Review on the thermo-physical properties and improving the performance of refrigeration system using nanofluids.

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Abstract— **Nanofluids as a working fluid are reckoned to be a promising choice for quite a few modern day heat transfer applications. The superior thermo-physical properties of nanofluids have led to a significant awareness for energy conservation and improvement in the efficiency of several thermal systems, encompassing refrigeration systems. Nanoparticles are suspended in a base refrigerant to form nanorefrigerants, a class of nanofluids. This paper consists of an extensive review of nanofluid based refrigeration systems, taking into account, their thermo-physical properties and performance characteristics. Thermal conductivity and other properties being dependent on temperature can increase the efficiency of thermal systems, while working at high temperature. A review consisting of a study of performance characteristics and thermo-physical properties has been presented in this paper. Moreover, recent studies related to nanofluid based refrigeration systems have been summarized in the paper.**

***Keywords*— nanofluids; heat transfer; thermal systems; nanorefrigerants; performance**

I. INTRODUCTION

Energy security is one of the biggest challenges in today's world. Energy is required on large scale in refrigeration and air-conditioning systems. It can primarily be achieved by improvement in the design of components of the systems. Secondly, a change in the type of working fluids , helps in improving the efficiency. Taking into account, the improvement in design parameters, compact systems such as shell and tube, plate type and micro channel type heat exchangers are being used nowadays. For the latter condition, i.e. change in type of working fluid, after an extensive research, it was concluded that a new form of fluid called as nanofluid gives improved results by significantly increasing the performance of the systems. Firstly, using nanoparticles helps in improving the solubility between the refrigerant and the lubricant. Secondly, the addition of nanoparticles enhances the heat transfer characteristics of the base refrigerant. Finally, the use of nanorefrigerant reduces the coefficient of friction and wear rate, in comparison to regular refrigerant. Simultaneously, the amount of energy consumption is also reduced along with reduced emissions, which otherwise results in global warming and greenhouse-gas effects.

II. LITERATURE REVIEW

Bhattad, et.al [1] have concluded that the freezing rate increases for optimum nanoparticle concentration due to increase in thermal conductivity and heat transfer coefficient, the thermal conductivity of nanofluid increases with temperature and volume concentration. However, it increases with decreasing particle size, the viscosity of nanofluid increases with the increase of the particle volume concentration. However, it decreased with the increase of temperature. Hence, pressure drop and friction loss also decreased with increase in temperature, specific heat of nanofluid also increased with temperature and volume concentration, density increased with the volume concentration of nanoparticle and decreased with increase in temperature, surface tension increased with the increase of the particle concentration and decreases with the increase of temperature.

I.M. Mahabubul [2] et.al analysed the thermal performance of Al_2O_3/R-134a nanorefrigerant. The thermal conductivity of Al_2O_3/R-134a nanorefrigerant was increased with an increase in temperature. Their results showed an enhancement of 28.58% in thermal conductivity for nanorefrigerant as compared to the base refrigerant. This enhancement also led to a 15% increase in the COP of the refrigeration system. The viscosity and density of the nanorefrigerant were also found to be augmented by 13.68% and 11%, compared to pure refrigerant. The specific heat capacity of the system was also found to be increased with an increase in temperature.

Omer A. Alawi [3] et.al through their experiments concluded that volume fractions and temperature had considerable effects on specific heat, density and viscosity of nanofluid based refrigerants. Their results indicated that when the volume of nanoparticle was increased, the viscosity was augmented. However, with an increase in temperature, the viscosity was decreased. Density also showed the same behaviour with increase in temperature. The specific heat increased by increase in temperature, while it decreased by an increase in the concentration of nanoparticle in the base fluid.

Dhamneya et.al [4] have experimentally studied the vapour compression refrigeration system by coupling it with evaporative cooling pad and nano-refrigerant , for improving the performance of the system in hot and dry climate condition. Performance of air cooled condenser minimized and COP decreased extensively in chillers due to decrease in heat transfer rate, therefore through experimental investigation, they concluded that combined evaporate cooling system and ice plant test rig offered appropriate heat rejection. The COP increased by 51% in hot and dry climate condition than the normal system.

Fig 2.1 Ice plant Test Rig

Ndoye, et.al [5] numerically studied the energy performance of nanofluids used in secondary loops of refrigeration systems. They developed a mathematical model in order to predict the energy performance of refrigerating systems using nanofluids for application in refrigeration plants of cold chain. It was based on a combination of effectiveness number of transfer unit method and classical heat transfer and fluid hydrodynamic correlations. They used a Performance Evaluation Criterion (PEC) which compared the heat flow rate transferred to the required pumping power in refrigeration system. They concluded through simulations that heat transfer nanoparticle concentration for laminar and turbulent flow regimes. However, pressure drop also increased with increase in concentration of nanoparticles. Through PEC, they concluded that optimized concentration was required for favourable energy performance as some of the nanofluids were less effective than the base fluid.

Ahmed et.al [6] have experimentally investigated the performance of chilled water air conditioning unit with and without alumina nanofluids. They have added the Al_2O_3 nanoparticles with water in cooling tank using different concentrations by weight. Also, they have continuously supplied alumina nanofluids to the cooling coil. The operating conditions included a variation of flow rate of chilled water/alumina nanofluid and the air through cooling coil. The experimental results showed that, less time was required to obtain the desired chilled fluid temperature for all concentrations compared to pure water. They concluded from the thermal performance of chilled water air conditioning unit that, there is an improvement of heat transfer characteristics of working fluid due to addition of nanoparticles.

III. THERMO-PHYSICAL PROPERTIES OF NANOFLUIDS

Thermal Conductivity

Thermal conductivity is an important property of nanofluids for the enhancement of heat transfer performance. The heat transfer rate and heat transfer coefficient largely depend on thermal conductivity. Studies have shown that thermal conductivity increases with the use of nanofluids and it depends on various parameters such as temperature, particle shape, particle size, volume fraction and pH value. For Al2O3/R-134a refrigerant an enhancement of 28% in thermal conductivity was found. O.A Alawi et.al investigated the thermal conductivity for CuO/R-134a using mathematical correlations. The investigation for nanorefrigerant performance was carried out for volume concentrations from 1 to 5% and nanoparticle diameter of 20 nm through the course of the analysis. Thermal conductivity increased with increase in nanoparticle volume concentrations. It also increased with increase in temperature of the mixture.

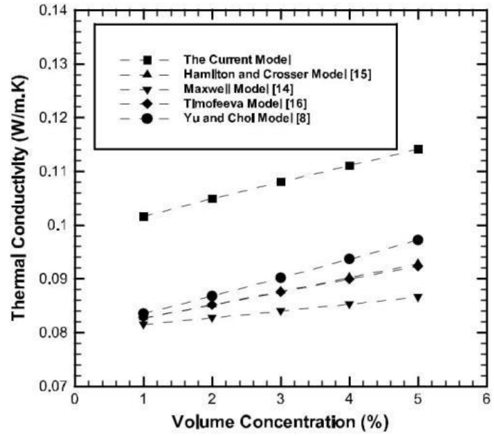

Fig 3.1 Variation of thermal conductivity of CuO/R134a as a function of particle volume . .

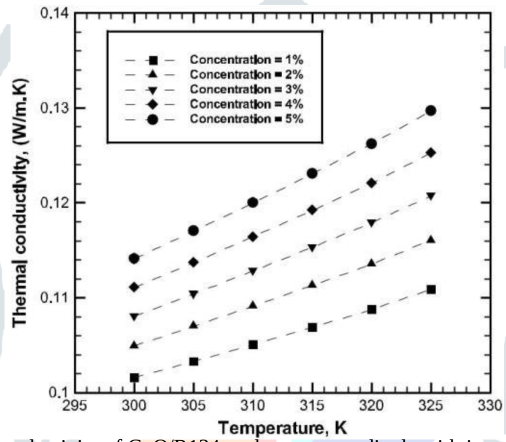

Fig 3.2 Thermal conductivity of CuO/R134a enhances accordingly with increase in temperature.

Viscosity

Viscosity is a significant thermo-physical property which influences both pressure drop and both pressure and heat transfer of nanofluid as the dynamic viscosity increases there is a drop in convective heat transfer coefficient and frictional pressure drop and hence the pumping power is increased. Mahabubul et.al carried out an investigation to determine the effect of volume fraction and temperature on viscosity of R134a, R141b and R123 based nanofluid and observed that viscosity of nanofluid formed, increased with nanoparticle concentration and decreased with increasing temperature. They also concluded that the viscosity of nanofluid increased by 13.68% comparatively for the same temperature. Alawi et.al experimentally investigated the effect of temperature and volume concentration on viscosity R123-TiO_2 nanofluid and found out that viscosity of nanofluid increase with increase in Volume concentration and decrease in temperature.

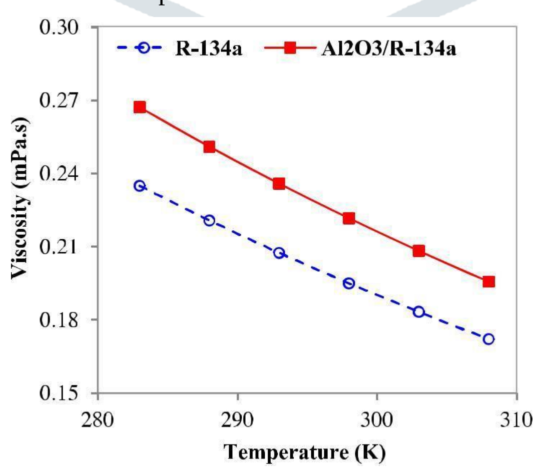

Fig 3.3 Variation of viscosity as afunction of temperature.

Density and Specific heat

Density and specific heat have significant influence on the heat transfer characteristics of nanofluid. Generally, density increases and specific heat decreases due to the addition of nanoparticles in the base fluid. Mahabubul[] et.al anlayzed thermo-physical properties Al_2O_3 /R134a nanofluid and found out that the density of Al_2O_3/R134a nanofluid increased by 11% in comparison to the base refrigerant for same temperature. Whereas the specific heat nanofluid is lower than that of R134a. Alawi et.al[] investigated effect of temperature and volume concentration on thermo physical properties of CuO/R134a nanofluid and observed that density of nanofluid increases with increase in volume concentration and decrease in temperature.

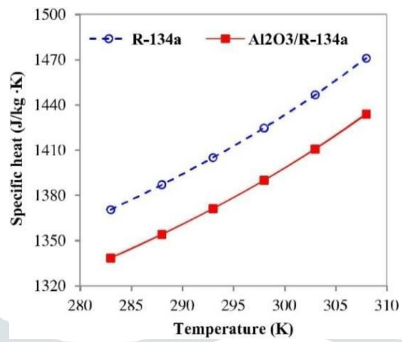

Fig 3.4 Variation of specific heat as a function of temperature.

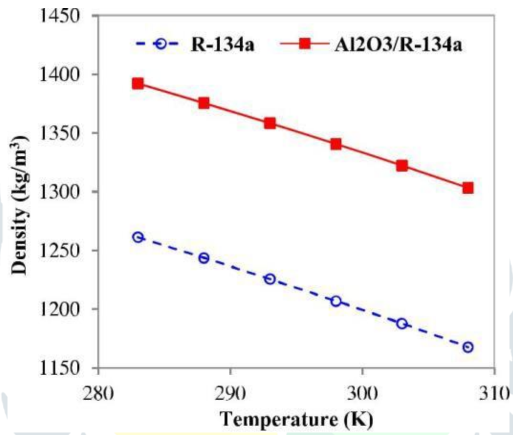

Fig 3.5 Variation of density as a function of temperature.

IV. PERFORMANCE ENHANCEMENT USING NANOFLUIDS

To meet the daily increasing demand for cooling especially in refrigerators, to avoid spoilage of food products many researchers are working on improving the design and properties of working fluids. Using nanofluids as refrigerants will impro ve the condensation as well as boiling heat transfer coefficient which results in light and compact refrigeration systems. These systems are energy efficient as the consumption of compressor power is less. Using nanoparticles as additives also increases the solubility between the base fluid and the lubricant, which in turn increases the life of compressor. A few significant facts that were observed during boiling and condensation phenomenon are:

1. A disturbance in a cluttered condition of nanoparticles reduce the boundary layer thickness due to which thermal resistance is decreased and heat transfer rate is increased.
2. Condensation results in nanoparticles getting deposited on the cooling or heating surface which increases the heat transfer rate and also the heat transfer coefficient.
3. The absorption of liquid particles by nanoparticles enhances the heat transfer rate.
4. Depending on the type of nanoparticles and concentration evaporation rate can be enhanced.
5. Mixing the nanoparticles into the base refrigerant decrease the freezing point and increases the boiling point.

V.CONCLUSION

A review of application of nanofluids in the refrigeration and air conditioning system is presented in this paper. Thermophysical properties of nanofluids and performance enhancement are discussed. Following conclusions can be made.

1. For optimum nanoparticle concentration, the freezing rate is increased due to increase in thermal conductivity and thermal heat transfer coefficient.
2. Thermal conductivity of nanofluid increases with increase in temperature and volume concentration. However it is increased with decreasing particle size.
3. The specific heat of nanofluid is also increased with volume concentration and temperature.

4. Density is increased with increased volume concentration of nanoparticle and decrease with an increase in temperature.

Nanofluids as a primary fluid are a significant application in the sector of refrigeration, lubrication, etc. as well as seco ndary fluid in condenser and evaporator as a result of their heat transfer enhancement characteristics.

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