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Application of SiO_2 Nanoparticles as Lubricant Additive in VCRS: An Experimental Investigation

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Abstract **- In this work, the SiO_2 nano-oil is proposed as a promising lubricant to enhance the performance of vapour compression refrigerator compressor. The stability of SiO_2 nanoparticles in the oil is investigated experimentally. It was confirmed that the nanoparticles steadily suspended in the mineral oil at a stationary condition for long period of time. The application of the nano-oil with specific concentrations of 1%, 2% and 2.5 %(by mass fraction) were added in the compressor oil. The VCRS performance with the nanoparticles was then investigated using energy consumption tests. The result shows the COP of system were improved by 7.61%, 14.05% & 11.90%, respectively, when the nano-oil was used instead of pure oil.**
Keywords: VCRS, COP, POE Oil

I.INTRODUCTION

In the face of imminent energy resource crunch there is need for developing thermal systems which are energy efficient. Thermal systems like refrigerators and air conditioners consume large amount of electric power. It is essential to develop energy efficient refrigeration and air conditioning systems with nature friendly refrigerants. The rapid advances in nanotechnology have lead to emerging of new generation heat transfer fluids called nanofluids.

Nanofluids are a relatively new class of fluids which consist of a base fluid with nano-sized particles (1–100 nm) suspended within them. These particles, generally a metal or metal oxide, increase conduction and convection coefficients, allowing for more heat transfer out of the coolant, provided excellent examples of nanometer in comparison with millimeter and micrometer to understand clearly as can be seen in Fig. 1.

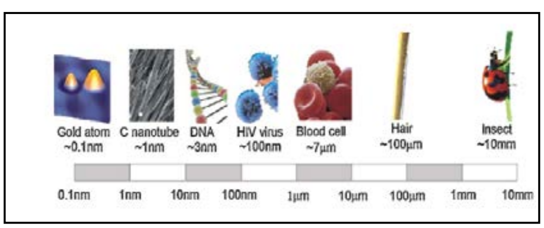

Fig.1 Length scale and some examples related [27]

Recently scientists used nanoparticles in refrigeration systems because of its remarkable improvement in thermo-physical, and heat transfer capabilities to enhance the efficiency and reliability of refrigeration and air conditioning system.

I. LITERATURE SURVEY

Many investigators have conducted studies on vapour compression refrigeration systems and to study the effect of nanoparticles in the refrigerant as well as lubricant on its performance.

Pawel et al. (2005)[5] conducted studies on nanofluids and found that Performance Analysis of a Refrigeration System Using Nano Fluid there is the significant increase in the thermal conductivity of nanofluid when compared to the base fluid and also found that addition of nanoparticles results in significant increase in the critical heat flux.

Bi et al. (2007) [1] conducted studies on a domestic refrigerator using nanorefrigerants. In their studies R134a was used the refrigerant, and a mixture of mineral oil TiO_2 was used as the lubricant. They found that the refrigeration system with the nanorefrigerant worked normally and efficiently and the energy consumption reduces by 21.2%. When compared with R134a/POE oil system. After that Bi et al. (2008) [1] found that there is remarkable reduction in the power consumption and significant improvement in freezing capacity. They pointed out the improvement in the system performance is due to better thermo physical properties of mineral oil and the presence of nanoparticles in the refrigerant.

Jwo et al. (2009) [2] conducted studies on a refrigeration system replacing R-134a refrigerant and polyester lubricant with a hydrocarbon refrigerant and mineral lubricant. The mineral lubricant included added Al_2O_3 nanoparticles to improve the lubrication and heat-transfer performance. Their studies show that the 60% R-134a and 0.1 wt % Al_2O_3 nanoparticles were optimal. Under these conditions, the power consumption was reduced by about 2.4%, and the coefficient of performance was increased by 4.4%.

Henderson et al. (2010) [3] conducted an experimental analysis on the flow boiling heat transfer of R134a based nanofluids in a horizontal tube. They found excellent dispersion of CuO nanoparticle with R134a and POE oil and the heat transfer coefficient increases more than 100% over baseline R134a/POE oil results.

Bi et al. (2011) [4] conducted an experimental study on the performance of a domestic refrigerator using TiO2-R600a nanorefrigerant as working fluid. They showed that the TiO2-R600a system worked normally and efficiently in the refrigerator and an energy saving of 9.6%.

Sendilkumar and Elansezhian (2012) [6] conducted an experimental study on the performance of a domestic refrigerator using Al_2O_3-R134a nanorefrigerant as working fluid. They found that the Al_2O_3-R134a system performance was better than pure lubricant with R134a working fluid with 10.30% less energy used with 0.2%V of the concentration used and also heat transfer coefficient increases with the usage of nano Al_2O_3.

Krishna sabareesh et al (2012)[7] conducted an experimental study on the performance of a domestic refrigerator using TiO_2 - R12 nanorefrigerant as working fluid. They found that the freezing capacity increased and heat transfer coefficient increases by 3.6 %, compression work reduced by 11% and also coefficient of performance increases by 17% due to the addition of nanoparticles in the lubricating oil.

Reji kumar and Sridhar (2013) [8] conducted an experimental study on the performance of a domestic refrigerator using R600a/mineral oil/nano- Al_2O_3 as working fluid nanorefrigerant as working fluid. They found that the refrigeration system with nano-refrigerant works normally. It is found that the freezing capacity is higher and the power consumption reduces by 11.5 % when POE oil is replaced by a mixture of mineral oil and Aluminium oxide nanoparticles.

T. Coumaressin and K. Palaniradja (2014) [9] conducted an experimental study on the performance of a domestic refrigerator using CuO-R134a nano-refrigerant as working fluid. The experimental studies indicate that the refrigeration system with nanorefrigerant works normally. Heat transfer coefficients were evaluated using FLUENT for heat flux ranged from 10 to 40 kW/m2, using nano CuO concentrations ranged from 0.05 to 1% and particle size from 10 to 70 nm. It is found that the evaporating heat transfer coefficient with the increase of 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.

Meibo Xing et al. (2014) [10] worked on a fullerene C60 nano-oil & he found that C60 nano-oil is proposed as a promising lubricant to enhance the performance of domestic refrigerator compressors. The stability of fullerene C60 nanoparticles dispersed in a mineral oil and the lubrication properties of the nano-oil were investigated experimentally. The applications of the nano-oil with the specific concentration of 3 g/l to two domestic refrigerator compressors were examined by compressor calorimeter experiments. The results shows the COPs of two compressors were improved by 5.6% and 5.3%, respectively, when the nano-oil was used instead of pure mineral oil.

In the literatures a number of reviews on thermal and rheological properties, different modes of heat transfer of nanofluids have been reported by many researchers. However, to the best of author's knowledge, there is no comprehensive literature on the nanoparticles as additives with conventional refrigerants and oils used in refrigeration system.

III. EXPERIMENTAL SET UP

A. Components

The vapour compression refrigeration system test rig consist of a compressor unit, condenser, evaporator, cooling chamber, controlling devices and measuring instruments those are fitted on a stand and a control panel. Electric power input to the compressor is given through thermostatic switch.

TABLE I REFRIGERATION SYSTEM SPECIFICATIONS

Capacity	500 watt at rated test condition
Refrigerant	R-134a
Compressor	Hermetically sealed
Condenser	Forced convective air cooled
Condenser fan motor	Induction type
Drier / filter	Dryall make
Expansion device	Capillary tube

Fig. 2 Photographic view of experimental set up.

B. Instrumentation

The temperatures at different parts of the experimental setup are measured using resistance thermocouples. Six resistance thermocouples were used for the experimentation. The suction pressure and discharge pressure at compressor are measured with the help of pressure gauges. The power consumption of the system was measures by a energy meter. A digital energy meter is also connected with the experimental setup.

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TABLE II MEASUREMENT EQUIPMENT

Refrigerant flow measurement	Rota meter
Pressure indication	Pressure gauges , 2 nos provided
Energy meter	3200 imp/kwh
Heater	1000w
Evaporator for refrigeration test rig	Immersed tube type , direct expansion coil
Temperature indication	Digital led
Insulation for water tank	Puf
Supply	230 volts, 50 Hz, 1 phase , AC.

IV. EXPERIMENTAL PROCEDURE

A. Preparation of nano- Refrigerant

Nanoparticles of Sio2 are added to the refrigeration system by adding them to the lubricant in the compressor of the system. The preparation and stability of this lubricant and nanoparticle mixture is very important. The lubricant oil, a type commonly used in refrigeration and air-conditioning systems was POE oil. This oil is selected owing to its common usage and superior quality.

Ultrasonic vibration is used to stabilize the dispersion of the nanoparticles. The process of preparation of nanofluid is as follows:

1) weigh the mass of Sio2 nanoparticles by a digital electronic balance with a measurement range of 10 mg to 210 g and maximum error of 0.1 mg; 2) Put Sio2 nanoparticles into the weighed POE oil and get the Sio2/POE oil; 3) Vibrate the mixture by an ultrasonic processor for 3 hours and get the well-dispersed Sio2/POE oil as show in figure 2(a) & (b). No surfactant is added in this work as there may be any influence in reduction of thermal conductivity and performance.

B. Nano- Refrigerant Concentration

Nano-particles with 1%, 2% and 2.5% (by mass) concentration ofSiO_2 in the POE oil is prepared and tested in the setup.

C. Charging of set up

N_2 gas at a pressure of 5 bar to 7 bar and this pressure is maintained for 45 minutes. Thus the system was ensured for no leakages. A vacuum pump was connected to the port provided in the compressor and the system was completely evacuated for the removal of any impurities. This process was carried out for all the trials. Through the service ports refrigerant was carefully added to the system. Precision electronic balance with accuracy ±1% was used to charge a mass of 150 gm. into the system. Every time the system was allowed to stabilize for 15 min.

V.PERFORMANCE TEST

The system was charged with refrigerant (R 134) and a POE oil with different concentration using a charging line attached to the system. The temperature data were captured continuously, and the readings were taken an interval of 15 min. It was ensured that a constant temperature and humidity prevails in the surrounding space, when the experimental readings were taken. The experiment involved the measurement of the temperature T1-T6 of compressor, condenser, expansion valve, evaporator and inlet –outlet of water temperature. The power consumption rate of the compressor was determined by noting the time taken by the digital energy meter for 10 pulses. Using these data, the heat transfer rate at the evaporator cabin and the power consumption rate in the compressor were calculated using the standard expressions as follows.

Fig. 3a. Ultrasonic vibrator

Fig. 3b. Before and after mixing of nanoparticles

Work done by compressor (Wc):

$$Wc = \frac{3600 \times 10}{EMC \times T}$$

Actual Coefficient of performance (C.O.P)ACT:

$$(C.O.P)ACT = \frac{\text{Refrigerating effect}}{\text{Work done by compressor}}$$

VI. Result & Discussion

A. Graph of compressor work done Vs Nanoparticle concentration

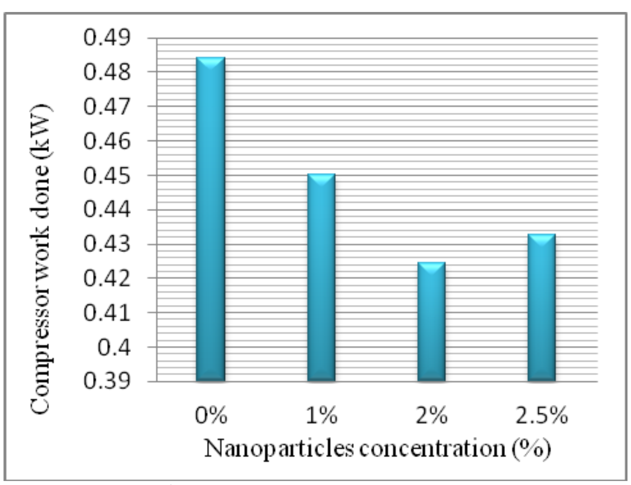

Fig. 4. Graph of compressor work done Vs Nanoparticle concentration

From above graph we conclude that as the nanoparticles concentration in POE oil increases, there is decrease in compressor work.Table below shows the all values:

TABLE III COMPRESSOR WORK

Nanoparticles concentration (%)	Compressor work done (kW)
0%	0.484
1%	0.45
2%	0.4245
2.5%	0.4327

B. *Graph of percentage change in COP*

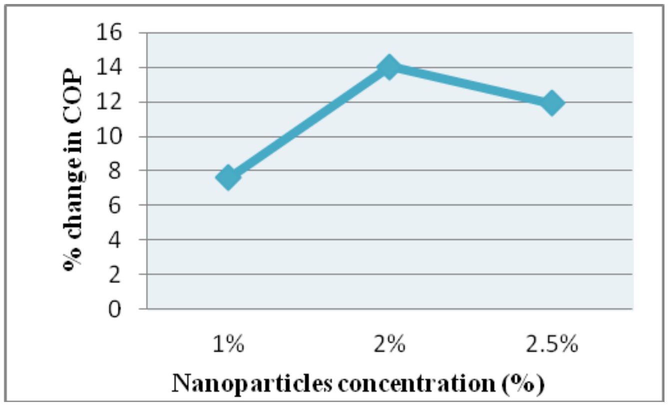

Fig. 5. Graph of percentage change in COP

Above graph shows the % increase in COP. Table IV below shows the all values

TABLE IV INCREASE IN COP

Nanoparticles concentration (%)	Increase in COP (%)
1%	7.61
2%	14.05
2.5%	11.90

VII. Conclusion

1. Based on the literatures, it has been found that the thermal conductivities of nanorefrigerants are higher than traditional refrigerants. It was also observed that increased thermal conductivity of nanorefrigerants is comparable with the increased thermal conductivities of other nanofluids.
2. It has been observed that energy saving can be achieved from a minimum value of 7.03% to a maximum value of 12.30% using nanolubricant compared to traditional refrigerants.
3. Exact mechanism of enhanced heat transfer for nanofluids is still unclear as reported by many researchers.
4. Nanofluids stability and its production cost are major factors that hinder the commercialization of nanofluids. By solving these challenges, it is expected that nanofluids can make substantial impact as coolant in heat exchanging devices.

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