# EXPERIMENTAL ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM USING NANO LUBRICANT WITH REFRIGERANT R-134A

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*It has been proved that due to addition of nanoparticals to the refrigerant results in improvement in thermophysical properties and heat transfer characteristics of the primary refrigerant, which improves the coefficient of performance of the refrigeration system. In this experimental analysis of vapour compression system, the performance study has been carried out by preparing the nanolubricant. In this experimental study, three cases are considered. The compressor of the system filled with pure polyolester oil, SUNISO-3GS oil and polyolester oil + titanium dioxide nanoparticles as lubricant. In the nanolubricant, the volume concentration of the nanoparticles is 0.2 %. The experimental study shows that vapour compression refrigeration system works smoothly with nanorefrigerant. In this experimental study, it has observed that when nanolubricant used in place of traditional Polyol ester oil, the refrigerating effect has been increased and the compressor power consumption has reduced by 27% and the refrigeration system coefficient of performance improves by 29%. The analysis shows that the enhancement factor in the evaporator is 1.2 when nanorefrigerants are used instead of pure refrigerant.The properties of refrigerant like thermal conductivity and density are also studied for the nanolubricant by using the Labview software, in which the thermal conductivity & the density of R134a and nanolubricant mixture are observed higher in comparison with the R134a and pure lubricant mixture.*

Keywords*: VCRS, R-134a, Nanolubricant, Coefficient of performance*

## 1. Introduction

The rapid development of nanotechnology has led to the emergence of a new class of heat transfer fluids called nanofluids. Many researchers have recently studied the effects of nanoparticles in the different refrigerant/lubricant on the efficacy of vapour compression refrigeration systems. Pawel et al. [1] studied nanofluids, they discovered that they had a significantly higher thermal conductivity than basic fluids. They also discovered that the crucial heat flux significantly increases when nanoparticles are added. Bi et al. [2] used $TiO_2$-R600a nanorefrigerant as a working fluid in experimental investigation of a home refrigerator for evaluation of performance. They demonstrated that the $TiO_2$-R600a system operated in the refrigerator normally and effectively, saving 9.6% of electricity. They too stated that the nano refrigerating system had a higher freezing pace than a system using only pure R600a. This article's goal is to present the findings of experimental research on a vapour compression device. The nanoparticle used in this research is alumina, and the refrigerant chosen is R134a. Bi et al [3] were used nanorefrigerants in experiments on a domestic refrigerator. They used R134a as a primary refrigerant and a mixture of mineral oil and $TiO_2$ as the lubricant in their experiments. They discovered that the nanorefrigerant-equipped refrigeration system operated regularly and effectively, consuming 21.2% less energy compared to a device using R134a/POE oil. Afterword, Bi et al. [4] discovered that the power usage had been noticeably reduced and the freezing capacity had significantly improved. They emphasised that better mineral oil thermophysical properties and the existence of nanoparticles in the refrigerant are to blame for the system's improved performance. Jwo et al. [5] studied on a cooling system using a refrigerant of hydrocarbon and mineral lubricant inplace of R-134a and polyester lubricant. $Al_2O_3$ nanoparticles were added to the mineral lubricant to enhance heat transmission and lubrication. According to their research, the sixty percent R-134a and 0.1 weight percent $Al_2O_3$ nanoparticles found the best. In these circumstances, the performance coefficient rose by 4.4% while the power consumption decreased by about 2.4%. In a horizontal tube, Henderson et al. [6] performed the experimental study on heat transfer of nanofluids based on R134a. With R134a and POE oil, they discovered better dispersion of CuO nanoparticle and the coefficient of heat transfer increased by more than 100% in comparison to initial R134a/POE oil findings. In a research by Bobbo et al. [7], the effects of individual wall carbon nanohorn) and $TiO_2$ dispersion on POE oil's tribological properties and R134a's solubility at various temperatures were examined. They demonstrated how the addition of nanoparticles can either enhance or worsen the behaviour of base lubricant. Using Brinkman's model, Mahbubul et al. [8] investigated R123-$T_iO_2$ nanorefrigerant viscosity at various nanoparticle concentrations and found that pressure drop dramatically increases as viscosity increases.

Bilir Nagihan and Kursad Ersoy [9] looked at how a two-phase constant area ejector could enhance a VCR system's performance by collecting kinetic energy during the expansion process and so lessening the compressor's workloadWhen different blends of hydrocarbons are utilised, Sattar et al. [10] showed that the performance of VCR system using the refrigerant R-134a improves. By the development of nanotechnology, numerous studies have investigated the impact of adding additives as a nanoparticles to the lubricant or refrigerant, or both, on the COP of the VCR system. Park and Jung [11] investigated how the inclusion of  nanotubesmade of carbon improved the heat transfer in refrigerants. Lee et al. [12] found improved lubricating properties in mineral oil with a 0.1% volume percentage of nanoparticles. The described experimental investigations Ku et al., [13] and Long et al., [14] imply that the viscosity fluctuations or the changing lubrication characteristics may be the causes of increased in the COP when nanoparticles are added to lubricating oil. According to Elcock [15], $TiO_2$ nanoparticles can be added to mineral oil to improve its solubility with hydrofluorocarbon (HFC) refrigerants. Additionally, according to the authors, the 134a and mineral oil refrigeration systems with nanoparticles of $TiO_2$ appear to operate similarly to HFC134a and POE oil systems while returning more lubricating oil from the compressor. Hindawi [16] conducted an experimental investigation on the heat transfer properties of refrigerant R22 with nanoparticles $Al_2O_3$ and it was discovered that nanoparticles improved the refrigerant's heat transfer qualities with smaller bubble sizes. The heat transfer properties of R11 refrigerant with nanoparticles $TiO_2$ were examined by Eastman et al. [17] who demonstrated the heat transfer augmentation reached 20% for the 0.01 g/L partical loading. The impact of nanotubes made of carbon on the heat transfer of R123 and R134a refrigerants was examined by Liu et al. [18]. According to authors, CNTs improve these refrigerants' nucleate boiling coefficient of heat transfer. Large improvements of 36.6% were observed by the authors at very low heat fluxes. Choi et al. [19] observed that the addition of carbon nanotubes made of multiwall increased the thermal conductivity of polyoil by 150%. The same type of results are reported by Yang [20], who found that polyoil containing 0.35% (v/v) carbon nanotubes improved thermal conductivity by 200%. It's crucial to remember that this rise in thermal conductivity was observed by a viscosity increase of three orders of magnitude. According to Wang and Xie [21], nanoparticles of $TiO_2$ can be utilised as additives to improve the mineral oil's solubility in HFC refrigerant. Additionally, compared to systems employing R134a and POE oil, refrigeration systems using blend of R134a and mineral oil containing $TiO_2$ nanoparticles seem to operate well by returning more lubricating oil from the compressor. Skye. H. et al. [22] studied the non-flammable Low-GWP Refrigerant Blending for the replacement of HFC-134a. Hady et al. [23] experimentally studied the performance of “chilled - water air conditioning unit using alumina nanofluids” for enhancement of Coefficient of Performance (C.O.P.) and energy saving. Majgaonkar et al. [24] suggested nano refrigerant improvement in system performance, but its application is obstructed by some factors like high-pressure drop, low specific heat, fouling and high production cost. Yıldız et al. [25] studied the impact of using nanofluids on the performance of refrigeration systems. V.C.Shewale et al. [26] conducted an experimental investigation of Ice plant using different concentrations of Nano lubricant with primary refrigerant R-134a. Hatami et al. [27] carried work on spherical particle in plane Couette fluid flow by multi-step differential transformation method. Song, et al. [28] investigated optical properties of TiO2/water suspension considering particle size distribution. Hatami et al. [29,30] carried out numerical analysis of heated cylinder by using natural convection. Ghasemi, E., et al. [31] has done analytical and numerical investigation of nanoparticle effect on peristaltic fluid flow in drug delivery systems. Mosayebidorcheh, S., and Mohammad Hatami. [32] carried out nalytical investigation of peristaltic nanofluid flow and heat transfer in an asymmetric wavy wall channel. Sharifa N. et al. [33] studied on convection of nanofluid in a wavy trapezoidal enclosure.

After complete literature review on nanolubricant, it has been found that many researchers worked on this topic, but very few investigations are carried out on Titanium dioxide ($TiO_2$) nanoparticals in MO, POE & PAG lubricants with primary refrigerant R134a in the area of heat pump, air conditioning and domestic refrigerator. The use of various nanolubricant with mineral oil research found in substantial amount, but no research has been found on Titanium dioxide ($TiO_2$) nanoparticals in POE lubricants with primary refrigerant R134a for vapour compression refrigeration system application. So no attempt has been found by any researcher on this topic using the computerised test rig of VCR system with Labview software. Here it is a sincere attempt to conduct experimental analysis of VCR system with $TiO_2$ with POE lubricant using R-134a as a primary refrigerant in to the computerised VCR system test rig with LABVIEW software. In this paper, three cases are considered. The system compressor filled with pure POE oil, SUNISO-3GS oil and POE+ $TiO_2$ nanoparticles as lubricant and the performance of the VCR system test rig are recorded for these three cases.

## 2. Experimental set up and Methodology:

### 2.1 Experimental set up

The set up of experiment, which is shown in Fig.1 and the simulation that is shown in Fig.2 mainly, consists of a hermetically sealed compressor, drier-filter, expansion device, and heat absorption chamber which work on VCR system. The test rig specifications are mentioned in table.1. Low pressure and low temperature vapour refrigerant coming from the evaporator are sucked by the compressor and in compressor its temperature and pressure increases and it releases its heat in to the condenser. After condenser it passes through the capillary tube in which liquid refrigerant is converted in to vapour and liquid which again goes to the evaporator where we get the refrigerating effect. For measuring the high pressure and low pressure separate pressure gauges are fitted in to the set up. All temperatures are recorded with the help of temperature indicator at different states of refrigerant and digital energy meter provided to record the input power required to run the compressor. The data acquisition system is incorporated to display all the data on the PC. The specifications of instruments used for measurement are given in table.2.

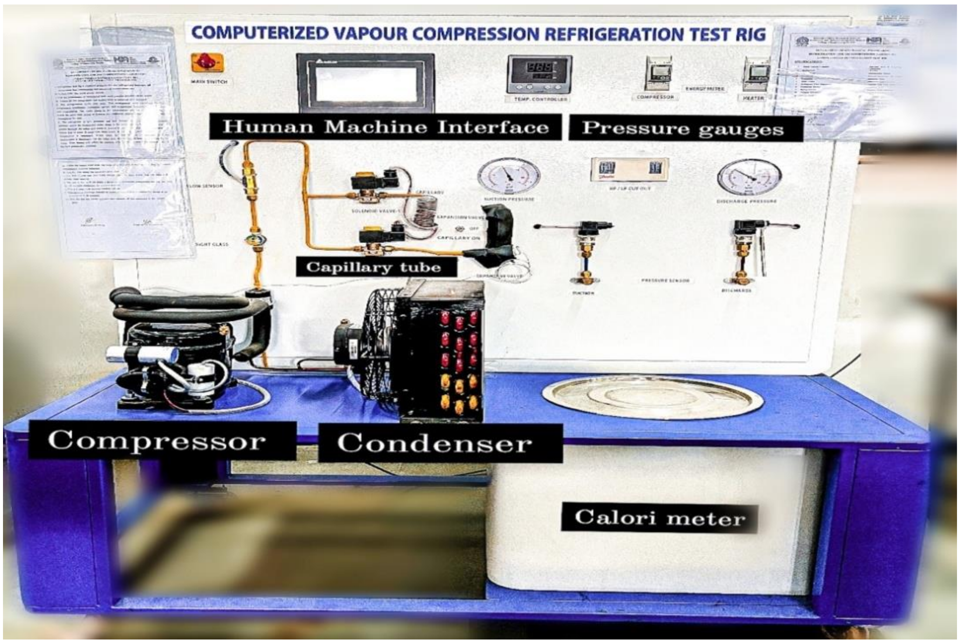


**Figure. 1. Experimental set-up**

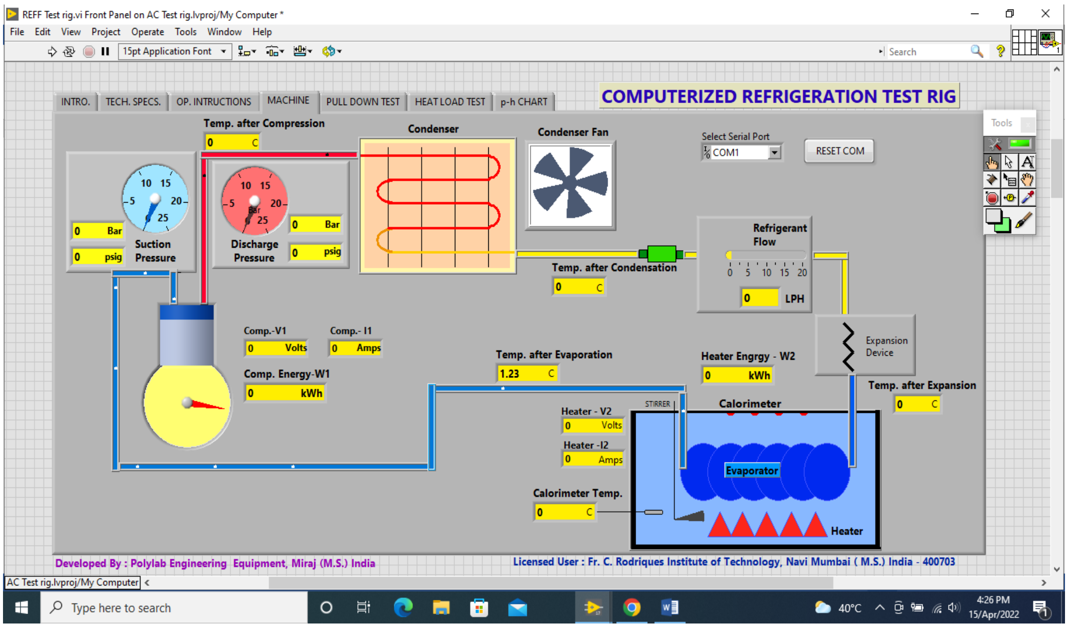


**Figure. 2. Simulation of experimental**

**Table. 1 Test rig Specification**

| Sr. No. | Component/Item | Specification |
|---|---|---|
| 1 | Compressor | Hermetically sealed |
| 2 | Condenser | Forced convection air cooled |
| 3 | Drier / Filter | Silica Gel Type |
| 4 | Refrigerant Flow Measurement | Turbine Type Flow Meter |
| 5 | Expansion device | Capillary tube |
| 6 | Capillary length | 2m (appro.) |
| 7 | Evaporator | Immersed Direct expansion type |

|  |  |  |
|---|---|---|
| 8 | Refrigerant | R 134a |
| 9 | Pressure Indication | Digital Pressure Transducers |
| 10 | Programming Language | Labview 2017 |
| 11 | Data Acquisition System Module | Advantech USB-4711A |
| 12 | Temperature Transmitters | 4-20 mA out-put, -50 to 100 deg C |
| 13 | Pressure Transmitters | 4 -20 mA out-put, 0-20 bar pressure range |
| 14 | Flow Transmitter | Flow range= 10 to 100 LPH, 4-20 mA out-put |

**Table. 2 Specification of instruments used for measurement:**

| Sr.No. | Measured Parameter | Instruments | Range | Uncertainty |
|---|---|---|---|---|
| 1 | Temperature | PT100 | -50 $^{0}$C to 100$^{0}$C | ±0.5% |
| 2 | Pressure | B.T.pressure gauge | 0-15 bar (L. Press.)0-20 bar (H.Press.) | ±0.5% |
| 3 | Power of comp. | Digital energy meter | 0-2000 W | ±0.2% |
| 4 | Nanoparticles mass | Digital Electronic balanced | 0.001to 250g | ±0.5% |

**Table. 3 Details of nanoparticles:**

| Sr.No | Nanoparticle details | Specification |
|---|---|---|
| 1 | Type of nano particle | Titanium dioxide ($TiO_2$) |
| 2 | Size | 15nm |
| 3 | Purity (%) | 99.6% |
| 4 | Bulk density | 0.15 – 0.25 g /cm$^3$ |
| 5 | Volume Concentration | 0.2, 0.3 and 0.4% |

**Table. 4 Properties of POE lubricant:**

| Sr.No. | Lubricant Properties | Units |
|---|---|---|
| 1 | Oil | POE |
| 2 | ISO VG | 22 |
| 3 | Kinematic Viscosity @ 40$^{o}$C (cSt) | 22 |
| 4 | Kinematic Viscosity @ 100$^{o}$C (cSt) | 4.1 |
| 5 | Viscosity Index | 82 |
| 6 | Pour Point ($^{o}$C) | -5.4 |
| 7 | Flash Point ($^{o}$C) | 198 |
| 8 | Density @ 15 $^{o}$C (g /cm$^3$) | 0.935 |

**2.2 Preparation of $TiO_2$ & POE nanolubricant**

$TiO_2$ nanoparticles used in this study have an average diameter of 15 nanometers. Tables 3 and 4 provide information on the properties of the lubricant and nanoparticles used to prepare nanolubricant. $TiO_2$ is dispersed in lubricant oil POE which is frequently used in R134a refrigeration and the two-step method is used to prepare the nanolubricant. Throughout the nanolubricant preparation process, no surfactant is introduced. Using a highly accurate digital weighing device, the required amount of $TiO_2$ nanoparticles dispersed in to the lubricant is precisely weighted (CONTECH Make). After use of a magnetic stirrer for two & half hours to complete the initial mixing process, the nanolubricant is homogenised using ultrasonic technology as shown in Fig.3 for the designated amount of time. This is crucial to ensuring that nanoparticles are evenly distributed throughout the lubricant base. Then the 2 step method is used to prepare the sample of nanolubricant. Prior to conducting the experiment, the prepared $TiO_2$ and POE nanolubricant is inserted into the compressor during the test using the service port.


**Figure.3. Ultrasonic immersible transducer with generator and samples of nanolubricant**

## 3. Analysis of performance

### 3.1 For Pull down test:

**A) Actual COP of the VCR system:**

Refrigerating Effect (RE) = $m \times C_p \times (\Delta T)/\Delta t$ (1)

Where, m = mass of water

$C_p$ = Specific heat of water (4.187 kJ/kgK)

$\Delta T$ = Temperature difference

Work input = Final energy meter reading – Initial energy meter reading in kWhr

Therefore, Coefficient of Performance (COP) **=** Refrigerating effect/ work input

**B) Theoretical COP of the VCR system:**

Theoretical COP = Refrigerating Effect / Work done

$$COP = (h_1 - h_4)/(h_2 - h_1) \quad (2)$$

## 4. Results and Discussion

### 4.1. Experimental Results

In this experimental study, three cases are considered. The system compressor filled with a) pure POE oil b) SUNISO-3GS oil and c) POE+ $TiO_2$ nanoparticles as lubricant. The volume concentration of nanoparticles in nanolubricant is 0.2 %.

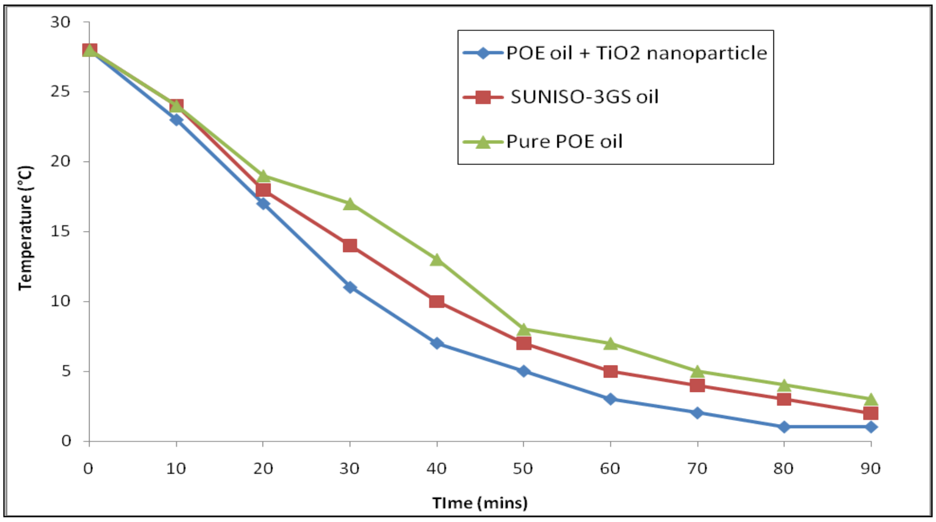


**Figure. 4. Temperature verses Time plot**

Fig.4 shows the plot of temperature verses time in which there is no pressure drop was observed due to friction in condenser and evaporator. It is evident from the figure that the POE oil + TiO2 nanoparticle mixture requires less time to reduce cooling load temperature. For instance, it takes 60 minutes with POE oil + TiO2 nanoparticle, compared to 80 and 90 minutes with SUNISO-3GS & POE oil, to drop the temperature of cooling load from 28 °C to 3 °C which shows the more effectiveness of POE oil + TiO2 nanoparticle mixture . Fig.5 shows the effect of refrigeration effect for the given three cases. It is evident that when compared to the other two situations, the POE oil + TiO2 nanoparticle mixture has a better refrigerating effect. With POE oil, it takes 90 minutes to lower the cooling load's temperature from 28°C to 3°C; if POE oil + TiO2 nanoparticles are used, the reduction is 24%. This is due to the nanoparticles speed up the pace at which heat is transferred from the evaporator's refrigerant side which gives the effective refrigerating effect.

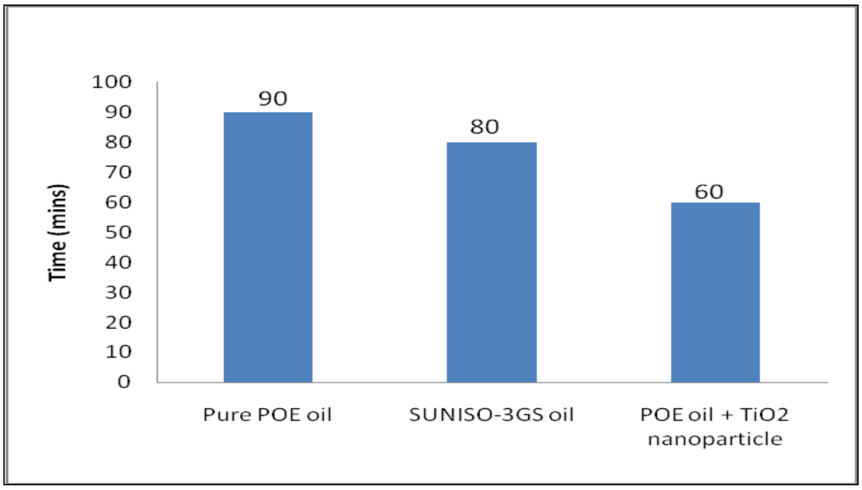


**Figure. 5. Nanopartical effect on Refrigerating effect**

Fig. 6 depicts the reduction in temperature of refrigerant in the refrigeration system's condenser. When compared to other situations, nanorefrigerant causes a significant drop in temperature of the refrigerant. The refrigerant is between 75 and 79 $^{o}$C at the condenser's intake temperature. The temperature at the condenser's outflow in the instance of the POE oil + $TiO_2$ nanoparticle mixture is 40

°C. The inclusion of nanoparticles in the refrigerant is what causes the condenser's increased heat transfer rate.

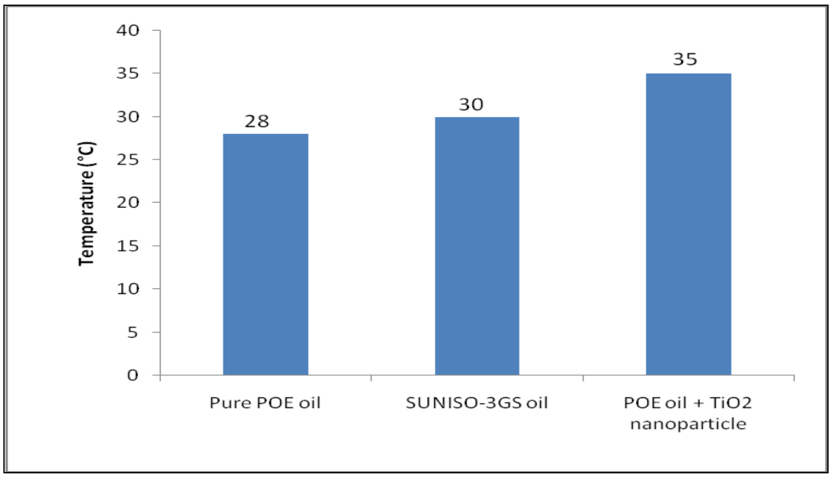


**Figure. 6. Decrease in temperature of refrigerant in condenser**

The compressor power consumption is compared in Fig.7 for all three cases. When POE oil + $TiO_2$ nanoparticle mixture is utilised, power consumption is reduced by 27% and reduced by 14% when SUSISO-3GS is used in place of POE Oil. The COP determined using the data of experiment displayed in Fig.8. The power input and cooling load are used to compute the real COP. For comparison, the theoretical values are also displayed. The histogram below makes it very evident that when compared to the other examples, the mixture of POE oil and TiO2 nanoparticles has the highest COP. The nano-refrigerant in the condenser is subcooled, which lowers the compressor's power usage and raises the COP. The reading from the energy meter and the cooling load are used to compute the actual COP. Enthalpy values from the critical locations are used from the P-h chart for R134a for the computation of theoretical COP.

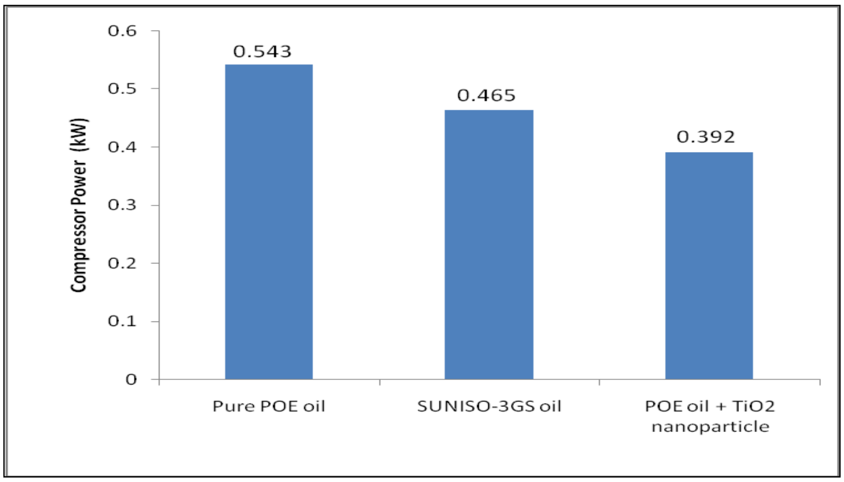


**Figure. 7. Comparison of compressor power**

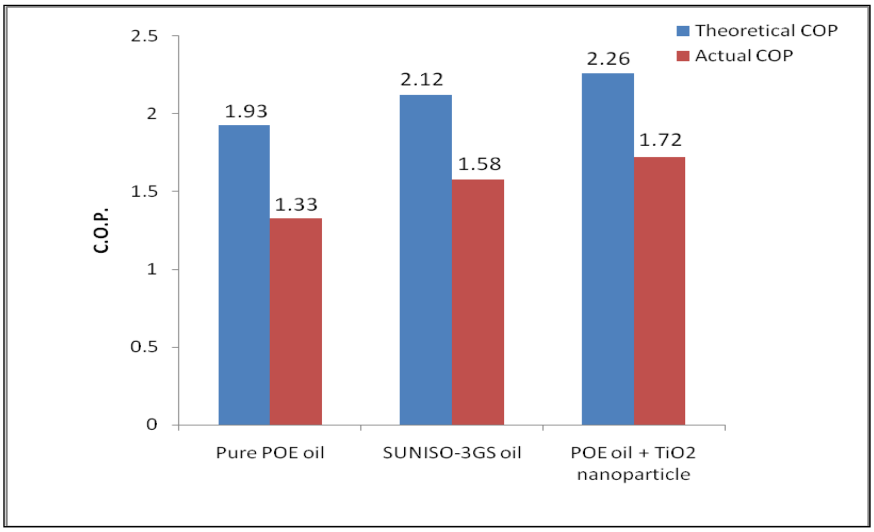


**Figure. 8. COP comparison for given cases**

Fig. 9 represents the variation of thermal conductivity on suction side for the pure POE oil, SUNISO-3GS oil & POE+ $TiO_2$ nanoparticles as lubricant. The thermal conductivity goes on increasing for SUNISO-3GS oil & POE+ $TiO_2$ nanoparticles as lubricant in camparision with pure POE oil and observed higher for nanolubricant. Fig. 10 shows the variation of density on suction side for the pure POE oil, SUNISO-3GS oil and POE+ $TiO_2$ nanoparticles as lubricant. In this study the same trend of increasing has been observed for density as thermal conductivity.

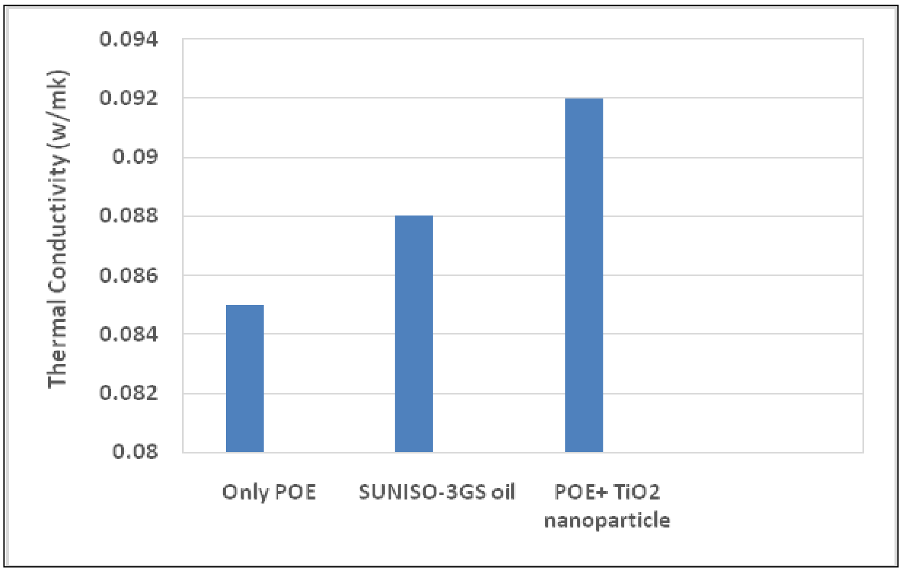


**Figure. 9. Variation of thermal conductivity for given cases**

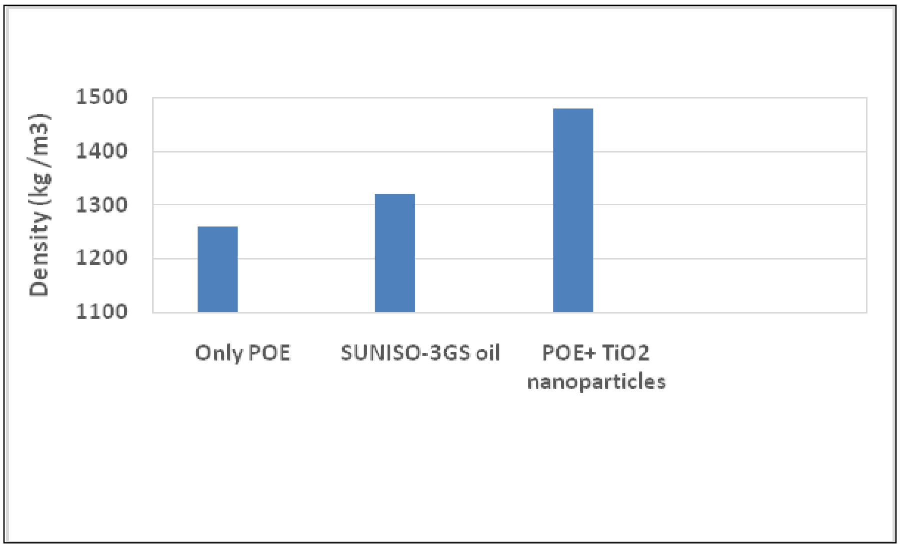


**Figure. 10. Variation of density for given cases**

### 4.2. Limitations

In this experimental study, the main limitation has been observed that as the nanoparticals are inserted in to the lubricant and the procedure of preparing nanolubricant is very costly and time consuming. Considering these things the output of enhancement of COP is not up to the mark for small capacity vapour compression refrigeration system.

## 5. Conclusions

In this paper, the experimental analysis of VCR system has been carried out for performance evaluation using various lubricants, including nanolubricants. The R134a refrigerant & the mixture of mineral oil with nanoparticles functioned normally. The refrigerating effect of the refrigeration system is higher when POE oil & $TiO_2$ nanoparticles oil mixture is used than when POE oil is used. When nanolubricant is used in place of traditional POE oil, the heat transfer properties of nanolubricant enhances due to this the regrigerating effect goes on increasing and the compressor's power is reduced by 27%. Due to increase in refrigerating effect and decrease in compressor work,the refrigeration system COP also improves by 29% when nanorefrigerant is used in place of traditional POE oil.The thermal conductivity and density goes on increasing for SUNISO-3GS oil and POE+ $TiO_2$ nanoparticles in camparision with pure POE oil. Considering the future scope, the performance of VCR system can be evaluated by using the different eco-friendly primary refrigerants & the mixture of mineral oil with nanoparticles.

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### Nomenclature

| | |
|---|---|
| $C_p$ | Specific heat [kJkg K-1] |
| h | Specific enthalpy [kJ kg-1] |
| k | Thermal conductivity [WmK-1] |
| m | Mass [kg] |

| | |
|---|---|
| $\dot{m}$ | Mass flow rate [kgs-1] |
| P | Pressure [bar] |
| RE | Refrigerating effect [kW] |
| T | Temperature [°C] |
| $W_{in}$ | Compressor power input [kW] |
| nm | Nanometre |
| COP | Coefficient of performance |
| HP | High pressure |
| LP | Low pressure |
| MO | Mineral oil |
| POE | Polyol ester |
| $TiO_2$ | Titanium dioxide |
| VCRS | Vapour compression refrigeration system |
| $\Delta T$ | Temperature difference [°C] |

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