Review on Applications of NanoFluids used in Vapour Compression Refrigeration System for Cop Enhancement

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Review on Applications of NanoFluids used in Vapour Compression Refrigeration System for Cop Enhancement

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Abstract: The present research paper focuses on the use of Nano additive refrigerants in vapor compression refrigeration system (VCRS) because of their amazing development during Thermo Physical along with heat transfer potential to improve the coefficient of performance (COP) and reliability of refrigeration system. Furthermore, challenges and future instructions of performance enhancement of VCRS using Nano additive refrigerants were presented. Lubricant oil is essential in the entire vapour compression refrigeration systems, mostly for the efficient function of the compressor. But, some assign of the oil is entire the cycle oil circulates with the refrigerant. Presently, an assortment of investigation is going on in the field of the Nano-particles like metals, oxides, carbon Nano-tubes or carbides. Nano-lubricants are unique type of Nano-fluids which are varieties of Nano-particles, lubricants and have a wide variety in the fields of refrigeration systems. This paper, has been done on the application of Nano-particles balanced in lubricating oils of refrigerating systems are reviewed. The aim of this investigation is to study and find which type of lubricant oil works better with Nano-particles in the area of refrigeration. From the review of literature, it has been observed that Nano-particles mixed with mineral oil gives enhanced results than polyolester (POE) oil.

1 .Introduction:

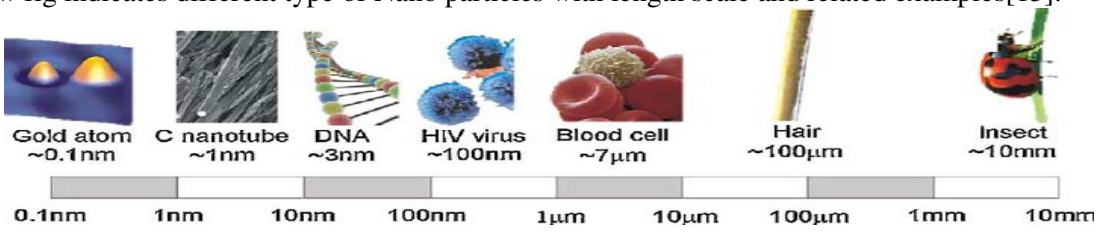
The cooling system's coefficient of performance (COP) is defined as the ratio of heat extracted from the system to the work supplied into the system. It can be improved in two ways: firstly, by increasing heat abstraction rate in evaporator, and secondly, by reducing the work done in a compressor[1]. Many researchers have investigated the possibility of introducing Nano particles into refrigerants to develop a new class of Nano products called "Nano refrigerants". Using Nano particles will increase heat transfer in cooling systems, thus improving system performance[2].In the VCR systems oil is essential for proper working of compressor. Its important role is to verify the existence of thin oil film allowed to the lubrication of mechanical moving elements, in order to keep against wear[3]. The lubrication agent also acts several important roles as tightness element, reducing the noise, helpful to eliminate the deposition of chemical impurities[4]. Nano-particles as additives are also considered to improve the lubrication properties of lubricant oil for the compressor of vapor compression refrigeration system[5]. Recently, different types of Nano-oils have attracted special notice because it has ability to reduce the friction and wear in compressor, which, in turn, improves the efficiency of the compressors and also reduces energy consumption. Thus, the use of Nano-oils is more beneficial to compressor performance [6].This research paper focuses on the energy consumption reduction by using Nano-lubricant. However, there is a limited research is available on Nano particles used as additives in VCR systems. It is open that this study will be helpful to overcome the challenges of Nano-lubricant[7].With the quick

improvement in Nanotechnology, it becomes possible to obtain Nano sized particles (1 to 100 nm.) of metals, oxides and carbides. These Nano particles have high thermal conductivity, are suspended in conventional heat transfer fluids which lead to new trend of heat transfer heat fluids called Nano-fluids. It has been introduced by Jeff Eastman and Steve Choi on Argonne International Laboratory in the year of 1995[8].Thermal systems like refrigerator and air conditioners consume more amount of electric power. Many researchers have carried out in the last decade to enhance the heat transfer rate to improve performance of the systems. To improve the properties of the system, Nano particles are either suspended in the refrigerant or lubricating oil[9].

The following are the characteristics of Nano-fluids as compared to solid and liquid suspensions.

a. Heat transfer performance between the particles and fluid is enhanced with the increasing of surface area of particles.
b. Particle clogging has been reduced.
c. Compressor pumping power is reduced as compared to base fluid to obtain same amount of heat transfer.
d. Dispersion stability improved [10].

Nano particles could be of metal like copper, nickel, aluminum, oxides like aluminum oxide, titanium oxide, copper oxide, silicon oxide. Base fluids like water, propylene glycol, ethylene glycol, engine oil and refrigerants [11]. Nano-fluids are prepared by production of Nano particles and then its distribution in the base fluid. There are two methods used for .Nano fluids have been prepared in two ways: one is single step method and another one is double step method. In first method Nano particles are simultaneously prepared and dispersed, while in the second method, the first Nano particles are prepared and then dispersed into the base fluid[12]. Nano-fluids are not simply the solid-liquid mixtures but they are the even suspension, stable suspension and strong suspension. There should not be any collection of particles and no change in chemical properties of the base fluid. To achieve all this, there are three ways A) to use ultrasonic vibrator B) to change pH value of suspension C) to introduce surface activators [13].Nano-fluids have huge application in different fields like refrigerators and air conditioners, cooling in engines, cooling electronic circuits, thermal reservoirs, nuclear cooling system, solar water heaters, defense space application, biomedical application, drilling and lubrication[14].This paper reviews application of Nano-fluids as lubricants in vapor compressor refrigeration system. The below fig indicates different type of Nano particles with length scale and related examples[15].



2. Thermal Conductivity of Nano fluid:

Thermal conductivity is the capability of material to transmit heat. It plays a vital role in the development of the energy efficient thermal system. If thermal conductivity improved and heat transfer coefficient also improved [16]. Several researchers have conducted experimental study using Al_2O_3Nano particles and lubricant of R134a refrigeration system as a base fluid[14]. Thermal conductivity was measured by using thermal analyzer in the temperature range between 10-40^{0}C[17]. It has been observed that thermal conductivity enhances by 2.0%, 4.6% and 2.5% for 1.0, 1.5 and 2.0 wt. % of Al_2O_3 at 40 ^{o}C and Nano fluids show better effects for high temperatures[18].Mahbululet. al. have conducted experimental analysis on flow boiling inside horizontal smooth tube using Al_2O_3/R134a Nano-refrigerant for 1.0 to 5 vol. % concentration and temperature range was 300 K to 325 K. The velocity of Nano-refrigerant was observed to be 5 m/s. and vapour quality was 0.2 to 0.7[19]. The Sitprasert model was described when the quantity of Nano particles increased sharply thermal conductivity also increased [19]. Experimental value found to be higher when compared with Maxwell, Yu and Choi model. Thermal conductivity was estimated and it is high at 20^{0}C temperature and 0.4% volume concentration and low at 5^0 C temperatures and 0.1% volume concentration. [20]. Nano fluids have higher thermal conductivity as compared to base fluids[21].Thermal conductivity of Nano fluids

can be improved in two ways one is to use Nano particles with higher thermal conductivity and other is to increase concentration of Nano particles in base fluid[22].

3. Viscosity of Nano fluids:

Volume fraction and temperature have major effect over the viscosity of Nano-fluids. It was prepared using TiO_2Nano particles and measured the viscosity it has been found that viscosity of base fluid increases by adding Nano particles. Nano fluid was prepared using mechanical stirrer and ultrasonic agitation for 70 minutes[23]. Viscosity of Nano fluid was estimated by using Redwood viscometer. It has been found that predominant in lower temperature range. [24].Experimental study was conducted on Al_2O_3/R141b Nano refrigerant and measured the viscosity of Nano refrigerant using LVDV series ultra-programmable viscometer[25]. O. A. Alawi reported that addition of Nano particles results of increases viscosity and decrease with increase of temperature. viscosity increased due to augmentation of Nano particle concentration when experimented the Nano lubricant flow boiling inside of the smooth tube[26]. It is reported that the viscosity of paraffin based Fe_3O_4 (size 25 nm. and 0.01 – 0.1 volume fraction) Nano fluid using TA instrument thermometer[27].viscosity of Al2O3/R141b Nano-refrigerant was estimated using Brinkman Model and found that adding of Nano particles on volume basis increases viscosity and decreases with increase of temperature[28].

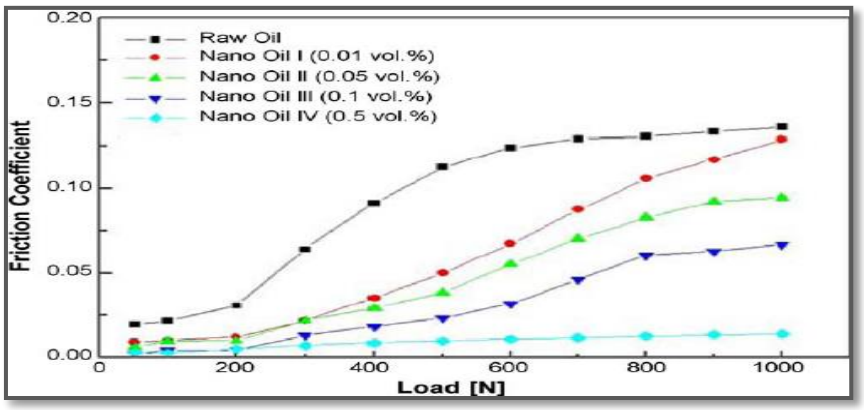


Figure 1 shows that Variation of friction coefficient vs load

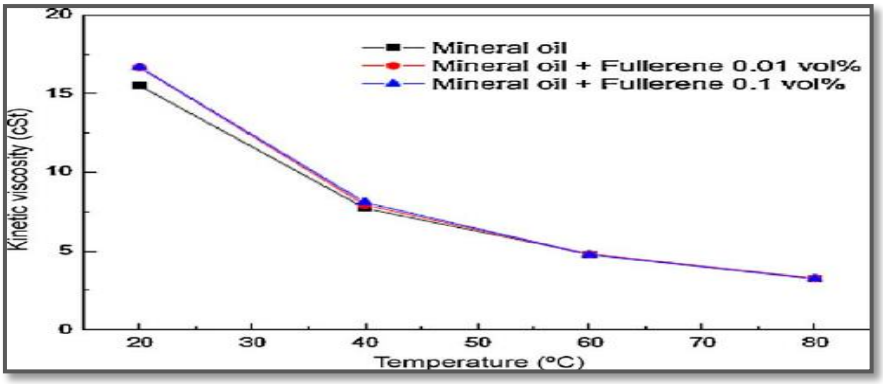


Figure 1 shows that variation of Kinetic viscosity vs particle concentration temperature

4. Heat Transfer Performance:

Heat transfer performance is a very important aspect to be considered to analyze the total performance of the system. Nano fluids' Phase change characteristics of the refrigerant are the governing factor to analyze the heat transfer phenomenon. Refrigeration system was analyzed using double pipe heat exchanger and CuO/R134a as Nano fluid and observed better heat transfer characteristics [29]. The heat transfer analysis also estimated by using Computational fluid dynamic concepts using FLUENT

software and mesh of test section was designed using GAMBIT software. Heat transfer coefficient was estimated it has been found that increases up to 0.55% of concentration of Cuo Nano particle and decreases for all values [30].Evaporator test section constructed as tube in tube type heat exchanger for Nano particle concentration of 0 to 1% and for heat flux of 10 to 40 kW/m^2. The result shows that while increasing the heat flux evaporating heat transfer coefficient also increases but after 0.55% of CuO Nano particle concentration, it decreases[31]&[32].The evaporating heat transfer coefficient increases up to 25 nm size of CuO Nano particle for all values of heat flux[33]. H. Peng et.al. carried out experimental analysis for various concentrations of CuO Nano particles and reported that improvement in heat transfer characteristics and also investigated on various mass fluxes and different vapour qualities and found out that for mass flux of 80 kg m2/sec and 0.1 wt. % of CuO Nano particle concentration, the improvement in heat transfer is found tobe 70.2% compared with the pure refrigerant[8]. Mahbulul et al. used Al_2O_3/R134a Nano refrigerant in flow boiling inside horizontal smooth tube and found out that the convective heat transfer coefficient and flow boiling heat transfer coefficient increases with the increase in Nano particle volume mixture[34].Al_2O3/R141b Nano fluid in horizontal smooth tube using mathematical model was analyzed and concluded that the increasing of particle volume fraction increases the heat transfer coefficient[35]. E. Acikkalp was observed that the maximum value of heat transfer coefficient to be 1755.8 W/m^2k for 5 % of volume particle concentration and at quality of vapour is almost 0.2. The minimum heat transfer coefficient improvement with 1 % volume and 0.3 vapour quality was found to be 383% compared to pure R141b refrigerant[36].The experimental analysis was conducted using R113/ VG68 oil mixture and carbon Nano tubes different combinations of refrigerant/oil/CNT and found enhancement of nucleate pool boiling can reach up to 61% when compared with, without carbon Nano-tube refrigerant -oil mixture[37].

5.Energy Performance:

D. Colorado and W. Rivera carried out the freeze capacity test and energy performance test to evaluate the performance of refrigeration system using Nano particles and found that using SUNISO 3GS oil and Al_2O_3Nano particles, COP improved by 35% by 33% and freezing capacity also increases when compared with pure POE oil/R134a system. Energy enhancement factor was 1.53 reported that 10.32% of energy saving was obtained when PAG OIL and Nano Al_2O_3 was used in R134a refrigeration system. Highest Cop of 4 obtained for length of capillary tube is 5 m[38].Performance test was conducted using three types of Nano lubricants, which are TiO_2Nano particles, Al2O3Nano particles and CuO Nano particles with SUNISO 3GS oil as base fluid[39].Freezing capacity enhanced with TiO_2Nano-lubricant and reduces the power consumption by 15.4%, 11.9% and 8.4% with TiO_2, Al_2O_3 and CuO Nano particles respectively[40].Performance of domestic refrigerator using R134a/mineral oil/ Al_2O_3Nano-refrigerant was concluded with double pipe heat, increases freezing capacity of the system when compared with the system using Al_2O_3Nano particles. Power consumption reduces by 30% with double pipe heat exchanger and coefficient of performance increases by 10% in comparison with pure mineral oil system[41]. R. K. A. Pattanayak was investigated R600a/POE oil system in domestic refrigerator and observed that when POE oil replaced with mineral oil and Al_2O_3Nano particles, the power consumption reduced by 11.5%. They showed that, it took about 42 minutes to bring evaporator temperature from28^0c to 5^0c for Nano refrigerant, 50 minutes for mineral oil and 60minutes for POE oil[42]. Performance test was conducted on hermetically sealed compressor using TiO_2Nano particles (size 21 nm.) and mineral oil of the refrigeration system and observed that power consumption was reduced about 10% to 9.33% and COP improved by 16.08%[43]. Domestic refrigerator using R600a and 0.1 grams/litre and 0.5 grams/litre concentration of TiO_2Nano particles was studied and concluded that 5.94% and 9.60% energy saved respectively using Nano-refrigerant. The system shows better performance than pure R600a and returns more lubricant back to compressor [23].

Based on the thorough research Table 1 Described the concentration of various Nano particles and power consumption. Energy saving is more in Tio_2 due to better heat transfer characteristics when compared to other Nano particle concentrations.

Table 1: Concentration of various Nano particles and Energy consumption

Mass Fraction	**POE**	**TiO_2**	**Al_20_3**	**CuO**	**Sio_2**
Energy Consumption	1.088	0.849	0.796	0.786	0.857
Energy Saving	3%	26.1	23.2	24.5	22.6
Concentration %	0	0.1	0.1	0.1	0.1

As per the above literature Table 2 Described the better concentration of various Nano particles .It has been found that most of the Nano particles gives good heat transfer characteristics when it mixed with 0.1 to 1% of volume concentration

Table 2 : Concentration of various Nano particles and combination of Refrigerants

Researcher	**Refrigerant**	**Nano Particle**	**Lubricant**	**Nano Particle**	**Evaluations**
Bi et al. HFC134a TiO_2–$Al2O_3$	HFC134	TiO_2–Al_2O_3	POE	0.06%–0.1%	Power consumption was reduced by adding of Nano particles in domestic refrigerator.
Subramani et al.	R134a	TiO_2	Mineral oil	300g	More effective Heat transfer performance by adding Nano particles
Kotu and Kumar e t al	Rs- 143a	TiO_2	Mineral oil	400g	The refrigerant heat transfers increased and reduced power consumption.
Elansezhian	R134a	Cuo - R13a	0.55%	0.55% to 1.5%	The result showed various key process of CUO improved the cop of the system
D.S. Kumar, R. Elansezhian,	R124A	TiO_2 - R12	0.1%	0.1% to 0.55	Reduces frictional coefficient and reduces power consumption.
H. Hussen,	R13A	TiO_2	0.2%	0.1% to 0.20	Power consumption was reduced and increases the cop of a compressor type of window air-conditioning system
O.A. Alawi, et al.,	R1225	TiO_4	0.5%	0.25%	Nano refrigerant effects in reduction of energy consumption and enhancement of heat transfer performance.

6. Conclusion

Many Researchers tried the Performance Enhancement of Simple Vapour compression system by using Nano fluids either in the form Nano refrigerant or Nano lubricant. It is clear that Nano-refrigerants have high thermal conductivity than traditional refrigerants. Increasing of Nano particle concentration on volume basis thermal conductivity also increases. Temperature, particle size, constancy and dispersion are the important factors to determining of thermal conductivity of Nano fluid. Increasing of Nano particles results of increase viscosity and decreases with increasing of temperature. Heat transfer

performance of the system increases with increasing Nano particle concentration. In some reported cases, it increased up to specific volume concentration of Nano particle and then decreases. The size and material of Nano particles also effect on the performance of VCR system. Particles with higher size caused to some problems like sedimentation, erosion, fouling and more pressure drop. The compressor work can be reduced by adding of Nano particles up to certain limit and then increased. Nano lubricant can be used in many industrial equipment and domestic purposes to enhance heat transfer performances and decreasing of energy consumption in a compressor. Nano fluids stability and its production cost is the main issue in commercialization of Nano fluids. Correct mechanism of improved heat transfer for Nano fluids is still unclear as per the investigation of many researchers. The studies on the Nano-lubricants are summarized in this review. It was found that Nano particles mixed with mineral oil gives better results than POE oil.

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