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Preparation and property analysis of nano-lubricant for vapour compression refrigeration system

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ABSTRACT

This paper presents the preparation and property analysis of ZrO_2 based nano lubricant for vapour compression refrigeration system. The structural and chemical characterizations of nano lubricant were performed by Scanning Electron Microscope (SEM), X-Ray Diffraction (XRD). Different concentration of nanofluid was used in this experiment. ZrO_2 nanoparticles dispersed in oil at various concentrations of 0.1, 0.2 and 0.3 vol. % using a Sonicator. Ultrasonic vibration was used to stabilize the dispersion of the nanoparticles. The viscosity of the Polyolester oil was measured for different volume percentages of nanoparticles in it, using a Redwood viscometer. Thermal conductivity of nano lubricant measured using KD2 pro thermal analyzer. The results revealed that the thermal conductivity increases with the addition of nanoparticles. The enhancement observed due to the Brownian motion of the particles. Finally, the cooling load temperature with respect to time history was studied.

KEYWORDS: Nano lubricant, Nano refrigerant, Refrigeration system, Nanoparticle

1. INTRODUCTION

Various methods have been tried out for improving the coefficient of performance (COP) of the vapour compression refrigeration (VCR) system, as reported in the literature. Bilir Nagihan and Kursad Ersoy (2009) have studied the role of a two-phase constant area of the ejector for the improvement in the performance of a VCR system by recovering the kinetic energy at expansion process, and thereby reducing the compressor work. Sattar et al. (2007) reported the performance improvement of a VCR system utilizing refrigerant R134a when various blends of hydrocarbons are used. With the advent of nanotechnology,in the literature survey, many have studied the effect of nanoparticles as additives, In the refrigerant or in the mineral oil used as the lubricant, on the COP of the VCR system. Park and Jung (2007) studied due to the addition of the carbon nanotubes the boiling heat transfer in refrigerants enhanced. Lee et al. (2009) state that an improvement in the lubrication characteristics are found when the refrigeration Mineral oil containing 0.1 vol. % of fullerene nanoparticles. Bi et al. (2008) studied that 0.1% mass fraction of TiO_2 nanoparticles in R134a and Polyolester (POE) oil systems are used to reduce the power consumption about 26%. Stability of nanoparticles in suspensions is one of the key issues which make application of nanoparticles in refrigerants, but It's hard because the fluid undergoes a phase change in every cycle. Very few research had been carried out which explains the actual role takes place by nanoparticles, for the enhancement of the energy efficiency in the VCR system. Regarding the option of addition of nanoparticles in the water, the reported experimental studies (Arulprakasajothi et al. 2015 & 2016) suggest either the variations in viscosity or the altered characteristics as the reasons for the observed improvement in the performance. The feasibility of adding nanoparticles in hydro fluoro carbon (HFC) refrigeration systems has been reported by Jwo et al. (2009).

Lubricants enhance the performance of a system in several ways when additives are added to it. The critical parameters improved are anti-friction, anti-wear, anti-corrosion, extreme pressure,detergent and anti-oxidant. With increasing complications in operating conditions and development in technology coupled with increasing lubrication requirements are the necessary factors for the exploration of the new kind of additives and optimum value of their concentrations. Nanoparticles are regarded as the most plausible prospect to meet these demands. The performance of composites, oils,fluids,etc. are enhanced due to the addition of nanoparticles, which is because of the high surface area/volume ratio leading to the extensive interaction between tribo contact points and lubricants containing nanoparticles.

Wu et al. (2007) examined the tribological properties of engine and a base oil with addition of CuO, TiO_2 and diamond nanoparticle as additives. From the reciprocating sliding tribo tester, friction and wear experiments, they found that CuO added to standard oils showed good friction reduction and anti-wear properties. The average friction coefficient of the base oil with CuO nanoparticles is decreased by 5.8%, as compared to the base oil without nanoparticles. Table.1 summarizes the use of nano lubricant in a refrigeration system.

Table.1.Details of nano lubricant used in refrigeration system

Nanoparticle (Diameter)	Volume fraction	Lubricant	Refrigerant	Remarks
Al_2O_3 (10nm)	1.6%	Polyolester	R134a	They found average heat flux increment for heat flux less than 40kW/m^2
Al_2O_3 (10&60nm)	-	Polyolester	-	Viscosity and density increased with respect increasing temperature
Fullerene	0.1%	Mineral oil	-	Friction characteristics and stability of nano lubricant.
Fullerene C60	1-3 g/L	Mineral oil	-	Friction coefficient decrease by 12.9, 16.1 and 19.6% for addition 1, 2 and 3g/L nanoparticle.
TiO_2	0.01%	Mineral oil	R12	Average heat transfer increment about 3.6% and reduced compressor work about 11%

2. PREPARATION OF NANO - LUBRICANT

ZrO_2 nanoparticles are added to the compressor lubricant of the refrigeration system. The preparation and stability of this lubricant and nanoparticle mixture are more important to the given study. The lubricant oil, commonly used in refrigeration systems was POE oil. This oil is selected owing to its common usage and superior quality.

Ultrasonic vibration method is used to stabilize the dispersion of the nanoparticles. The steps involved in preparation of nanofluid is as follows:

1) Weighing the mass of ZrO_2 nanoparticles by a digital electronic balance with a measurement range of 10 mg to 210 mg and maximum error of 0.1 mg.
2) Adding ZrO_2 nanoparticles into the POE oil and get the ZrO_2 /POE oil.
3) Vibrating the mixture by an ultrasonic processor for few hours and get the well-dispersed ZrO_2 /POE oil as shown in figure 3 to 7.The Surfactant is not added in the mixture since it may decrease the thermal conductivity and performance.
4) Then keep the container in the magnetic stirrer to get the well dispersed of nano-lubricant. Nano-particles (ZrO_2) with 0.1, 0.2 and 0.3 vol. % is added to the POE oil and tested in the setup are prescribed.

Figure.1.Zirconium Oxide Nanoparticle

Figure.2.Digital Electronic Balance

Figure.3.Ultrasonicator

Figure.4.Magnetic stirrer

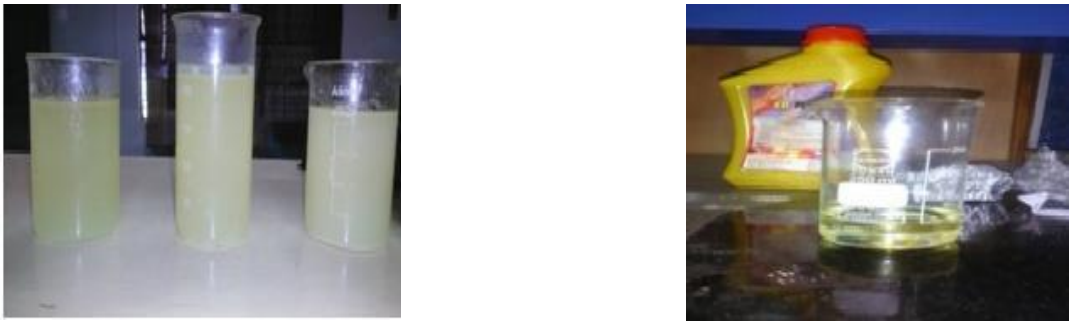

Figure.5.Pure POE Oil With [0.1, 0.2 and 0.3 vol. % of] Zirconium Oxide Nanoparticles

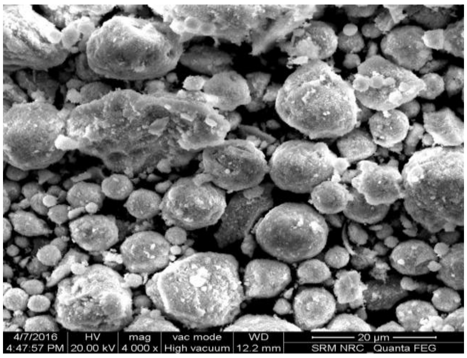

Figure.6.SEM image of Zirconium Oxide Nanoparticle

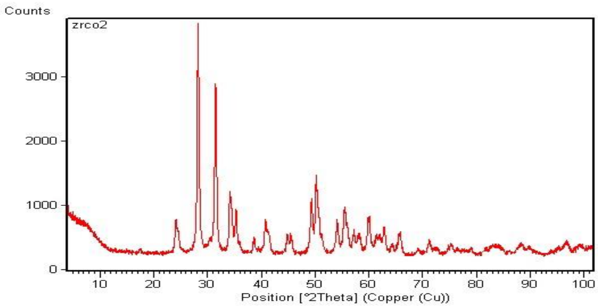

Figure.7.X-ray Diffraction Result of Zirconium Oxide Nanoparticle

3. VISCOSITY MEASUREMENT

The viscosity of the POE oil relates indirectly to the load carrying capacity and power consumption rate of the compressor used in a refrigeration system. The addition of foreign particles in the POE oil alters the viscosity of the oil. Lee et al. (2009) found that an addition of fullerene nanoparticles increased the viscosity of oil, and the enhancement was proportionate to the volume fraction. From the tribological characteristics of bearings we came to know that in a boundary lubrication system, an optimum level of the viscosity enhancement is attained, and it results in a notable reduction in the power consumption. Considering these observations from, the previous studies. The addition of nanoparticles must be low enough to make the process viable and effective in reducing the power consumption. The power consumption may be reduced by large volume fractions of nanoparticles, the addition of large volume fractions of nanoparticles might further reduce the power consumption, but would not be a reasonable choice as a significant volume fraction may promote agglomeration and subsequent sedimentation. The objective of the study is to determine the optimal percentage of nanoparticles in the POE oil for the reason that it gives a good enhancement in the COP reasonably. Different percentages of nanoparticles was added to the oil and viscosity of the oil was measured using a Redwood viscometer (Figure 8), the principle of the study was based on the laminar flow through a capillary tube which works based on the standard dimension under falling head. The viscosity variation across the temperature was also studied.

Figure.8.Redwood Viscometer

4. THERMAL CONDUCTIVITY MEASUREMENT

The KD2 Pro thermal analyzer is shown in figure 9. It measures thermal conductivity based on the principles of the transient line heat source. The thermal conductivity of pure POE oil and POE oil with different volume percentage of ZrO_2 was found.

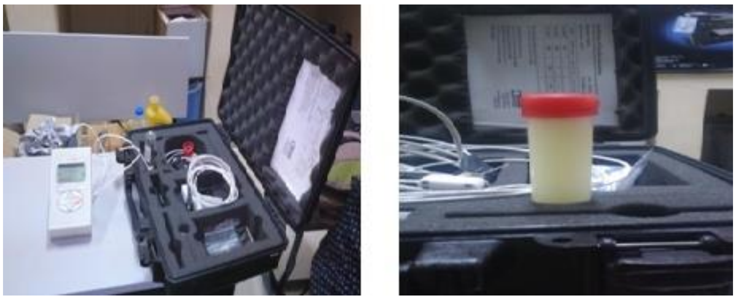

Figure.9.KD2-Pro Thermal Analyzer

5. RESULTS AND DISCUSSION

The kinematic viscosity values of pure POE oil and the modified POE oil with various temperatures is shown in Fig.10. It is evident from the graph that the representation that the viscosity of nano lubricant oil is more than that of the pure oil. The results also indicate that when the temperature range is lower an addition of nanoparticles, there is a noticeable increase in viscosity. The viscosity of modified POE oil increases with an increase in volume percentage of ZrO_2 nanoparticles. For all the volume fractions considered, the trend of viscosity variation obtained is in agreement with the pure POE oil.

As per the concept of hydrodynamic lubrication, an increase in the viscosity of the oil is a favour to load capacity, but not favorable to the frictional power loss. In the case of boundary, lubrication is concerned, an increase in the viscosity will reduced the friction power loss. In the present study, the percentage of increase in the viscosity of the modified POE oil on its original value is found to be more at lower temperatures. This decrease in the enhancement at higher temperatures can also be attributed to a reduction in the fluid layer resistance. It is interesting to notice that the relative effect of the volume fraction of the nanoparticles on the viscosity, at a given temperature.

Variation of thermal conductivity with vol. % of ZrO_2 particles is shown in Figure 11. From the figure, it was observed that the thermal conductivity increases with the addition of nanoparticles. This is due to the Brownian motion of the particles. The change of cooling load temperatures with time is shown in figure .12. From the figure, it was observed that the cooling load temperature decreases with increasing the time. The trend of modified POE oil was similar to pure POE oil but the cooling load temperature reduced when the vol. % of ZrO_2 nanoparticles was increased.

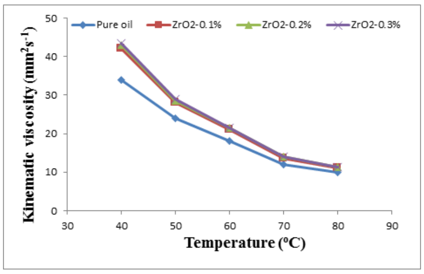

Figure.10.Variations in kinematic viscosity with temperature

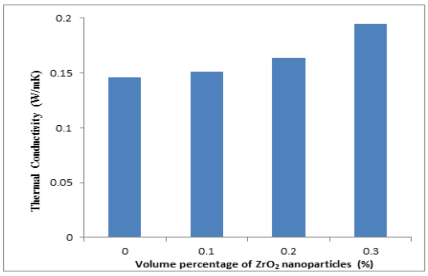

Figure.11.Variation of thermal conductivity with Vol. % of ZrO2 particles

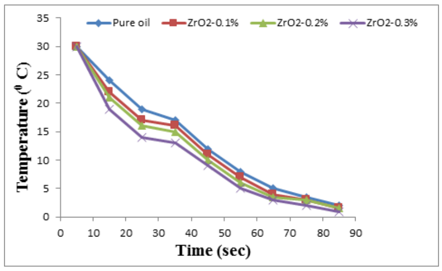

Figure.12.Variation of Cooling load temperatures with time

6. CONCLUSIONS

An examination of the possibility of enhancing the performance of a vapour compression refrigeration system by modifying the lubricating oil with zirconium oxide nanoparticle additive was performed in this experimental study. An enhancement in the property was observed with the addition of less volume fractions of nanoparticles in the lubricant. The viscosity and thermal conductivity were found to increase with the addition of nanoparticles in the POE oil. The cooling load temperature reduced when the vol. % of ZrO_2 nanoparticles was increased.

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