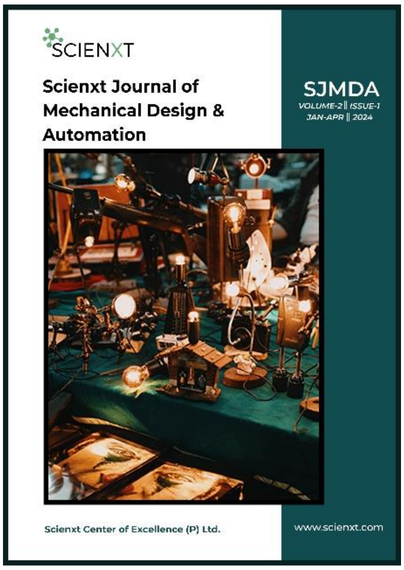

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Use of refrigerant with nano particles invapour compression refrigeration system

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Abstract:

Thermal conductivity plays essential role in heat transfer event. The conventional refrigerants used in the vapour compression refrigeration system are having small thermal conductivity. To raise thermal conductivity of these refrigerants and hence the heat transfer rate, Nano fluids are the topic of research by a number of the researchers. This paper investigate the reliability and performance of Vapour Compression Refrigeration System using carbon black nano powder mix with Polyolester (POE) oil / Mineral oil (MO) as nano lubricant and R134a refrigerant. POE Oil / Mineral Oil are mix with carbon black nano powder by ultrasonic sonication and stirring process to prepare the nano lubricants. These nano lubricants were use in the compressor of R134a refrigeration system instead of Polyolester (POE) oil. An research was done on the compatibility of POE/Mineral oil mixed with carbon nano black powder (at a concentration of 0.1 and 0.2 gram / liter) as nano lubricant and R-134a refrigerant. To perform this investigation, an experimental setup was designed and fabricated in the lab. The refrigeration system performance with the nano lubricant was investigate by using energy consumption and refrigeration effect investigation. The results indicate that R-134a and POE/Mineral oil with carbon black nano powder works normally and safely in the refrigeration system. The refrigeration system performance was superior to the conventional R-134a and POE oil system. Thus the above nano lubricants can be used in refrigeration system to considerably diminish energy consumption and improved Coefficient of Performance (COP).

Keywords:

Thermal conductivity; Heat transfer; Refrigeration systems; Carbon black nano powder; Nanolubricant; COP; Mineral oil; POE oil; R134a refrigerant;

1. Introduction:

In the emergent countries, the power generation is lagging behind the power requirement. The increase of power generation in the conventional method leads to massive expenses in addition to negative environmental impacts which threatens the entire human society. Some of the impacts are Acid rain, melting of glaciers, Sea level raising, Health impacts, Atmospheric pollution, Ozone depletion, etc.

To avert those threats, one of the ways is to generate the electrical energy from the Renewable sources. And the other way is increasing the energy efficiency by improved heat transfer methods. Now a day, Refrigerators and Air- conditioners came in the list of important equipment at the various places like households, industries, transportations, offices etc. Improving the heat transfer technology in this area by new methods will save lot of thermal energy, in-turn the electrical energy.

2. Nano partcles:

2.1. Information on nano particles:

Nanoparticles are the simplest type of structures with size in the nanometer range. In principle any collection of atoms bonded together with a structural radius of < 100 nm can be considered as nanoparticle. These can include fullerenes, metal clusters (agglomerates of metal atoms), large molecules, such as proteins and even hydrogen-bonded assemblies of water molecules, which exist in water at ambient temperatures. When studying about nanoparticles, a distinction must essentially be made between condensed "hard" matter nanoparticles generally termed as 'Nano clusters' and "soft" bio-organic nanoparticles and large molecules. The greatest difference arises from the fact that molecules have functionality which directly depends on the inter-positioning of their atoms, whereas the properties of Nano clusters are solely guided by the number of subunits they contain. For this reason clusters can be seen as an intermediate stage between single atoms/molecules and bulk materials. In general, the physical properties of materials are dependent on the dimensions of the material in question. It's properties (e.g. Conductivity, Elasticity, etc.) are scalable with respect to the amount of atoms in the material. Nano particles are applied in various forms as particles, tubes and wires.

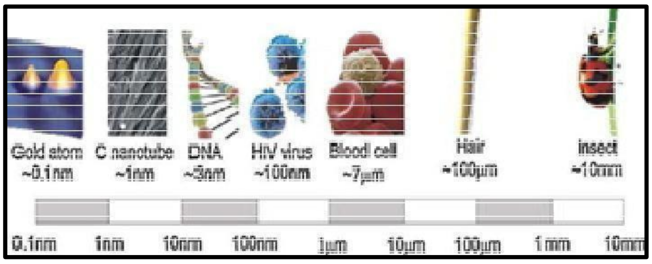

Figure. 1: Length scale and some examples related for nano particles [4]

2.2. Carbon nano particles:

Dr.S.Nallusamy et al. [32] investigated Carbon nanotubes over review on other heat transfer nano fluids and summarized the experimental details, results and improvements in research on the heat transfer characteristics of nano fluids, particularly carbon nanotubes for the purpose of recommending some probable reasons, why the suspended nanoparticles can enhance the heat transfer of conventional fluids and to provide a guideline or perspective for upcoming research.

Hassan Ebadi-Dehaghani et al. [31] investigated thermal conductivity of nanoparticles filled Polymers including carbon nano particles and presented that the introduction of nanoparticles resulted in an increase in crystallinity and so the thermal conductivity of composites.

Carbon fullerene, nano tubes and graphene are very costlier than Carbon black nano powders. Hence Carbon black nano powder is taken for study in this paper on economic considerations.

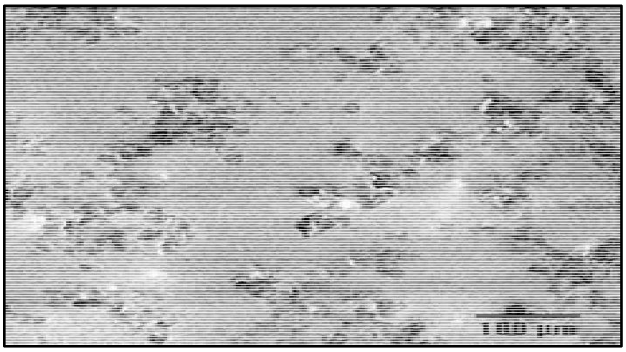

Figure. 2: TEM image of Carbon black Nano powder

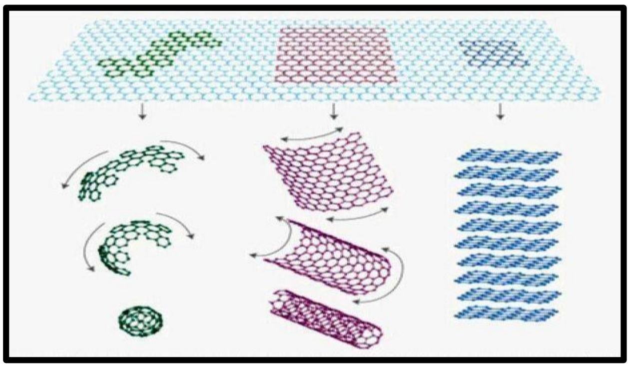

Figure. 3: Different carbon nanomaterials (fullerene, nanotube and graphene)

Table. 1: Physico-chemical data of carbon black nano powder used in this study

Properties	***Average Value***
Specific surface area	570±20 m /g
Average primary particle size	13 nm
Bulk density	0.1 g/cm^3
Purity	> 99%
Ash content	< 0.02%
pH value, 1% aq.	3.5

3. Literature review:

This literature review on Experimental analysis of Vapour Compression Refrigeration System using the refrigerant with Nano particles are classified into four sections. The first section concerns researches related to different nanoparticles and the following sections belong to Al2O3 nanoparticles, CuO nanoparticles and then TiO2 nanoparticles. All the above sections are the researches in the Refrigeration systems and the final fifth section deals with the usage of nanoparticles in other heat transfer areas.

3.1. Studies related to different nanoparticles:

Satnam Singh et al. [7] investigated the performance of the nano refrigerant and the challenges of using nano refrigerants in vapour compression cycle and concluded that it is worth to carry out an investigational work on the effect of different types of nano refrigerant with different base refrigerants under the variable conditions of compressor pressure ratio, evaporator and condenser parameters like pressure, temperature and pressure drop. He intimated the scope of using nano refrigerant as lubricating oil in vapour compression cycle and in vapour absorption system. He also listed out the challenges for the application of nano refrigerants in vapour compression cycle as high cost, instability & agglomeration, pumping power, pressure drop, erosion & corrosion of components and insufficient data availability.

Parvinder Singh [8] studied the application of Nano refrigerant in refrigeration system and concluded that Nano refrigerant is an advanced mode of heat transfer in refrigeration system and it was shown already by the researches that were held in the past. Now the new thing is the mixing of different nano particles of the same size and shape so that the effect can be studied out. The motive of his experimentation was to increase the heat transfer and other thermo physical properties.

Nilesh S. Desai et al. [9] reviewed the performance of refrigeration system using nano fluids and given importance to the pressure drop and pumping power of the refrigeration system with nano refrigerants. He concluded that Adding of nanoparticle in lubricating oil increases the load carrying capacity in comparison to plain oil. Considering present day energy scenario and the ever increasing severity in operating conditions of machineries, it is imperative that we should develop better tribological practices leading to reduced losses due to friction and wear. Journal bearings, being the more popular support mechanism in high speed applications, it has been the focus of research for many tribologists

N. Subramani et al. [2] investigated the performance of vapour compression refrigeration system with mineral oil and mineral oil with different nanoparticles added to it. He observed the strong chemical polarity of R134a to use the mineral oil as nano lubricant. He found that refrigeration system with nano lubricant works normally & safely and reduced the power consumption.

Vaishali P. Mohod et al. [5] reviewed the heat transfer enhancement and performance of various systems using nano refrigerant/nano lubricant. He reviewed the nano fluids with different concentration of nanoparticles to increase thermal conductivity. He concluded the following. The nano refrigerants have high thermal conductivity than traditional refrigerants. Thermal conductivity increases with increase of nanoparticle volume concentration and temperature. Temperature, particle size, dispersion and stability do play an important role in determining the thermal conductivity of nano fluid. Viscosity increases with the increase of nanoparticle volume concentration and decreases with the increase of temperature. Heat transfer performance of the system increases with increasing nanoparticle concentration. In some cases reported, it increases up to specific volume concentration of nanoparticle and then decreases. With the use of nanoparticles in refrigerant or lubricant, consumption of power reduces and freezing capacity of the system increases in almost all cases. For the better performance, dispersion and stability of nanoparticles is the matter of fact. Nano fluids stability and its production cost is the main issue in commercialization of nano fluids. Finally he reported that the exact mechanism of enhanced heat transfer for nano fluids is still unclear.

Sheng-shan Bi et al. [11] investigated experimentally the reliability and performance of a domestic refrigerator with nanoparticles in the working fluid. He focused upon the application of nanoparticles in the domestic refrigerators and found that the R134a and mineral oil with TiO_2 nanoparticles works normally and safely in the refrigerator. He studied the compatibility of nonmetallic materials in the system with the R134a and mineral oil-nanoparticles mixtures before the refrigerator performance tests. He then investigated the refrigerator performance with the nanoparticles using energy consumption tests and freeze capacity tests. Thus he concluded that the nanoparticles can be used in domestic refrigerators to considerably reduce energy consumption.

Prof (Dr.) R S Mishra [21] described the thermal modeling of Vapor Compression Refrigeration System using R134a in primary circuit and Al_2O_3-Water based Nano fluids in secondary circuit. The model uses information of the secondary fluids input conditions, geometric characteristics of the system, size of nanoparticles and the compressor speed to predict the secondary fluids output temperatures, the operating pressures, the compressor power consumption and the system overall energy performance. Such an analysis can be conveniently useful to compare the thermal performance of different nanoparticles (i.e. Al_2O_3, TiO_2, etc.) based Nano fluid as a secondary fluid in a Vapor Compression Refrigeration System. He analyzed the exergy destruction and the first & second law efficiencies of thermodynamics. Still a very vast area is available for exploration using combination/ modification/ hybrid system and these systems could be tested with alternative/ newer refrigerants which have low global warming potential values.

Juan Carlos Valdez LOAIZA et al. [26] made numerical study on the use of Nano fluids as secondary coolants in vapor compression refrigeration systems. He studied a simulation model for a liquid-to-water heat pump, with reciprocating compressor and double-tube condenser and evaporator. The multi-zone method was employed in the modeling of the heat exchangers. Different Nano particles (Cu, Al_2O_3, CuO and TiO_2) were studied for different volume fraction and particle diameters. Simulation results have shown that, for a given refrigerating capacity, evaporator area and refrigerant-side pressure drop are reduced when: (i) the volume fraction of nanoparticles increase; (ii) the diameter of nanoparticles decrease. Also, He found that nano fluid-side pressure drop and consequently pumping power increase with nanoparticle volume fraction and decrease with nanoparticle size.

A. Manoj Babu et al. [33] investigated the reliability and performance of refrigeration system using nano lubricant with HFC134a refrigerant. He mixed the mineral oil with nano particles such as Titanium Dioxide (TiO_2) and Aluminium Oxide (Al_2O_3). He used these mixtures as the lubricant instead of Polyolester (POE) oil in the R134a refrigeration system as R134a does not compatible with raw mineral oil. An investigation was done by him on compatibility of mineral oil and nanoparticles mixture at 0.1 and 0.2 grams / liter with HFC-134a refrigerant. He found that the HFC-134a refrigerant and nano fluid (mixture of mineral oil and various nanoparticles) worked smoothly and efficiently in refrigeration system. He also found that the TiO_2 based nano lubricant with the mixture of 0.2 gram/liter gave maximum result compared with mixture of 0.1 gram/liter. He concluded that the mineral oil with suspended nanoparticles is the main factor in the energy saving to improve the refrigeration effect.

3.2. Studies related to Al_2O_3 nanoparticles:

R. Reji Kumar et al. [1] analyzed the heat transfer enhancement in a domestic refrigerator and found the normal and safe working of R600a refrigerant and mineral oil mixture with nanoparticles. He also found that the freezing capacity of the refrigeration system is higher with mineral oil + alumina nanoparticles oil mixture compared with the system of POE oil.

N. Subramani et al. [6] has made a test rig for the refrigeration system with hermetic sealed reciprocating compressor. He has given importance to the preparation stableness of nano fluid by ultrasonic sonication method and tested it for 72 hours for any sedimentation. He studied about the R134a, which is the most commonly used refrigerant in domestic refrigeration and air conditioning equipment. His experimental studies indicates the normal working of refrigeration system with nano refrigerant and he found that the freezing capacity is higher and the power consumption reduces by 25 % when POE oil is replaced by a mixture of mineral oil and alumina nanoparticles.

D. Sendil Kumar et al. [18] designed and manufactured an experimental setup in his laboratory for the vapour compression refrigeration system. In his work, he investigated the refrigeration system with the nano refrigerant of aluminium oxide and PAG oil combination. He found that addition of Nano Al_2O_3 to the refrigerant shows improvement in the COP of the refrigeration system and the usage of Nano refrigerant reduces the length of capillary tube and is cost effective.

T.M. Yusof et al. [20] presented the performance of a minibar domestic refrigerator operating with and without nanoparticles of aluminium oxide (Al_2O_3). Two important parameters are discussed in his research, the power and the energy consumption. He investigated the performance of a domestic refrigerator working with POE - Al_2O_3. He found that the working fluid, refrigerant R134a, was compatible with POE- Al_2O_3. POE- Al_2O_3 with 0.2% concentration by volume is very stable according to the sedimentation study and it is able to reduce the energy consumption of the domestic minibar refrigerator. He suggested research on wide-ranging concentrations of POE- Al2O3 in order to obtain a good combination of POE-Al2O3 concentration and amount of refrigerant charge.

3.3. Studies related to CuO nanoparticles:

A. Senthilkumar et al. [10] carried out Performance Analysis of a Domestic Refrigerator Using CuO -R600a Nano- Refrigerant as working Fluid and found that the mixture of R600a with nano particles (CuO) works normally in the domestic refrigerator. He selected the particle concentration of 0.1 and 0.5 gram per liter of refrigerant and emphasized the strict control of refrigerant loading accuracy of ±1 gram to get the fruitful result.

T. Coumaressin et al. [12] mentioned the drawback of R134a and its high global warming potential and informed that addition of nano-particles to the refrigerant will increase the performance characteristics of the system that will directly lead us to safe environment as well. He had done CFD analysis of the vapour compression system on FLUENT software using CuO-R134a nano-refrigerant. He found that the nano-refrigerant works efficiently and normally in the system. At last result indicates that the evaporating heat transfer is improved.

Eed Abdel-Hafez Abdel-Hadi et al. [13] experimentally investigated the effect of using nano CuO-R134a refrigerant in the vapour compression system on the evaporating heat transfer coefficient. He designed an experimental test rig and constructed it for the testing purpose. The test section is a horizontal 'tube in tube' heat exchanger made from copper.

The refrigerant is evaporated inside an inner copper tube and the heat load is provided from hot water that passing in an annulus surrounding the inner tube. He concluded that the evaporating heat transfer coefficient increases with the increase of heat flux upto 40 KW/m2 with CuO nanoparticles.

Table. 2: Studies related to aluminium oxide nano particles

Researcher	**Average Diameter of particles**	**Mixturebase**	**Refrigerantused**	**Evaluation**
R. Reji Kumar et al.[1]	50 nm	Mineral oil	R600a	Power consumption of the compressor is reduced by 11.5% and COP of the refrigeration system is increased by 19.6 %.
N.Subramani et al.[6]	50 nm	Mineral oil	R134a	The time required for reducing cooling load temperature is lesser by 20 minutes for the SUNISO 3GS oil + alumina nanoparticle

				mixture.
D. Sendil Kumar et al.[18]	40-50 nm	Poly Alkylene Glycol oil	R134a	The COP of the system increases with increase in the length of the capillary tubeand the maximum COP of 3.5 is achieved for a capillary length of 10.5 m
T.M. Yusof et al.[20]	30 nm	POE Oil	R134a	POE-Al2O3 with 0.2% concentration by volume is very stable The highest reduction in energy consumption obtained was 2.1% at charging pressure of 42 psi.

Table. 3: Studies related to copper oxide nano particles

Researcher	**Average Diameter of particles**	**Mixture base**	**Refriger antused**	**Evaluation**
A.Senthilkumar et al.[10]	50 nm	Refrigerant	R600a	The cooling capacity of the domestic refrigerator was increased by 10 - 20% by using Nano – refrigerant.
T. Coumaressin et al. [12]	10-70 nm	CFD-Gambit and Fluent software	R134a	Evaporator heat transfer coefficient increases with the increase of Nano particles concentration up to 0.55% and then it decreases.
Eed Abdel-Hafez Abdel-Hadi et al. [13]	25 nm	Mineral oil	R134a	The evaporating heat transfer coefficient increases with the increase of heat fluxup to 40 KW/m for the CuO nanoparticles concentration ranged from 0.1 to 0.55 % . And then decreases for all values of heat flux.

Table. 4: Studies related to titanium oxide nano particles

Researcher	**Average Diameter of particles**	**Mixture base**	**Refriger antused**	**Evaluation**
Asst.Lect. Haider ali hussen [3]	20 nm	Mineral oil	R22	The average compressor work was reduced by 13.3%, which ultimately resulted in an increase of COP by 11.99%.

R. Saidur et al. [4]	1-100 nm	Mineral oil	R134a	The energy consumption saved is 26.1%.
Omer A. Alawi et al. [29]	10-200 nm	Mineral oil	R134	The energy consumption saved is 26.1% with 0.1% mass fraction.

3.4. Studies related to TiO2 nanoparticles:

Asst.Lect. Haider ali hussen [3] investigated the effect of dispersing a low concentration of TiO2 nanoparticles in the mineral oil based lubricant, as well as on the overall performance of a window type Air-Conditioner system using R22 as the working fluid. He found an enhancement in the COP of the refrigeration system and noted that the low concentration is the optimum volume fraction of nano particles with the nano lubricants. He also found that the ambient air temperature have the significant effect in the performance of the air conditioners with nano refrigerants.

R. Saidur et al. [4] reviewed the heat transfer performance of different nano refrigerants with varying concentrations and presented the pressure drop and pumping power of refrigeration system with nano refrigerants. He reported the pool boiling heat transfer performance of CNT refrigerants and found that the R134a and mineral oil with TiO2 nanoparticles works normally and safely in the refrigerator with better performance. He identified the fundamental properties such as density, specific heat capacity and surface tension of nano refrigerants were not experimentally determined yet in the researches.

Omer A. Alawi et al. [29] reviewed the thermal-physical properties of nanoparticles suspended in refrigerant and lubricating oils of refrigerating systems and presented the effects of nano lubricants on boiling and two phase flow phenomena. He found that the nano refrigerants have a much higher and strongly temperature-dependent thermal conductivity at very low particle concentrations than conventional refrigerant. He also found that R134a and mineral oil with TiO2 nanoparticles work normally and safely in the refrigerator with better performance.

3.5. Studies related to usage of nano particles in other heat transfer areas:

Jacqueline Barber et al. [14] reviewed boiling heat transfer enhancement with nanofluids and found that the water has the greatest aptitude to suspend non- coated nanoparticles in comparison with other base fluids such as Ammonia, Hydrocarbons, HFCs and HCFCs. He also emphasized the requirement of more experimental data with varying base fluids.

S. A. Fadhilah et al. [15] studied mathematical modeling on copper oxide nano particles for advanced refrigerant thermo physical properties and revealed that the thermal conductivity of refrigerant R134a is 0.0139 W/mK at Nano refrigerants experimentally. It is important to have superior thermal properties of the Nano refrigerant that could withstand the variation of temperature and pressures and the nanoparticles would not cause the clogging, corrosion, or pressure drop in the overall performance of refrigeration system.

Kristen Bartelt et al. [16] investigated the effect of CuO nanoparticles on the flow boiling of R-134a/POE mixtures in a horizontal tube. He found that the Nano lubricant with mass fraction of 0.5% have no effect on the heat transfer coefficient. However, For Nano lubricant with mass fractions of 1% and 2%, the heat transfer coefficient of the R- 134a/POE/CuO nano fluid was found increased in comparison to baseline experiments with corresponding R- 134a/POE mixtures. For a 1% Nano lubricant mass fraction, the nanoparticle caused a heat transfer enhancement between 42% and 82%, and for a 2% Nano lubricant mass fraction an enhancement between 50% and 101% was measured. He also noted that the presence of nanoparticle had an insignificant effect on pressure drop. It is unclear why the large increase in heat transfer with an insignificant pressure increase is realized. Moreover, obvious challenges with particle circulation and unknown effects on the compressor of an air-conditioning or refrigeration system have not been addressed. Nevertheless, these findings are compelling and further research should be undertaken.

Ali Najah et al. [17] presented an overview of the recent developments in the study of heat transfer and solar collector with the use of Nano fluids. He concluded the following. Nano fluids containing small amounts of nanoparticles have substantially higher thermal conductivity than base fluids. The thermal conductivity enhancement of Nano fluids depends on the volume fraction, size, type of nanoparticles and base fluid. Suspended nanoparticles remarkably increased the forced convective heat transfer performance of base fluid. At the same Reynolds number, the heat transfer of the Nano fluids increases with the increase the volume fraction of nanoparticles and decrease in nanoparticles size. He also presented an overview of studies about the performance of solar collector, such as flat-plate and direct solar-absorption collectors with the use of Nano fluids as working fluid and found that the effect of surface-to- volume ratio on thermal conductivity is more than the effect of the surface size of nanoparticles.

B.Kirubadurai et al. [19] studied the heat transfer enhancement in the nano fluids and emphasized the importance of mixing of nano particles for enhancement of heat transfer rate, and so the suitability of ultrasonic mixture for enhancement of thermal conductivity of nano fluids. He also found that heat transfer rate increases with increasing concentration of nanoparticle. Temperature of 260 C. He found that suspending 1% vol. fraction of nanoparticles into the refrigerant has increased the thermal conductivity about 3121.05% enhancements. Additional 1% vol. fraction has increased the thermal conductivity in range of 3.53-8.38% up to 5% vol. fraction. The viscosity of Nano refrigerant is also showing great percentage of enhancement which is about 44.45% once compared to the conventional refrigerant with only 1% of nanoparticles volume fraction. The heat transfer rate of a Nano refrigerant with 5% vol. fraction is about 1% enhancement. This study introduced trends to other researchers to investigate the thermo physical properties of

He concluded the following. Heat transfer rate is directly proportional to the Reynolds number and Peclet number of Nano fluid. The fine grade of Nano particles increases the heat transfer rate but it's having poor stability. Clustering and collision of nanoparticles is main factor to affect the heat transfer rate of Nano fluid. Concentration of nanoparticles increases the pressure drop of Nano fluid. Spherical shaped nanoparticles increases the heat transfer rate of Nano fluid compared with other shaped nanoparticles. Boiling was to reduce the enhancement of heat transfer rate. Spiral pipe is having higher heat transfer rate compared with the circular plain tube. Inclined tube possesses the low pressure drop compared with horizontal tube.

Rahul A. Bhogare et al. [22] compiled a comprehensive literature on the applications and challenges of Nano fluids and reviewed in Automobile sector. Literatures on the applications and challenges in terms of PhD and Master thesis, journal articles, conference proceedings, reports and web materials have been reviewed by him and reported. From his studies, It has been seen that Nano fluids can be considered as a potential candidate for Automobile application. As heat transfer can be improved by Nano fluids, the Automobile radiators can be made energy efficient and compact. Reduced or compact shape may results in reduced drag, increased fuel economy, and reduces the weight of vehicle. Exact mechanism of enhanced heat transfer for Nano fluids is still unclear as reported by many researchers. There are different challenges of Nano fluids which should be identified and overcome for Automobile- radiators application. Nano fluids stability and its production cost are major factors that hinder the commercialization of Nano fluids. By solving these challenges, it is expected that Nano fluids can make substantial impact as coolant in heat exchanging devices.

Sergio Bobbo et al. [23] presented the influence of the dispersion of single wall Carbon Nano horns (SWCNH) and Titanium dioxide (TiO_2) on the tribological properties of commercial POE oil together with the effects on the solubility of R134a at different temperatures. The results obtained showed that the tribological behaviour of the base lubricant here considered can be either improved or worsen, depending on the property (anti-wear or extreme-pressure behaviour), by adding small amount of Nano- particles. On the other hand, nanoparticles dispersion in the base oil did not affect significantly the solubility, suggesting the independence of the thermodynamic properties of the oil from the presence of nanoparticles.

I.M. Mahbubul et al. [24] studied the volumetric and temperature effects over viscosity of R123-TiO2-nano refrigerants for 5 to 20ºC temperature and up to 2 vol. %. The effect of pressure drop with the increase of viscosity has also been investigated. Based on the analysis it is found that viscosity of Nano refrigerant increased accordingly with the increase of nanoparticle volume concentrations and decreases with the increment of temperature. Furthermore, pressure drop augmented significantly with the intensification of volume concentrations and vapor quality. Therefore, low volume concentrations of Nano refrigerant are suggested for better performance of a refrigeration system.

Jose Alberto Reis PARISE et al. [25] studied the application of Nano fluids as condenser coolants of vapor compression heat pumps. A simulation model was developed for the performance prediction of a vapor compression heat pump using Nano scale colloidal solutions (Nano fluids) as condenser coolants. Preliminary results were obtained for the simulation of a 19 kW nominal capacity water-to-water/(H2O-Cu Nano fluid) heat pump. A 5.4% increase in the heating coefficient of performance, for a typical operating condition, was predicted for a nanoparticle volume fraction of 2%.

M. Kahani et al. [27] made an experimental comparison of heat transfer behavior between metal oxide nano fluid flows through helical coiled tube with uniform heat flux boundary condition. The experiments covered a range of Reynolds number from 500 to 4500. Experimental results indicated that a considerable heat transfer enhancement is achieved by both Al2O3 and TiO2 Nano fluids. In addition, because of greater thermal conductivity and smaller size of Al2O3 nanoparticles compared to TiO2 nanoparticles, Al2O3/water Nano fluid showed better heat transfer augmentation. Moreover, due to the curvature of the tube when fluid flows inside helical coiled tube instead of straight one, convective heat transfer coefficient and the pressure drop of both Nano fluids grew dramatically.

Mr. Sanjay V. Barad et al. [28] investigated the Thermal behaviour of Micro channel heat sink using Al2O3-water base Nano fluid. The model has been solved by ANSYS fluent 14.5 solver. It is revealed that the high thermal conductivity of nanoparticles relative to common pure fluids enhances the single-phase heat transfer coefficient for fully-developed laminar flow.

Increasing Nano particles concentration increases single-phase pressure drop compared to pure fluids at the same Reynolds number. At the same time, it decreases the wall temperature compared to pure fluids at the same Reynolds number. Higher single-phase heat transfer coefficients are achieved in the entrance region of micro- channels with increased nanoparticle concentration.

Mark A. Kedzierski [30] quantified the influence of copper oxide (CuO) nanoparticle concentration on the boiling performance of R134a/Polyester mixtures on a roughened, horizontal flat surface. He found that the use of 2% CuO volume fraction Nano lubricant with R134a results in a significantly smaller pool boiling heat flux than that exhibited with R134a and the Nano lubricant with the 4 % CuO volume fraction. He also insisted the further research with Nano lubricants and refrigerants are required to establish a fundamental understanding of the mechanisms that control Nano fluid heat transfer.

4. Materials and method:

4.1. Nano fluid preparation:

The initial step is the preparation of nano fluid by adding POE/Mineral oil and carbon nano particles at ratio of 0.1 and 0.2 grams / liter. Then the next step is putting the nano fluid into the compressor of the refrigeration system as a lubricant. The Carbon nano powder was procured from 'Reinste Nano Venture Ltd., New Delhi.' The properties of Carbon black nano powder is provided in Table I. The POE oil and Mineral oil, the types commonly used in refrigeration and air-conditioning systems, R68 refrigeration oil and RL3MO Mineral oil were procured from reputed dealer, 'Rishabh Enterprises, Chennai-17'. The nanoparticles were weighed by using electronic weighing balance for 0.1 and 0.2 grams and added to one liter of POE/Mineral oil and the mixture was heated and vibrated in ultrasonic oscillator for proper mixing of nanoparticles with oils. Stirring is done mechanically for complete mixing of particles. Thus four varieties of nano lubricants were made ready. The stability of mixture is important to ensure the suspension of the nano particles in POE/Mineral oil during prolong use of nano lubricant in the refrigeration system. The higher percentage of nanoparticles in the mineral oil will settle down easily.

4.2. Test carried out for Nanolubricants:

Tribology tests are required to know the characteristics of the prepared nano lubricants and to compare the characteristics with plain POE/Mineral oils. Viscosity, Density, Flash point and

Pour point tests are carried out at the international level Lab., 'The Italab Pvt. Ltd., and Chennai-1.' The comparison of properties of Nano lubricant with POE /Mineral oil are given in table V.

Table. 5: Properties of nano lubricants

Type of fluid	Viscosity at 40 C in centistokes	Density at 15 C in grams/cc	Flash point in ^{0}C	Pour point in ^{0}C
POE Oil [33]	49.88	0.9329	225	-22
Mineral Oil [33]	37.02	0.8522	214	-20
POE Oil with 0.1 gram/liter of Carbon particle	34.22	0.9763	236	-15
Mineral Oil with 0.1 gram/liter of Carbon particle	27.98	0.9078	185	-15

5. Experimental setup and testing:

5.1. Experimental set up:

The experimental refrigeration setup was fabricated with following components. A hermetically sealed reciprocating compressor for R-134a refrigerant, a forced type cool condenser, an expansion valve and an evaporator containing water. Five thermocouples, two pressure gauges and one energy meter are provided at respective locations to measure the temperatures at required locations, the inlet and outlet pressure of compressor and the power consumption.

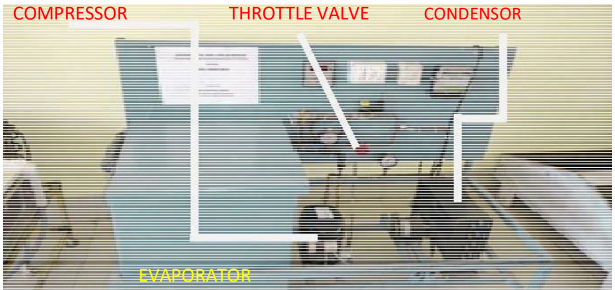

Figure. 4: Experimental set up

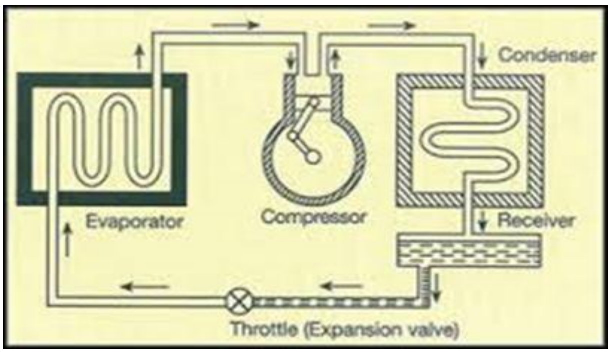

Figure. 5: Schematic of vapour compression refrigeration system

P1 - Refrigerant Pressure at Entry of Compressor

P2 - Refrigerant Pressure at Exit of Compressor

T1 - Refrigerant Temperature at Entry of Compressor

T2 - Refrigerant Temperature at Exit of Compressor

T3 - Refrigerant Temperature at Exit of Condenser

T4 - Refrigerant Temperature at Entry of Evaporator

T5 - Water Temperature inside Evaporator

Tank E - Energy Meter Reading

5.2. Performance test on Vapour compression refrigeration system:

The refrigeration system performance test includes energy consumption tests and freezing capacity tests. The type of evaporator used in this system is a water tank having a capacity of 11.2289 liters. To measure the energy consumed during refrigeration system operation, reading is noted from Energy meter. The test is carried out for 20min for each mixture of nano fluid by noting down the average drop in temperature of water from its initial temperature. The freezing capacity is determined by the mass of water stored in the evaporator.

5.3. Experimental procedure:

The refrigeration system experiment was carried out at various stages for different concentrations of carbon black nano powder with R-134a refrigerant. First performance test was carried by using R-134a and POE oil for base data. In this operation, Evaporator tank is filled with water and initial temperature of water was measured at various points. Now, the system was run for 20 min, and for every 5 min., all the pressure, temperature and energy readings are noted down. After the completion of test with POE oil, oil was completely drained out from compressor and system was completely vacuum out by vacuum pump for 15 min.

Again the compressor was charged with prepared nano lubricant and R-134a refrigerant and complete performance test was carried out and the same procedure was repeated for each concentration of carbon and the oil.

6. Observations and calculations:

6.1. Mass of water:

Water tank diameterD = 0.29 m

Height of tank h = 0.17 m

Density of water = 1000 Kg/ m

Mass of Water (m) = Density X Volume

= 1000 X 0.0112289

= 11.2289 Kg

Volume of water tank $V = \pi \times (0.29)^2 \times (0.17) \times 0.25$

$V = 0.0112289\ m^3$

6.2. Coefficient of performance (COP) calculations:

(a) Power input to compressor P = (Energy meter Finalreading – Energy meter Initial reading) x (3600) KJ

(b) Refrigeration Effect RE = (Mw*Cpw * dT) KJ(Here Mw = Mass of water in kg, Cpw = Specific heat of water = 4.182 kJ/kg K, dT =Drop in temperature in K)

(c) COP of refrigeration = RE/P

Table. 6: Readings for R134A with poe oil

Time (min)	P1 (psi)	P2 (psi)	T1 (^{0}C)	T2 (^{0}C)	T3 (^{0}C)	T4 (^{0}C)	T5 (^{0}C)	E (KWH)
0	15	160	32	39	36	23	31	2.15
5	15	170	32	59	39	14	25	-
10	20	175	32	66	41	13	20	-
15	20	175	32	66	41	12	18	-

20	20	175	32	67	41	11	13	2.3

Table. 7: Readings for R134A and poe oil with 0.1 gram per liter of carbon black nano powder

Time (min)	**P1 (psi)**	**P2 (psi)**	**T1 (^{0}C)**	**T2 (^{0}C)**	**T3 (^{0}C)**	**T4 (^{0}C)**	**T5 (^{0}C)**	**E(KWH)**
0	20	175	32	55	41	6	29	2.35
5	25	180	32	65	42	6	21	-
10	25	180	32	65	42	6	17	-
15	25	180	32	66	42	4	13	-
20	25	180	32	66	41	2	10	2.5

Table. 8: Readings for R134A and poe oil with 0.2 gram per liter of carbon black nano powder

Time (min)	**P1 (psi)**	**P2 (psi)**	**T1 ^{0}C**	**T2 ^{0}C**	**T3 ^{0}C**	**T4 ^{0}C**	**T5 ^{0}C**	**E (KWH)**
0	20	170	33	51	39	7	29	2.5
5	20	175	32	60	40	3	23	-
10	20	175	31	66	41	1	18	-
15	20	175	31	68	41	0	15	-
20	20	175	30	68	41	0	12	2.63

Table. 9: Readings for R134A and mineral oil with 0.1 gram per liter of carbon black nano powder

Time (min)	**P1 (psi)**	**P2 (psi)**	**T1 (^{0}C)**	**T2 (^{0}C)**	**T3 (^{0}C)**	**T4 (^{0}C)**	**T5 (^{0}C)**	**E (KWH)**
0	20	170	33	50	38	4	29	2.65
5	20	170	31	63	40	0	23	-

10	20	170	30	67	40	0	18	-
15	20	170	30	67	40	0	15	-
20	20	170	30	69	41	0	13	2.77

6.4. Nano power:

Time (min)	P1 (psi)	P2 (psi)	T1 ^0C	T2 ^0C	T3 ^0C	T4 ^0C	T5 ^0C	E (KWH)
0	20	170	31	58	38	1	29	2.85
5	24	170	30	66	40	1	22	-
10	24	170	30	70	41	1	16	-
15	24	170	30	71	41	1	11	-
20	24	170	30	71	41	1	8	3

6.5. Sample calculation procedure for R-134a and POE oil:

Power input to compressor

Power input to compressor 'P'= (2.3-2.15)

X3600 = 540 KJ

(a) Refrigeration Effect

Mw = Mass of water = 11.2289 kg,

Cpw = Specific heat of water = 4.182 kJ/kgK,

dT = (Initial Temperature – Final Temperature)

K = {(31+273) – (13+273)} = 18K

Refrigeration Effect 'RE' = 11.2289x4.182x18

= 845.266 KJ

(b) COP of refrigeration = RE/P = 845.266/540 =1.565.

(Similarly the calculations for other nano fluid mixture and R134a were carried out.)

7. Results and discussion:

primarily the test was carried out with R134a and POE oil, and then POE oil is replace by POE/Mineral oil nano lubricants which contain carbon black nano powder in the ratio of 0.1 and 0.2 gram/liter. It is found that the nano lubricant containing carbon black nano powder with R134a was working normally. Hence compatibility was observed in both the cases of R134a with POE/Mineral oils containing carbon black nano powder. The results are shown in the above Tables VI to X. It is found that Mineral oil with 0.2 gram/liter of carbon black nano powder obtain maximum temperature-variations of 21 0C in prescribed time of 20 minutes, which indicates that it has maximum heat removal capabilities. When compared to POE oil and Mineral oil with the same concentration of 0.2 gram/liter of carbon black nano powder, the nano lubricant of Mineral oil with 0.2 gram/liter of carbon black nano powder shows more heat removal capacity which is given in Table VIII and X. Also it is observed that the POE oil containing carbon black nano powder shows less efficient than Mineral oil containing carbon black nano powder. It is ensured that the cause would be the thermal property of Mineral oil is higher than POE oil.

It is found in both the cases of POE and Mineral oils, the nano lubricant having 0.2 gram/liter of nanoparticle are more effective than 0.1 gram/liter. This is due to when more amount of particle is added, the heat removal capacity also will be more. But if more amount of nanoparticles are added with the lubricant, it will affect the mixture stability and the particles will settle down early. Hence the maximum level of mixture ratio was taken as 0.2 gram/liter. In the case of POE with 0.2 gram/liter of carbon black nano powder, the Refrigeration Effect is found reduced, but the COP is increased due to lesser work done by the compressor.

The refrigeration performance test outcomes of R134a with POE oil and Mineral oil nano lubricants with carbon black nano powder were compared and the graphical representation is given in Figure 6. Energy consumed by the compressor, Refrigeration effect and COP for POE/Mineral oil with 0.1 gram/liter and 0.2 gram/liter concentration of carbon black nano powder are calculated and given in the following Table. XI.

From the above results it is clear that the performance of R134a with POE/Mineral oil nano lubricant containing carbon black nano powder are better than R134a with POE oil without carbon nano powder. The reason behind is due to the enhancement of the heat transfer characteristics by the carbon black nano powder.

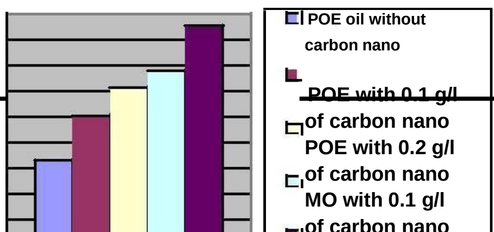

Figure. 6: Type of Nanolubricant Vs COP Graph

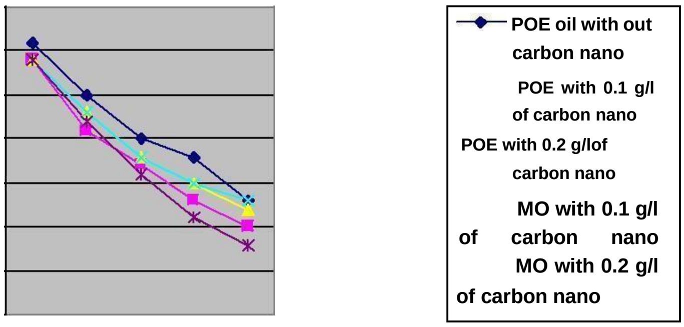

Figure. 7: Time vs temperature for different nanoluricants

Table. 11: Performance of vapour compression refrigenration system with nano lubricants

	Energy compressor(KJ)	*Refrigeration*	
Poe oil	540	845.266	1.565
Poe oil with 0.1 gram/liter of carbon nano	540	892.223	1.652
Poe oil with 0.2 gram/liter of carbon nano	468	798.307	1.706
Mineral oil with 0.1 gram/liter of carbon nano	432	751.348	1.739
Mineral oil with 0.2 gram/liter of carbon nano	540	986.144	1.826

8. Conclusion:

The trial investigation of carbon nanoparticles in Vapour compression refrigeration system was carried out with the following conclusion. 1. The R-134a refrigerant and nanolubricant of

POE/Mineral oil with carbon black nanopowder worked efficiently and efficiently in refrigeration system. 2. The Coefficient of Performance (COP) of the refrigeration system is enhanced in both the cases of nanolubricant comparing to R134a with Plain POE oil. COP is 16.67% higher when 0.2 grams/liter of Mineral oil-Carbon nano powder is used with R-134a due to improved refrigeration effect. 3. The Nano lubricant with carbon nano powder increases the COP with the increasing concentrations in both POE and Mineral oil. 4. Also it is found that the Mineral oil with 0.2 gram/liter of carbon black nano powder gave maximum result compared with mixture of 0.1 gram/liter of same oil and also 0.2 gram/liter of POE oil.

Hence the Mineral oil with suspended carbon nanoparticles is the main factor in the energy saving to improve the COP of Vapour compression refrigeration system.

9. Scope for further work:

9.1. Researches were carried out with CuO, Al2O3, and SiO2:

TiO2, Ni, ZnO, Fe and Diamond Nano particles that are mixed in various proportions with Refrigerants R11, R113, R123, R134a, R146b and R600a. Scope is there to research with Silver oxide, Beryllium oxide and Carbon Nano tubes, Fullerene and Graphenes because of their high thermal conductivity. Silver oxide, Carbon Nantubes, Fullerene and Graphenes are very costly and Beryllium oxide is dangerous to health if its dust is inhaled.

10. References:

(1) R. Reji Kumar, K. Sridhar and M.Narasimha, "Heat transfer enhancement in domestic refrigerator using R600a/mineral oil/nano-Al2O3 as working fluid," International Journal of Computational Engineering Research, Vol. 03, Issue 4, (2013), pp. 42-50.

(2) Subramani. N, Aswin Mohan and Dr.Jose Prakash. M, "Performance studies on a vapour compression refrigeration system using nano-lubricant," International Journal of Innovative Research in Science, Engineering and Technology, An ISO 3297: 2007 Certified Organization,Volume 2, Special Issue 1, (2013), pp. 522-530.

(3) Asst.Lect. Haider ali hussen,"Experimental investigation for TiO2 nanoparticles as a lubricant- additive for a compressor of window type Air-Conditioner System," Journal of Engineering, Number 2, Volume 20, (2014), pp. 61-72.

(4) R. Saidur, S.N. Kazi, M.S. Hossain, M.M. Rahman and H.A. Mohammed, "A review on the performance of nanoparticles suspended with refrigerants and lubricating oils in refrigeration systems," Renewable and Sustainable Energy Reviews 15, (2011), pp. 310-323.

(5) Vaishali P. Mohod and Nishikant W. Kale, "A Review on heat transfer enhancement using nanoparticles suspended with refrigerants/lubricating oils in refrigeration systems," International Journal of Innovative and Emerging Research in Engineering Volume 2, Special Issue 1 MEPCON (2015), pp. 191-194.

(6) N. Subramani and M. J. Prakash, "Experimental studies on a vapour compression system using nanorefrigerants," International Journal of Engineering, Science and Technology Vol. 3, No. 9, (2011), pp. 95-102.

(7) Satnam Singh, Kapil Sharma, Kundan Lal and Naveen Mani Tripathi, "To study the behaviour of nanorefrigerant in vapour compression cycle- a review," International Journal of Research in Engineering and Technology Volume: 04 Issue 04,| (2015), pp. 648-652.

(8) Parvinder Singh, "To study the application of nanorefrigerant in refrigeration system: a review," International Journal of Research in Engineering and Technology , Volume 04, Issue 06, (2015), pp. 414-417.

(9) Mr. Nilesh S. Desai and Professor P.R. Kulkarni , "A Review on performance of refrigeration system using nanofluids," International Journal for Scientific Research & Development, Vol. 3, Issue 02, (2015), pp. 2390-2394.

(10) A. Senthilkumar and R. Praveen, "Performance analysis of a domestic refrigerator using CuO-R600a nano - refrigerant as working fluid," Journal of Chemical and Pharmaceutical Sciences, JCHPS, Special Issue 9, (2015), pp. 30-33.

(11) Sheng-shan Bi, Lin Shi and Li-li Zhang, "Application of nanoparticles in domestic refrigerators," Applied Thermal Engineering, Vol. 28, (2008), pp. 1834-1843.

(12) T. Coumaressin and K. Palaniradja, "Performance analysis of a refrigeration system using nano fluid," International Journal of Advanced Mechanical Engineering, Volume 4, Number 4, (2014), pp. 459-470.

(13) Eed Abdel-Hafez Abdel-Hadi, Sherif Hady Taher, Abdel Hamid Mohamed Torki and Samar Sabry Hamad, "Heat transfer analysis of vapor compression system using nano Cuo-R134a," International Conference on Advanced Materials Engineering, IPCSIT, Vol. 15, (2011),