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Experimental Investigation on VCR system using Nano-refrigerant for COP Enhancement

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Nano fluids have high heat transfer potential, increased thermal properties in comparison with conventional working fluids which increases the Co-efficient of performance of the refrigeration system. The Present paper experiments are conducted on Vapour compression refrigeration system with R-134a as pure refrigerant and combination of Cuo-R134a as a Nano-refrigerant. Nano fluids have high heat transfer potential, increase thermal properties of conventional working fluids which increase the Co-efficient of performance of the refrigeration system. In this study the comparison of COP and power consumption of pure refrigerant R-134 and 1.6% concentrated Nano-refrigerant Cuo-R134a is investigated experimentally. Nano refrigerants are prepared by dispersing the Nano-particles of Copper oxides in base refrigerant R134a and are prepared in ultra Sonicator processor. In this experiment there is an increase of 16.66% of COP and 13.79% decrease in power consumption by using Nano-refrigerant comparing to pure refrigerant.

1. Introduction

Nano-refrigerants have high thermo-physical properties and can be used as an alternative refrigerant. They are used for their enhanced thermal properties in many types of equipment such as heat exchangers, radiators and solar collectors for their tuneable optical properties. Development of Nano particles has great deal to do with oil and gas industry.

Coumarssin et al., (2014) has done experiments by building an experimental apparatus using Nano refrigerant Cuo-R134a with concentration ranging from 0.05 to 1% and concluded that there is a great increase in the heat transfer characteristics by using Nano refrigerants. Hamad et al., (2014) has done experiments by preparing different concentration of Nano particles and injected at the compressor along with pure refrigerant and been observed that there is a great improvement of COP with Nano refrigerants and there is a decrement in the power consumption. It also been observed that there is increase in COP with increase in the concentration of Nano-particles. Salem ahmed et al., (2018) in their work have conducted experiments on air conditioning chill unit by adding Al_2O_3 with water ranging different weights and from the experimental results it has been observed that less time has been taken to obtain desire cooling temperature and also it has been observed that there is nearly 17% improvement in COP. Sharma et al.,(2015) in their work have conducted experiments by Al_2O_3 Nano refrigerant at 10 LPH volume flow rate at two different heat flux and experimental results shows that there is temperature drop of nearly 4 to 5% in condenser comparing to pure refrigerant R134a, there is temperature gain of 6 to 7% in the evaporator by using Nano refrigerant and there is a great reduction in power consumption of nearly 9 to 12%. Veera Raghavulu et al., (2018) in their paper discussed about usage of Nano particles in VCR system and discussed about the lubricant oil which can work better with the Nano particles in the area of refrigeration and they have concluded that there is great increment in heat transfer characteristics by using Nano particles with mineral oil rather than polyester oil (Camaraza-Medina et al., 2018). Mahabubul et al., (2015) has conducted experiments by taking 5% vol Al_2O_3 nano particles into R-134a refrigerant at temperature 283-303 K and maintained uniform mass flux and concluded that there is an increment of about 28.58% in thermal conductivity and also increment in performance of the system and concluded saying nano refrigerants will be promising in coming years. Shengshan et al., (2008) in their research work has conducted experiments by taking mineral oil with TiO_2 nano particles in HFC134a refrigerator. By using freeze capacity and energy consumption test the investigation of performance of nano-

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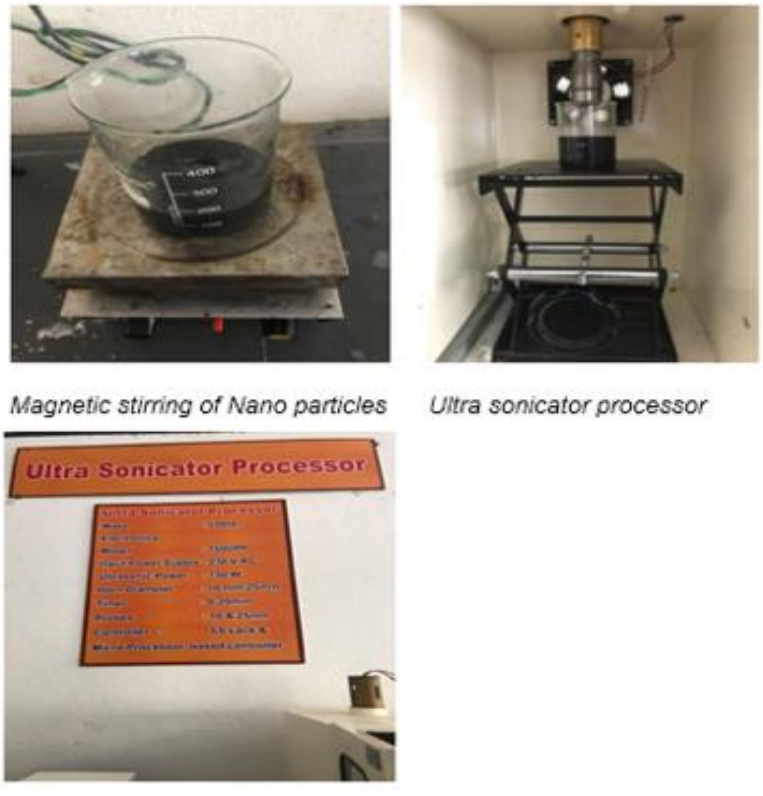
particles is done. They have concluded by saying that nano-refrigerant works normally and highly safe for the refrigerator and also said that energy consumption reduces gradually by using nano-particles (Zhou, 2018; Xu and Xu, 2018; Arifuzzaman et al., 2018; Sharma et al., 2018). Adyanshee et al., (2015) has done experiments by taking three different Al_2O_3 mass fractions of 0.47%, 0.952% and 1.42% using polyalkylne oil and done comparison for performance and power consumption. From their work it is concluded that increase in mass fraction of nano-refrigerant will increase the performance and reduce the power consumption. F.S Javadi and R Saidur has investigated about the effect of use of nano-refrigerant on environment. By using nano-refrigerant there will be a great reduction in the power consumption which will reduce the emission of greenhouse gases and there will be economic justification. Nilesh et al., (2015) has done experiments by taking SiO_2 nano-oil as lubricant to enhance the performance of compressor. They investigated by taking three different mass fractions of nano-particles and added them to the compressor oil and experimental analysis showed there is large increment in performance of the system when nano-oil is used instead of pure oil. S. Zeinali Heris et al., has investigated by taking Al_2O_3/water nano fluid at constant wall temperature in the circular tube. From the experimental results they have concluded that there is an enhancement in the heat transfer and also the heat transfer coefficient increases with increase in concentration of nano particles in nano fluid. Hung et al., (2013) has investigated on effect of using nano particles Al_2O_3/water on performance of air-cooled heat exchanger. They have conducted experiments by taking three different concentration at five different flow rates and three different heating powers. They have pointed that thermal management has to be optimized in coming future for greenhouse gases.

2. Preparation of Nano refrigerant

The Nano refrigerant used in this experiment is R134a-CuO. The preparation of Nano refrigerant is done by the use of magnetic stirrer and ultra Sonicator processor. 2 gm of 50 nm diameter of copper oxide is mixed with 150 ml of lubricating oil and stirred about 2 hrs with the help of magnetic stirrer. Then the Nano refrigerant is placed in ultra sonicator processor to obtain flow properties for the copper nanoparticles. Then the Nano particles are separated from the lubricating oil by filtration process. These Nano particles are injected into the compressor through suction port or charging port along with the base refrigerant R134a.



Magnetic stirring of Nano particles

Ultra sonicator processor

Specification of Ultra sonic processor

Figure 1: Preparation of Nano refrigerant

3. Experimental analysis

The experimental test is conducted on a domestic refrigerator with vapour refrigeration cycle working with refrigerant R-134a.

Refrigerator test rig was developed in order to investigate the performance of the system. In developing the reliable refrigerator test rig, consideration should be highly taken care especially the development method and measurement locations of pressure and temperature. These are very important to ensure that the test rig can produce reliable data. A test rig was developed as shown in the figure. There are five points of temperature measurement, two points of pressure measurement. The thermocouple wire was used to measure the temperature of refrigerant in the tube.

In order to know the performance characteristics of the vapour compression refrigeration system the temperature and pressure gauges are installed at each entry and exit of the component. Experiments are conducted by placing of shell and tube heat exchanger after the condenser. Different types of tools are also used tube cutter to cut the tubes and tube bender to bend the copper tube to the required angle. Finally the domestic refrigerator is fabricated as for the requirement of the project. All the values of pressures and temperatures are tabulated.

Figure 2: Experiment test rig with thermocouples and pressure gauges

Table 1: Readings for base refrigerant R134a

Condition	Temperature (^{o}C)	Pressure (bar)
Compressor (suction temperature and Pressure)	22 (T_1)	0.5 (P_1)
Compressor (discharge temperature and Pressure)	73.5 (T_2)	19.6 (P_2)
Condenser	49.2 (T_3)	19.6 (P_3)
Evaporator	-3.9 (T_4)	(P_4)

Table 2: Readings for nano refrigerant CuO-R134a

Condition	Temperature (^{o}C)	Pressure (bar)
Compressor (suction temperature and Pressure)	20 (T_1)	0.392 (P_1)
Compressor (discharge temperature and Pressure)	717 (T_2)	13.72 (P_2)
Condenser	48.1 (T_3)	13.72 (P_3)
Evaporator	-5.0 (T_4)	0.392 (P_4)

3.1 Calculations of performance parameters

1) Net Refrigerating Effect (NRE): The amount of heat extracted from evaporator

NRE=h_1-h_4 (1)

2) Mass flow rate per tonne of refrigeration, kg/min.

$$\mathrm{mf} = \frac{210}{\mathrm{NRE}} \quad (2)$$

3) Power required to drive the compressor = h_2-h_1
4) Power required for compression per tonne of refrigeration:

m_f x (h_2-h_1) (3)

5) Coefficient of Performance (COP): defined as ratio of net refrigeration effect to work done.

$$\mathrm{COP} = \frac{(\mathrm{h1}-\mathrm{h4})}{(\mathrm{h2}-\mathrm{h1})} \quad (4)$$

6) Heat to be rejected in condenser = h_2-h_3
7) Heat Rejection per tonne of refrigeration:

$$\frac{210}{\mathrm{NRE}} \times (\mathrm{h2}-\mathrm{h3}) \quad (5)$$

4. Results and discussions

The results of experimental data with pure refrigerant and Nano refrigerant are tabulated below.

Table 3: Experimental results of COP and Power consumption

Refrigerant	Carnot COP	Actual COP	Power consumption (kW)
R134a	5.06	3	1.16
CuO-R134a	5.04	3.5	1

The experiment is conducted by considering a domestic refrigerator which works on refrigerant R134a, in this particular paper the Nano refrigerant CuO with concentration 1.6% is taken. The coefficient of performance and power consumption has been calculated from the data obtained. From the above table and figures it is clear that there is an increment in the COP by using Nano refrigerants comparing to pure refrigerant and there is also decrement in the power required for the compressor for CuO-R134a refrigerant compare to R134a. So the heat transfer characteristics have been increased while using Nano refrigerant compare to pure refrigerant.

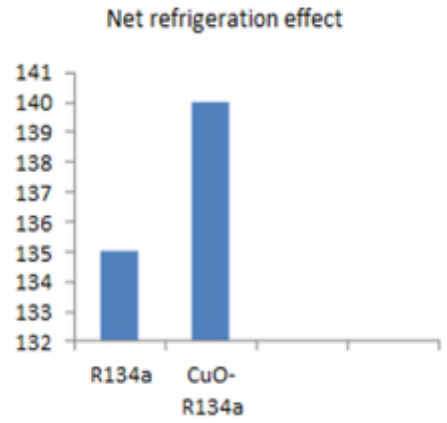


Figure 3: Net refrigeration comparison for refrigerants

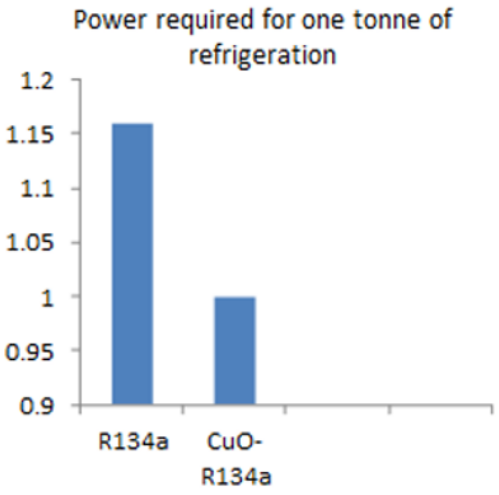


Figure 4: Power required comparison for refrigerants

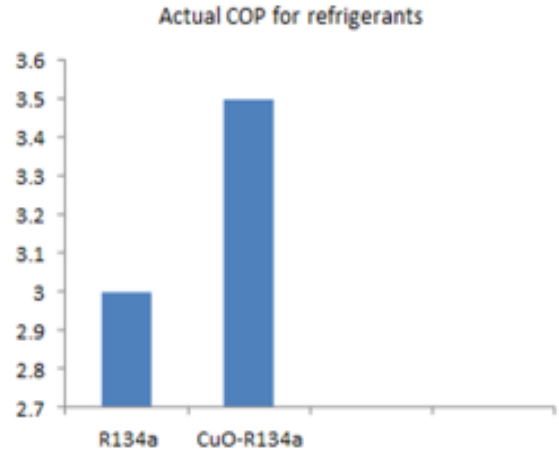


Figure 5: COP Comparison for refrigerants

5. Conclusions

From the experimental analysis it has been concluded that with the use of Nano refrigerant there is an increase of heat transfer characteristics.

There is an increment of 16.6% in COP while using Nano refrigerant CuO-R134a compare to using refrigerant R134a.

There is a decrement of 13.79% in power consumption for one tonne of refrigeration. Usage of Nano refrigerant is great alternative to present refrigerants.

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