APPLICATIONS OF NANOFLUIDS IN VAPOUR COMPRESSION REFRIGERATION SYSTEM: A REVIEW

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ABSTRACT : Currently the world is emphasized on energy saving purposes that could lead to better quality of human life. Nanofluids are promising fluids for heat transfer applications and have the potential to enhance heat transfer performance of thermal systems like refrigeration and air conditioning systems working on vapour compression refrigeration cycle by decreasing the amount of energy needed to operate. The conventional refrigerants have plays a vital role in global warming and depletion of the ozone layer. Therefore, there is need to improve the performance of vapour compression refrigeartion system with the help of using suitable refrigerant. Many researchers found that the addition of nanoparticles with refrigerants called nanofluid improves the performance of VCRS. Therefore this paper discusses the effect of various parameters of nanoparticles such as size, shape, concentration, etc. on the performance of vapour compression refrigeration system.

***IndexTerms* -** Nanofluids, VCRS, Nanorefrigerants, COP.

I. INTRODUCTION

In today's world, energy crisis is a major issue so it is required to reduce its consumption. Refrigeration and air conditioning are the mostly used equipments by the human beings for their comfort which consume large amount of energy. To reduce its consumption by the refrigeration systems, it is necessary to develop an energy efficient thermal system. For this purpose some change in the refrigeration system or fluid flowing in the system (refrigerant) is required.

Presently for economic point of view most of the refrigerator's use conventional vapour compression cycle which increases the coefficient of performance (COP) of the system and reduces the energy consumption. Many researchers have developed a new standard of fluid called the nanofluid which has got high surface area which prevents the particles being clogged. So we have replaced the conventional fluid with the nanofluid which possesses unique thermal properties which can improve the heat transfer and is energy efficient is thermal systems. The nanofluids are the mixtures of the base fluid and the nanoparticles. Nanofluids are prepared by suspending nano sized particles (1-100nm) in conventional fluids and have higher thermal conductivity than the base fluids. The base fluid can be water, ethanol, glycol, water based brine, refrigerant, engine oil, lubricant, etc. and nanoparticles can be Al, Cu, Al2O3, CNT etc. combined together to form a colloid called nanofluid. Lot of work has been done by using nanoparticles, specifically in refrigerator, on replacing the base fluid with nano fluid which has enhanced the performance of the same.

In this paper, the research works related to applications of nanofluids in vapour compression refrigeration system for improving performance have been reviewed. Applications of nanofluids are well grouped into three parts i.e. nanorefrigerant, nanolubricants and secondary fluids.

II. LITERATURE SURVEY

R Krishna Sabareesh et al [1] conducted experiment on VCRS using TiO2 nanoparticles with mineral oil and R12 as refrigerant and found that the COP of the system increased and power consumption reduced after using the nanofluid. A. Manoj Babu et al. [2] performed experiment on the vapour compression refrigeration system using nanolubricant TiO2/MO and Al2O3/MO with HFC-134a refrigerant and found that TiO2/MO nanolubricants show higher enhancement than Al2O3/MO. Also, the energy consumption was significantly reduced. Sheng-shan Bi et al [3] investigated performance of domestic refrigerator using HFC134a refrigerant and mineral oil mixture with TiO2 and Al2O3 and 0.1% mass fraction of TiO2 nanoparticles in place of POE oil got 26.1% less energy consumption which in result increased the COP of the system. Sheng-shan Bi et al [4] conducted another experiment by mixing nano particles (0.5g/L TiO2) with the refrigerant R600a without any reconstruction and got the result of 9.6% less energy consumption in the domestic refrigerator. N Subramani and M.J.Prakash [5] did the experiment on VCRS using R134a refrigerant mixed with Al2O3/ SUSISO 3GS oil and found that 25% less energy consumption with 33% increased COP. D. Sendil Kumar and R. Elansezhian [6] took a combination of Al2O3-PAG oil used as nano-refrigerant in R134a for conducting experiment on VCRS and found that10.32% less energy used with 0.2% volume of the concentration. M Mahbubul et al [7] took 0.5 to 2% volume concentration of Al2O3 nano particle with refrigerant R141b which resulted in increased thermal conductivity and viscosity. F S Javadi et al [8] took a combination of R-134a refrigerant with TiO2 and Al2O3 nanoparticles in 0.1% mass fraction and found that there is more energy reduction when compared with domestic refrigerator. R. K. Adhayashee et al [9] conducted experiment on domestic refrigerator using Al2O3/PAG (Polyalkylne Glycol) oil with refrigerant HFC134a (tetrafluoroethane) and found that the coefficient of performance of the domestic refrigerator was increased by 12.14%, 27.8% and 39.46% with 0.47%, 0.952% and 1.42% mass fractions of Al2O3 nanoparticles respectively. Also the power consumption was reduced by 10%, 20%, 26.6% and the freezing capacity was also increased for above mass fraction of Al2O3 nanoparticles. In this paper, the research works related to applications of nanofluids in vapour compression refrigeration system for improving performance have been reviewed. Applications of nanofluids are well grouped into three parts i.e. nanorefrigerant, nanolubricants and secondary fluids. P.B.Maheshwary et al [10] took ZnO/R-134a nanorefrigerant analyzed for two different shapes of ZnO nanoparticles and found that 25.26% and 42.5 % enhancement in the thermal conductivity of spherical and cubic shape ZnO nanoparticles in R-134a refrigerant.

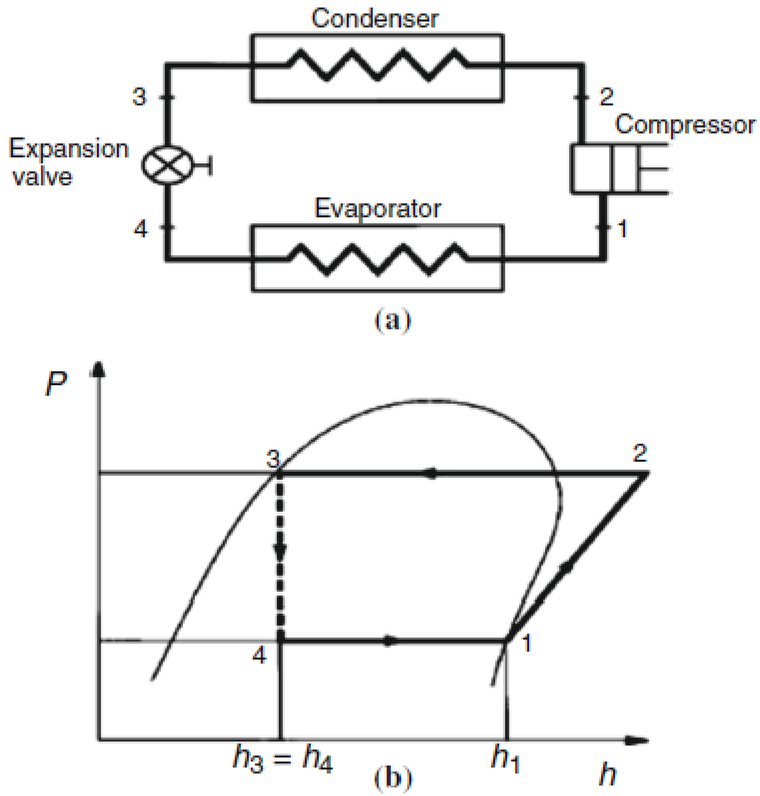
III. THEOROTICAL MODEL OF VCRS

Generally vapour compression refrigeration system has four components i.e., compressor, condenser and expansion valve as shown in Fig.1. From the figure vapour compression refrigeration cycle consists of four processes:

(1-2) isentropic compression in compressor,

(2-3) condensation at constant pressure,

(3-4) adiabatic expansion in expansion valve,



(4-1) evaporation at constant pressure.

Figure 1: (a) Schematic and (b) P–h diagram of a vapour compression refrigeration system

IV. PREPARATION OF NANOFLUIDS

Nanofluids can use in the vapour compression refrigeration system to enhance the performance. The efficiency of the system depends upon the properties of the refrigerant. Normally R600a, R22, R600 and R134a are used in refrigeration system as a refrigerant. It is prepared in two steps: single step method and two step method. These can be done by using the chemical method or mechanical methods. In single step method nanoparticles are made and dispersed in liquid simultaneously. In two step method nanoparticles are made separately and then dispersed afterwards maintaining the stability of nanofluid. Fig.1 provides the flowchart for producing nanofluids. Generally, two step method is preferred over single step method because it is comparatively easier and more economical.

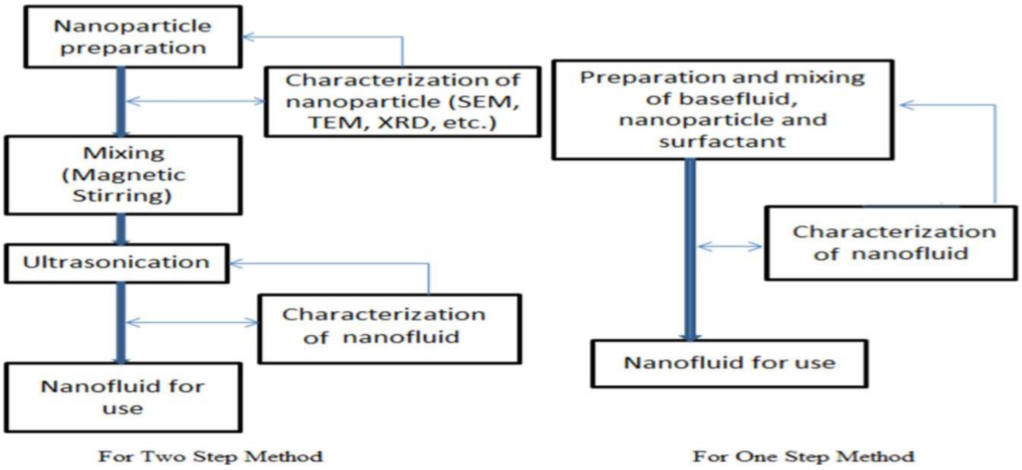


Figure 2: Flowchart for producing nanofluids [11]

V. PROPERTIES OF NANOFLUIDS

The thermophysical properties are important to gauge the effectiveness of a nanofluid or a nanorefrigerant. The thermal conductivity, viscosity, specific heat, latent heat, density and surface tension are some of the most important thermophysical properties of a fluid.

i. Thermal conductivity

Thermal conductivity is one of the important property of nanofluids for enhancing the heat transfer performance. The heat transfer coefficient and heat transfer rate depends on thermal conductivity. The thermal conductivity increases with the use of nanofluidn and depends on the parameters like volume concentration, temperature, particle size, particle shape, preparation method, etc. [12]. That is why many researchers have given utmost importance to thermal conductivity in their studies and they have also proved that the thermal conductivity of a nanofluid increases non-linearly with temperature. Mahbubul et al. [7] concluded that the thermal conductivity of nanorefrigerant increases accordingly with the increase of particle volume fraction. The thermal conductivity of pure R-134a refrigerant decreases linearly with increasing temperature. P.B.Maheshwary et al [10] observed that the thermal conductivity of nanorefrigerant was increases linearly with temperature. The increment in thermal conductivity due to addition of spherical and cubic ZnO nanoparticles over pure R-134a refrigerant is 25.26% and 42.5 %, respectively.

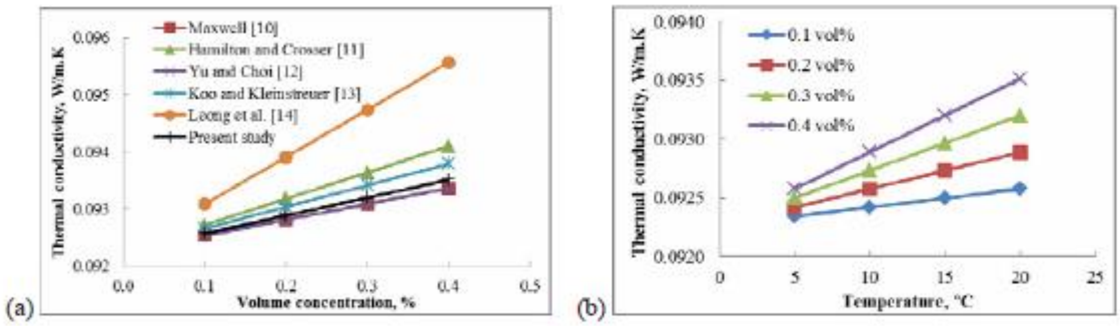


Figure 3: (a) Thermal conductivity Vs particle volume fraction; (b) Thermal conductivity Vs temperature for different volume fraction of nanorefrigerant. [7]

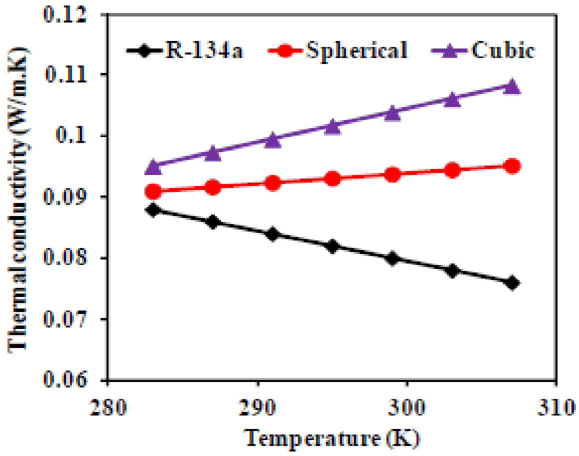


Figure 4: Influence of spherical and cubic shape ZnO nanoparticles on thermal conductivity of R-134a refrigerant. [10]

ii. Viscosity

Viscosity is another important thermophysical property which influences both heat transfer coefficient and pressure drop of nanofluid. As dynamic viscosity increases, the convective heat transfer coefficient decreases and the frictional pressure drop and hence pumping power increases. Even though the enhancement in the thermal conductivity and heat transfer of nanorefrigerants is much higher than the enhancement in viscosity; it is still important to study the viscosity variations brought by nanoparticles into the base fluid. R Krishna Sabareesh et al [1] discussed the relative effect of the volume fraction of the nanoparticles on the viscosity, at a given temperature. For instance at 40°C, the increase in viscosity is 19% for a nanoparticle volume fraction of 0.005%, whereas, for 0.01% and 0.015% volume fractions of nanoparticles, the increase in the viscosity was 24.6% and 28% respectively. Mahbubul et al. [7] found that the viscosity of Al2O3/R141b nanorefrigerant at 20ºC temperature for 0.1 to 0.4 volume concentrations of nanoparticles and shows viscosity increases linearly with the increase of volume fractions. P.B.Maheshwary et al [10] observed that the addition of spherical and cubic shape ZnO nanoparticles in R-134a refrigerant increases viscosity of nanorefrigerant. Cubic ZnO loaded nanorefrigerant has higher value of viscosity.

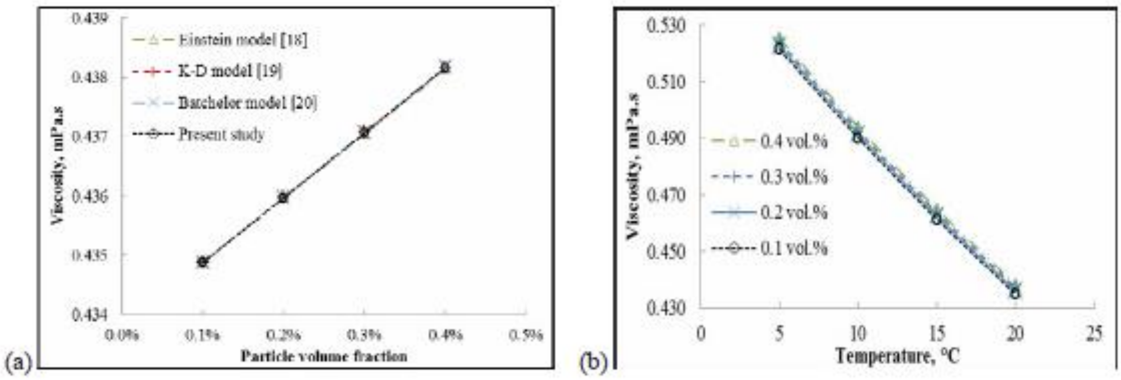


Figure 5: (a) Viscosity as a function of particle volume fraction; (b) Viscosity as a function of temperature for different volume fraction of nanorefrigerant. [7]

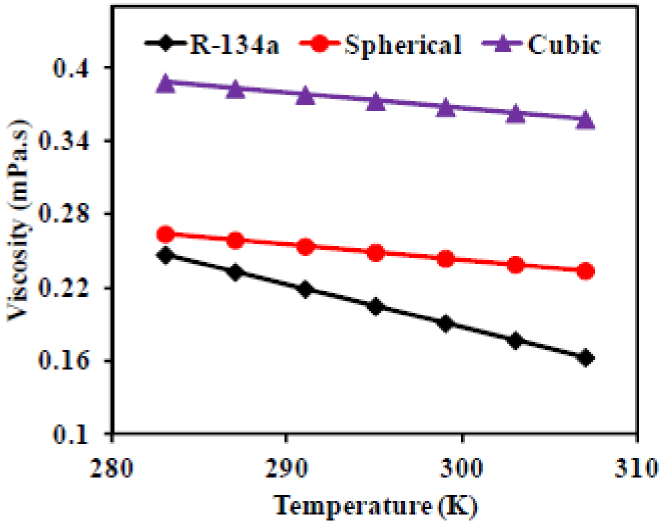


Figure 6: Influence of spherical and cubic shape ZnO nanoparticles on viscosity of R-134a refrigerant. [10]

iii. Density

For proper lubrication of a compressor, the viscosity and density of the nanolubricant are important parameters. Mahbubul et al. [7] observed that the density of Al2O3/R141b nanorefrigerant for 0 to 0.4 volume % of Al2O3/R141b nanorefrigerant at 20ºC temperature increases with the increase of volume concentrations and decreases with increase in temperature. The increment trend was almost linear. Kedzierski [13] found the same trend as density of suspensions decreases with the increase of temperature for CuO/lubricant nanofluid and observed that the decrease trend was slower up to 15ºC and after 15ºC density decreased rapidly. P.B.Maheshwary et al [10] observed that spherical and cubic ZnO loaded R- 134a nanorefrigerants have higher density than pure R-134a refrigerant.

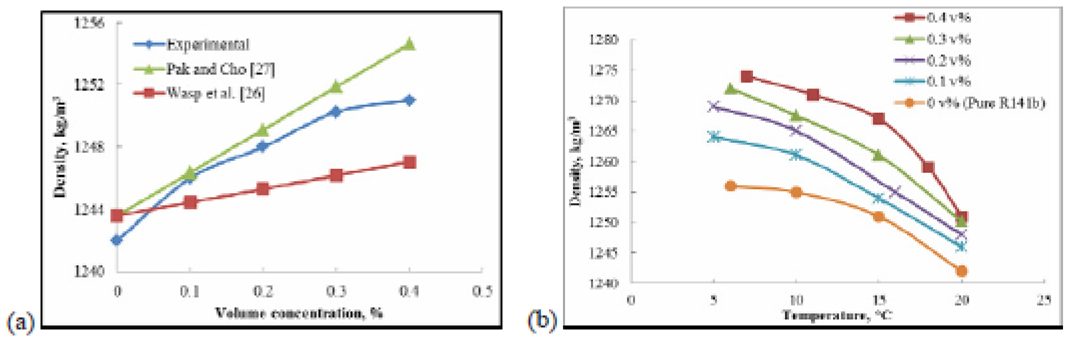


Figure 7 :(a) Density as a function of particle volume fraction; (b) Density as a function of temperature for different volume fraction of nanorefrigerant. [7]

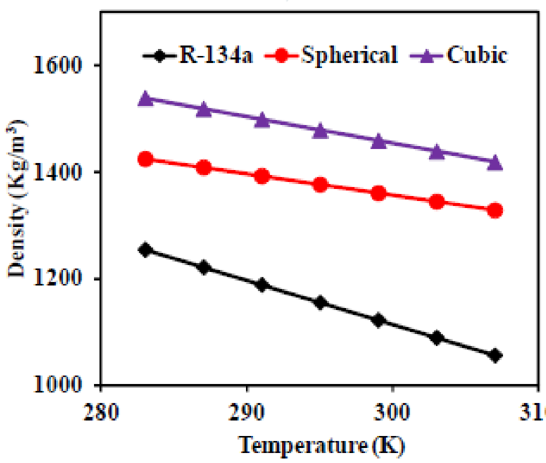


Figure 8: Influence of spherical and cubic shape ZnO nanoparticles on density of R-134a refrigerant. [10]

iv. Specific heat

The specific heat capacity of nanofluids and nanorefrigerants is another thermophysical property which is important because of its utilisation in energy and exergy performance analysis of the system. Shahrul et al. (2014) observed that the specific heat of nanofluids mainly depends on the type of nanoparticles, volume concentration of nanoparticles, temperature and the type of base fluid. Thus the specific heat of nanofluids can either increases or decreases by the addition of nanoparticles. Generally, the specific heat of a nanofluid deteriorates if the specific heat of the nanoparticles is lesser than the specific heat of base fluid. Alawi et al., (2015) investigated thatspecific heat increases by increasingnanorefrigeranttemperature from 300 K to 325 K and decreases byincreasingvolumeconcentrationranges from 1 to 5% of CuO/R134a.P.B.Maheshwary et al [10] observed that for fixed value of concentration of nanoparticles, specific heat of nanorefrigerant decreases than pure R-134a refrigerant. This decrease in specific heat with the addition of nanoparticles is attributed to the lower specific heat of added particles.

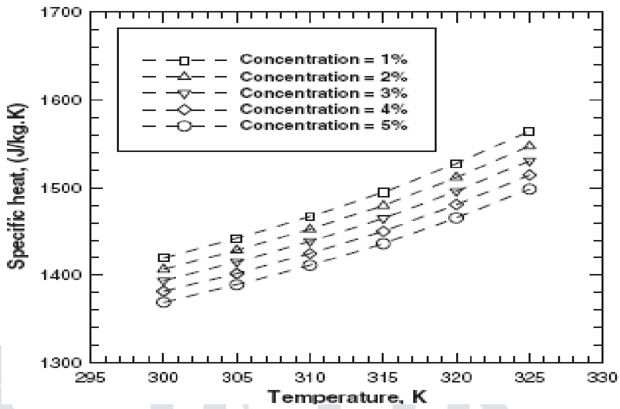


Figure 9: Specific heat of CuO/R134a enhances accordingly with increase in temperature. [13]

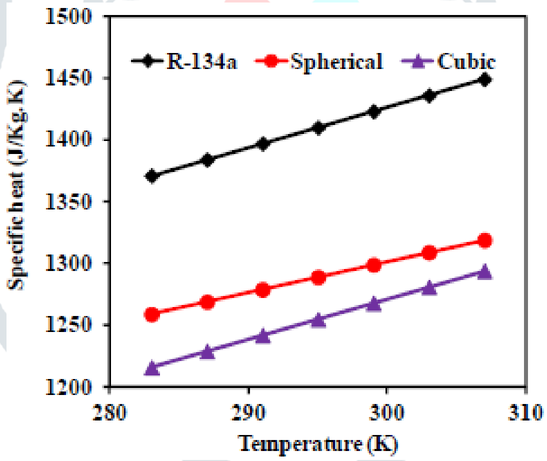


Figure 10: Influence of spherical and cubic shape ZnO nanoparticles on specific heat of R-134a refrigerant. [10]

VI. PERFORMANCE ENHANCEMENT OF VCRS USING NANOREFRIGERANTS

Many researchers are focusing on how to improve the design and properties of working fluid because of increasing demand of cooling in day-to-day life especially in refrigerators and to avoid spoiling of food items,. Use of nanofluids as refrigerants (nanorefrigerants) will improve the boiling as well as condensation heat transfer coefficients [7], which leads to more compact and light refrigeration systems. Also for more energy efficient system it consumes less compressor power.

i. Coefficient of performance (COP)

N Subramani and M.J.Prakash [5] calculated the coefficient of performance (COP) using the experimental data. The actual COP is determined using the cooling load and the compressor power input. The theoretical values are also shown for comparison. From the histogram it is found that for all cases the actual COP is less than the theoretical COP and it is very much clear shown that the SUNISO 3GS + alumina nanoparticle mixture has the highest COP when compared with the other cases.

R. K. Adhayashee et al [9] analysed that the COP of the system is enhanced by the presence of nanoparticle in the lubricating oil. Also as they increase the mass fractions of the nanoparticles, the COP is gradually increased.

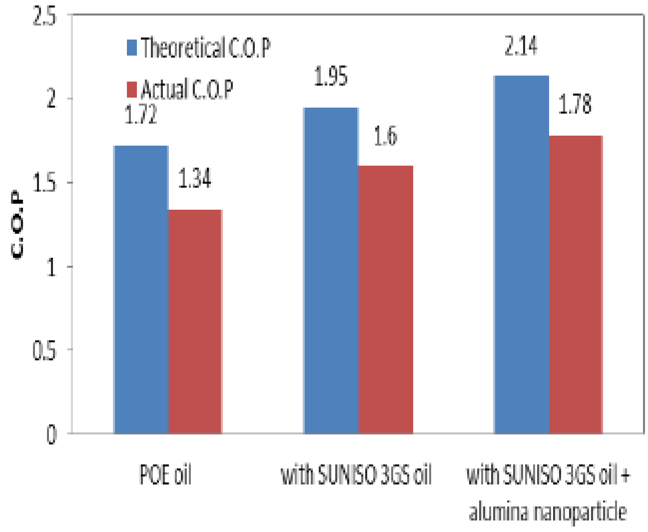


Figure 11: Comparison of Coefficient of Performance (COP) for the three cases. [5]

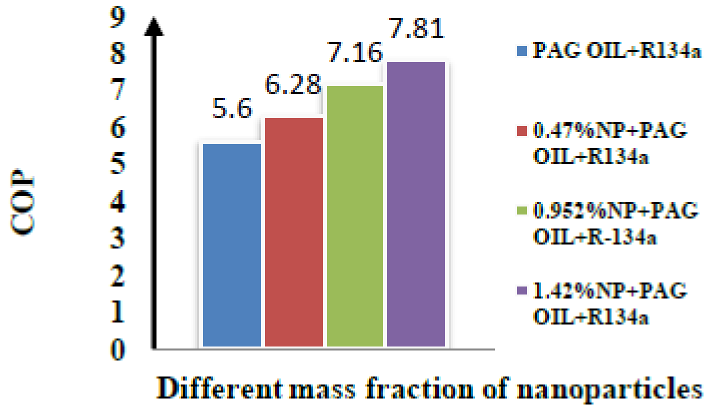


Figure 12: Comparison of COP for different mass mass fractions of nanoparticles fraction of nanoparticles. [9]

ii. Energy Consumption

N Subramani and M.J.Prakash [5] discussed the comparison of power consumption of the compressor. The reduction in power consumption is 18% if the SUSISO 3GS is used instead of POE Oil and a reduction of 25% is observed when SUNISO 3GS is mixed nanoparticles. Bi et al. (2007) reported that for a refrigeration system using R134a as refrigerant the power consumption can be reduced by 26.1 % if mineral oil with TiO_2 nanoparticle is used instead of POE oil. R. K. Adhayashee et al [9] found that the energy consumption reduces as the mass fractions of the nanoparticle increases in the lubricant oil (PAG oil). The presence of nanoparticles reduces friction and increases the viscosity of the lubricant oil.

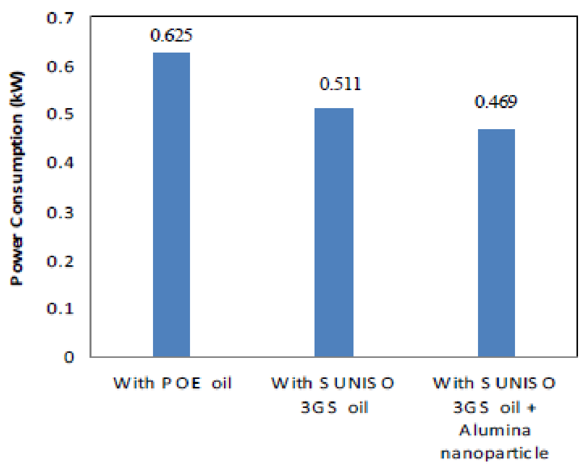


Figure 10: Comparison of power consumption [5]

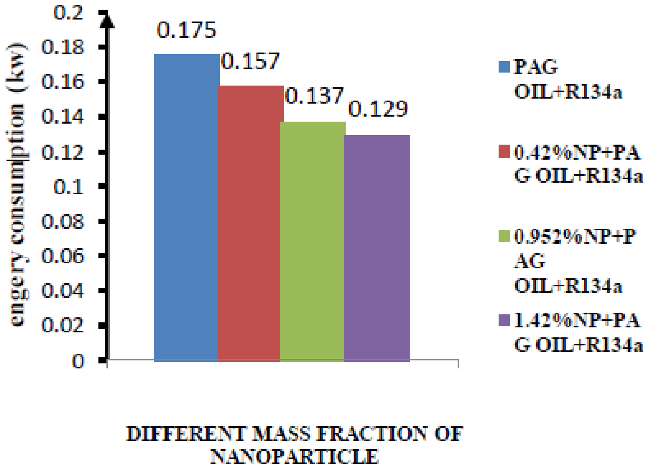


Figure 13: comparison of energy consumption for different mass fractions of nanoparticles [9]

iii. Refrigerating Effect

N Subramani and M.J.Prakash [5] found that, the freezing capacity of the SUNISO 3GS + Alumina nanoparticle mixture is higher when compared with the other two cases The time taken to reduce the temperature of the cooling load from 28ºC to 1ºC with POE oil is 110 minutes and it reduces by 27 % if SUNINSO 3GS oil + alumina nanoparticle is used. This is due to the fact the nanoparticles present in the refrigerant enhances the heat transfer rate in the refrigerant side of the evaporator.

R. K. Adhayashee et al [9] found that the refrigerating effect increases as the mass fractions of nanoparticle increases. With the increase in percentage of mass fractions of the nanoparticles ,the thermal conductivities of the nanofluid increases which results in enhanced heat transfer effect.

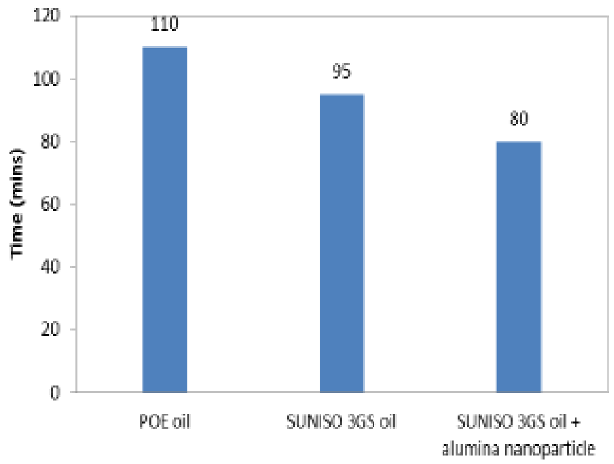


Figure 14: Effect of nanoparticle on the freezing Capacity [5]

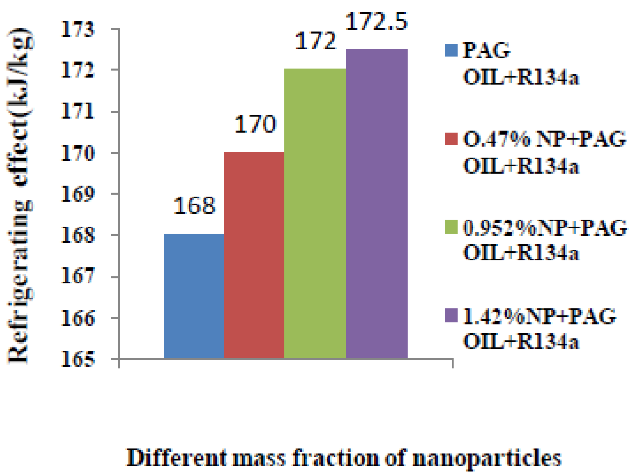


Figure 15: comparison of refrigerating effect different mass fractions of nanoparticles. [9]

VII. CONCLUSION

From the present study it is observed that the application of blend of nanofluids (nanorefrigerant and nanolubricant) enhance the refrigeration system performance because of their improved heat transfer characterictics. Based on the literature review it is observed that:

- The thermal conductivity of a nanorefrigerant is higher than that of the base fluid. It is confirmed that the thermal conductivity increases with the volume concentration/mass fraction of nanoparticles in the working fluid.
- The viscosity of nanorefrigerants was found to increase with the increase in particle volume fraction and decrease with the increase in temperature.
- Nanorefrigerants can greatly reduce the energy consumption of a refrigeration system.
- COP of refrigeration system increases by the addition of nanoparticles in the refrigerant.

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