerium oxide is weighed using the digital balance. This amount is placed in the mixing vessel, the container is closed tightly and the container is evacuated from the air using vacuum pump and weight of the container after the vacuum to ensure that the amount of nanoparticles that were weighed was not lost:

$$\varphi\% = \frac{\left(\frac{w}{\rho}\right)np}{\left(\frac{w\rho}{\rho}\right)np + \left(\frac{w}{\rho}\right)r} \qquad (3)$$

where, φ, ρ ,and w denote percentage of volumetric fraction, density ,and materials weight, respectively (Haque *et al*., 2016) In order to achieve a stable solution of Nano refrigerant, the sample exposed to ultrasonic waves for one hour. The ultrasonic device is manufactured by Germany, (power = 320 W, frequency = 35 kHz). The aforementioned steps were taken to break up the potential agglomerates, which in turn yields a homogenized and stable Nano refrigerant. This study achieved success in obtaining a homogeneous mixture of refrigerant with nanoparticles for a period more than two hours while the mixing process continued for one hour on the ultrasonic only, this gave an indication that the use of nanoparticles as a mixture with refrigerant may help to obtain a more homogeneous and stable mixture for a longer time, which makes us start a series of research in this field soon, as the research plan of this study includes studying the effect of nanoparticles on thermos-physical properties of refrigerant as well as on improving the performance of refrigeration system.

Table1: The quantities obtained in grams from the mixtures

Mixture number	Percentages CuO (%)	Percentages CeO_2 (%)	Molar Concentration Cu $(NO_3)_2$ $3H_2O$ (m/l)	Molar Concentration Ce $(NO_3)_3$ $6H_2O$ (m/l)	Molar concentration of mixtures (m/l)	Quantity g
1	50	50	0.20867	0.09673	0.1527	12.67
2	60	40	0.25040	0.07753	0.181258	11.44
3	70	30	0.30007	0.01750	0.21530	10.97
4	40	60	0.16694	0.11622	0.13651	13.07
5	30	70	0.12568	0.13556	0.13260	13.85



(a) (b)

Fig. 1: (a) The mixing vessel of this study (b) Model of mixing vessel from literature review

Results and Discussion

Nanoparticle's characterization was carried out at the Huazhong University in China on September 24, 2019 by using XRD analysis on a X'Pert PRO used Cu Kα radiation, 15 mA, 30 kV, (5-100o) 2θ range, 0.0167o step size and 8 min-1 scanning speed. PANalytical–Empyrean and Scanning Electron Microscopy (SEM) images (TESCAN VEGA3), 20.0 kV of an accelerating voltage are obtained. The XRD pattern was scanned from 20 to 80 degrees and the XRD profile confirmed the nano crystalline nature of CuO. The characteristic diffraction peak was observed at 2ϴ = 32.509, 35.438, 35.539, 38.731, 38.941, 46.264, 48.743, 53.466, 58.312 and 61.549 correlated to (110), (002) (-111), (111), (200), (-112), (-202), (020), (202), (-113) crystal planes, respectively. All of the peaks are agreed in position and intensity with database standard (JCPDS 00-045-0937) of the face centered cubic CuO crystal with the fluorite structure. *The absence of additional diffraction peaks confirms the nano-crystalline nature and purity of the samples*. The XRD pattern was scanned from 20 to 80 degrees and the XRD profile confirmed the nano crystalline nature of CeO_2.

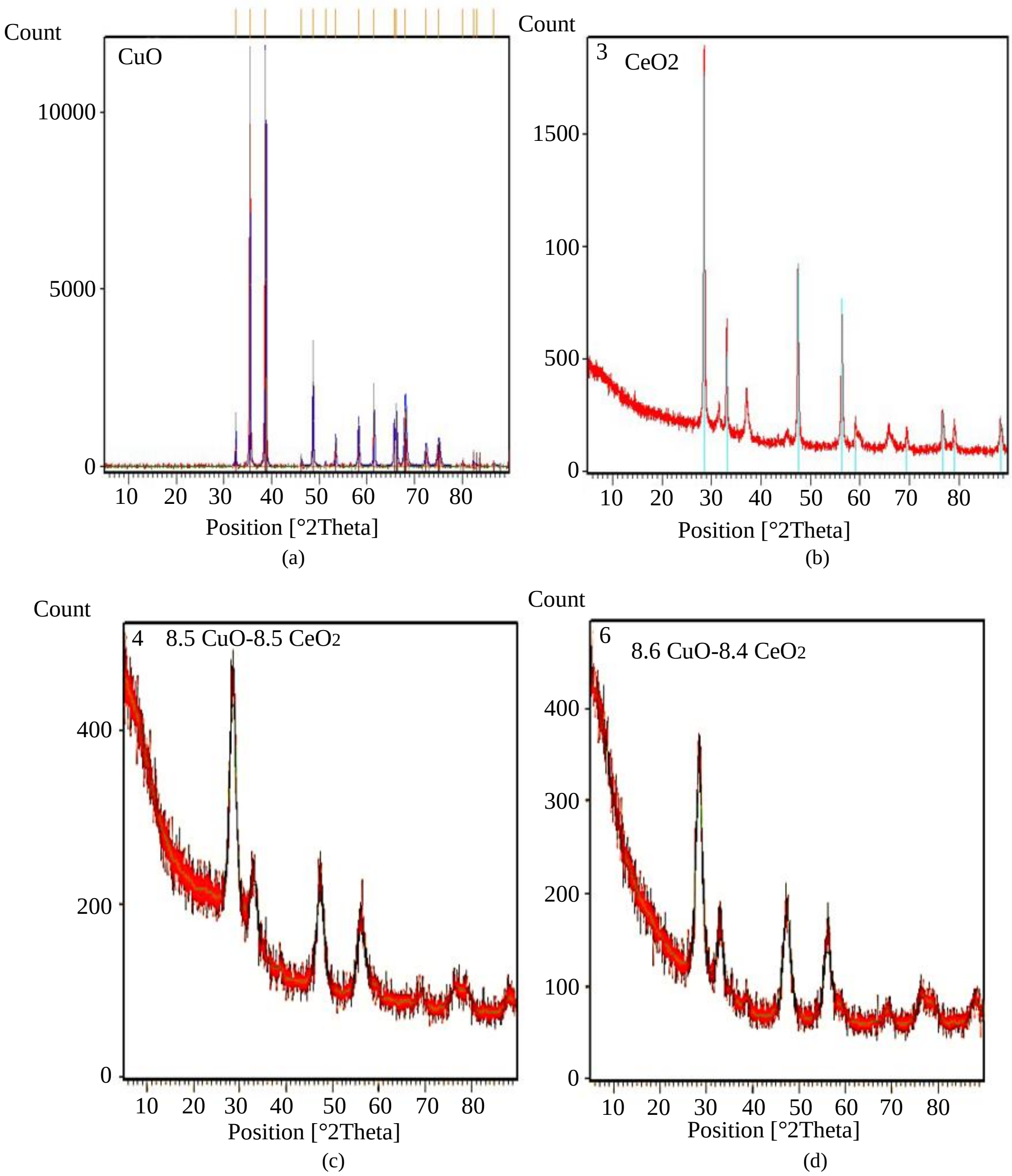


Fig. 2: XRD pattern of (a) pure Cupper Oxide (b) pure cerium Oxide (c) 0.5 CuO,0.5 CeO_2 (d) 0.6 CuO, 0.4 CeO_2 at Huajong University in China

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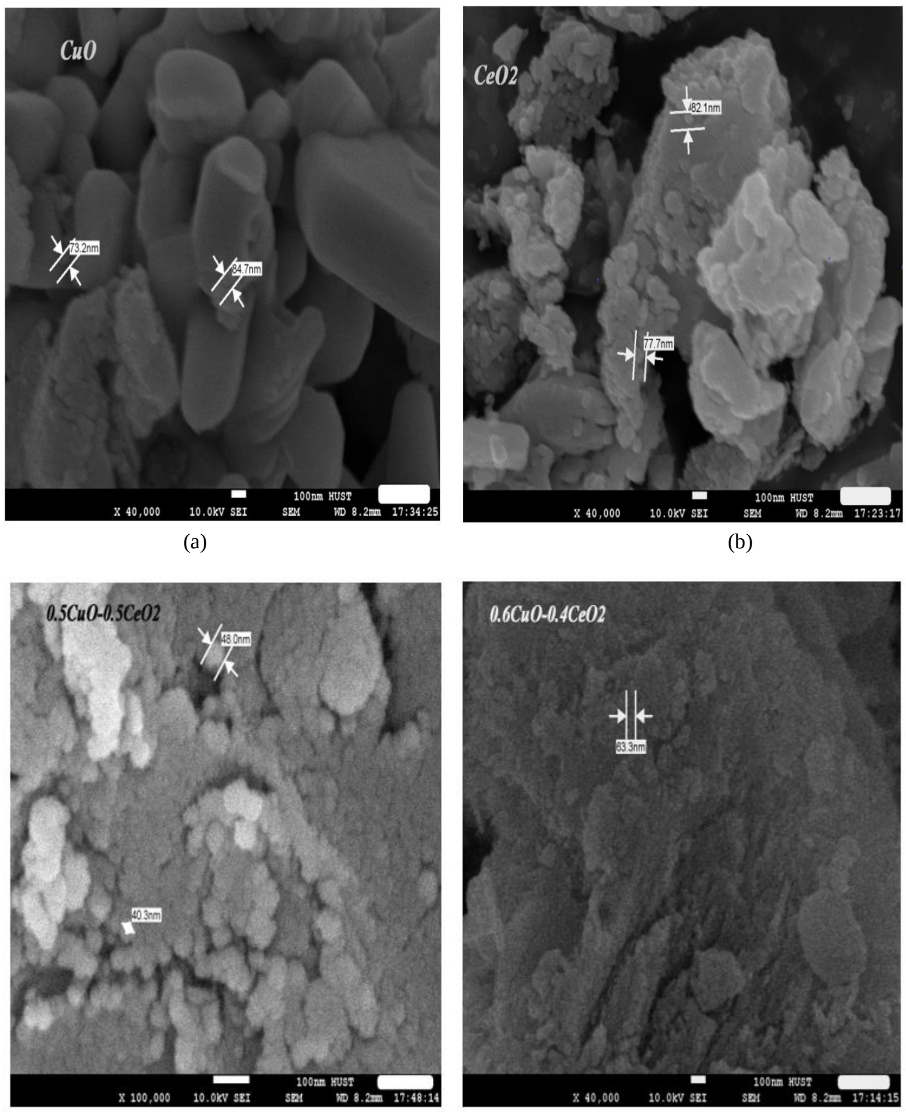
The characteristic diffraction peak was observed at 2ϴ = 28.550, 33.077, 47.490, 56.328, 59.096, 69.407, 76.736, 79.079, 88.451 and 95.432 correlated to (111), (200), (220), (311), (222). (400), (331), (420). (422), (511) crystal planes, respectively. All of the peaks are agreed in position and intensity with database standard (JCPDS 00-004-0593) of the face centered cubic CeO_2 crystal with the fluorite structure. The absences of additional diffraction peaks confirm the nano-crystalline nature and purity of the samples. The results of preparing nanoparticles are presented in Fig. 1. The SEM images proved that particles of samples were approximately spherical in shape and with the particle sizes of CuO, CeO_2, 0.5 CuO + 0.5CeO_2 and 0.6 CuO + 0.4CeO_2 were observed to 78.95, 79.9, 44.15 and 63.3 nm based on SEM images respectively, as seen in Fig. 2 and 3. This study succeeded in preparing nanoparticles in a cheap and easy way with suitable diameters as compared with other complex Methods and the research plan of this study depends on the use of cerium oxide for the first time as a single material and as a mixture with copper oxide to investigate its effects on performance of refrigeration system as well as Thermophysics properties of refrigerant. It is expected that this study will open the door to many researches later on to reveal new properties of cerium oxide as a mixture with copper oxide, especially they were prepared by the same method as a homogeneous mixture which have the properties of both cerium oxide and copper oxide.



(a) (b) (c) (d)

Fig. 3: Scanning Electron Microscopy Images for (a) Spheral CuO, (b) Spheral CeO_2, (c) Spheral 0.5CuO+0.5CeO_2, (d) Spheral 0.6 CuO + 0.4CeO_2

Conclusion

Most researches report that use nano-lubricants and nano-refrigerants worked safely in the VCRs. In addition, application of nano-refrigerants and nano-lubricants, leads to reduction of energy consumption, increases freezing capacity and increases the performance of the refrigeration system but this depends on the type of nanoparticle used and its concentration. In some investigations it was observed that the performance of the system improves up to a specific value of concentration then reduces. Using nano-lubricant has a better tribology characterization for, example friction reduction and wears rate as compared to pure compressor lubricant. This achieves longer life of mechanical parts, especially a compressor. While nano-refrigerant has better Thermophysics properties due to suspended nanoparticles which has better thermal conductivity as compared to the base refrigerant, the appropriate selection of types and concentrations of nanoparticle has an important role to enhance the performance of the refrigeration system. In this study, the use of nanoparticles as a metal, a metal oxide and a hybrid was reviewed and here the difference between this study and previous studies was shown, where the nanoparticles were used as a mixture prepared from two oxides with two different properties, but in the same way this a new concept of nanoparticles as a mixture was introduced to investigate the verify the effect of each component of the mixture over the other and whether this mixture prepared from two materials with different properties will produce a third materials that has better properties than its basic components and will the preparation of nanoparticles as *a* mixture contribute to solving the problem of stability.

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Author's Contributions

HudaElslam Mohamed: Prepared the nanoparticles and studying its effect on the performance of refrigeration system and thermos physical properties later, as well as the cooperation between

Unal Camdali and Metin Actas: In reviewing the paper linguistically.

Ethics

The author of this paper adhered to the criteria of citation and tried to show the previous results in this field with accuracy based on the latest studies from 2017 to 2020.

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Abbreviations

PAG: Poly Alkylene Glycol
COP: Coefficient of Performance
VCRs: Vapor Compression Refrigeration System
POE: Polyol ester oil
MO: Mineral Oil Capella
D: Mineral Oil
LPG: Liquefied Petroleum Gas
GWP: Global Warming Potential
ODP: Ozone Depleting Potential
Wt: Mass fraction
VOL: Volume fraction
XRD: X-Ray Diffraction
SEM: Scanning Electron Microscopy
HVAC: Heating, Ventilation and Air conditioning

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Chemical Symbols

CuO:	Copper Oxide
TiO_2:	Tanium Dioxide
Al_2O_3:	Aluminum Oxide
ZnO:	Zinc Oxide
R134a:	1,1,1,2-Tetrafluoroethane
SiO_2:	Silicon Dioxide
Ag:	Silver
R152a:	1,1 Difluoroethane
R600a:	Isobutane
H-BN:	Hexagonal Boron Nitride
Cu:	Copper
ZrO_2:	Zirconium Dioxide or Zirconia
$HAuCL_4$:	Tetrachloro (hydrido) gold
Au:	Gold
MWCNT:	Multiwall carbon nanotube
CNT:	Carbon NanoTubes