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Review Article

A Review on Performance of Domestic Refrigeration System using Nano-Refrigerants

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Abstract

Many researchers are heading towards innovations and experiments on different refrigerants, due to environmental effects and lower efficiency of conventional ones. Heat transfer capacity of the refrigerant decides the performance of the refrigeration system. To improve thermal conductivity and ultimately heat transfer rate lubricant (POE oil/Mineral oil) are enhanced with Nanoparticles. Mixing of Nano-fluid with base refrigerant improves overall COP of the system and decrease power consumption. This paper is an attempt to review past and on-going research work in Nano refrigerants. This work focuses on the experimental study of the performance on base refrigerant (R134a) with Nano-material. Many researchers observed the performance of Nano refrigerant in different proportion by varying Nanoparticles size and shape. The effect of usage of Nano-materials on the thermal conductivity and coefficient of performance (COP) of the refrigeration systems has been studied. The effect on the rate of heat transferred through system and working parameters of set up is observed.

Keywords: *Nano-fluid, Nanoparticles, Nano refrigerants, Nano lubricants, COP,* Al_2O_3*,* TiO_2

1. Introduction

Nowadays the use of refrigeration and air conditioning equipment is increased significantly in domestic as well as an industrial application. Gases emitted from this equipment directly affect the ozone layer, which is responsible for global warming. Already chlorofluorocarbons (CFCs) is phase-out and replaced by R134a (Hydro fluorocarbon refrigerant) which is commonly used in domestic refrigerators and some other vapor compression systems. R134a is having zero ozone depletion potential (ODP), but it has a high Global Warming Potential (GWP) of 1300. So we need to identify long-term alternative for the refrigerant to meet requirements with respect to system performance and is an important area of research. Refrigeration is simply heat removal process. To do this heat should be removed from the body. This heat must be transferred to another body whose temperature is below that of the refrigerated body. Simple vapor compression system consists of four major components compressor, expansion valve, condenser, and evaporator (See Figure 1) in which total cooling load is carried at one temperature by single evaporator but in many applications like large hotels, food storage, and food processing plants, food items are stored in different compartment & at different temperatures. So there is need of multi-evaporator vapor compression refrigeration system. The systems under vapor compression technology consume a huge amount of electricity; this problem can be solved by improving the performance of the system. The thermal conductivity of Nano-fluids has been found to be higher than the average refrigerants used and conductivity increases as the concentration of Nanoparticles in the fluid are raised, that is, thermal conductivity is directly proportional to the concentration of Nanoparticles. This is the major reason why Nanoparticles are being considered as additives to conventional refrigerant systems, thus forming Nano-fluids. There is much higher heat transfer when using a Nano refrigerant compared to regular refrigerants. Some of the added benefits of using Nano-fluids are there is a decrease in power consumption of the system (by as much as 25-30%), as well as an increase in the coefficient of performance of the refrigerating device. The use of Nanoparticles is done in various applications and Nano-fluids added in refrigerants can be considered as the present as well as the foreseeable future of domestic and industrial refrigeration.

1.1 Nanofluid

Nano-fluid can be delineated as an advanced form of fluid which can be processed by suspending particles having a size range between 1-100 nanometers.

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Thousands of atoms are present in smallest Nanoparticles of few nanometers. Nanoparticles have distinct properties from their parent material. Interaction of nanoscale particles is different within their molecular bond and nature of the response is different for mass and energy applications. Nano-fluids basically belong to a two-phase system, in which the solid phase is dispersed in the liquid phase. But, literature also shows that in many cases Nano-fluids are also considered as a single phase fluid in which Nanoparticles are simultaneously produced and dispersed. There is an enhancement in thermo-physical properties such as thermal conductivity, convective heat transfer coefficients, thermal diffusivity and viscosity of Nano-fluids as compared to base fluids like oil or water. This improvement in thermo-physical properties demonstrated great potential in many fields of engineering applications such as refrigerators and air conditioning systems, solar water cooling system, heat exchanger, transformer cooling oil, an electronic circuit, nuclear cooling system, defense, and space. The Nanoparticles used as a colloidal substance in the preparation of Nano-fluids are usually metals such as copper, nickel, and aluminum or metal oxides like titanium oxide, aluminum oxide, silicon oxide, copper oxide (See Table 1). Nano-fluids possess following characteristics as compared to normal solid-liquid suspensions high specific surface area (SSA) and therefore, more heat transfer surface between particles and fluids, suspended Nanoparticles in base fluid results enhancement in thermal conductivity, Reduced pumping power to achieve an equivalent heat transfer intensification which results system minimization, reduce particle clogging leads to lesser energy consumption thereby improving heat transfer and heat carrying capacities, Adjusting properties such as thermal conductivity and surface wettability by varying particle concentrations to make it suitable for different applications. In order to prevent agglomeration of Nanoparticles in Nano-fluid following methods are employed

A) To change pH value of suspension.
B) To use surface activators/dispersants.
C) To use ultrasonic vibration.

Proper implementation of above techniques changes surface properties of suspended particles and restrain clustering. Following table represents the thermal conductivity coefficient of some Nanoparticles. Assuming water as a source of coolant to be a datum. Thermal conductivity of water (k) = 0.55 W/m-K.

Table 1 Different Nanomaterials with Thermal Conductivity

Sr. No.	Materials	Thermal conductivity(k)= W/m-K
1	Al_2O_3	36.0
2	MgO	48.4
3	SiO_2	10.4
4	TiO_2	8.4
5	ZnO	13.0
6	CuO	40.0
7	SiC	120
8	Gold	317
9	Copper	401
10	Carbon black	3000

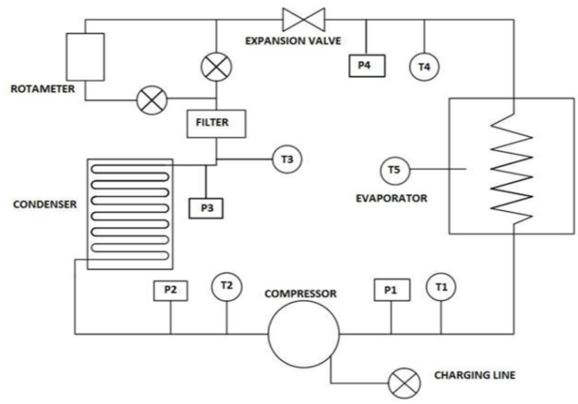

Figure 1: Line Diagram of Domestic Refrigeration Test Rig

P1 – Refrigerant Pressure at the inlet of Compressor
P2 – Refrigerant Pressure at the outlet of Compressor
P3 – Refrigerant Pressure at the outlet of Condenser
P4 – Refrigerant Pressure at the outlet of Expansion valve T1 – Refrigerant Temperature at the inlet of Compressor T2 – Refrigerant Temperature at the outlet of Compressor T3 – Refrigerant Temperature at the outlet of Condenser T4 – Refrigerant Temperature at the inlet of Evaporator T5 – Temperature inside Evaporator Tank

2. Literature Review

N. Kamaraj *et. al.* : The author investigated the experimental analysis of the vapor compression refrigeration system using R-134a as a base refrigerant & Nano lubricant in the proportion of 0.1 & 0.2 gram/liter of mineral oil and the same proportion with Polyester oil and carbon black Nano-powder. It was observed that carbon black Nano-powder worked smoothly and efficiently in a refrigeration system. The coefficient of performance increases in both the cases as compared to R-134a with plain POE oil, but mineral oil with 0.2gram/liter gives maximum result compared to 0.1 gram/liter of same oil & 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 the Vapor compression refrigeration system.

N. Subramani *et. al.* : The researcher had conducted an experimental study on the vapor compression system using Nano refrigerant as a mixture of R-134a & Al_2O_3 with POE/mineral oil. They have given attention to the preparation of stableness of Nano-fluid by ultrasonic vibration method and tested it for 72 hours for any agglomeration & sedimentation. Their experimental study indicates that the normal working of a refrigerant system with Nano refrigerant. Also freezing capacity is higher & the power consumption reduces by 25% when POE oil is replaced by a mixture of mineral oil & Al_2O_3 Nano-particle. The coefficient of Performance of the refrigeration system also increases by 33% when the conventional POE oil is replaced with Nano refrigerant.

Manoj Babu *et. al.* : In this research paper, the analyzer conducted a performance on refrigeration system using Nano lubricant with R-134a refrigerant. They mixed the mineral oil with Nano particle such as TiO_2 & Al_2O_3. They have used this mixture as the lubricant instead of POE oil in R-134a refrigeration system as R-134a does not suitable for raw mineral oil. An investigation was done on the compatibility of mineral oil and Nano-particles mixture at 0.1 and 0.2 gram/liter with R-134a. Afterward, performing the experiment with Nano refrigerant works smoothly & efficiently in the refrigerant system. Also, it is found that TiO_2 based Nano lubricant with a mixture of 0.2 gram/liter gave maximum result compared with a mixture of 0.1 gram/liter of same Nano lubricant.

R. Rejikumar *et. al.* : The researcher analyzed the heat transfer enhancement in domestic refrigerator & found the normal & safe working of R600a refrigerant and mineral oil mixture with Al_2O_3 Nanoparticle. It is found that the freezing capacity of the system is higher with mineral oil & Al_2O_3 Nanoparticle oil mixture compared with the system of POE oil.

D. Bondre *et. al.* : Authors conducted an experimental analysis of the domestic refrigerator using Nano-Refrigerant as a mixture of R-134a and Al_2O_3 with POE oil. They prepared stable solutions of Nano-Fluid (Al_2O_3 Nanoparticle and POE oil) with 0.05%, 0.1% and 0.2% by mass fraction. It was observed that Nano-Fluid work smoothly and 0.1% Nano-fluid solution gives maximum efficiency. With 0.1% Nano Fluid solution the COP of the refrigeration system was improved by 17.27% and power consumption was reduced by 32.48% as compared to a normal refrigeration system.

D. Sendil Kumar *et. al.* : In this research paper, the author carried an experimental study on the performance of domestic refrigerator using Nano refrigerant in the system. A mixture of Nano-particle Al_2O_3& polyalkylene glycol (PAG) oil with R-134a was the working fluid in the refrigeration system. It was found that the system works fluently and efficiently. The performance of Nano refrigerant with 0.2% of concentration is better than conventional refrigeration system. After the addition of Nano-particle (Al_2O_3) in the refrigerant shows improvement in coefficient of performance of the refrigeration system & the usage of Nano refrigerant reduces the length of the capillary tube and also it is cost effective.

R.S Mishra *et. al.* : The author performed the thermal improvement in vapor compression cycle system with different refrigerants such as R-134a, R-404aand R-407a with Nano-particle Al_2O_3, CuO and TiO_2. It was observed that with the help of Nano refrigerant there was an improvement in the thermal performance of the system. Maximum enhancement is achieved by using R-134a/CuO Nano refrigerant in primary circuit & water in the secondary circuit of VCR's. The lowest improvement was observed using R404a/TiO_2 Nano refrigerant in the primary circuit and water in the secondary circuit of VCR's.

T. Coumaressin *et. al.* : The author has mentioned the drawback of R-134a 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 a safe environment as well. They had done CFD analysis of the vapor compression system on FLUENT software using CuO-R134a Nano-refrigerant. It is found that the Nano refrigerant works efficiently and normally in the system & the result indicates that the evaporating heat transfer is improved. The entire author's literature review is summarized in Table 2.

3. Scope of research

From the literature survey, it is found that COP in case of Nano refrigerant is improved significantly as compared to the normal refrigerant. The long-term alternative refrigerants identified are HFCs and HCs. HFCs have fewer tendencies to mix with mineral oil and HCs are flammable. R134a, an HFC refrigerant has taken a major share in residential, commercial as well as domestic sector. The results show that Nano-fluids have the remarkable potential to improve the heat transfer properties of refrigerant. In spite of the wide acceptance of conventional refrigerants, their relatively high levels of global warming potential (GWP) possess serious atmospheric issues to the world. Conventional refrigerants can be replaced by Nano refrigerants and used as a great alternative.

Moreover, challenges with particle dispersion, particle circulation and its effects on the compressor have not been studied in details. However, the present investigations are evoking that further detailed research should be done. Future research needs to be done on the effect of Nanoparticles material, their quantity, method used for dispersion of particles in oil, time for dispersion process, material size and shape on refrigeration effect, COP enhancement and effect on other parts of the refrigeration circuit. Experimental results on the fundamental properties such as specific heat, density, and viscosity of Nano- refrigerants are limited in the literature, so there are potentials to explore research to determine these properties experimentally also.

Table 2 Literature Reviews

Author	Refrigerant	Nano-Particle	Lubricant	Conclusion
N. Kamaraj *et.al.*	R-134a	Carbon Black	POE/ Mineral oil	COP increase with 16.67% with 0.2/gm of carbon black per liter of POE
N. Subramani *et. al.*	R134a	Al_2O_3	POE/mineral oil.	Power consumption reduces by 25% with mineral oil and Al_2O_3
Manoj Babu *et. al.*	R134a	TiO_2, Al_2O_3	Mineral Oil	COP of Nano refrigerant Is more as compared to R-134a
R. Rejikumar *et. al.*	R600a	Al_2O_3	Mineral Oil	Freezing capacity increases as compared to conventional POE oil
D. Bondre *et.al.*	R-134a	Al_2O_3	POE oil	COP increases 17.2% and Power consumption reduces by 32.48% with 0.1% Nano-fluid solution
D. Sendil Kumar *et. al.*	R134a	Al_2O_3	PAG Oil	Improved COP and the use of the Capillary tube as an expansion device made system cost effective
R.S Mishra *et. al.*	R-134a,R-404a and R407a	Al_2O_3,CuO,TiO_2		Maximum enhancement is achieved by using R134a/CuO
T. Coumaressin *et. al.*	R-134a	CuO		Evaporating heat transfer is improved.

Conclusion

The study helps to determine the suitable environment-friendly working fluids such as Nano-refrigerants for modern refrigeration systems. By learning and understanding the basic vapor compression refrigeration systems the performance of the refrigeration system can be optimized. The knowledge gained from understanding the application of Nano- refrigerants in domestic refrigeration systems can also be applied in the design of more efficient, energy saving systems including solar and power plant cooling, ice plant, improvement of diesel generator efficiency. By considering the present energy crisis in our country a lot of research has been carried out to reduce power consumption. Based on literature reviews, it is clear that there is wide scope to Nano refrigerant in the future. After overall reviewing of the performance of Nano-particle in the base fluid, it can be concluded that the use of Nano-particle enhances the working of the system and improves the overall coefficient of performance of the system.

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