Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 8, August -2017

Review on Enhancement of CoP of Refrigeration System by Inclusion of Nano particles in Refrigerant

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Abstract:-*Nanofluid is the stable suspensions of nano particles in base fluids. Nanofluid exhibits many interesting properties and can be applied in many applications for enhancing performance and effectiveness. This article discusses the enhancement of CoP of refrigeration system by inclusion of nano particles in refrigerant. The novel nanorefrigerant is a nanofluid that shows better heat transfer performance over conventional refrigerants. Low volume concentration of Nano particles in refrigerant can improve the performance of a refrigeration system in the temperature range from 4℃ to 160℃. It decreases the energy consumption and improves efficiency of system. It was observed that addition of nano particles in refrigerant reduced energy consumption up to 26.1% and improved performance by 4.4%. Moreover it is observed that it increase CoP and 11% reduction in compressor work. However, increased density of nanorefrigerant, stability of nano particle in refrigerant, lower specific heat and increased pressure drop & pumping powers are the major challenges associated with inclusion of nano particles in refrigerant. Nano refrigerant can be employed in industry only after carefully addressing these few barriers and challenges which have been identified in this article.*

Keywords : *Nano particles; Refrigerant; Nano fluid; Domestic Refrigerator*

1. INTRODUCTION

Nanotechnology is the study and operation of matter at 100 nanometer scale. It is proved that chemical, physical and mechanical behaviors of material considerably change at the nano scale, which encourages use of such enhanced behavior of nano materials for new generation technology.
In general, refrigerant's performance normally suffers from its poor heat transfer properties. The earlier studies on use of micro scale solid particles in fluid as refrigerant showed two major problems.

- Rapid settling of the solid spherical particles at base in the fluids.
- Blockage of micro channels and surface cut.
- Agglomeration of particles

Inclusion of nano particles in refrigerants is found promising to overcome these problems. It was experimentally proved that stability of nano particles can be improved by developing proper dispersants in fluids and ultrasonication process. Hence, the heat transfer performance of such fluids can be significantly improved.
Nanofluids are prepared by suspending nano sized particles in conventional fluids and have higher thermal conductivity than the base fluids. Nanofluids are superior then parent base fluid and micro particles refrigerants in following respect.

- Excellent heat transfer capability of nanofluid.
- Better scattering stability with principal Brownian motion.
- Less chances of particle blockage because of better nanofluid stability
- Refrigeration system required reduced pumping power as compared to base fluid to obtain equivalent heat transfer.

Nowadays nano particles are available in a very wide variety of materials, shape and size. Nano particles are available in main two categories, viz. one is metal oxide ceramics, such as titanium, zinc, aluminum and iron oxides and others are pure metal nano particles like, Au, Ag and Cu.
The rationale behind inclusion of Nano particles in refrigerant is because of its proved remarkable improvement in thermo physical and heat transfer capabilities to improve the performance of refrigeration systems. In a vapor compression refrigeration system the nanoparticles can be added to the lubricant (compressor oil). When the refrigerant is circulated through the compressor it carries drops of lubricant and nanoparticles mixture (Nano lubricants) so that the other parts of the system will have Nano lubricant-refrigerant combination.(Teshome Bekele Kotul et. al.)

2. Literature Review

Since last two decade there is extensive research on nano technology. In last decade there is significant breakthrough on development of nano particles and nanofluid. The use of nano particles in refrigerant is started since 2003. The major research in nanorefrigerant is discussed subsequently.

Wang and Xie found that TiO_2 nanoparticles could be used as extracts to improve the solubility between mineral oil and hydro fluorocarbon (HFC) refrigerant. The refrigeration systems using the mixture of R134a and mineral oil appended with nanoparticles TiO_2, appeared to give better performance by returning more lubricant oil back to the compressor, and had the similar performance compared to the systems using polyolester (POE) and R134a. (Wang RX et.al.,2003)

Pawel et al. conducted studies on Nanofluids and found that there is significant increase in the thermal conductivity of Nanofluid compared to the base fluid. They also found that addition of nanoparticles results in significant increase in the critical heat flux. (Pawel K. P.l et. al.,2005)

Bi et al. conducted studies on a domestic refrigerator using Nano refrigerants. Authors used R134a as the refrigerant and a mixture of mineral oil with TiO_2 nano particals additives as the lubricant. They found that the refrigeration system with the Nano refrigerant worked normally and efficiently and the energy feeding reduces by 26.1%. When compared with R134a/POE oil system. (Bi S. et. al.,2007)

Bi et al. found that there is remarkable decrease in the power feeding and significant improvement in freezing capacity. They pointed out the improvement in the system performance is due to better thermo physical properties of mineral oil and the presence of nano particles in the refrigerant (Bi S. et. al.,2008).

Lee et al. studied the friction coefficient of the mineral oil mixed with 0.1 vol.% fullerene nano particles. Authors indicated that the friction coefficient decreased by 90% in comparison with raw lubricant, which lead to the conclusion that nanoparticles can improve the efficiency and reliability of the compressor. (Lee K et. al.,2009)

Jwo et al. conducted studies on a refrigeration system replacing R-134a refrigerant and polyester lubricant with a hydrocarbon refrigerant and mineral lubricant. Their studies showed that the 60% R-134a and 0.1 wt. % Al_2O_3 nanoparticles were optimal. Under these conditions, the power consumption was reduced by about 2.4%, and the coefficient of performance was increased by 4.4%. (Jwo et.al., 2009)

Peng et al. performed experiments on the nucleate pool boiling heat transfer characteristics of refrigerant/oil mixture with diamond Nano particles. They found that the nucleate pool boiling heat transfer coefficient of R113/oil mixture with diamond nanoparticles is larger than the R113/oil mixture. They also projected a general association for calculating the nucleate pool boiling heat transfer coefficient of refrigerant/oil mixture with nanoparticles, which well satisfies their experimental results. (Hao Peng et.al., 2010)

Henderson et al. conducted an experimental analysis on the flow of boiling heat transfer of R134a based Nanofluids in a horizontal tube. They found excellent scattering of CuO nanoparticle with R134a and POE oil. The heat transfer coefficient increased more than 100% over baseline R134a/POE oil. (Henderson et al., 2010)

Bobbo et al. conducted a study on the effect of scattering of single wall carbon Nano horns (SWCNH) and TiO_2 on the tribological properties of POE oil together with the effects on the solubility of R134a at different temperatures. They showed that the tribological behaviour of the base lubricant can be either improved or degrade by adding nanoparticles (Bobbo S. et.al., 2010)

Shengshan Bi et al. conducted an experimental study on the performance of a domestic refrigerator using TiO_2-R600a Nano refrigerant as working fluid. They showed that the TiO_2-R600a system worked normally and efficiently in the refrigerator and observed energy saving of 9.6%. They too cited that the freezing velocity of Nano refrigerating system was more than that with pure R600a system. (Shengshan Bi, 2011)

Mahbubul et al. has also investigated that the volumetric concentration and temperature effects on viscosity of R123-TiO_2 Nano with volumetric concentration up to 2%. Furthermore, pressure drop increased significantly with the increase of volume concentrations and vapor quality. (I.M. Mahbubul et. al.,2012)

Mahbubul et al. found that the viscosity of Nano refrigerant increases with the increase of nanoparticles concentrations and the viscosity improvement due to same particle concentration is different for different types of refrigerants. (I.M. Mahbubul et. al.,2013)

M.A. Akhavan et al. has experimentally proved that heat transfer coefficient increases by adding the nanoparticles to refrigerant/oil mixture. Moreover he also experimented that utilizing a nanofluid enhances the heat transfer coefficient by increasing the vapor quality as well as mass flux. The same behavior is observed for pure refrigerant and refrigerant / oil mixture. (M.A. Akhavan et. al. 2015)

Liu and Kie has reviewed in his article that most experimental and all numerical results have exhibited that TiO nanofluid can enhance the convection and boiling heat transfer coefficient in various heat transfer processes. However the shape of tube, plate or enclosure, the type of fluid and the material of the heat transfer surfaces are still important influence factors but affect the convection heat transfer coefficient to a different degree. (Liu and Kie, 2017)

Azmi et. al. has reviewed in his article that a great number of studies on the blend of nanorefrigerant and nanolubricant were being summarized and concluded that because of their improved heat transfer attributes and improvement in COP and energy saving, it is safe to assume that nano refrigerants and nano lubricants will be utilized as a part of numerous modern refrigeration system and gadgets sooner rather than later. (Azmi et. al. 2017)

3. PROCESS OF INCLUSION OF NANO PARTICLES IN REFRIGERANT - SYNTHESIS

Arunn defined nanofluid as a fluid with a colloidal dispersion of nano-sized particles of another substance. A colloid is typically made of two substances. In a colloid the two substances are distinguishable but can interact through weak surface molecular forces. (Arunn, 2008.)
Following three methods are generally adopted for preparation of nanofluid:

1. Nanoparticles dispersed in powder form in the base fluid,
2. Synthesis of nanoparticle by chemical precipitation and
3. Synthesis by organic reduction.

Widely used method of preparing nanofluid is by suspending nanoparticles into base fluids, some special requirements are necessary such as even suspension, durable and stable suspension, low agglomeration of particles and no chemical change of fluid. There are three general methods used for preparation of stable nanofluid.

- Addition of acid or base to Change the pH value of suspension
- Adding surface active agents and/or dispersants to disperse particles into fluid
- Using ultrasonic vibration.

The most common two step preparation process is shown in below Figure-1 and These methods can change the surface properties of the suspended particles and can be used to suppress the formation of particle clusters in order to obtain stable suspensions. The use of these techniques depends on the required application of the nanofluid(Gupta H.K. et. al.).

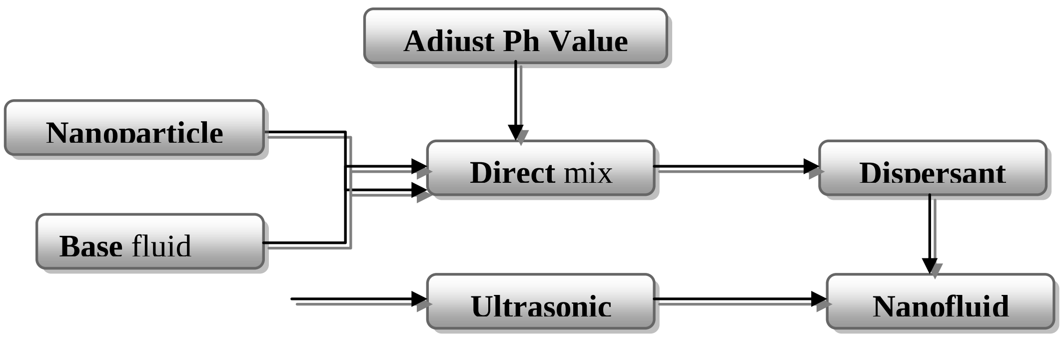

Fig 1 : Two step preparation process of nanofluid

4. REVIEW OF PROMISING CHARACTERISTICS OF NANO REFRIGERANT

It was observed that the basic properties required from the refrigerant are appreciably satisfied by nano particle additives in refrigerant fluid or lubrication oil. Basic experimental results of use of inclusion of nano particles in fluid are mentioned below. The suspended nanoparticles increase the surface area and the heat capacity of the fluid due to the very small particle size.

1. Inclusion of nano particles improves the thermal conductivity and so it can improve efficiency of refrigeration systems.
2. As heat transfer (i.e. conduction, convective, boiling) is improved by nanofluids, heat exchanging devices like refrigeration system can be made energy efficient and compact.

The experiments on nano particles addition in fluid at low volume concentration suggest positive results that advocate why not use nano refrigerant in refrigeration system. The contribution of authors towards application of nano refrigerant is shown below, that indicate successful and considerably efficient application of nano refrigerant is feasible.

Table 1 : Inclusion of nano particles in refrigerants and their effects

Sr. No.	Refrigerant	Nano Particles used	Effects / Results	Contributor	Year
1.	R134a	TiO_2	Energy consumption reduced by 26.1%.	Bi S. ,Shi L., Zhang L.,	2007
2.	R134a	Al_2O_3 (0.1 wt%)	2.4% reduce energy consumption and CoP increase 4.4%.	Ching Song Jwo, Lung Yue Jeng, Tun Ping Teng, Ho Chang,	2009
3.	R113/oil mixture	VG68 oil with diamond nano particles (0 to 5% wt)	-	Hao Peng, Guoiang Ding,	2010
4.	R134a/POE	CuO	Coefficient increase more than 100%.	Kristen Henderson, Young-Gill Park,	2010
5.	R134a/POE	S.W.C.N.H. & TiO_2	Improved tribological behaviour.	Sergio Bobbo, Laura Fedele,	2010
6.	R600a	TiO_2 (0.5 g/L)	9.6% less energy usage.	Shengshan Bi, Kai Guo, Zhigang Liu, Jiangato Wu,	2011
7	R134a, R407C, R410a and R425a	$NiFe_2O_4$/ Mineral oil B32	6% Energy efficiency ratio increased	Wang R, Wu Q, Wu Y	2010
8	R12	TiO_2/ Mineral Oil	Increased CoP and 11% reduction in compressor work	Sabareesh RK, Gobinath N, Sajith V, Das S, Sobhan CB	2012
9	R152a	ZnO (0.5%)	21% less energy utilization. Also suction pressure and discharge pressure were reduced to 10.5% and evaporator temperature was reduced by 6%	Kumar DS, Elansezhian R	2014
10	R134a	Al2O3	Thermal conductivity, dynamic viscosity, and density of nano refrigerant increased by 28.58%, 13.68%, and 11%, respectively.	Mahbubul IM, Saadah A, Saidur R, Khairul MA, Kamyar A	2015

5. Major Problems observed with inclusion of nano particles in refrigerant.

5.1 Stability

The key issues associated with nanofluid are its short lived colloidal state. Nano particles agglomerate and settle down into the base fluid as a separate compound after short time. Therefore it did not behave as nanofluid and loses its remarkable characteristics. Ultrasonication process is one of the best suited method for activate nano particles. Surfactant coating is also used to improve surface charge on the nanoparticles so that they stay repelling each other and doesn't agglomerate and settle down.

5.2 Retention of Nanofluid Purity

Effective filtration and stirring system for recirculation of refrigerant nanofluid is key to maintain purity of the nanofluid. It delivers better heat transfer.

5.3 Increased Density of nano refrigerant

Inclusion of nano particles in refrigerant, it was observed that it increase the density of the fluid considerably. That affects adversely by increasing pressure drop and pumping power. So, it is evident to identify suitable ratio of nano particle inclusion that improve efficiency and performance of the system.

6. Conclusion

Nanofluid with effective cooling and lubricating properties, look promising for the application as nano refrigerant. Researchers experiments support the effective results of nano refrigerant. Empirical review suggest that thermal conductivity of nano refrigerant is increased significantly even upto 150% and energy consumption is reduced upto 26.1% (Bi S. et. al.,2007) and performance of refrigeration system is improved by 4.4% (Jwo et.al., 2009) by utilizing various nano particles in different experimentation. Moreover results indicated increased CoP and 11% reduction in compressor work (Sabareesh RK, 2012). However increased density of nano refrigerant may demand extensive research for successful application of nano refrigerant.

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