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Vapour compression refrigeration systems using nano materials mixed with R718 in secondary circuit of evaporator for enhancing thermodynamic performances

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Abstract

Now a day's refrigeration based equipment are most important for industrial and domestic applications. These systems utilized more energy as compared with other appliances. For reducing energy consumption, nanoparticle based refrigerant has better properties in terms of increased the heat transfer performance of base refrigerant in the vapour compression refrigeration system. Several types of solid and oxide materials could be used as the nanoparticles to be suspended in the conventional refrigeration systems. In this paper, the effect of the suspended copper oxide (CuO), Titanium Oxide (TiO_2), Aluminum Oxide (Al_2O_3), into eco friendly refrigerants (i.e. R134a, R407c and R404a) is investigated.
The use of nano refrigerant as a primary fluid in vapour compression refrigeration systems was studied in detailed and simulation program was develop to solve nonlinear equations of the system model using NTU approach and the effect of changes in performance parameters to the second law performance in terms of exergetic efficiency of VCR system carried out. The effect of the thermal conductivity, dynamic viscosity, and heat transfer rate of the nano-refrigerant/refrigerant of VCRS on system performance have been presented.

Keywords: VCR, Energy-Exergy Analysis, Energy-Exergy Analysis, Nano refrigerants

1. Introduction

Now a day's refrigeration based equipment are most important for industrial and domestic applications. Those systems utilize more energy compare to other appliances. The refrigeration systems have been severely investigated to reduce the energy consumption in many research articles. Hence, nanoparticle based refrigerant has been introduced a superior properties refrigerant that increased the heat transfer performance of base refrigerant of the refrigeration system. Many types of solid and oxide materials could be used as the nanoparticles to be suspended into the conventional refrigerants. In this project work, the effect of the suspended copper oxide (CuO), Titanium Oxide (TiO_2), Aluminum Oxide (Al_2O_3), into the R134a, R407c and R404 eco-friendly refrigerant will be investigated by using mathematical modeling.
The use of nano refrigerant a primary fluid in vapour compression refrigeration systems was studied and computational simulation program for the same is supposed to develop to solve the nonlinear equations of the system model. Also in this research work it is supposed to analyze the effect of these changes to the second law performance of the system. The investigation includes the thermal conductivity, dynamic viscosity, and heat transfer rate of the nano-refrigerant/refrigerant with complete system geometry of VCRS. It is also expected that after implementation of these systems in our existing systems how much cost can be reduce by this research work.

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2. Vapour compression Refrigeration systems

Vapour compression is used to transfer heat from low temperature zone higher temperature zone. It has four thermodynamics process as below. Isobaric Evaporation, Isentropic Compression, Isobaric Condensation, Throttling (Expansion), Vapour compression cycle can be used in temperature range 50 to -40°C easily. Nowadays, there is a high energy consumption associated with refrigeration and air conditioning systems. Most of these facilities are based on the vapour compression cycle. In order to reduce their consumption, it is necessary both to have efficient systems and to operate them properly. To achieve these objectives, it is convenient to use complete models, which take under consideration a large amount of factors and facilitate the design of efficient systems. The heat transfer from the refrigerant at the compressor discharge line to the condenser inlet has been modeled, due to the considerable length of the line in the experimental chiller facility, using expression. The condenser behavior is modeled by dividing the heat exchanger into two zones: the superheated vapor zone and the condensing zone, assuming no sub-cooling at the condenser outlet, as it has been stated in the assumptions. The overall heat exchanger is then For the computation of the convection heat transfer coefficient associated to the refrigerant one can distinguish between the convection heat transfer coefficient in the superheated vapor zone modeled with two energy balances, one using the secondary fluid heat flow rate.

3. Literature Review

A few studies have been illustrated as a part of literature review related to theoretical study and experimental investigation of refrigeration systems based on first law and second law analysis with different pairs of refrigerants, nanoparticle behaviour and application of nano fluid in vapour compression refrigeration system.

Jwo et al. [4] investigated the replacement of polyester lubricant and R-134a refrigerant with mineral lubricant and hydrocarbon refrigerant. The mineral lubricant contains Al_2O_3 nanoparticles to improve the lubrication and performance of heat-transfer. Their studies show that the R-134a at 60% and Al_2O_3 0.1 wt % nanoparticles were optimum .Under these conditions, the consumption of power was reduced by 2.4%, and the C.O.P. was increased by 4.4%. Peng et al. [5] investigated with an experiment that nucleates boiling heat transfer property of refrigerant/oil mixture containing diamond nano particles. The refrigerant used was R113 and the oil was VG68. They found out that the nucleate pool boiling heat transfer coefficient of R113/oil mixture with diamond nanoparticles is larger than the R113/oil mixture. They also proposed a general correlation for calculating nucleate boiling coefficient heat transfer of mixed refrigerant/oil with nanoparticles, which fully satisfies their experimental results. Henderson et al. [6] conducted an experimental analysis on the flow boiling heat transfer coefficient of R134a (refrigerant) based nano fluids 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. Bobbo et al. [7] conducted a study on the influence of dispersion of single wall carbon Nano horns (SWCNH) and Ti2O3 on the tribological properties of POE oil together with the effects on the solubility of R134a at different temperatures. They showed that the tribological behavior of the base lubricant can be either improved or worsen by adding nanoparticles. On the other hand the nanoparticle dispersion did not affect significantly the solubility. Bi et al. ([8] conducted an experimental study on the performance of a domestic refrigerator using Ti2O3 -R600a nano refrigerant as working fluid. They showed that the Ti2O3-R600a system worked normally and efficiently in the refrigerator and an energy saving of 9.6%. They too cited that the freezing velocity of nano refrigerating system was more than that with pure R600a system. The purpose of this article is to report the results obtained from the experimental studies on a vapour compression system. Lee et al. [9] investigated the friction coefficient of the mineral oil mixed with 0.1 vol.% fullerene nanoparticles, and the results indicated that the friction coefficient decreased by 90% in comparison with raw lubricant, which lead us to the conclusion that nanoparticles can improve the efficiency and reliability of the compressor. Wang and Xie [10] found that Ti2O3 nanoparticles could be used as additives to enhance the solubility between mineral oil and hydrofluorocarbon (HFC) refrigerant. The refrigeration systems using the mixture of R134a and mineral oil appended with nanoparticles Ti2O3, posses to give best performance by returning more vol of lubricant oil return to the compressor, and had the similar performance compared to the systems using polyol-ester (POE) and R134a. In the present study the refrigerant selected is R600a and the nanoparticle is alumina. Isobutane (R600a) is more widely adopted in domestic refrigerator because of its better environmental and energy performances. In this paper, a new refrigerator test system was built up according to the National Standard of India. A domestic R600a refrigerator was selected. Al_2O_3-R600a nano-refrigerant was prepared and used as working fluid. The energy consumption test and freeze capacity test were conducted to compare the performance of the refrigerator with nano-refrigerant and pure refrigerant so as to provide the basic data for the application of the nanoparticles in the refrigeration system. Heris et al.[11] in their experiment they have examined the convective heat transfer coefficient through a circular tube maintaining temperature of tube wall for boundary condition for nano fluids consisting containing Al_2O_3 and CuO oxide nanoparticles in water considering water as a base fluid. In the experiment they have chosen a tube having 6 mm diameter and length 1meter copper tube. Thickness of copper tube is taken 0.5 mm and another outer stainless steel tube having 32 mm diameter. In their experiment nano fluid flow inside the copper tube and saturated stean in the annuli section of the steel tube makes constant wall temp. The fluid after then goes to a heat exchanger where water was used for cooling the test chamber. The experimental result concluded that homogeneous model (single phase correlation of nanofluid) was not able to calculate enhancement of coefficient of heat transfer of nanofluid. The experimental result shows that the heat transfer coefficient predicted for CuO/water and Al_2O_3 /water of homogeneous model were very close to each other but when they increase the vol. % concentration of nanoparticle much higher coefficient of heat transfer observed for Al_2O_3 /water. They have concluded that the coefficient of heat transfer of nanofluid depend upon many factor such as nanoparticle diameter and thermal conductivity of nanoparticle, movement of nanoparticle suspension process of nano particle etc. Y. He et al. [12] conducted an experiment to find out the behavior of nanofluid under laminar and turbulent flow. Their experiment consist a heating and cooling unit, a flow loop and a measurement unit. The test section consist a straight vertically oriented copper tube having 1834 mm length and 6.35 outer 3.97 mm inner diameter. In the experiment they heated the tube with help of 2 silicon rubber flexible heater. For the constant heat flux condition in the test section they provided a thermally insulated layer. For measurement the pressure drop 2 pressure transducer ware used. They have experimented the effect of Reynolds number nanoparticle size, concentration of nanopraticle in the base fluid. They concluded that suspension of nanoparticle into the host fluid the enhancement of thermal conductivity of base fluid may achieved and as well we go for decreasing particle size and increasing concentration the enhancement increases. Thus the nanoparticle concentration and particle size paly major role in enhancement of thermal conductivity of base fluid in both turbulent and laminator flow. They have also concluded that the pressure drop by using nanofluid were close to the base fluid. Kulkarni et al., [13] investigated the heat transfer performance also fluid dynamics performance of nanofluids using SiO2 nanoparticle suspended in the ration of 60:40 weight % in to the EG/water mixture. A test section they have taken for this experiment having copper tube 3.14 mm inside and 4.76 mm outer diameter and 1m length. To measure the wall temperature they fitted 6 no. of thermocouple on surface of the copper tube along the length, the outlet and inlet temperature measurement they used 2 thermocouple at the outlet and inlet section respectively. To isolate the thermal heat transfer two plastic fitting ware provided at the inlet and outlet section respectively. To obtain the constant heat flux four strip heater were used. The whole test section was insulated with 10 cm fiber glass to reduce the heat loss from the test section to the ambient. To maintain the constant inlet temperature of fluid four shell and tube type heat exchanger with counter flow were used. In their experiment they have investigated the effect of enhancement of convective heat transfer of nanofluid with diameter of nanoparticle 20nm, 50nm and 100nm in the turbulent region by increasing volume concentration of nanoparticle and pressure drop recorded when they increase the concentration of nanoparticle in the nanofluid. Hwang et al., [14] investigated the convective heat transfer coefficient of Al_2O_3 /water based nanofluid. In their experiment nanofluid considered flowing through circular tube having 1.812 mm inside diameter and maintaining constant heat flux for fully developed laminar regime. Al_2O_3 /water based nanofluids with various volume % concentration 0.01% to 0.3% are manufactured with two-step method. They have also obtained the thermo physical property of nanofluid such as density, viscosity, heat capacity and thermal conductivity. They have concluded that the convective heat transfer coefficient enhancement occurs with 0.01 and 0.3 vol % concentration of nanoparticle in fully developed laminar regime and heat transfer enhancement about 8 % obtained under the same Reynolds number of base fluid. They also concluded that enhancement in heat transfer coefficient were much higher that the thermal conductivity enhancement at the same vol % concentration of nanoparticle. Sharma et al.,[15] investigated to evaluate friction factor and heat transfer coefficient with a inserted twisted tape in the flow region of tube with Al_2O_3 nanpfluid they have consider a test section of L/D ration 160 and 1.5m length. For uniform heating test section were wrapped with 1 Kw .The aluminum strip having 0.018mm width and 1mm thick are used. Test section is subjected to 180° twist br holding both end of test section in lathe machine obtaining 5, 10 and 15 twist ratio. Ther result show enhancement in heat transfer coefficient with Al_2O_3 nanoparticle into the base fluid compare to the base water. The heat transfer coefficient was 23.7 % higher that the water at Reynolds number 9000. Yu et al., [16] investigated the heat transfer coefficient of silicon carbide nanoparticle having diameter 170nm and 3.7 vol % suspended into the pure water and found that an increment in heat transfer coefficient about 50-60 % compared to host fluid.their test section was stainless steel tube with 4.76 mm outside diameter and 2.27 inside diameter. Their test rig have heat exchanger flow meter horizontal tube, pre heater as a closed loop system. They concluded that enhancement is 14-32 % higher that the predicted value for single phase turbulent correlation of heat transfer. Also they found that the pressure loss is little lower than the Al_2O_3 water nanofluid. Torii and Yang [17] investigated the heat transfer coefficient of suspended diamond nanoparticle into the host fluid by maintaining constant heat flux. Their test section contain a flow loop, a digital flow meter, a pump, a reservoir and a tank. The test is prepared stainless steel tube having 4.3 mm outer diameter 4.0 mm inner diameter and 1000 mm length. The whole is heated with a dc electrode heater considering joule heating. They reported that (i) the heat transfer performance of nanofluid increases with the suspension of diamond nano particle into the water compared to pure water. (ii) Reynols number variation influence the enhancement occurs in heat transfer coefficient. Rea et al., [18] investigated the heat transfer coefficient and viscous pressure loss for Al_2O_3 /water and zirconia-water nanoparticle based nanofluid flowing loop. The stainless steel vertical heated test section considered having outer diameter of 6.4 mm, an inner diameter of 4.5 mm and 1.01 m length. The test section 8 T type thermocouples sheathed and insulated electrically and soldered onto the outside wall of the tube along axial direction 5, 16, 30,44, 58, 89 and 100 cm from heated inlet section of the test facility. To measure the fluid temperatures Two same T-type thermocouples were inserted into the flowing passage of the channel after and before of the test section. They observed that the heat transfer coefficients increased 17% and 27%, in fully developed region compare to base water. The heat transfer of zirconia–water nanofluid increases by approx 2% at 1.32 vol. % in the inlet region and 3% at 1.32 vol % in the fully developed region. The observed pressure loss for nanofluids was higher than the base water having good agreement with predicted model for laminar flow. Murshed et al [19] carried out experiments with spherical and rod-shaped TiO_2 nanoparticles. The spherical particles were 15 nm in diameter and the rod-shaped particles were 10 nm in diameter and 40 nm in length. The base fluid was deionized water. The measurement method was transient hot wire. It should be mentioned here that they used oleic acid and cetyltrimethyl ammonium bromide (CTAB) surfactants (0.01 to 0.02 vol %). They maintained a nearly neutral (pH 6.2 to 6.8) suspension. For the first time, a nonlinear correlation between the volume fraction and conductivity enhancement was observed here at lower concentrations. This is interesting with respect to the temperature effect and pure metallic particles. They found that the conductivity enhancement was higher for rod-shaped particles than for spherical particles. Enhancement up to 29.7% was found with 5% spherical particles and up to 32.8% with rod-shaped particles. They attributed this to the higher shape factor (n =6) of the rods than of the spheres (n =3) in the Hamilton–Crosser [20] model. Xuan and Li [21] were first to show a significant increase in the turbulent heat transfer coefficient. They found that at fixed velocities, the heat transfer coefficient of nano fluids containing Cu nanoparticles at 2.0 vol% was improved by as high as 40% compared to the host water. The Dittus Boelter correlation failed to obtain the improved experimented heat transfer behavior of nanofluids. Recent unpublished work shows that the effect of particle size and shape and dispersion becomes predominant in enhancing heat transfer in nano fluids. Even greater heat transfer effects are expected for nano fluids produced by the one-step process. Therefore, there is great potential to “engineer” ultra-energy-efficient heat transfer fluids by choosing the nanoparticle material as well as by controlling particle size, shape, and dispersion. Mahbubul and Saadah [22] investigated the thermal performance of Al_2O_3/R134a nano refrigerant C.O.P. of nano refrigerant increased about 15% and thermal conductivity about 28.8 %, dynamic viscosity about 13.68 % and density of nano refrigerant about 11 % compare to the pure refrigerant in their study they have considered uniformly mass flux of nano refrigerant in a horizontal smooth tube. Faulkner et al. [23] conducted fully developed laminar convection heat transfer tests and made the startling discovery that water-based nanofluids containing CNTs provide significant enhancements to the overall heat transfer. First, the heat transfer coefficient of the nanofluids increase with Reynolds number. The heat transfer coefficient of the nanofluid were roughly twice those of plain water at the upper end of the Reynolds number range tested, and it appears that this enhancement will continue to increase with larger Reynolds numbers. Second, nanofluids outperform water, but nanofluids with low particle concentrations (1.1 vol %) perform better than those with higher concentrations (2.2 and 4.4 vol%). This is an unexpected and, indeed, counterintuitive result. This negative concentration dependence of the heat transfer enhancement could be due partially to the interaction between particles. Faulkner et al. proposed that the pseudo turbulence induced by rolling and tumbling CNT agglomerates in a microchannel results in micro scale mixing, which enhances the laminar heat transfer coefficient. Since heat transfer applications operate over a wide range of Reynolds numbers and heat fluxes, additional work is needed to develop nano fluids that can provide the most significant benefit to specific heat transfer applications. Wen and Ding [24] were first to study the laminar entry flow of nano fluids and showed a substantial increase in the heat transfer coefficient of water-based nano fluids containing γ-Al_2O_3 nanoparticles in the entry region and a longer entrance length for the nano fluids than water. Also in 2006 they have studied the laminar entry flow of water-based nano fluids containing multi walled carbon nanotubes (CNT nano fluids). For nano fluids containing only 0.5 wt% Carbon nano tubes, the maximum convective heat transfer coefficient enhancement reaches above 350% at Re equal to 800. Such a higher enhancement could not be considered purely for thermal conductivity enhancement. They proposed possible mechanisms such as thickness of thermal boundary layer, particle rearrangement, due to the presence of carbon nanotubes, and very high aspect ratio of Carbon nano tubes. Lee et al. [25]. They measured thermal conductivities of nano fluid at temperatures between 21 and 55°C, and the results were nothing less than miraculous. Over this small 34° C rise in temperature, the thermal conductivity enhancement was more than three times higher. With Al_2O_3, the enhancement increased from 2% to 10.8% at a 1% particle volume fraction and it went from 9.4% to 24.3% at a 4% particle-volume fraction. The same increase for CuO–water nano fluids was 6.5% to 29% for a 1% particle-volume fraction and 14% to 36% for a 4% particle fraction. This puts the entire phenomenological concept regarding nano fluids completely in perspective. In fact, all the theories proclaimed before this work was published crumpled at this observation because none of them could predict such a strong temperature effect. The other important observation from the preceding result is that at elevated temperatures, neither Al_2O3 nor CuO-based nano fluids comply with the Hamilton–Crosser model. This is because the model is completely insensitive to temperature variations between 21 and 55°C. This clearly indicates that agreement of the Al_2O3 nano fluids with the Hamilton–Crosser model. Joaquin Navarro et al [26] in his investigation performance analysis of vapour compression refrigeration cycle (system) using R1234yf as a replacement of R134a. In their work, they the performance of vapour compression refrigeration system using both the refrigerant R1234yf and R134a with presence of internal heat exchanger also without internal heat exchanger under a large range of operating condition. Experimental result is obtained with varying evaporator temperature and condenser temperature and use of internal heat exchanger. From their result C.O.P and cooling capacity decreased 13 and 6 % respectively when R134a is replaced by R1234yf. However the presence of internal heat exchanger can help to control the reduction about 6 and 2 % respectively. The experimental result agreed with the mathematical analysis of the system considering pressure drop negligible.

4. Result and Discussion

A computational program has been developed to solve non linear equation of vapour compression refrigeration cycle for case (iii) mentioned in abstract. Considering same geometric parameter of the VCRS model theoretical analysis has been done using EES software for nano refrigerant flowing in primary circuit and R718 (water) flowing in secondary circuit of VCRS and results are given below.

4.1 Thermo physical property of nano refrigerant

In this section variation of thermo physical property of base refrigerant using nanoparticle suspended into base refrigerant at 5 Vol % are shown below.

4.1.1 Thermal conductivity of nano refrigerant using different nanoparticle and base refrigerant

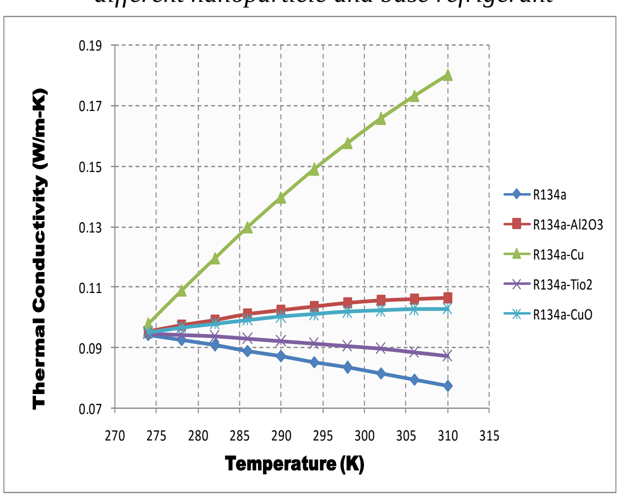

Fig.1: Variation of Thermal conductivity with Temperature of R134a using different nanoparticles

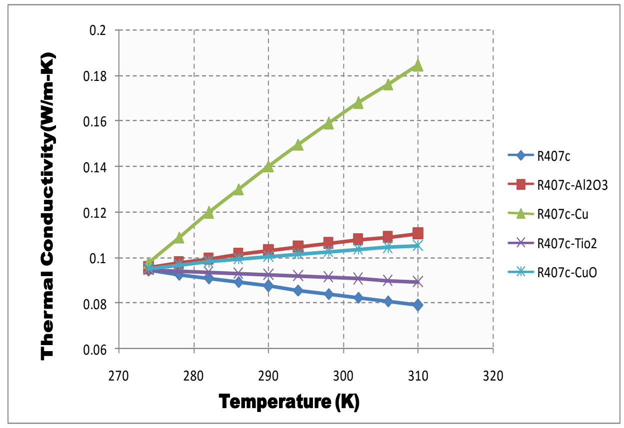

Fig.2; Variation of Thermal conductivity with Temperature of R407c using different nanoparticles

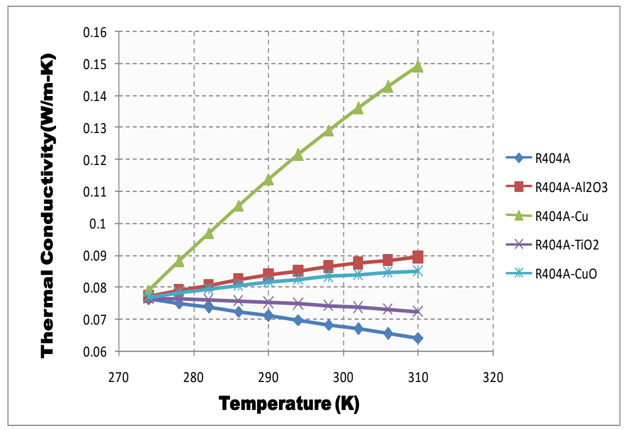

Fig.3. Variation of Thermal conductivity with Temperature of R404A using different nanoparticles

Fig. 1-3 show the enhancement in thermal conductivity of nano refrigerant when different kind of nanoparticle is suspended into the host refrigerant. The enhancement factor varies from 0.06 to 2 for different nanoparticle. From the Fig 3, the cu nanoparticle have more EF at higher temperature which value is approx 2.

4.1.2 Density of nano refrigerant with different nanoparticle and base refrigerant

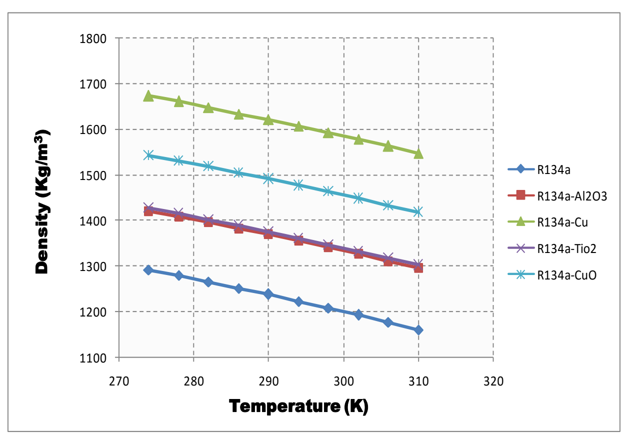

Fig.4 Variation of Density with Temperature of R134a using different nanoparticles

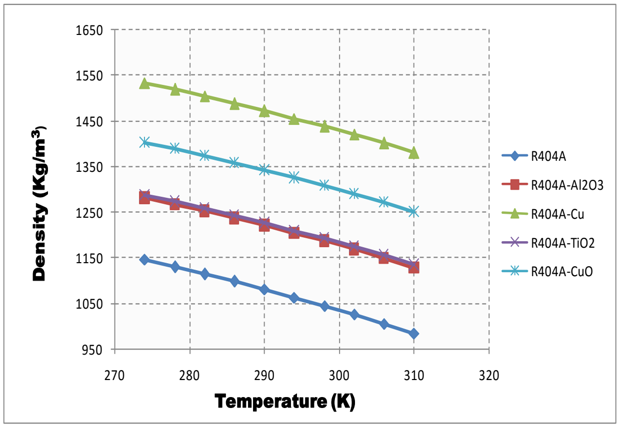

Fig.5 Variation of Density with Temperature of R404A with temperature using different nanoparticles

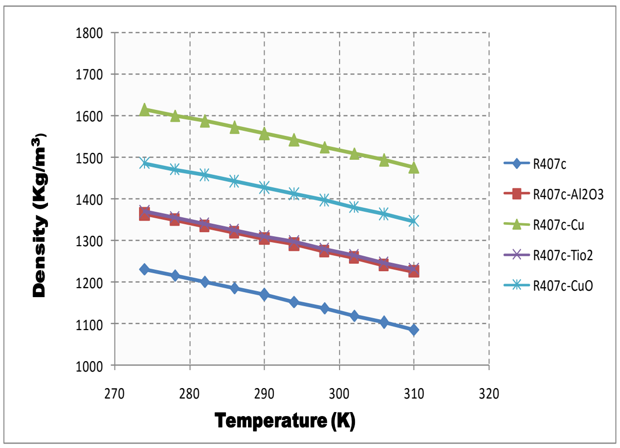

Fig.6 Variation of Density with Temperature of R407c using different nanoparticles

Fig.4-6 shows variation in density of nano refrigerant subject to temperature variation. Fig-4, shows that density variation of nano refrigerant is similar to pure refrigerant as higher temperature low density and lower temperature high.

4.1.3 Dynamic viscosity of nano refrigerant using different nanoparticle and base refrigerant

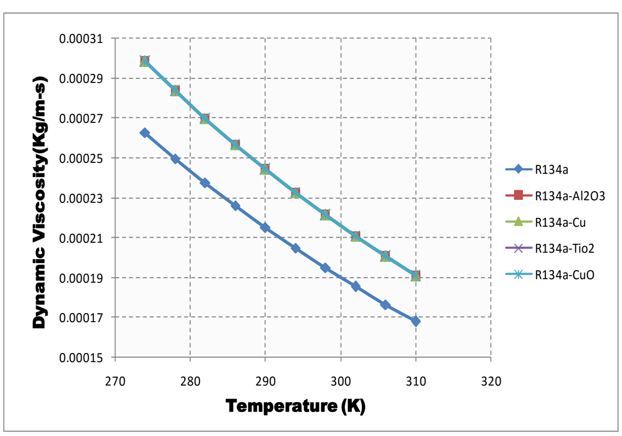

Fig.7 Variation of Dynamic viscosity with Temperature of R134a using different nanoparticles

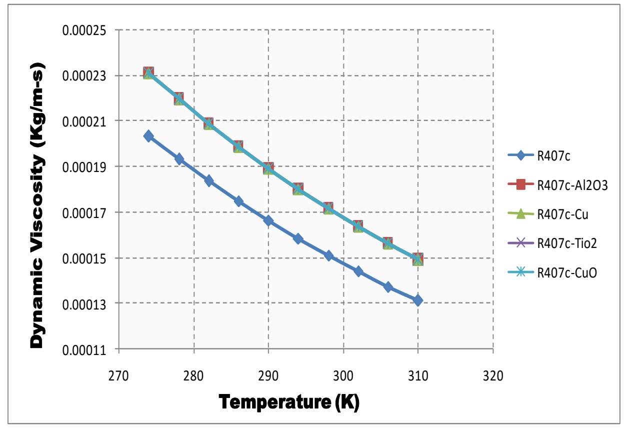

Fig.8 Variation of Dynamic viscosity with Temperature of R407c using different nanoparticles

Fig.6-9 shows variation in Dynamic viscosity of nano refrigerant subject to temperature variation.

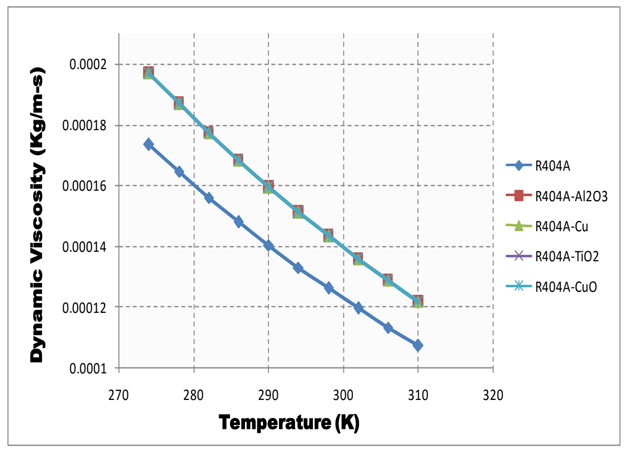

Fig.9: Variation of Dynamic viscosity with Temperature of R404A using different nanoparticles

Fig-9 shows that Dynamic viscosity variation of nano refrigerant is similar to pure refrigerant as higher temperature low viscosity and lower temperature high.

4.1.4 Specific heat of nano refrigerant using different nanoparticle and base refrigerant

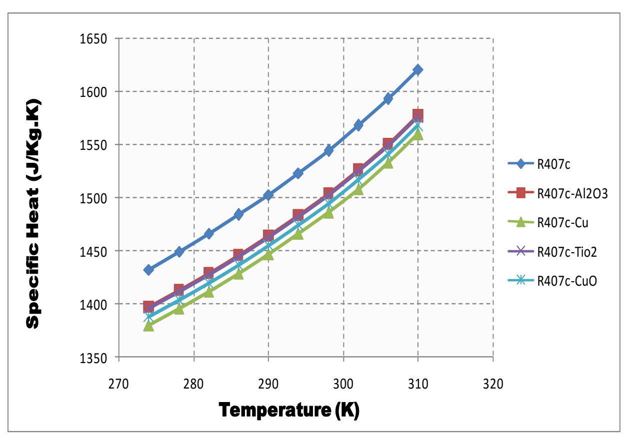

Fig.10 Variation of Specific heat with Temperature of R407c using different nanoparticles

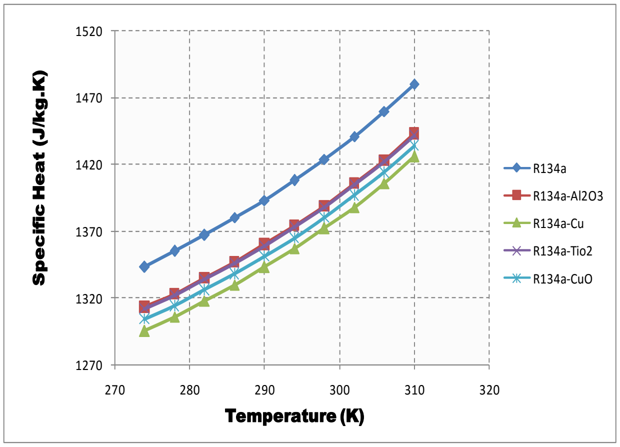

Fig.11 Variation of Specific heat with Temperature of R134a using different nanoparticles

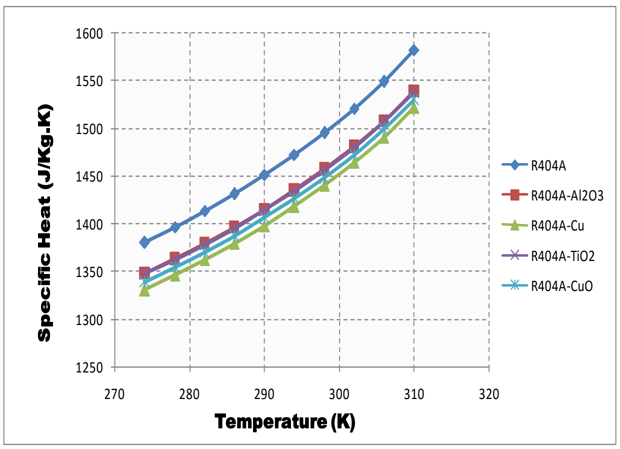

Fig.12 Variation of Specific heat with Temperature of R404A using different nanoparticles

Fig. 10-12 shows variation in specific heat of nano refrigerant subject to temperature variation. Fig shows that Specific heat variation of nano refrigerant is similar to pure refrigerant as higher temperature High Specific heat and lower temperature low. But when we go for higher vol % concentration of nanoparticle Specific heat will reduce.

4.2 Effect of volume fraction on Thermo physical property of nano refrigerant with different nanoparticle and base refrigerant (at 280K temperature

Density ratio shown Fig 13 is defined as the ratio of density of nano refrigerant (nanoparticle mixed with pure refrigerant) to the density of pure refrigerant. Thermal conductivity shown in Fig 14 is defined as the ratio of thermal conductivity of nano refrigerant (pure refrigerant mixed with nanoparticle) to the thermal conductivity of pure refrigerant.

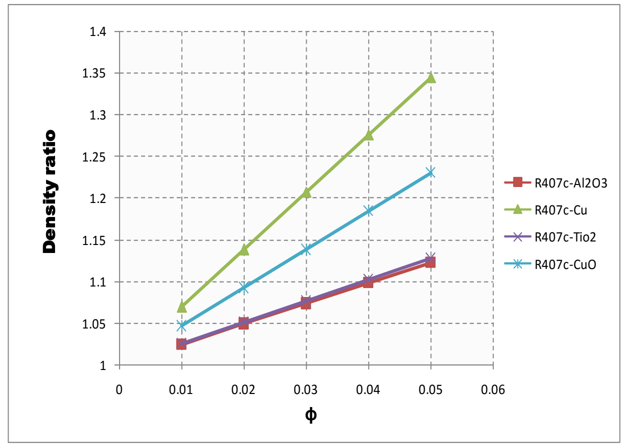

Fig.13 Variation of Density Ratio with volume fraction (ϕ) of R407c using different nanoparticles

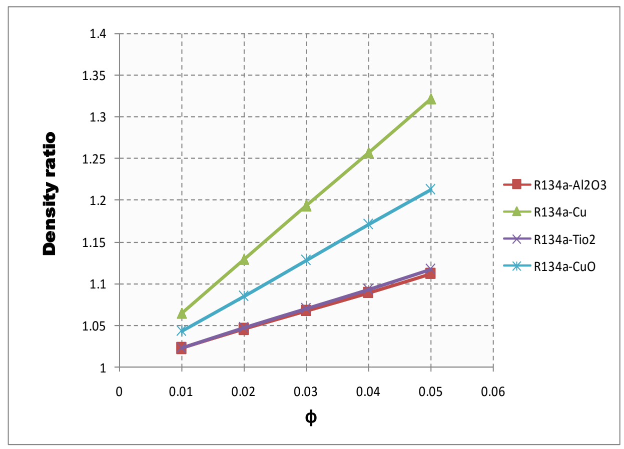

Fig.14 Variation of Density Ratio with volume fraction (ϕ) of R134a using different nanoparticles

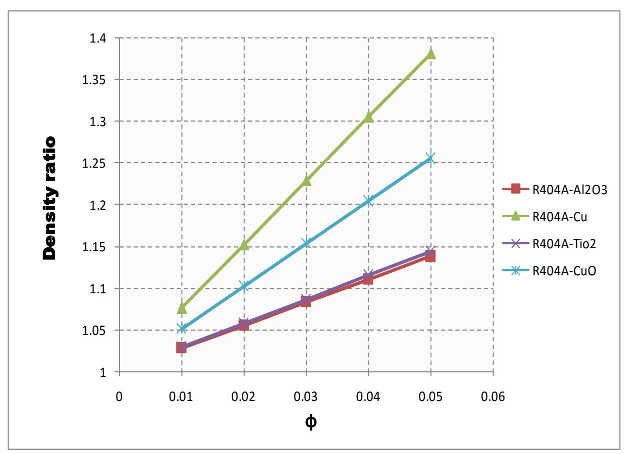

Fig.15. Variation of Density Ratio with volume fraction (ϕ) of R404A using different nanoparticles

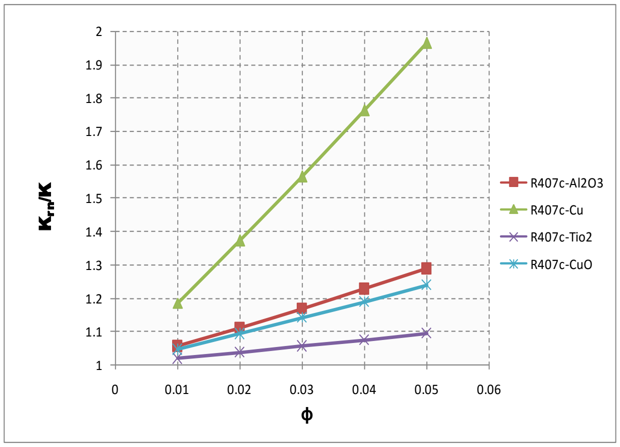

Fig.16 Variation of Thermal conductivity Ratio with volume fraction (ϕ) of R407c using different nanoparticles

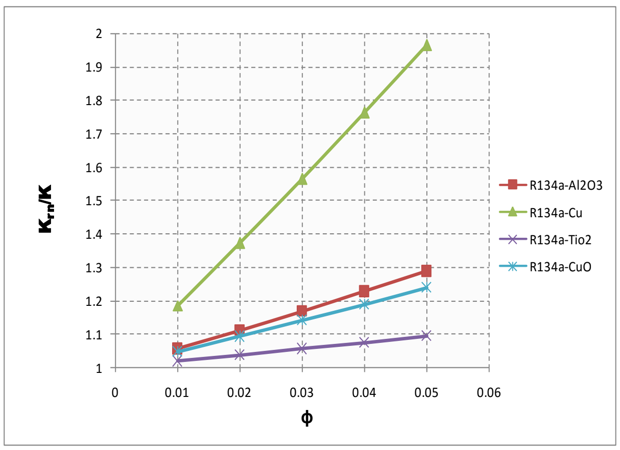

Fig.17 Variation of Thermal conductivity Ratio with volume fraction (ϕ) of R134a using different nanoparticles

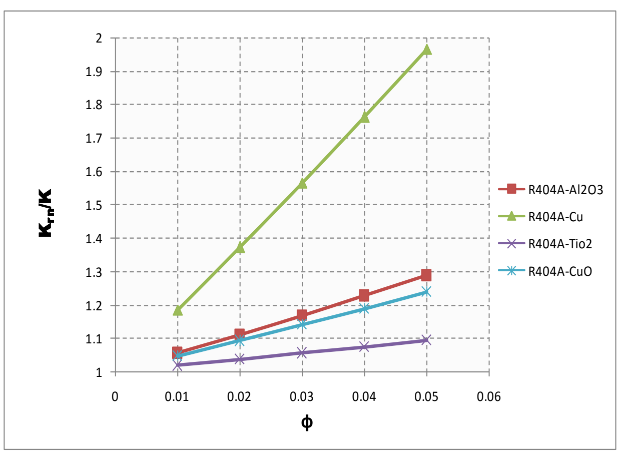

Fig.18 Variation of Thermal conductivity Ratio with volume fraction (ϕ) of R404A using different nanoparticles

Fig 15-18 shows that conductivity ratio of pure refrigerant to nano refrigerant increases with increasing concentration of nanoparticle into the host refrigerant. We can see that Cu nanoparticle based nano refrigerant have higher cond. Ratio than other nanoparticle and have approx two times higher than base refrigerant at 5 vol % concentration.

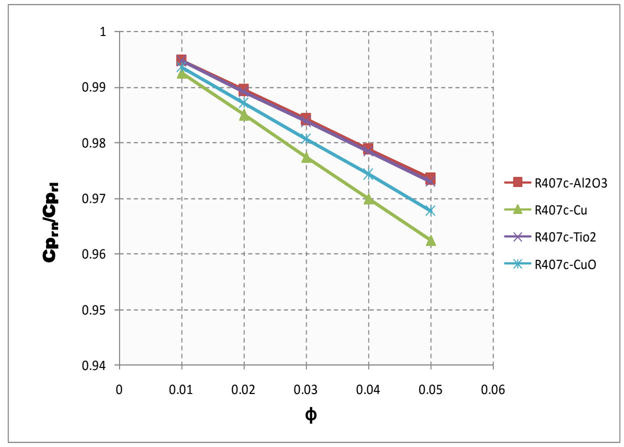

Fig.19 Variation of Specific heat ratio with volume fraction (ϕ) of R407c using different nanoparticles

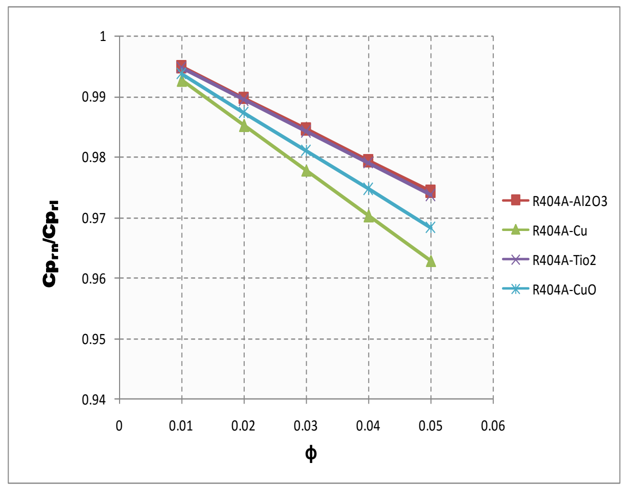

Fig.20: Variation of Specific heat ratio with volume fraction (ϕ) of R404A using different nanoparticles

Specific heat ratio shown in Fig 17-20 is defined as the ratio of specific heat of nano refrigerant (nanoparticle mixed with pure refrigerant) to the specific heat of pure refrigerant.

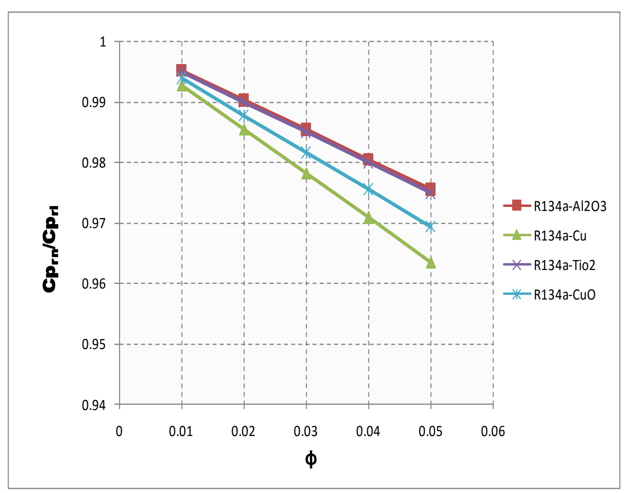

Fig.21 Variation of Specific heat ratio with volume fraction (ϕ) of R134a using different nanoparticles

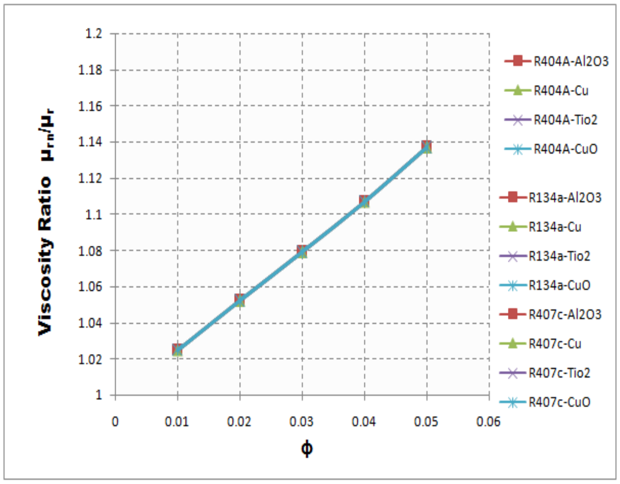

Fig.22 Variation of Viscosity ratio with volume fraction (ϕ) of all Nano refrigerant

Viscosity ratio shown in Fig 22 is defined as the ratio of Viscosity of nano refrigerant (nanoparticle mixed with pure refrigerant) to the Viscosity of pure refrigerant.

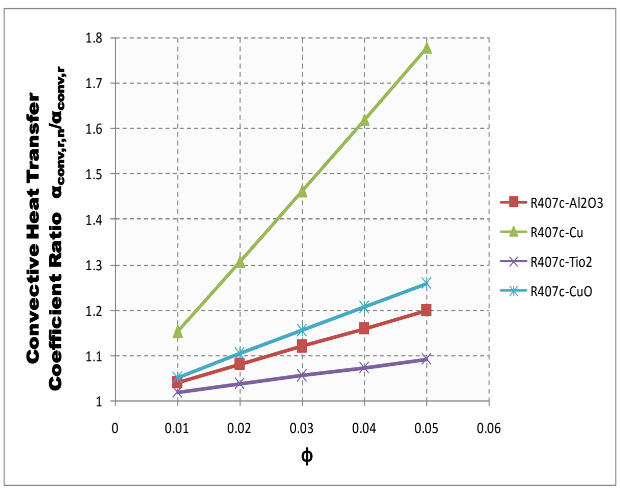

Fig.23. Variation of Convective heat transfer coefficient ratio with volume fraction (ϕ) of R407c using different nanoparticles

Convective heat transfer coefficient ratio shown in Fig 23-25 respectively is defined as the ratio of convective heat transfer coefficient of nano refrigerant (nanoparticle mixed with pure refrigerant) to the Convective heat transfer coefficient of pure refrigerant. Heat transfer Enhancement Factor shown in Fig.23-25 is defined as the ratio of heat transfer coefficient of nano refrigerant (nanoparticle mixed with pure refrigerant) to the heat transfer coefficient of pure refrigerant.

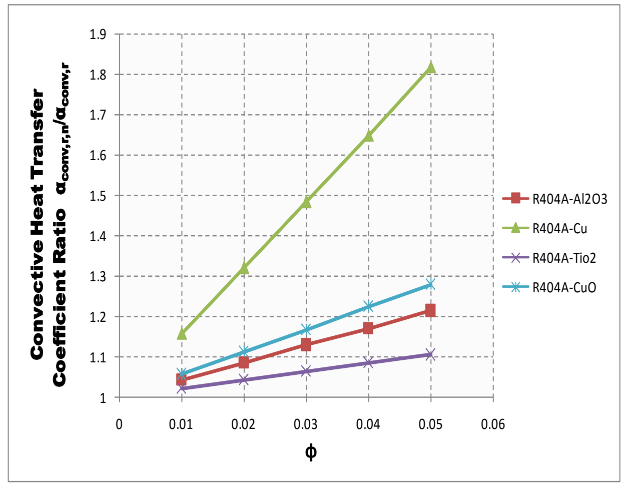

Fig.24 Variation of Convective heat transfer coefficient ratio with volume fraction (ϕ) of R404A using different nanoparticles

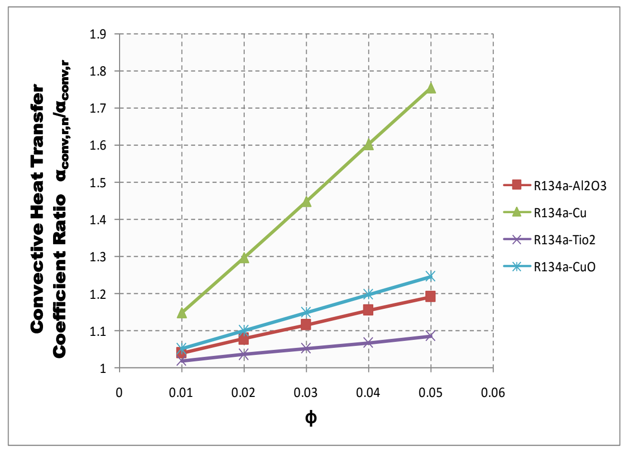

Fig.25. Variation of Convective heat transfer coefficient ratio with volume fraction (ϕ) of R134a using different nanoparticles

Fig 23-24 shows the convective heat transfer coefficient Ratio increases by increasing the concentration of nanoparticle. And copper nanoparticle based nanorefrigerant have highest convective heat transfer coefficient ratio than other particle its value ranges from 1 to 1.7.

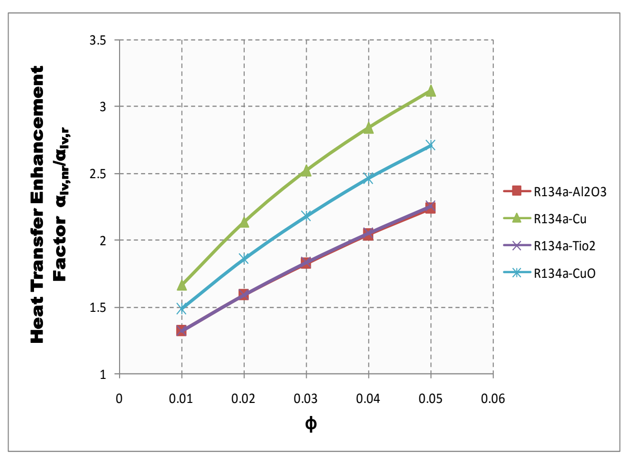

Fig.26. Variation of Heat transfer Enhancement Factor with volume fraction (ϕ) of R134a using different nanoparticles

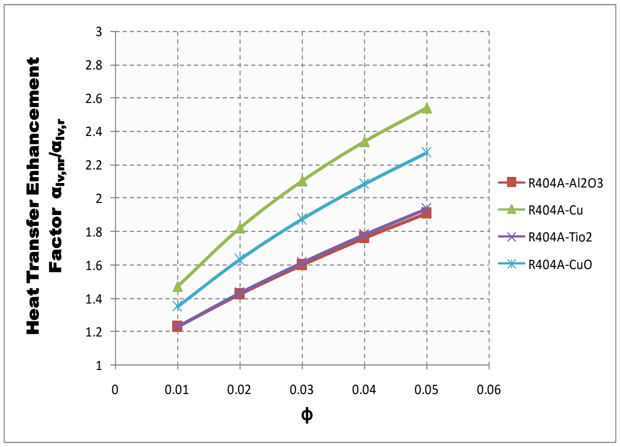

Fig.27 Variation of Heat transfer Enhancement Factor with volume fraction (ϕ) of R404A using different nanoparticles

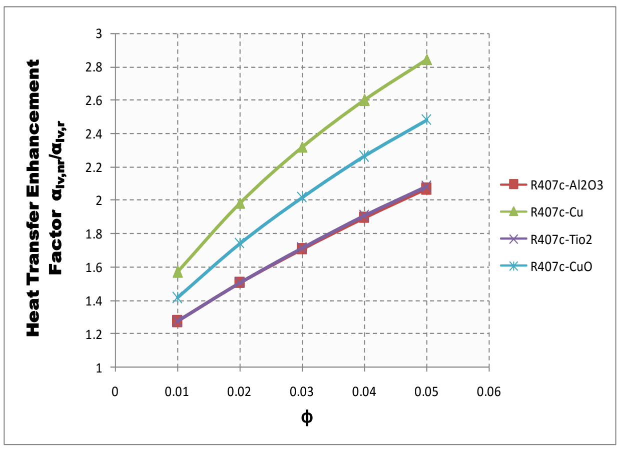

Fig.28 Variation of Heat transfer Enhancement Factor with volume fraction (ϕ) of R407c using different nanoparticles

Fig 25-28 show the heat transfer enhancement factor of nano refrigerant with different nanoparticle its value ranges from 1.2 to 3.2. As it can be seen that R134a with cu nanoparticle have highest EF approx 3.2 at 5 vol %. EF increases with increasing vol %.

4.3 Effect of nanoparticle volume fraction (ϕ) on the first law of thermodynamics (C.O.P.) of VCRS

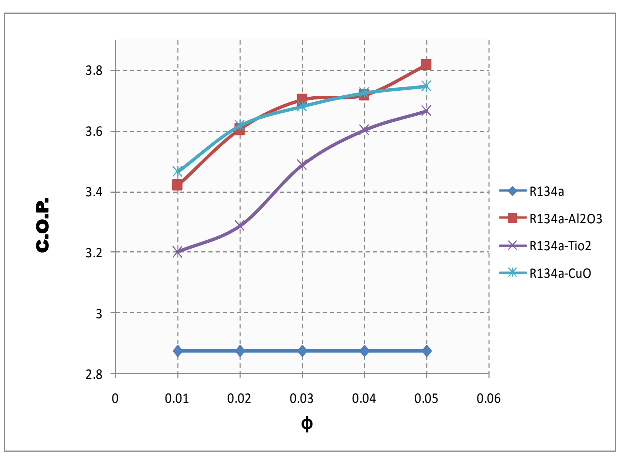

Fig.29 Variation of C.O.P with volume fraction (ϕ) of VCRS with R134a using different nanoparticles

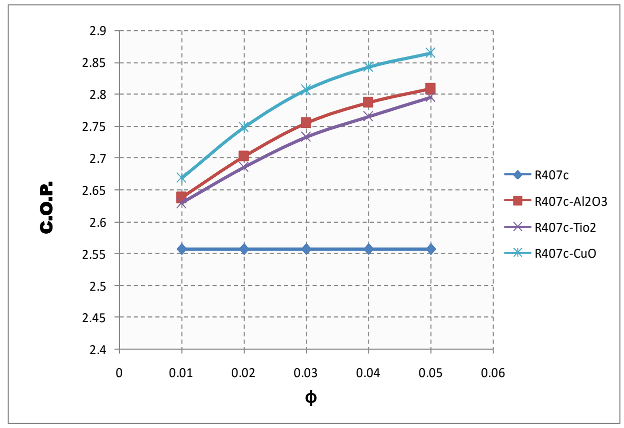

Fig.30 Variation of C.O.P with volume fraction (ϕ) of VCRS with R407c using different nanoparticles

Fig 28-31 shows that 1st law of thermodynamics enhancement of VCRS can be achieved by using nano refrigerant as a working fluid in VCRS. Fig.30 show that the maximum enhancement theoretically achieved about 35 % with combination of R134a with Al_2O_3 nanoparticle at 5 vol % based nano refrigerant. C.O.P. enhancements of VCRS with different combination of nano refrigerant.

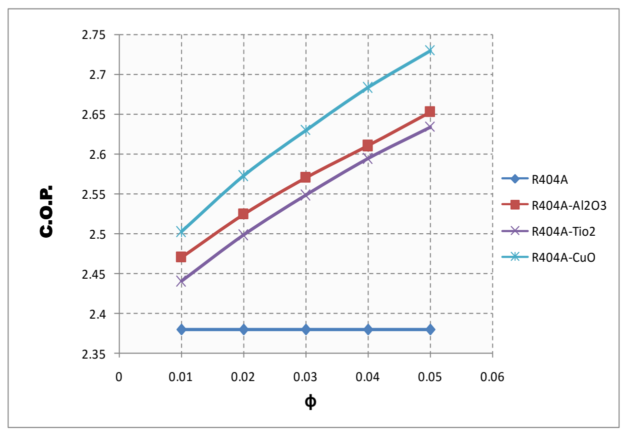

Fig.31: Variation of C.O.P with volume fraction (ϕ) of VCRS with R404A using different nanoparticles

4.4 Effect of nanoparticle volume fraction (ϕ) on the Exergy destruction ratio of VCRS

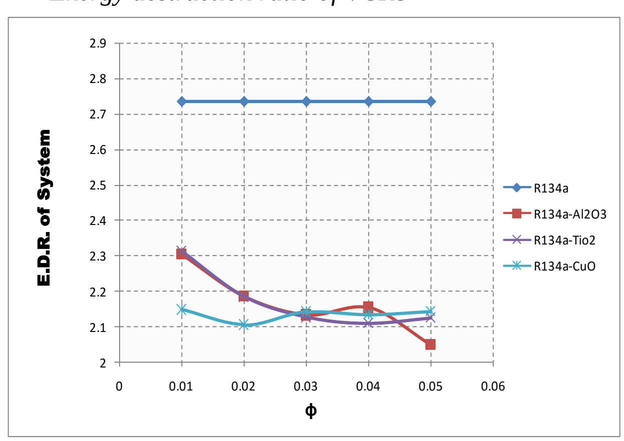

Fig.32 Variation of Exergy destruction ratio with volume fraction (ϕ) of VCRS with R134a using different nanoparticles

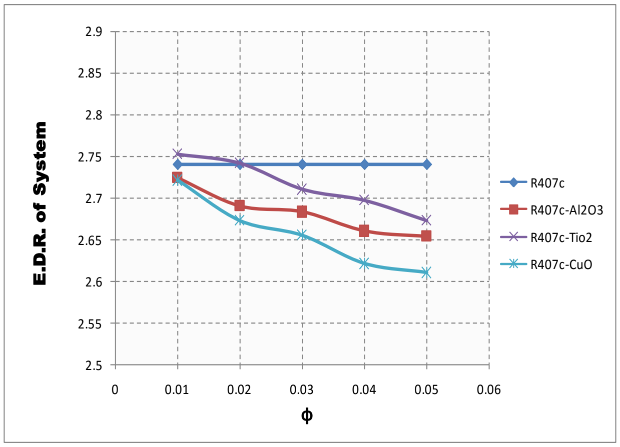

Fig.33 Variation of Exergy Destruction ratio with volume fraction (ϕ) of VCRS with R407c using different nanoparticles

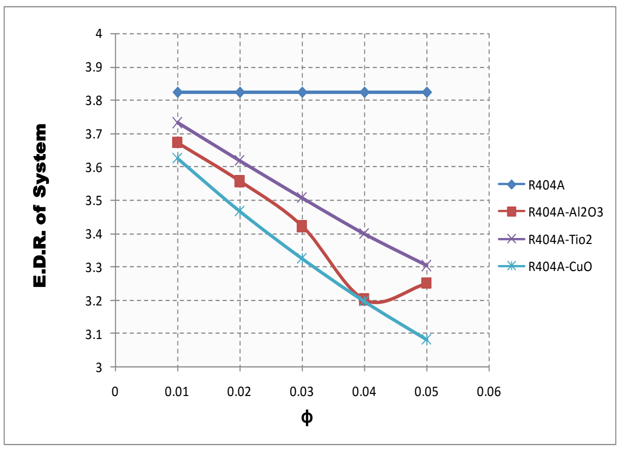

Fig.34 Variation of Exergy destruction ratio with volume fraction (ϕ) of VCRS with R404A using different nanoparticles

Fig 31-34 shows that the E.D Ratio of VCRS will reduce by using nanoparticle based nano refrigerants.

4.5 Effect of nanoparticle volume fraction (ϕ) on the second law efficiency of VCRS

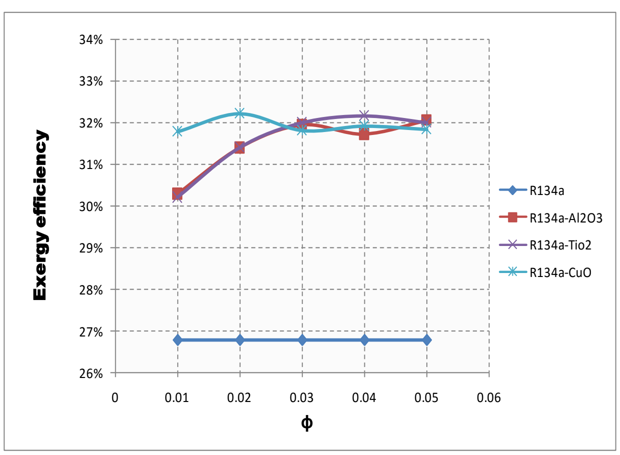

Fig.35 Variation of Exergy Efficiency with volume fraction (ϕ) of VCRS with R134a using different nanoparticles

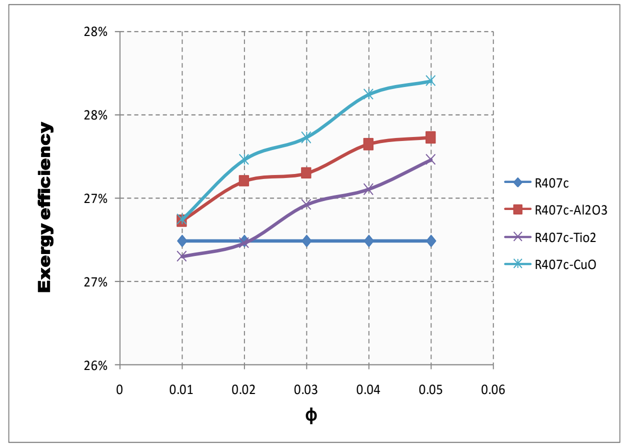

Fig.36. Variation of Exergy Efficiency with volume fraction (ϕ) of VCRS with R407c using different nanoparticles

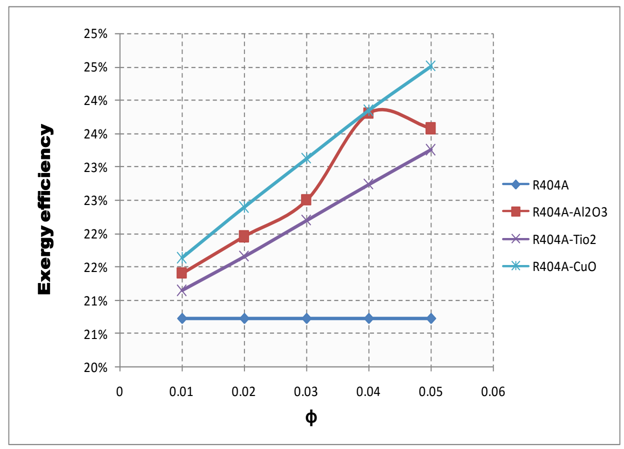

Fig.37 Variation of Exergy Efficiency with volume fraction (ϕ) of VCRS with R404A using different nanoparticles

Fig 33-37 shows that second law efficiency of vapour compression refrigeration system will increase by using nano-refrigerant. It can seen that the 2nd law efficiency of vapour compression refrigeration system using nano-refrigerant R134a/CuO is much higher than the other nano-refrigerant having value approx 30%.

A computational program has been developed to solve non linear equation of vapour compression refrigeration cycle for case (ii) mentioned in abstract. Considering same geometric parameter of the VCRS model theoretical analysis has been done using EES software for nano fluid (nano particle mixed with R718) flowing in secondary circuit and eco friendly refrigerant in primary circuit of VCRS and performance results are given in table-1.

Table 1: Enhancement in C.O.P using Al_2O_3 at 5 vol % nano fluid in secondary circuit as compared without nano refrigerants

For Al_2O_3 at 5 vol %		
Refrigerant	C.O.P.	Improvement C.O.P.
R134a	3.406	18%
R404A	3.0635	16.0%

R407c	3.110488	17.0%
R-152a	3.4102	18.0%
R-600	3.3402	17.1%
R-600a	3.466	20%
R-125	3.033016	15.0%
R-290	3.54312	20%

5. Conclusions

The research work presented in this thesis work following conclusion have been drawn.

- Use of nano particles enhances thermal performance of vapour compression refrigeration system from 8 to 35 % using nano refrigerant in primary circuit
- Use of nanoparticles enhances the thermal performance of vapour compression refrigeration system from 7 to 19 % using nano fluid in secondary circuit.
- Maximum enhancement in performance was observed using R134a/Al_2O_3 nano refrigerant in primary circuit and water in secondary circuit of VCRS.
- Lowest enhancement in performance was observed using R404Aa/TiO_2 nano refrigerant in primary circuit and water in secondary circuit of VCRS.

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