Effect of Aluminium oxide Nano filler in Tetrafluoroethane (R-134a) Refrigerant

Dhairysheel Ambhore, Akash Tiwari, Ujval Patel, Jishnu Patil, M. Ramachandran
MPSTME, SVKM'S NMIMS University, Maharashtra, India
jishnupatil724@gmail.com

Abstract. In today’s world, refrigeration plays an important role to satisfy human needs. People are doing several researches to enhance the performance of Refrigeration systems. Aiming to improve the characteristics of the old refrigerants by introducing nano particles in it, nano refrigerant is a process of combination of nano particle with the refrigerant for the sake of better refrigeration process. To study the thermal conductivity and viscosity at different volume concentration, this paper presents a review on mechanism for improvement in VCRS performance by using Nano refrigerants. We are using eco-friendly refrigerant that is R134a and nano particle Al2O3, comparing coefficient of performance (COP) of pure refrigerant and Nano refrigerant. In general, with the increment of nanoparticle concentration the viscosity is increased and instantaneous enhancement of thermo physical properties such as thermal conductivity is seen. The viscosity of Nano refrigerant has been influenced by the viscosity of the conventional refrigerant.

Keywords: Nano-refrigerants, Refrigeration cycle; Thermal conductivity, Coefficient of Performance

1. Introduction
Now days we are facing a huge problem of global warming (i.e. average temperature of earth is increasing). Government policies on energy saving have been implemented in many countries worldwide with the purpose to reduce energy consumption, consequently reducing the cost and also greenhouse gas emissions. Usage of eco-friendly refrigerant could be an effective solution to the global warming problem. Refrigeration is a human need (preservation) but it results in global warming. For refrigeration, refrigerator uses different types and composition of refrigerant. While researching we found that nano particles in refrigerant affects the efficiency and performance of refrigeration system. These results in an increase in the improvement of thermo-physical and heat transfer characteristic of refrigerant. The vapour compression cycle is a type of refrigeration system in which the vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. As we have seen above the cycle uses refrigerant. In these, we also found that nano particle in refrigerant is the good alternative and also provides a desired output. The contribution of these refrigerants represents between 1-2% of greenhouse gas emissions. It has been reduced considerably since 1987. Tetrafluoroethane (also known as norflurane (INN), R-134a, Freon 134a, Forane 134a, Genetron 134a, Suva 134a, or HFC-134a) is a haloalkane refrigerant with thermodynamic properties similar to R 12 (dichlorodifluoromethane) but with insignificant ozone depletion potential and a somewhat lower global warming potential (1,430, compared to R-12's GWP of 10,900). It has the formula CH2FCF3 and a boiling point of −26.3 °C (−15.34 °F) at atmospheric pressure. R-134a cylinders are colored light blue. Attempts at phasing out its use as a refrigerant with substances that have lower global warming potential, such as HFO-1234yf, are underway. Tetrafluoroethane is a non-flammable gas used primarily as a "high- temperature" refrigerant for domestic refrigeration and automobile air conditioners. These devices began using tetrafluoroethane in the early 1990s as a replacement for the more environmentally harmful R-12 and retrofit kits are available to convert units that were originally R-12-equipped. Other uses include plastic foam blowing, as a cleaning solvent, a propellant for the delivery of pharmaceuticals (e.g. bronchodilators), wine cork removers, gas dusters, such as Dust-Off, and in air driers for removing the moisture from compressed air. Tetrafluoroethane has also been used to cool computers in some overclocking attempts. It is the refrigerant used in plumbing pipe freeze kits. The gas is often mixed with a silicone-based lubricant. It can also be used as a solvent in organic chemistry, both in liquid and supercritical fluid. Dichlorodifluoromethane or difluoromonochloromethane is a
colorless gas is also known as R-22. It is commonly used as a propellant and refrigerant. R-22 is often used as an alternative to the highly ozone-depleting CFC-11 and CFC-12, because of its relatively low ozone depletion potential of 0.055, among the lowest for chlorine containing halo alkanes. As an additional environmental concern, R-22 is a powerful greenhouse gas with a global warming potential equal to 1810.

2. Literature Review

Mahbubul et al. (2011) in this paper prepared Al2O3/R141b. Nano refrigerants by shaking mixture of the nanoparticle of 13 nm size And 99.5% purity and refrigerant continuously for 24 h at 240 rpm in An orbital incubator shaker at a constant temperature of 15 °C. Thermal conductivity increases with the increase of volume concentrations and temperatures [1]. Jiang (2013) measured the thermal conductivity of various Nano refrigerants and showed that the improvement is highly influence by nanoparticle aggregation and forming of nanoparticle clusters. They have also developed a model for Predict Nano refrigerant thermal conductivity Thermal conductivity increases with increase in its nanoparticle volume fraction [2]. Mahbubul (2011) studied the effects of various parameters on thermal conductivity of R113, R141b and R134a based Nano refrigerants dispersed with Cu, Al, Ni, CuO, Al2O3 and carbon nanotube. Thermal conductivity increases with increase in temperature [3]. Alawi (2012 ) with Nano refrigerant Al2O3/R141a summarized that Nano refrigerant thermal conductivity increases with increase in particle volume Fraction, (ii) Nano refrigerant thermal conductivity increases with Decrease in particle size (or increase in aspect ratio for carbon nanotube), (iii) Nano refrigerant thermal conductivity increases with increase in temperature. [4]. Mahbubul (2013) (viscosity of nanorefrigerants) with Nano refrigerant Al2O3/R134a of size less than 200nm states that Viscosity increases with the increase in particle volume fraction [5]. Alawi (2014) investigated the effect of volume concentration and Temperature on thermos physical properties of Al2O3/R134a Nano refrigerant and observed that the viscosity of Nano refrigerant increases with increase in volume concentration and a decrease in temperature [6]. BI (2011) with a Nano refrigerant of size 20nm showed that the refrigerator's performance could improve by 26.1% with 0.1% mass fraction of TiO2 nanoparticles dispersed in R134a[7]. Subramani & Prakash (2014) reported the enhancement of freezing capacity, reduction of compressor power by 25% and enhancement of COP by 33% using Nano refrigerant.[8]. Kumar (2014) experimentally investigated the effect of Al2O3/R134a Nano refrigerant with PAG oil on energy consumption of refrigeration system and observed 10.3% reduction of energy consumption by using 0.2% concentration of nanoparticle [9]. Mahbubul (2013) observed 15% improvement of COP by Using Al2O3- R134a Nano refrigerant. They observed the effect of different properties on the COP while using Nano refrigerant. COP canenhance by 15%, 3.2% and 2.6% due to thermal conductivity, density and specific heat respectively [10]. Soliman (2015) reported 13.5% less energy consumption and 10.5% more performance by using Al2O3-R143a [11]. Kedzierski (2014) found out that the Nano refrigerants were significantly have a better pool boiling heat transfer. In addition, the absolute nanoparticle surface density that resides on the heat transfer surface was the main factor to the boiling heat transfer enhancement [12]. Sharif (2016) performed an experimental study to examine the relationship between the thermal conductivity and viscosity with the volume concentration of the Al2O3/PAG Nano lubricants specifically used in the Automotive Air Conditioning (AAC) system. The thermal conductivity was shown to be enhanced up to 4% at 1% of volume concentration. However, the viscosity increases 7.58 times higher than the PAG lubricant at 0.4% volume concentration [13]. Zawawi (2012) a year later he extended the work using SiO2 nanoparticles dispersed into the PAG lubricant. The thermal conductivity and viscosity of the Nano lubricants reported increased with volume concentration but decreased with temperature. However, because of the Nano lubricants were specifically designed for the AAC system the author has suggested the specific concentration of SiO2/PAG and Al2O3/PAG to be used. These are because the excessive viscosity of lubricant would affect the performance and power consumption of the compressor in the refrigeration system [14].

Cremaschi (2016) found nanoparticles addition in lubricant do not impede with POE characteristics of oil solubility [15]. Manoj (2014) analyzed Al2O3 and TiO2 Nano lubricants and observed COP enhancement in both Nano lubricants, where Nano lubricants TiO2/MO showed higher than Al2O3/MO Nano lubricants with significant energy consumption. [16]. Yusof (2015) have analyzed the energy reduction and performance enhancement by using Nano lubricants in a refrigerator system. With 0.2% volume concentration of Al2O3/POE Nano lubricants, the result shows 7% COP optimization with 2.1% energy consumption reduction which is highest. [17]. Kedzierski (2016) analyzed the copper oxide /POE Nano lubricants effect on pool boiling heat transfer with the refrigerant R134a. The finding shows significant enhancement in the heat transfer (up to 275%) at only 0.5% mass fraction of copper oxide /POE Nano lubricants. Additionally, they also exposed that a small increase in the thermal conductivity contributes to substantial enhancement in the heat transfer [18]. Akhavan (2013) have analyzed the effect of copper oxide/R600a/POE Nano refrigerants condensation inside a horizontal smooth tube and proved that addition of copper oxide nanoparticles enhanced the condensation heat transfer compared to lubricant mixture with baseline refrigerant. Peng (2015) stated that For normal lower boiling point refrigerants, the following two methods can be adopted: (i) two step or one step method for preparation of Nano lubricant and then mixing with refrigerant. [20]

| Technical specification of test rig |
|----------------------------------|
| Compressor Power                | 0.25 KW                     |
| Refrigerants                    | R134a, R22                  |
| Compressor                      | Reciprocating type, hermetically sealed |
3. Preparation of Nano Refrigerant

As we have seen above, to reduce the global warming problem we have to use the eco-friendly refrigerant. So by reviewing different research paper, we decided to use refrigerant R134a, as it has zero potential to cause the depletion of ozone layer and very little greenhouse effect, it belongs to the family of hydrofluorocarbon (HFC). Its chemical name is tetrafluoroethane. It is safe for normal handling as it is non-toxic, non-flammable and non-corrosive. On other hand when nanoparticles are dispersed in refrigerant (termed as nano-refrigerant), then it directly enhances the refrigerant thermal properties and thereby performance of refrigeration system is found to be improved. The following methods are used to prepare Nano refrigerant by mixing nanoparticles in refrigerant are single step method and two step method. The single-step method is a process of combining the preparation of nanoparticles with the synthesis of Nano fluids, for which the nanoparticles are directly prepared by physical vapour deposition (PVD) technique or liquid chemical method. The two-step method for preparing Nano fluids is a process by dispersing nanoparticles into base liquids. This step-by step method isolates the preparation of the Nano fluids from the preparation of nanoparticles. As a result, collection of nanoparticles may take place in both steps, especially in the process of drying, storage, and transportation of nanoparticles. The agglomeration will not only result in the settlement and clogging of micro channels, but also decrease the thermal conductivity. Simple techniques such as ultrasonic agitation or the addition of surfactants to the fluids are often used to minimize particle aggregation and improve dispersion behaviour. Since Nano powder synthesis techniques have already been scaled up to industrial production levels by several companies, there are potential

| Component          | Specification                                    |
|--------------------|--------------------------------------------------|
| Nano Refrigerant   | Al2O3                                             |
| Condenser          | Copper tubes, aluminium fins, forced convection air cooled |
| Expansion device   | Capillary tubes                                   |
| Evaporator         | Copper coil tubing through which refrigerant is circulated, it cools water, heater is at bottom to balance the cooling |
| Condenser Size     | 9x9x2 Rows                                       |
| Condenser Fan Motor| 1/83 HP X 1350 RPM                               |
| Condenser Fan      | 8’ Diameter X 4 Blade                             |
| Evaporator Size    | 5/16 X 30                                        |
| Capillary Tube     | 0.050’ X 10 ft.                                  |

**Actual Experimental Setup**
economic advantages in using two-step synthesis methods that rely on the use of such powders. But an important problem that needs to be solved is the stabilization of the suspension prepared. Two-step preparation process is extensively used in the synthesis of Nano fluids by mixing base fluids with commercially available Nano powders obtained from different mechanical, physical and chemical routes such as milling, grinding, and sol-gel and vapor phase methods. An ultrasonic vibrator or higher shear mixing device is generally used to stir Nano powders with host fluids. The most common two-step method is shown in figure.

4. Block diagram of two step method
The Nano refrigerant for this work is prepared in National Chemical Laboratory, Pune. Al$_2$O$_3$ Nanoparticles with concentration of 0.5wt%, and 0.1wt% were measured by digital weight balance. Each mass fraction of nanoparticles is mixed with R134a Resultant nano refrigerant was homogenized for 15 minutes followed by sonication for up to 4 hours using ultrasonicator.

![Graphs](image)

**Thermal conductivity as a function of nano Particle volume concentration**

Thermal conductivity of pure refrigerant i.e. R134a is 0.0139W/m-K and it gives a graph of a nano particle percentage in a refrigerant and its change in thermal conductivity with respect to it. Viscosity of pure refrigerant i.e. R134a is at 26°C is 0.0001934 Pa.s. Above graph shows the change in viscosity with respect to volume fractional of nano particle in refrigerant. It shows the linear increment after the viscosity of pure refrigerant.

**Results**

| P1 (bar) | P2 (bar) | T1 °C | T2 °C | T3 °C | T4 °C |
|----------|----------|-------|-------|-------|-------|
| 2.1      | 23.8     | 2.8   | 79.5  | 45.3  | 1.9   |

P1= Suction pressure; P2= Discharge pressure; T1= Temperature after condensation; T2= Temperature after compression; T3= Temperature after evaporation; T4= Temperature after expansion; T5= Chamber temperature; h1= Enthalpy at evaporator outlet temperature; h2= Enthalpy at condenser inlet temperature; hf3=hf4= Enthalpy at condenser outlet temperature. From refrigeration table h1= 394 KJ/kg; h2= 429 KJ/kg; hf3=hf4= 189 KJ/kg

\[
\text{COP (theoretical)} = \frac{h_1 - h_4}{h_2 - h_1} = 5.857
\]

\[
\text{COP (actual)} = \frac{R.E.}{W.D.}
\]
R.E = m x Cp x (Tf – Ti) = 2.5 x 4.187 x (26.7 – 9.4) = 210.396 kJ
Power = V x I x cos Φ = 230 x 0.5 x 0.85 = 115 W = 0.115 kW
Therefore, WD = Power x time = 0.115 x 15 x 60 = 103.5 kJ
COP (actual) = R.E
W.D

COP (theoretical) = \frac{h_1 - h_4}{h_2 - h_1} = \frac{9.17}{9.17} = 1.72

5. Conclusion
The thermal conductivities of nano refrigerants are higher than traditional refrigerants. It was also observed that increased thermal conductivity of nano refrigerants is comparable with the increased thermal conductivities of other nano refrigerants. Nanoparticle factor that can be effect to thermos-physical properties is nanoparticle size, type of nanoparticle, shape of nanoparticle size and etc. Refrigerant type need to be environmental friendly to minimized the Global Warming Potential (GWP) factor. The use of nano-refrigerants enhances the heat transfer characteristic of nano-refrigerant relative to pure refrigerant. The addition of 0.5% of Al2O3 nano particles in the base refrigerant will lead to improvement in the overall performance of the VCRs than that of pure base refrigerant. However increase in the percentage of nano particle in the base refrigerant will result in decreased system performance

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