A Review on Performance of Refrigeration System Using Nanofluids

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Abstract— Recently scientists used nanoparticles in refrigeration systems because of their remarkable improvement in thermo-physical and heat transfer capabilities to enhance the efficiency and reliability of refrigeration and air conditioning system. Heat transfer performance of different nanorefrigerants with varying concentrations was reviewed and review results are presented as well. Pressure drop and pumping power of a refrigeration system with nanorefrigerants were obtained from different sources and reported in this review. Based on results available in the literatures, it has been 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, latest up to date literatures on this property has been summarized and presented in this paper as well.

Key words: Nanoparticles, nanorefrigerants, Refrigeration, Thermal conductivity.

I. INTRODUCTION

The rapid industrialization has led to unprecedented growth, development and technological advancement across the globe. Today global warming and ozone layer depletion on the one hand and spiraling oil prices on the other hand have become main challenges. Excessive use of fossil fuels is leading to their sharp diminution and nuclear energy is not out of harm’s way. In the face of imminent energy resource crunch there is need for developing thermal systems which are energy efficient. Thermal systems like refrigerators and air conditioners consume large amount of electric power. It is essential to develop energy efficient refrigeration and air conditioning systems with nature friendly refrigerants. The rapid advances in nanotechnology have lead to emerging of new generation heat transfer fluids called nanofluids.

Nanofluids are a relatively new class of fluids which consist of a base fluid with nano-sized particles (1–100 nm) suspended within them. These particles, generally a metal or metal oxide, increase conduction and convection coefficients, allowing for more heat transfer out of the coolant. Saidura et al. [5] provided excellent examples of nanometer in comparison with millimeter and micrometer to understand clearly as can be seen in Fig. 1.

By addition of nanoparticles to the refrigerant results in improvements in the thermo physical properties and heat transfer characteristics of the refrigerant, thereby improving the performance of the refrigeration system. In a vapor compression refrigeration system the nanoparticles can be added to the lubricant.

Compared to conventional solid–liquid suspensions for heat transfer intensifications, nanofluids possess the following advantages:

- High specific surface area and therefore more heat transfer surface between particles and fluids.
- High dispersion stability with predominant Brownian motion of particles.
- Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
- Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
- Adjustable properties, including thermal conductivity and surface Wettability, by varying particle concentrations to suit different applications.

II. LITERATURE REVIEW

Many investigators have conducted studies on vapor compression refrigeration systems and to study the effect of nanoparticle in the refrigerant as well as lubricant on its performance. Pawel et al. (2005) conducted studies on nanofluids and found that Performance Analysis of a Refrigeration System Using Nano Fluid there is the significant increase in the thermal conductivity of nanofluid when compared to the base fluid and also found that addition of nanoparticles results in significant increase in the critical heat flux.

Bi et al. (2007) conducted studies on a domestic refrigerator using nanorefrigerants. In their studies R134a was used the refrigerant, and a mixture of mineral oil TiO2 was used as the lubricant. They found that the refrigeration system with the nanorefrigerants worked normally and efficiently and the energy consumption reduces by 21.2%. When compared with R134a/POE oil system. After that Bi et al. (2008) [1] found that there is remarkable reduction in the power consumption 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 nanoparticles in the refrigerant.

Jwo et al. (2009) [6] conducted studies on a refrigeration system replacing R-134a refrigerant and polyester lubricant with a hydrocarbon refrigerant and mineral lubricant. The mineral lubricant included added Al2O3 nanoparticles to improve the lubrication and heat-transfer performance. Their studies show that the 60% R-
134a and 0.1 wt % Al2O3 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%.

Henderson et al. (2010) [11] conducted an experimental analysis on the flow boiling heat transfer of R134a based nanofluids in a horizontal tube. They found excellent dispersion of CuO nanoparticle with R134a and POE oil and the heat transfer coefficient increases more than 100% over baseline R134a/POE oil results.

Bi et al. (2011) [9] conducted an experimental study on the performance of a domestic refrigerator using TiO2-R600a nanofluids as working fluid. They showed that the TiO2-R600a system worked normally and efficiently in the refrigerator and an energy saving of 9.6%.

Sendilkumar and Elansezhian (2012) [4] conducted an experimental study on the performance of a domestic refrigerator using Al2O3-R134a nanofluids as working fluid. They found that the Al2O3-R134a system performance was better than pure lubricant with R134a working fluid with 10.30% less energy used with 0.2% of the concentration used and also heat transfer coefficient increases with the usage of nano Al2O3.

Krishna sabareesh et al (2012) conducted an experimental study on the performance of a domestic refrigerator using TiO2 - R12 nanofluid working fluid. They found that the freezing capacity increased and heat transfer coefficient increases by 3.6 %, compression work reduced by 11% and also coefficient of performance increases by 17% due to the addition of nanoparticles in the lubricating oil.

Reji kumar and Sridhar (2013) [8] conducted an experimental study on the performance of a domestic refrigerator using R600a/mineral oil/nano-Al2O3 as working fluid. They found that the refrigeration system with nano-refrigerant works normally. It is found that the freezing capacity is higher and the power consumption reduces by 11.5 % when POE oil is replaced by a mixture of mineral oil and Aluminium oxide nanoparticles.

T. Coumaressin and K. Palaniradja (2014) [6] conducted an experimental study on the performance of a domestic refrigerator using CuO-R134a nano-refrigerant as working fluid. The experimental studies indicate that the refrigeration system with nanofluids works normally. Heat transfer coefficients were evaluated using FLUENT for heat flux ranged from 10 to 40 kW/m2, using nano CuO concentrations ranged from 0.05 to 1% and particle size from 10 to 70 nm. It is found that the evaporation heat transfer coefficient with the increase of CuO concentration up to 0.55% then decreases. At 0.55% concentration the evaporating heat transfer coefficient has its highest value for all values of heat flux.

Meibo Xing et al. (2014) [12] worked on a fulleren C60 nano-oil & he found that C60 nano-oil is proposed as a promising lubricant to enhance the performance of domestic refrigeration compressors. The stability of fullerene C60 nanoparticles dispersed in a mineral oil and the lubrication properties of the nano-oil were investigated experimentally. The applications of the nano-oil with the specific concentration of 3 g/l to two domestic refrigerator compressors were examined by compressor calorimeter experiments. The results shows the COPs of two compressors were improved by 5.6% and 5.3%, respectively, when the nano-oil was used instead of pure mineral oil.

In the literatures a number of reviews on thermal and rheological properties, different modes of heat transfer of nanofluids have been reported by many researchers. However, to the best of author’s knowledge, there is no comprehensive literature on the nanoparticles as additives with conventional refrigerants and oils used in refrigeration system. It is hope that this review will be useful to fill identified research gaps and to overcome the challenges of nanorefrigerants.

### III. POOL BOILING HEAT TRANSFER PERFORMANCE

The phase change heat transfer characteristics of the refrigerant- based nanofluids in the heat exchangers, especially in the evaporator, is an important factor to consider. In order to investigate the overall performance of the heat exchangers of refrigeration systems using refrigerant-based nanofluids, the heat transfer characteristics of them must be known. It is reported that the concentration of nanoparticles in nanorefrigerants has influence on the boiling heat transfer coefficient as the thermo-physical properties, influence the boiling heat transfer coefficient such as thermal conductivity and viscosity and they change with the change of concentration of nanoparticles in the base fluid.

The researches on the boiling heat transfer characteristics of refrigerant-based nanofluids are focused on the pool boiling heat transfer and there are no notable published researches on the boiling cooling heat transfer characteristics of refrigerant based nanofluids.

Wu et al. observed that the pool boiling heat transfer was enhanced at low nanoparticles concentration of TiO2 in R11 but deteriorated under the condition of high nanoparticles concentration. Researches on the boiling heat transfer characteristics showed that the type of nanoparticles or fluid, the nanoparticles concentration, the heat flux and the type of heating surface have influences on the nucleate boiling heat transfer of nanofluids.

### IV. LUBRICITY AND MATERIAL COMPATIBILITY

A few investigations were carried out with nanoparticles in refrigeration systems to use advantageous properties of nanoparticles to enhance the efficiency and reliability of refrigerators.

For example, Wang and Xie found that TiO2 nanoparticles can be used as additives to enhance the solubility of the mineral oil in the hydro fluorocarbon (HFC) refrigerant. In addition, refrigeration systems using a mixture of HFC134a and mineral oil with TiO2 nanoparticles appear to give better performance by returning more lubricant oil back to the compressor compared to systems using HFC134a and POE oil.

Peng et al. discussed the replacement of the R134a refrigerant and polyester lubricant with a hydrocarbon refrigerant and mineral lubricant. The mineral lubricant with Al2O3 nanoparticles (0.05, 0.1, and 0.2 wt %) was used to improve the lubrication and heat transfer performance. Experimental results indicated that the 60% R134a and 0.1
wt% Al₂O₃ nanoparticles were optimal. Under these conditions, the power consumption was reduced by 2.4%, and the coefficient of performance was increased by 4.4%. These results show that replacing R134a refrigerant with hydrocarbon refrigerant and adding Al₂O₃ nanoparticles to the lubricant effectively reduced power consumption.

Lee et al. presents the friction and antwear characteristics of nano-oil composed of refrigerator oil and fullerene nanoparticles in the sliding thrust bearing of scroll compressors. The friction coefficient of fullerene nano-oil at the lower normal loads (>1200 N) under the fixed orbiting speed (1800 rpm) was 0.02 while that of pure oil was 0.03, indicating that the fullerene nanoparticles dispersed in the base refrigerant oil improved the lubrication property by coating the friction surfaces. However the differences between friction coefficients for both nano-oil and pure oil were found to be negligible at higher normal loads conditions (>1200N), indicating that the nanoparticles in the base oil have little effect on the enhancement of lubrication between the friction surfaces. The friction coefficient of nano-oil at various speeds of the orbiting plate in the sliding thrust bearing was found to be less than that of pure oil over the entire orbiting speed ranging between 300 and 3000 rpm. This is presumably because fullerene nanoparticles, which were inserted between the friction surfaces, improved the lubricating performance by increasing the lubricant oil viscosity and simultaneously preventing direct metal surface contacts.

The tribological properties of fullerene nanoparticles-added mineral oil were investigated as a function of volume concentration of fullerene nanoparticle additives (e.g., 0.01, 0.05, 0.1, and 0.5 vol%) by Jaekeun L. Authors reported that the nano-oil containing the higher volume concentration of fullerene nanoparticles resulted in the lower friction coefficient and less wear in the fixed plate, indicating that the increase of fullerene nanoparticle additives improved the lubrication properties of regular mineral oil.

From fig. 2 the friction coefficient of nano-oil IV was found to be 0.02, which is the lowest friction coefficient among various nano-oils. Therefore, it can be stated that oil with more fullerene nanoparticle additives shows enhanced lubrication property.

V. VISCOSITY OF NANO-OIL

Fig. 3 shows the kinematic viscosity of nano-oils as a function of volume fraction of fullerene nanoparticles in suspension for temperature ranging from 40 to 80 °C. There was no considerable change in the kinematic viscosity of nano-oil at the various volume fractions of nanoparticles, indicating that the kinematic viscosity of nano-oils is a weak function of oil temperature considered. Fig. 4 shows the change of kinetic viscosity as a function of volume fraction and temperature of the oil. When particles are added, the increase rate of viscosity of the nano-oil is within 1%. In the temperature range for a compressor with time, the viscosity of the nano-oil is about the same as for the mineral oil, but the viscosity of the nano-oil increases by 7% at 20 °C in comparison with the mineral oil.

![Image](image_url)

Figure 3. Kinematic viscosity of nano-oils as a function of fullerene nanoparticles concentration and oil temperature ranging from 40 to 80 °C

![Image](image_url)

Figure 4. Kinetic viscosity of fullerene-in-oil as a function of particle concentration and temperature

VI. CONCLUDING REMARK

- Based on the literatures, it has been found that the thermal conductivities of nanorefrigerants are higher than traditional refrigerants. It was also observed that increased thermal conductivity of
nanorefrigerants is comparable with the increased thermal conductivities of other nanofluids.

- It has been observed that heat transfer enhancement can be achieved from a minimum value of 21% to a maximum value of 27.5% using nanorefrigerants compared to traditional refrigerants.
- Exact mechanism of enhanced heat transfer for nanofluids is still unclear as reported by many researchers.
- Nanofluids stability and its production cost are major factors that hinder the commercialization of nanofluids. By solving these challenges, it is expected that nanofluids can make substantial impact as coolant in heat exchanging devices.

VII. PRESSURE DROP PERFORMANCE OF NANOREFRIGERANT

In the modern avenue of research, refrigerant-based nanofluids formed by suspension of nanoparticles in pure refrigerants have been used as a new kind of working fluid to improve the performance of refrigeration systems. Presence of nanoparticles in suspension form may change the pressure drop characteristics of the fluid, so this characteristic needed to be understood in selecting the refrigerant. Liquid solid phase pressure drop characteristics and liquid solid and vapor phase (phase change) pressure drop characteristics of nanofluids are studied by different researchers. Li and Kleinstreuer studied by simulation of the pressure drop characteristics of solid and liquid phase of fluid.

Pressure drop developed during the flow of coolant is one of the important parameters determining the efficiency of nanofluids application. Pressure drop and coolant pumping power are closely associated with each other. There are few properties which could influence the coolant pressure drop: density and viscosity. It is expected that coolants with higher density and viscosity experience higher pressure drop. This has contributed to the disadvantages of nanofluids application as coolant liquids. Yu et al. and Lee et al. investigated viscosity of water based Al2O3 nanofluids and ethylene glycol based ZnO nanofluids. Results clearly show, viscosity of nanofluids is higher than base fluid. Praveen et al. in their numerical study reviewed that density of nanofluids is greater than base fluid. Both properties are found proportional with nanoparticles volume fraction. Several literatures have indicated that there is significant increase of nanofluids pressure drop compared to base fluid. Lee and Mudawar revealed that single phase pressure drop of Al2O3 nanofluids in micro-channel heat sink increases with nanoparticles concentration. Vasu et al. studied the thermal design of compact heat exchanger using nanofluids. In this study, it is found that pressure drop of 4% Al2O3 + H2O nanofluids is almost double of the base fluid. Pantzali et al. reported there was substantial increase of nanofluids pressure drop and pumping power in plate heat exchanger. About 40% increase of pumping power was observed for nanofluids compared to water.

Peng et al. reported that the frictional pressure drop of refrigerant-based nanofluids flow boiling inside the horizontal smooth tube is larger than that of pure refrigerant, and increases with the increase of the mass fraction of nanoparticles. The maximum increase of frictional pressure drop was found to be about 20.8% under the experimental conditions. Fig. 5 shows the pressure drop of nanorefrigerants with different concentrations and R113.

VIII. FUTURE RESEARCH

As far as for better understanding of nanofluids, further research is needed. An important focus for future research should be determining the key energy transport mechanism in nanofluids. Mostly heat transfer depends on Thermal conductivity of nanofluid. The thermal conductivity of nanofluids can be a function of parameters such as particle shape, particle agglomeration etc. therefore future research should be focused on finding out the main parameters affecting the thermal conductivity of nanofluids. Theoretical predictions should be evaluated in terms of agreement with experiments regarding concentration, particle size and temperature dependence. Currently, the available nanoparticles are limited and their specifications are not accurate. The challenging point is to obtain the desirable nanoparticles product. The development of the nanoparticle production technique will be very helpful for the nanofluid research. We have to face public concern about their safety both in production and in use. Nanofluids engineers would be prudent to pursue green designs by choosing nontoxic...
or biodegradable nanoparticles. So in last we can say that low cost, high volume.

From the literature survey it is observed that till the optimal nanofluid is not founded which will tell that the combination of base refrigerant and nanofluid.

**IX. CONCLUSION**

The effects of variable density and variable specific heat on maximum pressure, maximum temperature, bearing load, frictional loss and side leakage in high-speed journal bearing operation are examined. The calculation results are compared with the results calculated under various properties of lubricating oil with nanoadditives used in hydrodynamic bearing like load carrying capacity, friction loss, wear resistance.

The study reveals that by adding in nanoparticle in lubricating oil, it is found that increase in load carrying capacity in comparison to plain engine oil. Considering present day energy scenario and the ever increasing severity in operating conditions of machineries, it is imperative that we develop better tribological practices leading to reduced losses due to friction and wear. Journal bearings, being the more popular support mechanism in high speed applications, have been the focus of research for many tribologists.

**REFERENCES**


