COMPARSION OF THERMAL CONDUCTIVITY AND RHEOLOGICAL PROPERTIES OF NANO LUBRICANTS

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***Abstract*:** Nowadays, different materials with various nanostructures are used as additives for improving properties of lubricants. Many researchers have tried to improve the thermal physical properties of lubricants and to decrease friction coefficients. One approach is simply the use of additives in the base lubricant to change its properties. Recently, nanoparticles have emerged as a new kind of additive because of their size, shape and other properties. A nanolubricant is a new kind of engineering lubricant made of nanoparticles dispersed in the base lubricant. The objective of this thesis is to improve thermal properties of nanolubricant for refrigeration application. This paper will also give recommendations for lubrication of compressor in refrigeration compressors based on the results. In this study, Copper oxide (CuO) and zinc oxide (ZnO) nanoparticles were used to prepare nanolubricant to enhance the thermo physical properties and lubrication characteristics. In this work the base lubricant used was polyolester oil dispersed with nanoparticles of 40 nm used as additives with various concentrations. Dispersion procedure used to prepare nanolubricant containing different amounts of nanoparticles (0.25, 0.5, 0.75, and 1%) by magnetic stirrer and sonicator. The thermo physical properties of nanolubricants, i.e., viscosity, density, thermal conductivity and frictional coefficient were investigated.

I. INTRODUCTION

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 in wide application such as in heat exchanger, automotive cooling and refrigeration system. Figure 1 provides an example of nanometer size of particles in comparison with millimeter and micrometer in order to understand the concept of nanoparticles clearly.

In the past few decades, rapid advances in nanotechnology have lead to emerging of new generation of coolants called "nanofluids". The nanofluid is a new type of heat transfer fluid by suspending nano-scale materials in a conventional host fluid like ethylene glycol, water, lubrication oils etc, and has higher thermal conductivity than the conventional host fluid. Such thermal nanofluids for heat transfer applications represent a class of its own difference from conventional colloids for other applications. Compared to conventional solid–liquid suspensions for heat transfer intensifications, nanofluids possess the following advantages.

1) High specific surface area and therefore more heat transfer surface between particles and fluids.
2) High dispersion stability with predominant Brownian motion of particles.
3) Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
4) Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
5) Adjustable properties, including thermal conductivity and surface wet ability, by varying particle concentrations to suit different applications.

Sheng- shan Bi, Lin shi, Li- li Zhang (2008) stated that the refrigerator system worked normally and efficiently when the mineral oil with TiO2 nanoparticles of 50 nm average particle diameter is used as a lubricant. The mass concentration was about 0.1%. The energy consumption was observed to be lowered by 26.1% when compared with the system with HFC134a- POE oil. [1]

Satnam Singh, Kapil Sharma, Kundan Lal, Naveen Mani Tripathi (2015) have found that the addition of Al2O3 nanoparticles to the refrigerator lubricant, Polyol-ester (POE) oil at 0.2% mass concentration resulted the decrease in the friction coefficient by 90% with the overall increase in the system efficiency. The results also revealed that the addition of nanoparticles increases the critical heat flux. [2]

R.Santhanakrishna & V.Shanmugam (2016) has done the preparation and property analysis has done on the ZrO2 based nanolubricant for a VCR. The structural and chemical characterizations of nanolubricant were performed by Scanning Electron Microscope (SEM), X- Ray Diffraction (XRD). ZrO2 nanoparticles dispersed in oil at various concentrations of 0.1, 0.2 and 0.3 vol. %. Ultrasonic vibration was used to stabilize the dispersion of the nanoparticles. The results showed that viscosity of nano lubricant oil is more than that of the pure oil and it is observed that the thermal conductivity increases with the addition of nanoparticles. [4]

T.M. Yusof, A.M. Arshad (2015) has found that the experimental study was done on a domestic refrigerator with Al2O3- POE nanolubricant. The Al2O3 nanoparticles were mixed with Polyolester (POE) lubricant to form nanolubricant at 0.2% concentration by volume. The results showed that the energy consumption of the refrigeration system with POE-Al2O3 at optimum refrigerant charge was the minimum and maximum COP of 321Wh and 2.67. The highest percentage of energy consumption reduction was 2.1% at optimum refrigerant charge. [7]

M.E.Haque, R.A.Bakar (2016) has done the performance of a domestic refrigerator was analyzed with TiO2- POE and Al2O3-POE Nanolubricants. The nanoparticles concentration was about 0.05% and 0.1%. The mixtures were then kept vibrating in an ultrasonic homogenizer for half an hour to fully separate the nanoparticles and to prevent agglomeration and sedimentation of particles. The results revealed that the POE oil containing 0.1% TiO2 to reduce the cooling load temperature from 10 °C to -7 °C, which is 50% less than the pure POE oil system. Result also shows the freezing capacity of 0.05% of Al2O3 is 60% less than the pure POE oil system. [8]

D. Senthilkumar (2017) stated that the refrigeration system was analyzed with the Al2O3 nanopowder- PAG(Polyalkylene Glycol) oil used as nanolubricant in the refrigerator system working with R134a refrigerant. The volume percentile was about 0.2%. The performance of the system was found out using energy consumption test and freeze capacity test. The results showed that the performance was better than pure lubricant with R134a working fluid with 10.32% less energy and also heat transfer coefficient increases with the usage Al2O3 nanopowder. The COP of the nano Al2O3 refrigerant system increases by 15%.[9]

Yongjian Gaoa, Guoxu Chena, YaOlib (2001) said that the property analysis was carried on the tribological properties of Oleic acid modified- modified TiO2 nanoparticles in water. cis- 9- octadecenoic acid (OA), CH3(CH2)7CH=CH(CH2)7CO2H, surface-modified TiO2 nanoparticle was synthesized using a sol–gel method, and its tribological properties in water were inestigated using a four ball tester. The fluid posses excellent load carrying capacity, good investigated using a four-ball tester. The fluid posses excellent load-carrying capacity, good extreme pressure, anti wear and friction reduction properties at boundary lubrication condition in water. [10]

Vaishali p. Mohod, Nishikant w. kale (2017) stated that the vapour compression refrigeration system works normally and safely with the Al_2O_3 nanolubricant. Stable nanolubricant has been prepared with VG68 Polyolester oil for the study. Three different mass concentrations 0.04%, 0.06% and 0.08% of Al2O3 nanoparticles with 20 nm size has been used for the study. The results indicate that refrigeration system with nanorefrigerant works normally and safely. It is found that the freezing capacity is higher and power consumption reduces by 14.71% and the coefficient of performance increases by 28.93% [12]

M.S.Bandgar, R. N. Kare (2016) has done an experimental investigation was carried out on a vapour compression refrigeration system working with the SiO_2- POE(polyolester)/ SiO_2- mineral oil nanolubricant and R600a as the working fluid. Investigation was done on the compatibility of POE/Mineral oil mixed with Silica (SiO2) Nano powder (at a concentration of 0.5%, 1% and 1.5% by mass fraction). The results showed that at mass fraction of 0.5% for all combinations of Nano-oils. It was found that the time required reducing the temperature of water to 10℃ is less and the power consumption reduces by 12.02% when POE oil is replaced by a mixture of (MO+ 0.5% Silica). It has been observed that C.O.P. is increased by 11.66% when POE is replaced by a Nanolubricant (mineral oil + 0.5% of SiO2). [13]

Nilesh S. Desai and P.R.Patil (2015) stated that the vapour compression refrigeration system worked safely and normally with the SiO_2- mineral oil nanolubricant. The nanoparticles were steadily suspended in the mineral oil at a stationary condition for long period of time. 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. [14]

Dr. K.Dilip Kumar, T.Ayyappahas (2016) done an experimental study was carried out on a vapour compression refrigeration system working with the Al_2O_3- POE nanolubricant. The nanooil was prepared with specific concentrations of 1.5%, 1.7% and 1.9 %(by mass fraction). The result shows the COP of system were improved by 19.14%, 21.6% & 11.22%, respectively, when the nano- oil was used instead of pure oil. The thermal conductivities of nanorefrigerant are higher than traditional refrigerants. From the experimental investigations Actual COP is increased up to 21.6% at 1.7%.mass concentration. After that it decreases so optimum percentage is 1.7% of Al2O3 for given 0.06 TR systems. [15]

WU Di, LIU Shi (2014) has done a vapour compression refrigeration system performance was analyzed with the addition of Ag nanoparticles and CNT in the refrigerator lubricant. The optimal amount is 4 mg/L CNT in nano-fluid. Ag/carbon nano-tube (CNT)/water nanofluids were prepared by dispersing Ag nanoparticles and CNT into water as a base fluid. The solution was kept stirring for another 5 min and then filtered to remove any un-dissolved impurities. The resultant solution was centrifuged at a speed of 14000 rpm. With the addition of a small amount of Ag NPs in the pure water, the efficiency under the same conditions was ranked as PVP/ Ag > L-cys/ Ag > PAN/ Ag > OA/ Ag. Adding a small amount of CNT in the mixture, the effect was enhanced further. As more CNT became dispersed in the working fluid, the opposite effect was observed. [16]

Jayendra, Sanket, Sagar(2017) has done an experimental study was carried out on the performance of a vapour compression refrigeration system working with Al_2O_3- mineral oil nanolubricant. The mass fraction of nanoparticles in lubricant was 0.06%. This study indicates that the power consumption of compressor is decreased by 11.5% and the freezing capacity is also higher. The coefficient of performance of the system also increased by 19.6% when POE oil changed with mixture of nanoparticles mineral oil. [17]

R. KAdyanshee Pattanayak, Nilamani Sahoo (2015), in an experimental investigation, the desired amount of Al_2O_3 nanoparticles are added to the PAG (Polyalkyle Glycol) lubricant oil and for even distribution of nanoparticles in the lubricant oil, the mixture (PAG oil and nanoparticles) has to place in an ultrasonic vibrator for 6-7 hours. The power consumption of the compressor was reduced by 10%, 20% and 26.6% and the coefficient of performance of the refrigerating system was improved by 12.14%, 27.8% and 39.46% for mass fractions of 0.47%, 0.952% and 1.42% of Al_2O_3 nanoparticles. [18]

D. Sendil Kumar & Dr. R. Elansezhian (2012), The experimental investigation was carried out on a VCR system where Nano Al2O3-PAG oil was used as nano-refrigerant in R134a vapour compression refrigeration system. The nanoparticles of Al_2O_3 in the range 40-50 nm were mixed with PAG to synthesize nanolubricant in a recommended method for nanofluid. The results were showed that the addition of Nano Al_2O_3 in to the refrigerant is to improvement in the COP of the refrigeration system. Usage for Nano refrigerant reduces the length of capillary tube and cost effective. [19]

Damola S. Adelekana, Olayinka S. Ohunakina, Taiwo O. Babarinde (2016), The experimental investigation is carried out of varied mass charges of Liquefied Petroleum Gas (40 g, 50 g, 60 g and 70 g) enhanced with varied TiO2 Nanoparticle/mineral oil concentrations(0.2 g/L, 0.4 g/L and 0.6 g/L nano-lubricants) in a R134a compressor of a domestic refrigerator. The TiO2 nanoparticles (15 nm size, 99.7% in purity, and produced by Alfa Aesar) in the range of 0.0001–110 g are added to a measured volume of mineral compressor oil. The results showed almost equal evaporator air temperatures and reduction in power consumption for all tested nano-lubricant concentrations except at 70 g charge of LPG using 0.6g/L nano-lubricant. [23]

M. S. Bandgar, Dr. K. P. Kolhe& Dr. S. S. Ragit (2016), An investigation was done on the compatibility of POE/Mineral oil mixed with Silica (SiO2) Nano powder (at a concentration of 0.5%, 1% and 1.5% by mass fraction) as Nano lubricant. The refrigeration system performance with the Nano lubricant was investigated by using energy consumption and refrigeration effect test. The results were showed that the increase in COP is 4.39% when POE oil is replaced with mineral oil. It is found that the VCR system using (Mineral oil+0.5%SiO_2) as lubricant has highest COP. When Nano lubricant (0.5% SiO_2 + Mineral oil) is used instead of pure mineral oil then COP is increased by 12.61%. [24]

Mohammed Ajmal A, Sunir Majilya (2017) has investigated the influence of CuO nanoparticles on the tribological characteristics of Polyolester (POE) oil is experimentally investigated and Surface roughness, viscosity were studied. Three different mass fractions of nanoparticles 0.025%, 05% & 0.1% are dispersed with 50 ml of POE oil. Each sample is kept under ultrasonic agitation process for 60 minutes. The results were showed that the potential of nanolubricants in reducing the friction coefficient compare to that of the pure lubricant. [25]

R. K. Adyanshee Pattanayak, Prasheet Mishra (2016), the experimental investigation is carried out by the use of nano fluid in enhancement of the performance of a domestic refrigerator. The amount of nanoparticles are added with the mineral oil and for uniform distribution of the nanoparticles in the oil, the mixture (Mineral oil and nanoparticles) is placed in an ultrasonic vibrator for 6-7 hours. The nanofluid prepared is of the mass fraction of 0.2% & 0.5% respectively. The results were showed For 0.2%, 0.4% mass fraction of nanoparticles, the coefficient of performance of the system increases by 7.75% & 14.48% for PAG oil and 19.38% & 25.3%for mineral oil respectively. [27]

II. PREPARATION OF NANOFLUID

Several researchers carried out the synthesis of nanofluids using two step and single step method. In case of two step method, the nanoparticles are produced initially and then it is added into the working fluid. In case of single step method the dispersion of nanoparticle is done directly into the working fluid.

2.1 Ball milling equipment

Ball milling is a grinding method that grinds nanotubes or nanoparticles into extremely fine powders. During the ball milling process, the collision between the tiny rigid balls in a concealed container will generate localized high pressure. Usually, ceramic, flint pebbles and stainless steel are used. In order to further improve the quality of dispersion and introduce functional groups onto the Nanoparticle surface, selected chemicals can be included in the container during the process. The factors that affect the quality of dispersion include the milling time, rotational speed, size of balls and balls/ nanotube amount ratio.

- The nanoparticles are grinded in the ball milling equipment to make them to the required particle size.
- The ball milling is done for 8 hours to completely remove the clusters in the powder.

2.2 Agate mortar grinding

The only purpose of any mortar and pestle set is to grind solids into fine powders but under conditions that are highly controlled as to not produce any heating effects and to minimize and control any effects due to stretching of sometimes deformable materials. This is probably the most ancient device one is likely to find in a modern scientific laboratory. Because of the ability to control the grinding, and also to virtually eliminate contamination from the mortar and pestle set itself, agate is the preferred material and is used in laboratories and in grinding of herbs. If a mortar and pestle of metal construction is used, it is generally recognized that metal particles enter the ground powder, thereby presenting either a health concern or else a contaminant is precision scientific measurements are to be made on the ground powder.
The nanoparticles after ball milling are again grinded in an Agate mortar for two hours with immediate heating in a Muffle furnace for a period of two hours.

- The temperature of around 700 is maintained in the furnace to completely remove the moisture in the powder.

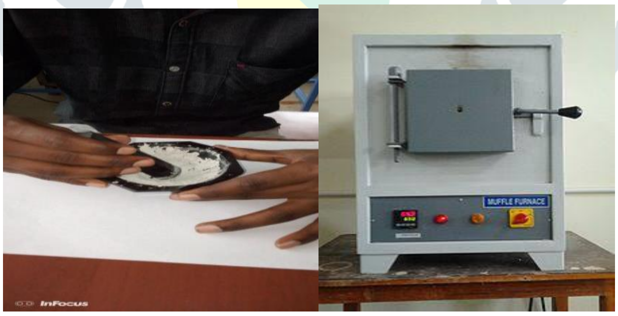

Fig 1: Reducing the size of nanoparticles by using agate motor

From the following calculation we have obtained the exact weight of nanopowder to be mixed in base oil. Volumetric concentration is found by using the below equation

(Volume %) = (vol of nanofluid)/ (vol of nanofluid + vol of base fluid)

2.3Magnetic stirrer

A magnetic stirrer or magnetic mixer is a laboratory device that employs a rotating magnetic field to cause a stir bar (also called "flea") immersed in a liquid to spin very quickly, thus stirring it. The rotating field may be created either by a rotating magnet or a set of stationary electromagnets, placed beneath the vessel with the liquid. Because of its small size, a stirring bar is more easily cleaned and sterilized than other stirring devices. They do not require lubricants which could contaminate the reaction vessel and the product. Magnetic stirrers may also include a hot plate or some other means for heating the liquid. Therefore by using this magnetic stirrer we mixed the proper amount of CuO & ZnO particles in base oil with respect to the required volumetric concentration by following procedure.

1) Place a beaker which is filled with POE oil and particular amount of nano particles obtained from calculation according to 0.25% volumetric concentration.
2) Drop the magnetic stirrer in that beaker and switch on the machine.
3) Allow the stirring action for 25-30 minutes.
4) Carry the same procedure for the remaining three concentrations i.e., 0.5%, 0.75% and 1%.

2.4 Ultrasonication

Sonication has numerous effects both chemical and physical. Sonicator transforms the sound waves into mechanical energy which will help to mix the MgO particles in base oil appropriately. This sonication process is followed after stirring process.

1) Following procedure is carried out for sonication process.
2) Place the stirred nano oil beaker on holder in sonicator.
3) Lift up the sonicator upto certain height such that the cone shaped probe gets immersed in nano oil.
4) Close door of the sonicator and specify the time in controller.
5) Allow the sonication action for 3600sec.
6) Carry the same procedure for 0.25% concentrated oil for three times simultaneously.
7) Carry the same procedure for the remaining three concentrations i.e. 025%, 0.5%, 0.75% and 1%.

3. Thermo – physical properties of nanolubricant

The thermal conductivity of a material is a measure of its ability to conduct heat. It is commonly denoted by K. Heat transfer occurs at a lower rate in materials of low thermal conductivity than in materials of high thermal conductivity. For instance, metals typically have high thermal conductivity and are very efficient at conducting heat, while the opposite is true for insulating materials like Styrofoam. Correspondingly, materials of high thermal conductivity are widely used in heat sink applications and materials of low thermal conductivity are used as thermal insulation. The reciprocal of thermal conductivity is called thermal resistivity.

3.1 Estimating thermal conductivity by using Hamilton & Crosser model

The Hamilton and Crosser model do not take the consequence of particle size on thermal conductivity into consideration, but it becomes somewhat charge on particle size due to the statement that nanoparticle thermal conductivity raises with increasing particle size .However, the method still is unable to predict experimental data for particle sizes larger than 30 nm since particle size craving diminishes with growing particle size.

Model Calculation:

The thermal conductivity of the specimen fluid is calculated by the following equation

$$\frac{K_{nf}}{K_f} = \frac{K_{np} + (n-1)K_f - (n-1)\emptyset(K_f - K_{np})}{K_{np} + (n-1)K_f + \emptyset(K_f - K_{np})} K_f$$

3.2 Estimating Thermal conductivity by using Maxwell Garnett Model

Maxwell (1873) developed the first theoretical model for effective thermal conductivity of two component mixtures considering negligible interfacial resistance at the interface between the host phase and inclusions. This model defines the effective thermal conductivity of isotropic, linear, nonparametric mixtures with randomly distributed spherical inclusions. The inclusions are considered to be small compared to volume of the effective medium and are separated by distances greater than their characteristic sizes. Extension of this model to nanofluids expresses the thermal conductivity of nanofluids as an effective value of the thermal conductivities of the inclusions and the base fluid, which takes the form (Maxwell, 1873)

$$\frac{K_{nf}}{K_f} = \frac{2K_{np} + K_f + \emptyset(K_{np} - K_f)}{K_{np} + K_f - 2\emptyset(K_{np} - K_f)}$$

3.3 Estimating Thermal conductivity by using Wien & ding model

$$\frac{K_{nf}}{K_f} = \frac{(1-\emptyset)(K_{np} + 2K_f) + 3\emptyset K_{np}}{(1-\emptyset)(K_{np} + 2K_f) + 3\emptyset K_f}$$

3.3 Experimental Equipment and Procedure for Calculating Thermal Conductivity

Thermal conductivity of the nanolubricant were measured by KD 2 Pro thermal analyzer which uses transient hot wire method. All the samples were measured at controlled condition of 25±°C. For accuracy the experiment was repeated for three times and the average values were plotted in the graph. Thermal conductivity of CuO and ZnO nanolubricants were measured at different concentrations like 0.25%, 0.5%, 0.75% and 1% by volume.

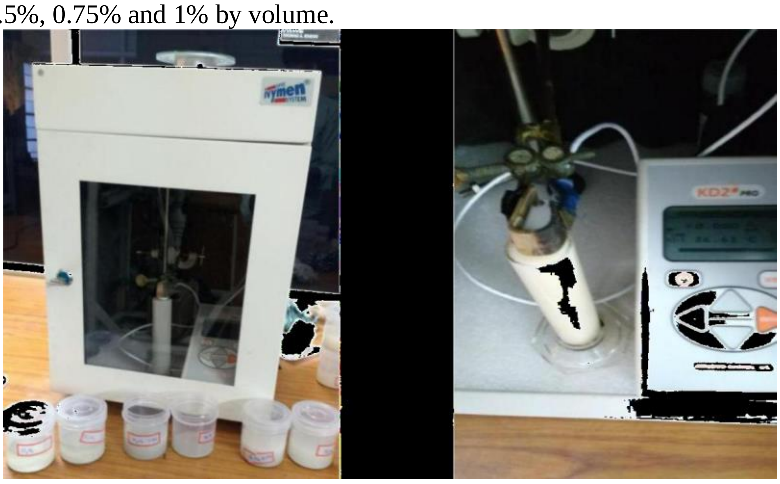

Fig 2: KD 2 Pro thermal analyzer

3.4 Measurement of electrical conductivity of nanolubricant

Electrical Conductivity is a measure of the ability of a substance/solution to conduct an electric current (this electric current is carried by ions and the chemical changes that occur in the solution). An electrical conductivity meter (EC meter) was used to measures the electrical conductivity of the nanolubricants.

Electric Conductivity depends on:

- Concentration of ions (higher concentration, higher Electrical Conductivity); the determination of the Electrical Conductivity is a rapid and convenient means of estimating the concentration of ions in solution. Since each ion has its own specific ability to conduct current, Electrical Conductivity is only an estimate of the total ion concentration.
- Temperature of the solution (higher temperature, higher Electrical Conductivity); The Conductivity of a solution is highly temperature dependent, therefore it is important to either use a temperature compensated instrument, or calibrate the instrument at the same temperature as the solution being measured.
- Specific nature of the ions

The experimental setup of electrical conductivity meter:

Fig 3: Electric Conductivity Meter

3.5. Viscosity

Viscosity is the property of fluid. It is defined as the internal resistance offered by the fluid to the movement of one layer of fluid over an adjacent layer. It is due to the Cohesion between the molecules of the fluid. The fluids which obey the Newton law of Viscosity are called as Newtonian fluid. The dynamic viscosity of fluid is defined as the shear required to be produced per unit rate of angular deformation. Here we have determined the kinematic viscosity and absolute viscosity of the given lubricating oil I.e., POE oil at different temperatures using Redwood Viscometer and later we have found the kinematic viscosity and absolute viscosity of the silicon nitride nanolubricating oil at different temperatures.

Fig 4: Redwood Viscometer

4. Results & Discussions:

Thermo physical properties of nano lubricants like

1. Viscosity
2. Thermal conductivity has been evaluated at different temperatures and % concentration of nano particle in the base oil.

In this work the optimum concentration was taken considering the thermal physical properties of Nanolubricants.

5.1 Viscosity of Nano Lubricants:

Viscosity is one of the most important parameters, which plays a basic role in the lubricating process. So in this research, attention was focused on measuring and evaluating viscosity variations in nano-lubricants. For the purpose of surveying the effect of concentration of nano particles and temperature on viscosity of lubricants, the dynamic viscosities of nano-lubricants in between 15 °C - 50 °C and also at 0.25, 0.50, 0.75 and 1 wt% were measured.

Table 1- Viscosity of CuO NanoLubricants at 40°C

% Concentration	Einsten[12]	Brinkman[25]	Batchelor[36]	Experimental
0%	0.0393	0.0393	0.0393	0.0330
0.25%	0.0395	0.0395	0.0395	0.0641
0.5%	0.0397	0.0397	0.0397	0.0775
0.75%	0.0400	0.0400	0.0400	0.0860
1%	0.0402	0.0402	0.0403	0.0880

Table 2- Viscosity of ZnO NanoLubricants at 40ºC

% Concentration	Einsten[12]	Brinkman[25]	Batchelor[36]	Experimental
0%	0.0473	0.0473	0.0473	0.0480
0.25%	0.0485	0.0485	0.0485	0.0541
0.5%	0.0505	0.0505	0.0505	0.0675
0.75%	0.0570	0.0570	0.0570	0.0760
1%	0.0592	0.0592	0.0592	0.0790

Table 1 and 2 shows the variation of dynamic viscosity for different temperatures and concentration of CuO nano particles. Results shows that viscosity has been decreased with increase of temperature and maximum variation was absorbed at lower temperatures. Experimental result illustrates that maximum viscosity has been enhanced at 40°C for 1 % concentration of CuO and ZnO nano particles without surfactant. The enhanced viscosity may also leads to increase in compressor work and reduces the pressure ratio. Also enhanced viscosity can reduce the coefficient of friction and improves the life of the compressor. From the above results of dynamic viscosity of CuO and ZnO nanolubricant for various concentrations were measured at 40ºC and found maximum enhancement of 46.68% and 43.34% for CuO & ZnO nanolubricants

5.8 Thermal Conductivity of Nano Lubricants

Thermal conductivity of the base POE oil, CuO and ZnO nanolubricant were measured with KD2 pro thermal analyzer at steady room temperature for different mass concentration and the results were compared with the theoretical models given by various researchers. Experimental values obtained were in accordance with the models suggested by the authors. Table shows that the thermal conductivity value increases with volume concentration and the maximum enhancement of 60% at 1% concentration has been observed for both the nanolubricant. As per the literature enhanced thermal conductivity leads to improve the heat transfer coefficient in the condenser and evaporator. Also shell temperature of the compressor can be reduced which improves the life of the compressor.

Table 3- Thermal Conductivity of Nanolubricants

Ø	Hamilton[25]		Maxwell[20]		Wein & ding[25]		Experimental		
	Al2O3	**ZnO**	**Al2O3**	**ZnO**	**Al2O3**	**ZnO**	**POE**	**Al2O3**	**ZnO**
0%	-	-	-	-	-	-	**0.167**	-	-
0.25%	0.241	0.200	0.281	0.281	0.257	0.251	**0.167**	**0.253**	**0.264**
0.5%	0.242	0.220	0.283	0.280	0.260	0.258	**0.167**	**0.260**	**0.265**
0.75%	0.253	0.238	0.284	0.284	0.268	0.263	**0.167**	**0.265**	**0.265**
1%	0.260	0.258	0.286	0.286	0.270	0.274	**0.167**	**0.268**	**0.268**

6.0 Conclusion

The nanoparticles revealed to be promising candidates as additives, to develop a new class of lubricants, which are suitable and effective in different operating environments. Thermo–physical properties of the nanolubricants of 3 samples (POE, CuO and ZnO) were analyzed at different concentrations for refrigeration application and the following conclusions are drawn.

1) The variation of viscosity of nanofluids is observed to be nonlinear with increase of particle concentration
2) Dynamic viscosity of CuO nanolubricant was max enhancement at 1% concentration was 83.34%, compared to pure base oil.
3) Dynamic viscosity of ZnO nanolubricant was max enhancement at 1% concentration was 80.79%, compared to pure base oil.
4) Thermal conductivity of CuO nanolubricant was maximum at 1% concentration at 35°C was 47.92% without compare to the POE oil.
5) Thermal conductivity of ZnO nano lubricant was maximum at 1% concentration at 35°C was 47.92% without compare to the POE oil.
6) In future scope Thermo physical properties for different kinds of Nanoparticles can be studied for increasing efficiency of refrigeration.
7) Nanoparticles having high thermal conductivity can be used for enhancing performance of refrigerator.
8) The behavior of various Nanoparticles can be studied at different concentrations for enhancing the thermo-physical properties.

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