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Use of Nanoparticles in the Domestic Refrigeration System – A Review

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***Abstract*—In modern days, Refrigeration systems are key factors for industrial and domestic applications. The main problem with the conventional systems is that they consume more energy as compared to other appliances. The conventional refrigeration systems have been investigated thoroughly in many ways to reduce the energy consumption. The mixture of nanoparticles with the conventional refrigerant, increases the thermodynamic properties of the systems, which results into less energy consumption. If Nanorefrigerants are introduced in the domestic refrigeration system instead of refrigerant, the higher performance can be guaranteed. This review paper reveals the study on the different nanoparticles used in the refrigeration system and the effect of the same on the performance of the refrigeration system.**

***IndexTerms*—Nanorefrigeration system, Nanoparticles, Nanorefrigerant**

I. INTRODUCTION

The expeditious industrialization has led to very high magnification, development and technological progression across the world. It has given elevate to a number of incipient concerns. Today, Global warming and Ozone layer depletion on one hand and spiraling oil prices on the other hand have become major challenges. More and more utilization of fossil fuels is leading to their sharp diminution and nuclear energy is not out of harm's way. In the face of expeditious approaching energy resource crunch there is desideratum for developing thermal systems which consume less energy than the conventional systems. Thermal systems like refrigerators and air conditioners consume substantial amount of energy in terms of electric potency. So avenues of developing energy efficient refrigeration and air conditioning systems with nature amicable refrigerants need to be explored The expeditious advances in nanotechnology have led to emerging of incipient generation heat transfer fluids called nanofluids. Nanofluids are prepared by suspending nanoparticles sized (1-100nm) in conventional fluids and they have higher thermal conductivity than the conventional base fluids.

II. NANOREFRIGERATION SYSTEM

Recently scientists are using nanoparticles in refrigeration systems because of its extraordinary improvement in thermo-physical, and heat transfer capabilities to enhance the efficiency and dependability of refrigeration and air conditioning system. In general, performance of any refrigerant undergoes from its poor heat transfer properties like other conventional thermofluids. Maxwell initiated a work of fiction concept of dispersing solid particles in base fluids to break the fundamental limit of heat transfer fluids having low thermal conductivities. Most of these previous studies on this concept used millimeter or micrometer solid particles, which lead to major problems such as express settling of the solid spherical particles in the fluids, clogging in micro channels and surface scrape. In addition, the high pressure drop caused by these particles limited their practical applications. Nanorefrigerants are established to have good potential to overcome these problems.

The Nanorefrigerant research generally have two ways to add nanoparticles in refrigeration. The first way is by suspending nanoparticles directly to the base refrigerant whereas the other way is to suspend the nanoparticles into the lubricant itself to analyze the system performance. Interestingly, the concept of dispersing nanoparticles in lubricant is also gaining popularity among researchers. They observed a favourable system performance by the addition of nanoparticles into the lubricant.

LITERATURE STUDY

There are several research work already done to improve the performance of a refrigeration system with the help of different alternatives.These are review of literature subjected to Nanorefrigeration system, one of the best way to increase the performance of the conventional refrigeration system.

K. T. Pawaleet al. 2017[1] investigated the performance evaluation of vapour compression refrigeration system with different volume fractions of Al_2O_3 nanoparticles. The experimental setup is shown in the fig 2.1.

Fig. 2. 1Experimental setup

The researchers have used 165 liters domestic refrigerator and Al_2O_3 nanoparticles for their experiment. For the preparation of nanofluid, they have taken the 0.5 wt% and 1.0 wt % of the nanoparticles in order to mix them with the R134a refrigerant. The tests were conducted on simple VCRS first without Nanorefrigerant (R134a) as shown in Fig. 2.1 and then with Al_2O_3 Nano-Refrigerant and results were compared at these two conditions. Refrigeration effect was estimated by means of energy meter connected to heater. Ultimately the heater was supplying heat to evaporator by means of heating water and same amount of heat was removed by refrigerant after achieving steady state. Theoretical COP is evaluated as 4.17 for pure R134a. On the other hand, with R134a+0.5% Al_2O_3 and for R134a+1% Al_2O_3 theoretical COP is found to be 3.75 and 3.54 respectively. Actual COP is evaluated as 2.69 for pure R134a. On the other hand, with R134a+0.5% Al_2O_3 and for R134a+1% Al_2O_3 actual COP is found to be 3.52 and 2.92 respectively. R134a+0.5% Al_2O_3 shows the improvement in actual COP by 30.85% and R134a+1% Al_2O_3 shows the decline in actual COP by around 8.55%. The graph for the comparison of COP is shown below in the fig. 2.2.

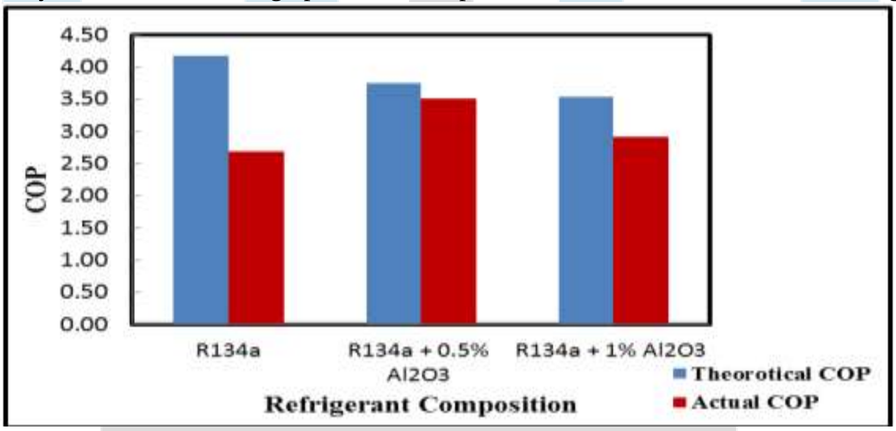


Fig. 2. 2 Graph for the comparison of COP for different volume ratio

during the experiment phase, the addition of 0.5% of Al_2O_3 Nanoparticles in the base refrigerant lead to improvement in the overall performance of the VCRS than that of pure base Refrigerant. However, increase in the percentage of Nanoparticles in the base refrigerant ended with decreased system performance.

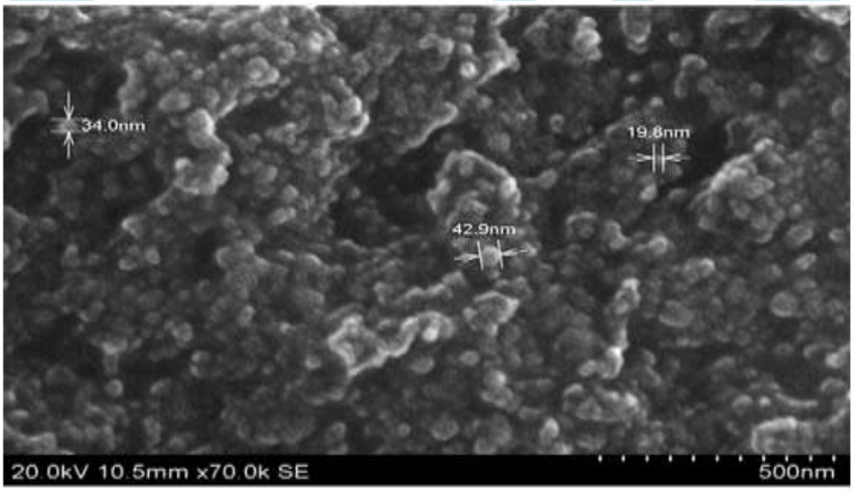
Omer A. Alawi et al. (2015)[2]have published a research paper on the applications of the Nanoparticles and nanofluids in the refrigeration, air-conditioning, and heat pump systems. Thermo physical properties of Nanoparticles suspended in refrigerant and lubricating oils of refrigerating systems were reviewed. The effects of nanolubricants on boiling and two phase flow phenomena were presented as well. Based on results available in the literatures, they have presented that nanorefrigerants have a much higher and strongly temperature-dependent thermal conductivity at very low particle concentrations than conventional refrigerant. This can be considered as one of the key parameters for enhanced performance for refrigeration and air conditioning systems. The results indicatethat HFC134a and mineral oil with TiO_2 Nanoparticles work normally and safely in the refrigerator with better performance. The energy consumption of the HFC134a refrigerant using mineral oil and Nanoparticles mixture as lubricant saved 26.1% energy with 0.1% mass fraction TiO_2 Nanoparticles compared to the HFC134a and POE oil system.

Vipin Nair et al. (2016)[3]have presented a review paper on the present, past and the future of the nanorefrigerants. In this review paper, they have addressed the different methods for the preparation of Nanoparticles. They have presented a review with the help of which one can compare the properties of different Nanoparticles that were used in the past. They have done an attempt to summarize all the aspects of nanorefrigerants such as its preparation, thermo-physical properties, pressure drop in nanorefrigerants, boiling heat transfer and performance of nanorefrigerants in various domestic refrigerators. The thermal conductivity is one of the most important thermo-physical properties of nanorefrigerants because the boiling and convective heat transfer coefficients are a function of the thermal conductivity of the fluid. The addition of Nanoparticles to the refrigerant generally leads to an increase in viscosity of the resultant nanorefrigerants which; as a result, will increase the pressure drop during the flow. However, the improved thermal conductivity and heat transfer performance overshadows the increase in viscosity and pressure drop. Even though the enhancement in the thermal conductivity and heat transfer of nanorefrigerants is much higher than the enhancement in viscosity; it is still important to study the viscosity variations brought by Nanoparticles into the base fluid.

R. Krishna Sabareesh et al. (2012)[4] have used the TiO2 nanoparticles for the refrigeration application.They investigated the effect of dispersing a low concentration of TiO2 nanoparticles in the mineral oil based lubricant, on its viscosity and lubricationcharacteristics, as well as on the overall performance of a Vapor Compression RefrigerationSystem using R12 (Dichlorodifluoromethane) as the working fluid. The values for the system utilizing the raw mineral oil as the lubricant, and with mineral oil having 0.01% volume fraction of TiO2 nanoparticles were compared. To ensure the repeatability in the value of COP, both the experimental cases were repeated five times under the same environmental conditions. Table 4 shows the COP values for the VCR system, with the raw mineral oil and modified mineral oil as the lubricant. The values are found to repeat closely, and the average value was estimated to be 1.22. The COP values of the same system when operated with modified mineral oil as its lubricant,

gave an average COP value of 1.43. In the presence of nanoparticles in the mineral oil, the average heat transfer rate increased by about 3.6%, whereas the compressor work reduced by about 11%, which ultimately resulted in the COP improvement of about 17%. The experimental results suggest the nanoparticle additive to be a very effective option in reducing the power consumption of the system.

HaoPeng et al. (2011)[5] experimentally investigated effect of nanoparticle size on nucleate pool boiling heat transfer of refrigerant/oil mixture with nanoparticles. For the preparation of the test fluid, refrigerant R113, ester oil VG68, and Cu nanoparticles with three different average diameters of 20, 50 and 80 nm were used. Experimental conditions includes a saturation



pressure of 101.3 kPa, heat fluxes from 10 to 80 kW m^{-2}, nanoparticle concentrations in the nanoparticles/oil suspension from 0 to 30 wt%, and nanoparticles/oil suspension concentrations from 0 to 5 wt%. The experimental results indicate that the nucleate pool boiling heat transfer coefficient of R113/oil mixture with Cu nanoparticles is enhanced by a maximum of 23.8% with the decrease of nanoparticle size from 80 to 20 nm under the present experimental conditions, and the enhancement increases with the decrease of nanoparticles/oil suspension concentration or the increase of nanoparticles concentrations in the nanoparticles/oil suspension.

R. Saidur et al. (2011)[6]have found that nanorefrigerants have a much higher and strongly temperature-dependent thermal conductivity at very low particle concentrations than conventional refrigerant. This can be considered as one of the key parameters for enhanced performance for refrigeration and air conditioning systems, because of its superior thermal performances. The comparison of thermal conductivity for dierent nanoparticles is shown in the following fig 2.4.The results indicate that HFC134a and mineral oil with TiO_2 nanoparticles works normally and safely in the refrigerator with better performance. The energy consumption of the HFC134a refrigerant using mineral oil and nanoparticles mixture as lubricant saved 26.1% energy with 0.1% mass fraction TiO_2nanoparticles compared to the HFC134a and POE oil system.

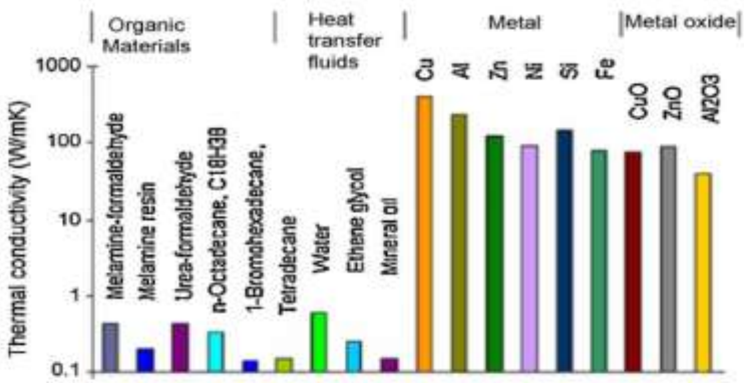


Fig. 2. 4Comparison of the thermal conductivity of common liquids, polymers and solids

Elena Serrano et al. (2009)[7]have researched the various applications of the nanoparticles in their research paper. They have showed the various applications of the nanoparticles with the benefits of nanoparticles for each of the applications. In many cases, the materials we have today are not able to provide the solution at the efficiency required at a feasible cost. Thanks to the unprecedented control over the size, structure, and organization of matter that many nanotechnologists around the World are getting, novel materials with unique properties are already contributing to overcome some of these challenges.
Sheng-shan Bi et al. (2008)[8]experimentallyinvestigatedthe reliability and performance of a domestic refrigerator with nanoparticles in the working fluid. Mineral oil with TiO_2 nanoparticles mixtures were used as the lubricant instead of Polyol-ester (POE) oil in the 1,1,1,2-tetrafluoroethane (HFC134a) refrigerator. The compatibility of nonmetallic materials in the system with the HFC134a and mineral oil–nanoparticles mixtures was studied before the refrigerator performance tests. The refrigerator performance with the nanoparticles was then investigated using energy consumption tests and freeze capacity tests. The results indicate that HFC134a and mineral oil with TiO_2 nanoparticles works normally and safely in the refrigerator. The refrigerator performance was better than the HFC134a and POE oil system, with 26.1% less energy consumption used with 0.1% mass fraction TiO_2 nanoparticles compared to the HFC134a and POE oil system. The same tests with Al_2O_3 nanoparticles showed that the different nanoparticles properties have little effect on the refrigerator performance. Thus, nanoparticles can be used in domestic refrigerators to considerably reduce energy consumption.
Aly M. A. Soliman et al. (2016)[9] theoreticallyinvestigated the performance of a vapor compression cycle with nanoparticles additives in the working fluid. Four different nano materials with R143-a refrigerant were investigated. The performance of the cycle was studied for different condensation and evaporation temperature. By using enthalpy which is obtained through nanorefrigerant density, a model is developed to investigate the performance parameter of the cycle. The model was validated using two of the data given in the literature. The results showed that the coefficient of performance is increased by using nanomaterials additives compared to the pure refrigerant and the maximum value was obtained for R143- a/CuO mixture.

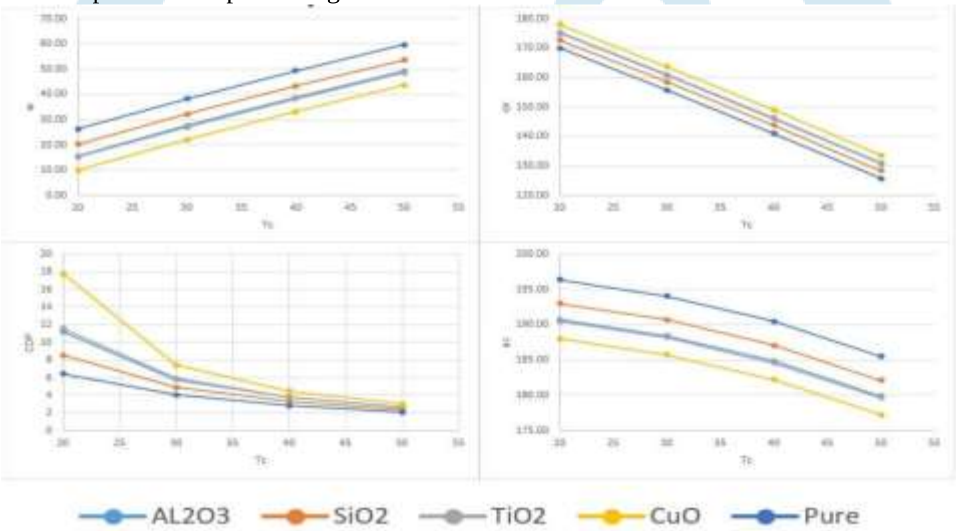


Fig. 2. 5Comparison of Work consumption, COP, Heat interactions for different nanomaterials

As shown in the figure 2.5, we can see that out of all nanofluids mixture that was used in the experiments, CuO gives the maximum performance. The results showed that COP was 3.44 by using the model while it was 1.64 actually and 3.34 theoretically with deviation of about 2.9%.

III. Conclusion

Literatures different applications of Nanoparticles in Mechanical systems are reviewed. There are two approaches for any Nanoparticles to be added in the refrigeration system. First one is to introduce the nanoparticles directly into refrigerant when it is in liquid form. Another approach is to mix the nanoparticles in the lubricant oil and then perform the same process that we used to perform at domestic level. The second approach is getting attention of researchers nowadays, as there are no complexions in the process of making of nanolubricant, and improved results are seen at the end. It is concluded that Nanoparticles actually increase the performance of the refrigeration system when used in the proper fraction. The higher fraction will lead to higher power consumption and thus will result in lower performance. Hence, it is required to find the optimum fraction of nanoparticles that can be used in Domestic refrigeration system and increase the performance of the domestic refrigeration system without much modifications.

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