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RESEARCH PAPER

Performance improvements of vapour compression refrigeration system (VCRS) using new ecofriendly low GWP refrigerants in primary circuit and nano mixed R718 in secondary circuit of evaporator

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ABSTRACT

This paper discussed the various aspects of nano-fluids as nano-refrigerants such as its synthesis, thermo-physical properties, pressure loss in nano-refrigerants, boiling heat transfer and their performance. Nano-refrigerants are the newest consideration for research due to its definite properties such as higher evaporator overall heat transfer coefficient due to its higher thermal conductivity and condenser heat transfer coefficient due to its enhanced boiling heat transfer. The Comparison have been done for using new HFO refrigerants in primary circuit of evaporator and brine flow in the secondary circuit of evaporator and found that by using HFO refrigerants the thermodynamic first and second law performances improved up to 10% and by using nano materials, its thermodynamic performances improved from 8% to 16% using HFO-1336mzz (Z) in primary circuit.

Key words: *Nano-fluids, Thermo-physical properties enhancement, Thermodynamic Performance improvements*

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INTRODUCTION

A nano fluid can be defined as the fluid system in which nano-particles are dispersed in the base fluid. A nano-refrigerant is a refrigeration fluid used in refrigeration system in which suspended nanoparticles are well-dispersed in a continuous base refrigerant. It has a very long history that has contributed in the development and enhancement of modern refrigeration system (Maxwell, 1873). As with time when nano-technology started playing major roles in almost all the areas of science and technology, Choi in the year 1995 introduced to the world with a different concept of making nano-refrigerant. The main reason for the study and the research related to nano-fluids was to improve the thermal conductivity (k) of different fluids. It has been observed that the thermal conductivity of the base fluid increases significantly with the addition of nano-particles; by the mixing of carbon nano tube (CNT) in R-113, the thermal conductivity increased by 105%.The main advantage of using nano-refrigerants are their size which assisted to develop lighter refrigeration systems and for developing less power-consuming compressors and more energy-efficient systems. Secondly, better boiling heat transfer of nano-refrigerants, it has been experimentally investigated that boiling heat transfer performance of nano-refrigerants is superior to conventional base refrigerants. Large number of studies have been conducted on pool boiling of nano-refrigerants though both pool boiling and flow boiling play major roles in the refrigeration systems S.U.S. Choi, (1995); The application of nano-refrigerants also improves other thermo-physical properties like rheology, specific heat and interfacial properties, like contact angle and surface tension. Other works in the field of nano-refrigerants includes lowering of friction coefficient of raw oil by replacing it with nano-oil with effective lubricating properties..

PREPARATION OF NANO-REFRIGERANTS

A. TWO-STEP METHOD:

Two-step method is the most widely used method for preparing nanofluids. Nanoparticles, nanofibers, nanotubes, or other nanomaterials used in this method are first produced as dry powders by chemical or physical methods. Then, the nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling. Two-step method is the most economic method to produce nanofluids in large scale, because nano powder synthesis techniques have already been scaled up to industrial production levels. Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate. The important technique to enhance the stability of nanoparticles Due to the difficulty in preparing stable nanofluids by two-step method, several advanced techniques are developed to produce nanofluids, including one-step method. In the following part, we will introduce one-step method in detail in fluids is the use of surfactants. However, the functionality of the surfactants under high temperature is also a big concern, especially for high-temperature applications.

B. ONE-STEP METHOD:

To reduce the agglomeration of nanoparticles Eastman *et al*. developed a one-step physical vapor condensation method to prepare Cu/ethylene glycol nanofluids. The one-step process consists of simultaneously making and dispersing the particles in the fluid. In this method, the processes of drying, storage, transportation, and dispersion of nanoparticles are avoided, so the agglomeration of nanoparticles is minimized, and the stability of fluids is increased. The one-step processes can prepare uniformly dispersed nanoparticles, and the particles can be stably suspended in the base fluid. The vacuum submerged arc nanoparticle synthesis system is another efficient method to prepare nanofluids using different dielectric liquids. The different morphologies are mainly influenced and determined by various thermal conductivity properties of the dielectric liquids. The nanoparticles prepared exhibit needle-like, polygonal, square, and circular morphological shapes. The method avoids the undesired particle aggregation fairly well. One-step physical method cannot synthesize nanofluids in large scale, and the cost is also high, so the one-step chemical method is developing rapidly.

PHYSICAL-PROPERTIES OF NANO-REFRIGERANTS

Some of the physical properties that are primarily important in the case of nano-refrigerants are thermal conductivity, viscosity and contact angle and surface tension. These properties should be optimized to enhance the effectiveness of the nano-refrigerants.

A. THERMAL CONDUCTIVITY:

Many important research investigations have been conducted on the study of thermal conductivity of water-based nano-fluids and nano-refrigerants. Thermal conductivity of CNT-based nano-refrigerants is enhanced compared to the base refrigerants fluid (W. Jiang *et al* 2009). In their study, CNT nano particles of different aspect ratios were selected to be mixed with R-113 as the base refrigerant. They concluded that conductivity enhancement in case of CNT-R113 nano-refrigerants was higher compared to CNT-water nano-fluids. They also observed that the larger aspect ratio of CNT nano particles improved the conductivity of CNT R-113 nano-refrigerants. Y.J. Hwang *et al*. (2006) carried out experiments to measure thermal conductivity of different nano-fluids in which plain water and ethylene glycol were used as base fluids and MWCNT, silicon oxide (SiO_2) and cupric oxide (CuO) were the nano-particles dispersed in the water and ethylene glycol(base-fluid). They concluded that the conductivity of the nano-fluids depended by the individual thermal conductivity of the constituent nano-particles and the base fluids. Moreover, it also depends on the factors like volume fraction of nano-particles its size, temperature, the material used for the formulation of the base fluid, pH and the methods used for the extraction of nano-particles like 'Sonication'. Hence, it can be seen that how the thermo-physical properties of nano-refrigerants are playing a major role in the area of refrigeration system and this is the only reason that maximum researches so far have been conducted experiments on the improvement of the thermal conductivity, and also been stated that thermal conductivity of nano fluid improves non-linearly with increasing temperature.

B. VISCOSITY:

Viscosity of nano-refrigerants is the next important parameter (after thermal conductivity) that has drawn the attention of researchers working in this domain. The incorporation of nano-particles into the refrigerants increases the viscosity of the resultant nano-refrigerant. This increase eventually increases the pressure differential during the flow but increase in thermal conductivity and heat transfer coefficient compensates the effect encountered due to increased viscosity on pressure drop. Einstein (1906) was the first person who proposed a model for the viscosity for the fluids suspended with nano-particles. But he never mentioned the effect of size of the particles that were used for the formation of the nano-fluids. The size of the particles might be in the range of mm, μm or nm. But apart from many unexplained results discussed by Einstein, this work opened the door of future research in this area. After that different flow models were proposed but none of them explain the role of size of the particle on viscosity measurements, X. Wang, (1999). A.K. Sharma, A.K. Tiwari, A.R. Dixit, (2016): explained in his recent research, the flow parameters of different time independent nano-fluids in their review article. They summarized that major fraction of nano-fluids shows linear dependency on the shear stress with changing rate of shear i.e they exhibit Newtonian behavior when loading of particles was increased as far as shape of the nano-particles are concerned, spherical shaped nano-particles show Newtonian behavior. Many researchers also concluded that viscosity of nano-refrigerant may increase with the improvement in their volume fraction.

C. OTHER THERMO-PHYSICAL PROPERTIES:

Boiling and condensation heat transfer plays very important role for nano-refrigerants. Both these parameters depend on other physical properties apart from conductivity, and rheology of nano-refrigerant. Properties like IFT are one of the important parameters that greatly change the performance of a refrigeration system. It was observed by Cheng *et al*. 2007 that IFT of plain water decreases with the addition of surface active agents in the base fluid. In the year 2006, J.R., *et. al.*, (2006): investigated IFT of CNT-water nano-fluid and observed 14% increase in the same as compared to that of pure water. On the contrary S.S. Khaleduzzaman, *et. al.*, (2013) postulated that it is highly difficult to get the IFT variation because of nano-fluids as it can increase or decrease in the either ways by the addition of nano-particles. The other properties that are relevant to nano-refrigerants is specific heat capacity. In their study, I.M. Shahrul, *et. al.*, (2014): observed that specific heat is a function of type of nano-particles and the type of continuous base fluid; therefore it can either increase or decrease in a case of nano-fluids. W. Jiang , G. Ding, and H. Peng, (2009): have shown that thermal conductivity of R113-CNT nano-refrigerants increased by 50% to 104%. The thermal conductivity was measured by

Transient Plane Source (TPS) technique. They have postulated that the aspect ratio to diameter of nano-tubes had direct effect on the improvement of thermal conductivity and observed the thermal conductivity of R113 based nano-refrigerants was increased by 20% at a volume fraction of 1%. Almost same trend was displayed by all the nano refrigerants used in the investigation. I.M. Mahbubul, R. Saidur and M.A. Amalina, (2012) investigated the rheology of R123/TiO_2 nano-refrigerants and have observed an increase in the viscosity. Also observed that the impact of volume fraction of particle and temperature on thermo physical properties of R141b based nano-refrigerants prepared with Al_2O_3. The researchers reported that thermal conductivity of nano-refrigerants increased with the addition of particle concentration and temperature. S.Ozturk, Y.A. Hassan and V.M. Ugaz, (2013): developed the nano sheets made of graphene MWCNT based on nano-refrigerants. From the experimental data authors concluded that nano sheets have unique potential to improve thermal conductivity.

PRESSURE DROP STUDIES IN NANO-REFRIGERANTS

The main purpose to study the pressure drop is to get over the decrease in efficiency caused by the increase in the viscosity in the nano-refrigerants. Numerous experimental studies have been conducted to investigate single phase pressure drop phenomena of different fluids formulated with the help of nano-particles. The increase in pressure drop can lead to the requirement of more power to circulate nano-refrigerant. So far, a desired conclusion on the effects caused by increased pressure drop has not been reported. So to design an efficient refrigeration system with nano-refrigerants more experimental studies are required. H. Peng, *et. al,* (2009.a,b) performed the experiments to study the frictional pressure differential properties of CuO;R113 nanoparticle-refrigerant combination. In their studies they concluded that with the inclusion of nanoparticles to the refrigerant, pressure drop increased. Moreover frictional pressure differential increased by 20.8% at molar flux of 100kg/m^2 and a molar fraction of 0.5 wt%. Apart from this, as the quality of the vapour increased, the flow parameters changed to annular flow and as result pressure differential increased.

I.M. Mahbubul, R. Saidur and M.A. Amalina, (2012, 2013.b,c) did experiments with nano-particles Al_2O_3 an refrigerant R141b inside a smooth horizontal tube. They observed an improvement in the pressure drop upto 181%. Likewise Omer A. Alawi *et al*, 2015 performed the experiments with the TiO_2 nano-particle and R123 nano refrigerant and they observed enhancement in pressure drop by 42.5% at 0.5% volume fraction.

BOILING HEAT TRANSFER IN NANO-REFRIGERANTS

In last few years researchers have been focusing on the studies to enhance the role of nano-particles on pool boiling and flow boiling heat transfer of nano-refrigerants. There are possibilities of optimizing these two phenomena to enhance the heat transfer performance of nano-refrigerants.

The research community has published very specific studies conducted for boiling processes in nano-refrigerants. K.J. Park and D. Jung, (2007.a,). conducted experiments with refrigerant-nanoparticle combination of R123-CNT in a horizontal circular tube and observed that increase in nucleate boiling was responsible for increasing heat transfer coefficient upto 36.6%.In the same year, the researchers conducted experiments with R-22–CNT combination of nano-refrigerant and observed an increase of 24.7% in nucleate boiling of heat transfer coefficient. In the year 2007, K. Jung, *et. al.*, (2007(b) performed experiments with R-123, R-134a-CNT combination in a plane tube and observed a decrease in heat transfer coefficient. M.A.Kedzierski and M. Gong, (2009): worked with R-134a-CuO refrigerant-nanoparticle combination evaluated an increase in boiling heat transfer in the range of 50 to 275%. D.W. Liu and C.Y. Yang, (2007): used combination of R141b-Au performed the experiments in a horizontal plane tube and observed that the heat transfer coefficient was more than double at 1% particle concentration. X.F Yang, Z.H. Liu, (2011): performed experiments with R141b-Au combination and observed that heat transfer coefficient was doubled. The researchers had performed the experiments in plain copper tube. K. Bartelt, Y Park and A. Jacobi, (2008): worked with the R-134a-CuO refrigerant-nanoparticle combination with polyolester (POE) and conducted experiments in horizontal tubes they manifested an increment in heat transfer coefficient by 42%. K. Henderson, *et. al*, (2010): also performed with R-134a-CuO combination in the same horizontal tubes with POE as lubricant and observed development in the heat transfer coefficient by 101 %. H.Peng, *et. al*, (2009.b)worked with R-113-CuO combination and observed that maximum heat transfer improvement attained was 29.7%. B.Sun and D.Yang, (2013.a,b): performed experiments with R-141b-CuO combination and observed that heat transfer coefficient was increased about 1.14 times. I.M. Mahbubul, *et. al.*, (2015) carried out experiments with R-134a-Al2O3 combination and observed significant increment in heat transfer coefficient. M.A Akhavan, *et al.*, (2015): did experiments with R-600-CuO combination with POE as lubricant and noticed that heat transfer coefficient may increase upto 63%.

AGGREGATION OF PARTICLES IN NANO-REFRIGERANTS

The nano-particles present in the base fluid have Brownian movement in addition to weak Vander wall forces and high surface free energy. This phenomenon leads to the cluster formation of nano-particles and they get sedimented. This will finally impact the performance of nano-refrigerants. S.S. Bi, L. Shi and L. Zhang, (2008): did experiments on the stability of refrigerant-nanoparticle combination of R113, R123, R141b-TiO_2 with surfactant span 80 and found the system was highly stable. H. Peng, *et. al.*, (2015.c) worked with R141b-MWCNT combination and found that the presence of anionic, cationic and non-ionic refrigerants controlled the aggregation significantly. L.Lin, H. Peng and G. Ding, (2016): worked with TiO_2/NM56/R141b nano-lubricant-refrigerant mixture and found that presence of lubrication oils prevents the aggregation. M.Xing, R.Wang and J.Yu, (2014): worked on fullerene C60 nano-oil and observed that the COP and compressor power were improved by 5.26% and 5.3%, respectively. They also observed decrease in the compressor temperature which is a desirable property in the refrigeration system

RESULTS AND DISCUSSION

Nano-refrigerants have very promising future with lots of advantages and challenges that should be pursued by the researchers working in this field. This review article is an attempt to address- such promises and attempts that have taken place to improve the efficiency of nano-refrigerants and apparently increase their performance. So the researchers have reported an increase in about 127% in steady state hydro-dynamic diameter with the use of R-141b nano-refrigerant and researchers have also observe an increase in boiling heat transfer by 129% with the use of R-134a nano-refrigerant. Further there is requirement of more work to be done on R-134a nano-refrigerant so that cooling can be more than 6%. As can be easily monitored throughout the article that how using nano-refrigerants resulted in less power consumption likewise the improved k is parameter that drastically increases with the help of nano-refrigerant therefore we are in the era in which more experimental investigation are required in the area of nano-refrigeration. Many researchers have also reported that the quantum of work should be increased on condensation heat transfer of nano-refrigerants. Oxides of metals such as Al_2O_3, TiO_2 and CuO can be put under the category of challenging nano spices that can improve the thermal conductivity of nano-refrigerants. Furthermore, the addition of surfactants of all types (anionic, cationic and non-ionic) inhibits the aggregation of nano-particles in the nano-refrigerants. Likewise, presence of lubricating oils prevents the aggregation behavior.

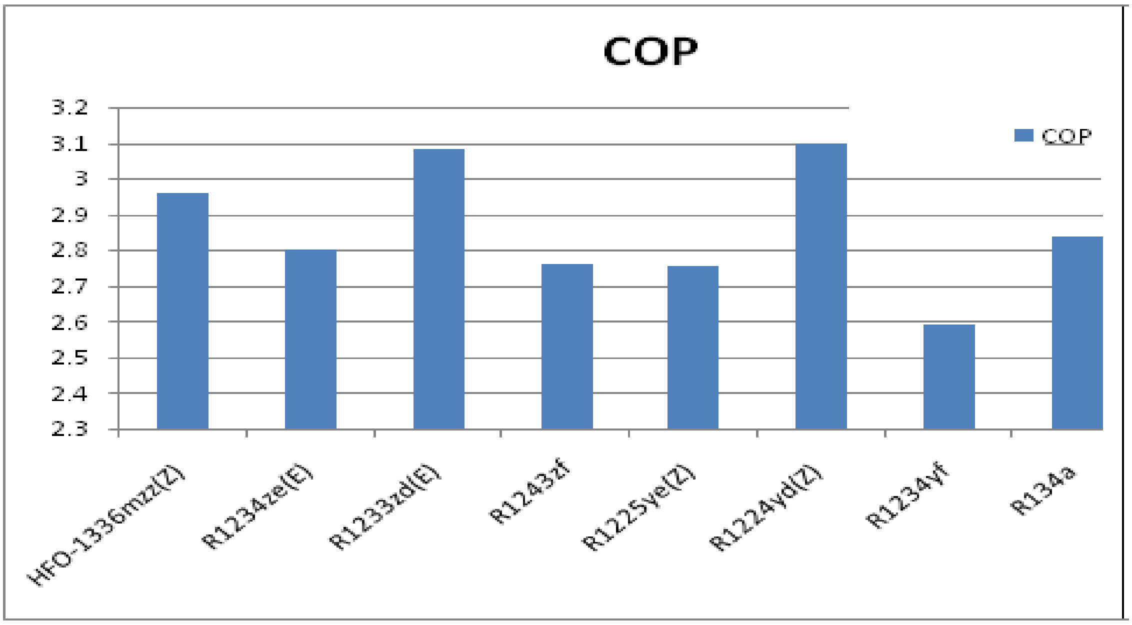

Fig. 1: Fig-1: Comparison of first law performance (coefficient of performance) using different ecofriendly low GWP refrigerants with HFC-134a in VCRS

Fig-1, shows the variations of first law performance in terms of coefficient of performance (COP) with different ecofriently low GWP refrigerants flowing in the primary circuit of evaporator and R718 fluid flowing in secondary circuit of evaporator. It is found that R1224yd(Z) gives best first law thermodynamic performance (COP) and slightly higher than R1233zd(E) and lowest COP was found by using R1234yf in primary circuit of evaporator

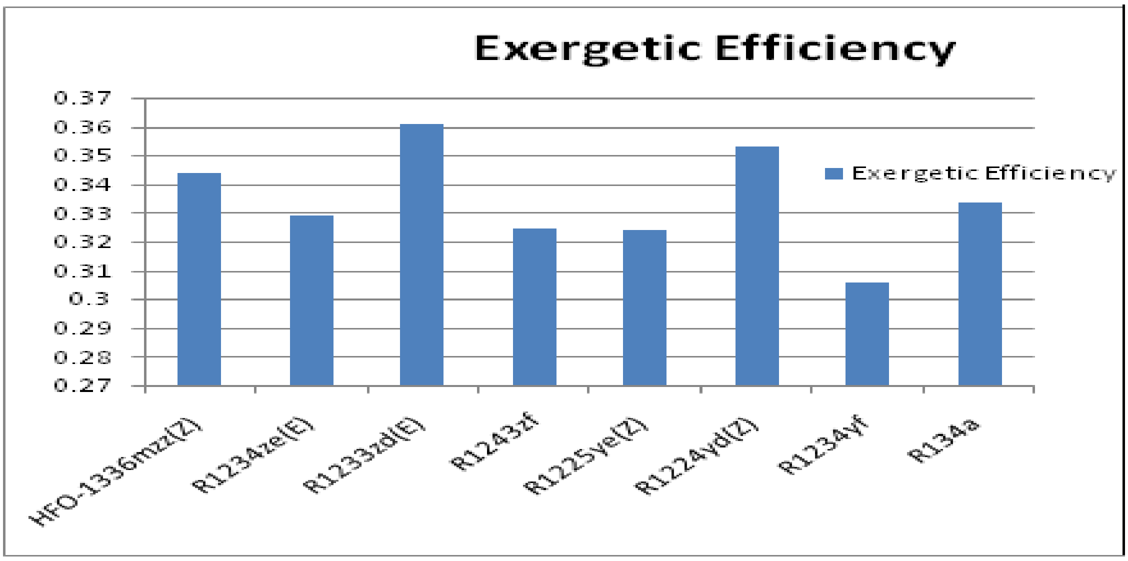

Fig. 2: Comparison of second law exergetic performance using different ecofriendly low GWP refrigerants with HFC-134a in VCRS

Fig-2, shows the variations of second law exergetic performance with different ecofriently low GWP refrigerants flowing in the primary circuit of evaporator and R718 fluid flowing in secondary circuit of evaporator and found that that R1233zd(E) gives better second law exergetic performance as compared to R1224yd(Z) and lowest second law exergetic performance was found by using R1234yf in primary circuit of evaporator.

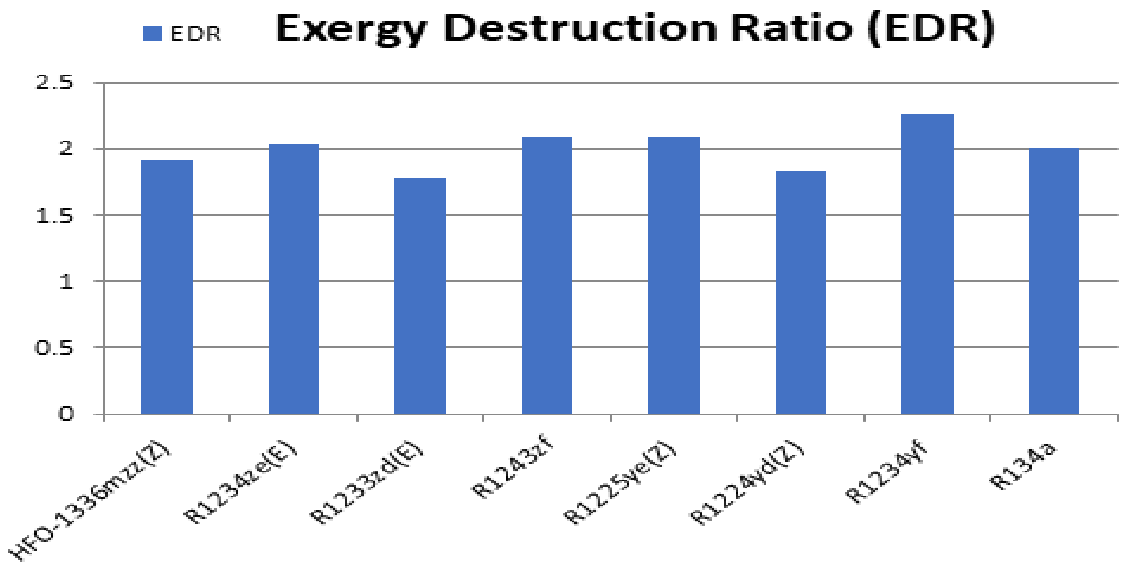

Fig. 3: Comparison of Exergy Destruction Ratio using different ecofriendly low GWP refrigerants with HFC-134a in VCRS

Fig-3 shows the thermodynamic performances of HFO1336mzz(Z) refrigerant flowing in primary circuit of evaporator and Brine is flowing in the secondary circuit of evaporator. It is found that EDR is also lower than R1233zd(E) and higher than R1243zf, R1234yf and R1225ye(Z) and R-134a. The lowest second law exergetic performance was observed by using R1234yf.

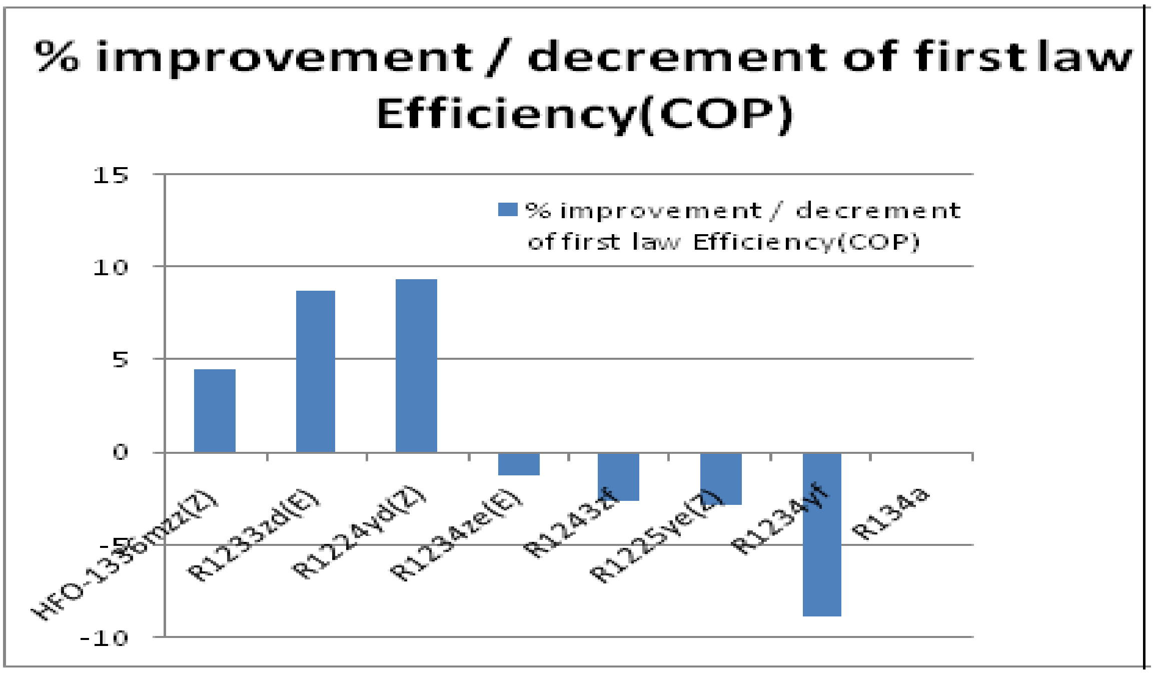

Fig. 4: Percentage improvement using following ecofriendly low GWP refrigerants with respect to HFC-134a in VCRS

Fig-4: shows the % improvement / decrement of first law performance (% COP) by using different ecofriendly low GWP refrigerants flowing in the primary circuit of evaporator and R718 fluid flowing in secondary circuit of evaporator and found HFO-1236mzz(Z), R1233zd€ and R1224yd(Z) gives 10% higher first law performance as compared to R134a and R1234ze(E), R1243zf, R1234yf gives 10% lower first law performances.

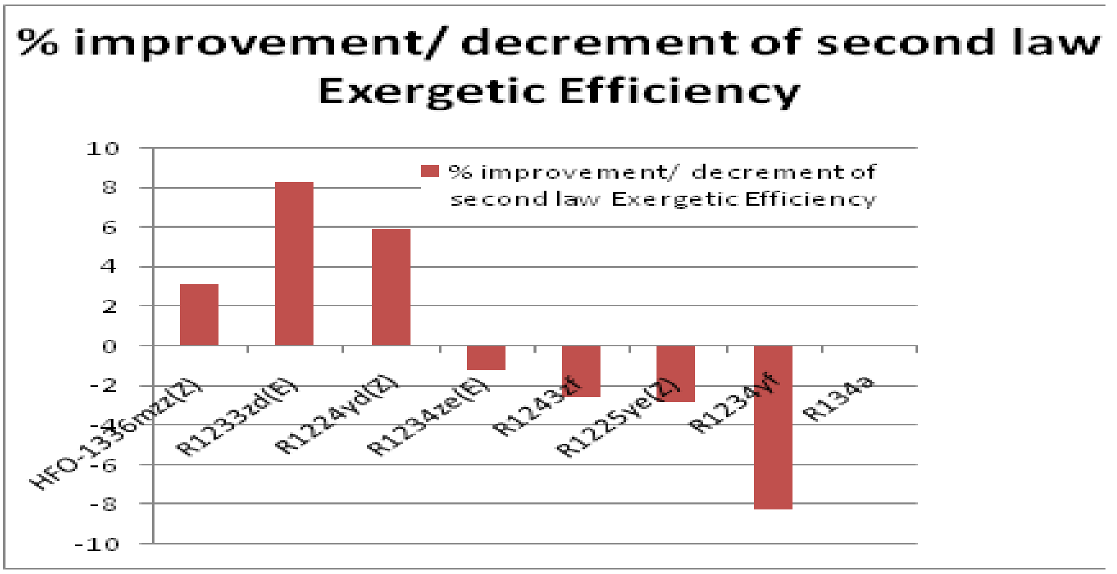

Fig. 5: Percentage improvement using following ecofriendly low GWP refrigerants with HFC-134a in VCRS

Fig-5 shows the performance improvement/decrement in the second law exergetic efficiency by using different low GWP refrigerants flowing in the primary circuit of evaporator and R718 fluid flowing in secondary circuit of evaporator and found that the second law exergetic performance was improved by 8.16% without Nano materials using R-1233zd(E) 5.86 using R1224yd(Z) and 3.059% using HFO-1336mzz(Z) for replacing R134a.

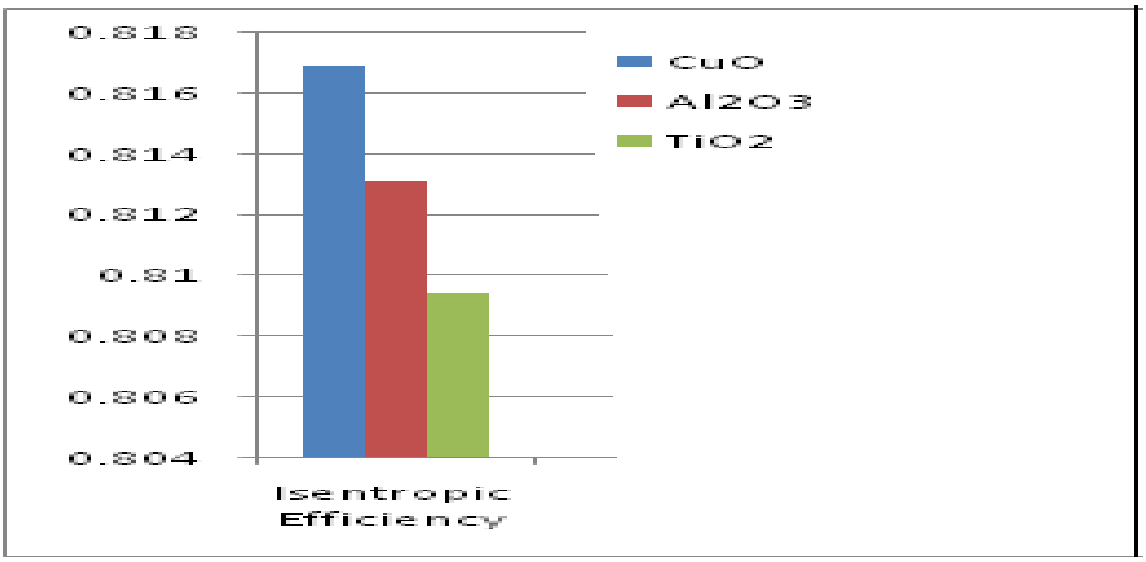

Fig. 6: Variations of compressor's Isentropic efficienciey with Nano particles mixed with in R718 fluid flowing in secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator.

Fig-6: demonstrates variations of compressor's Isentropic efficiency with Nano particles mixed with in R718 fluid flowing in secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. It has been found that Isentropic efficiency by using CuO is highest and by using TiO_2 is lowest that significantly affecting first and second law efficiency of VCR system.

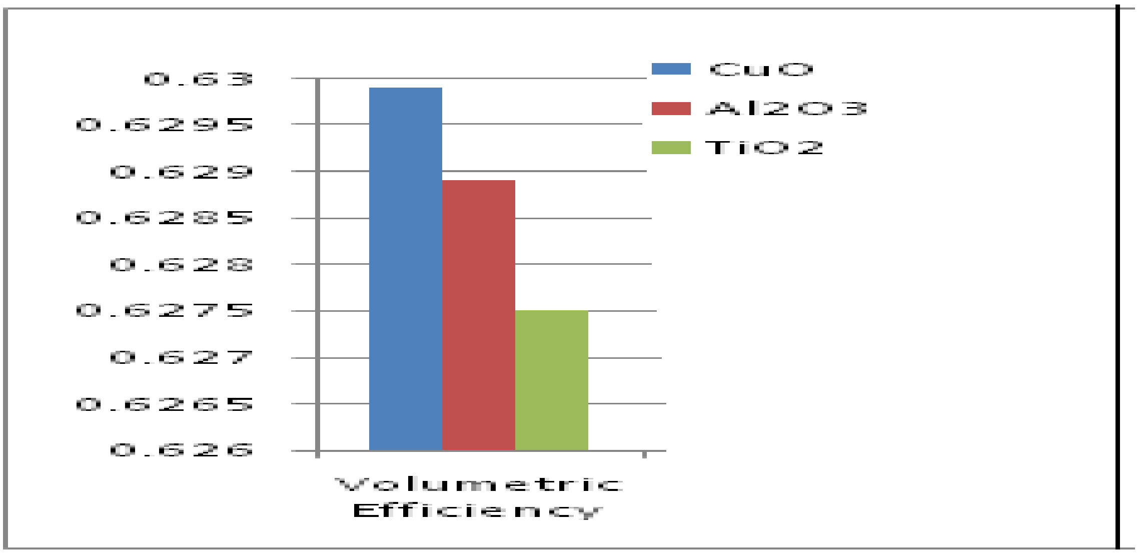

Fig. 7: Variations of compressor's volumetric efficiency with Nano particles mixed with in R718 fluid flowing in secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator.

Fig-7 demonstrates variations of compressor's volumetric efficiency with Nano particles mixed with in R718 fluid flowing in secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. It has been found that volumetric efficiency by using CuO is highest and by using TiO2 is lowest that significantly affecting first and second law efficiency of VCR system.

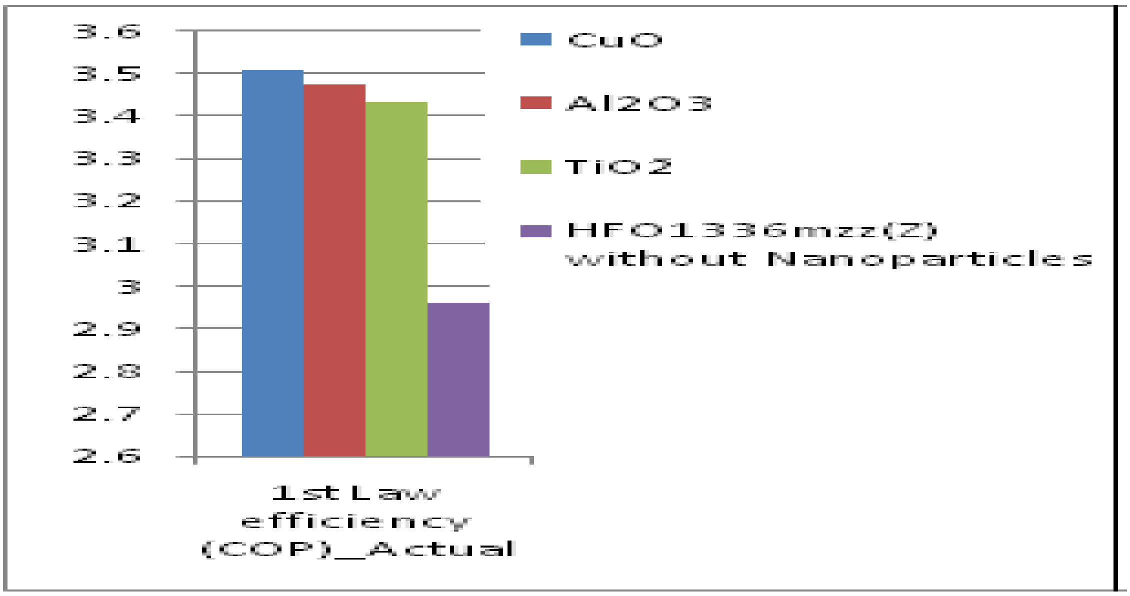

Fig. 8: Variations in first law efficiency of VCRS by using HFO1336mzz(Z) ecofriendly refrigerant in VCRS

Fig-8 shows the variations of first law performance by using different Nano materials mixed with in R718 fluid flowing in secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. By comparing results of system's properties with-and- without Nanoparticles, higher COP was observed by using CuO and lowest by using TiO2. It has also been found that enhancement in COP by using CuO, Al2O3, and TiO2 is about 18.5%, 17.5%, and 15.95%, respectively.

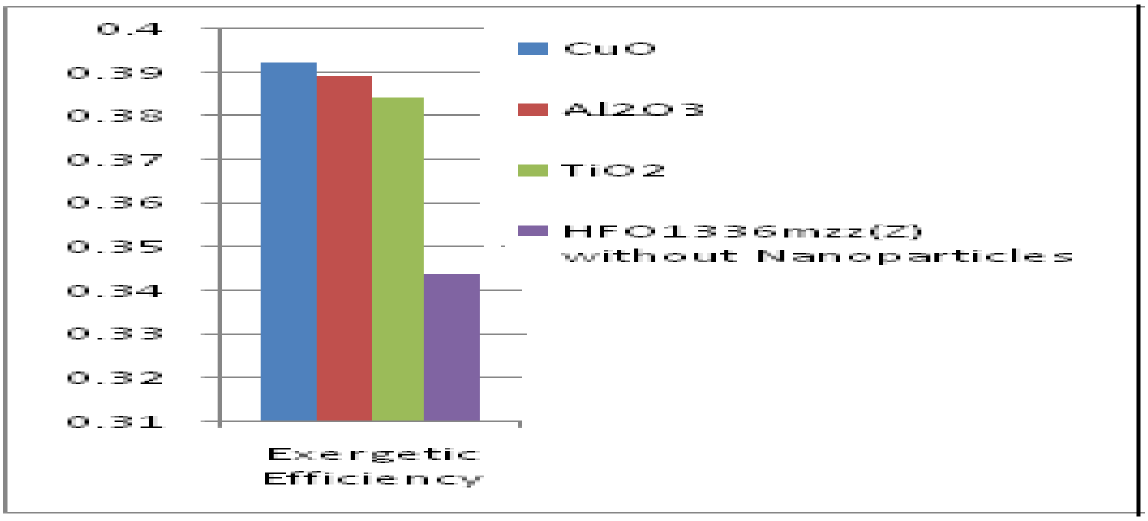

Fig. 9: Variations in Exergetic efficiency of VCRS by using HFO1336mzz(Z) ecofriendly refrigerant

Fig-9: shows the variations in Exergetic Efficiency by using different Nano materials mixed with in R718 fluid flowing in secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. By comparing results of system's properties with-and- without Nanoparticles, higher COP was observed by using CuO and lowest by using TiO2. It has also been found that enhancement in second law in condenser tube is by using CuO, Al2O3, and TiO2 is about 15.9%, 14.45%, and 12.95 respectively.

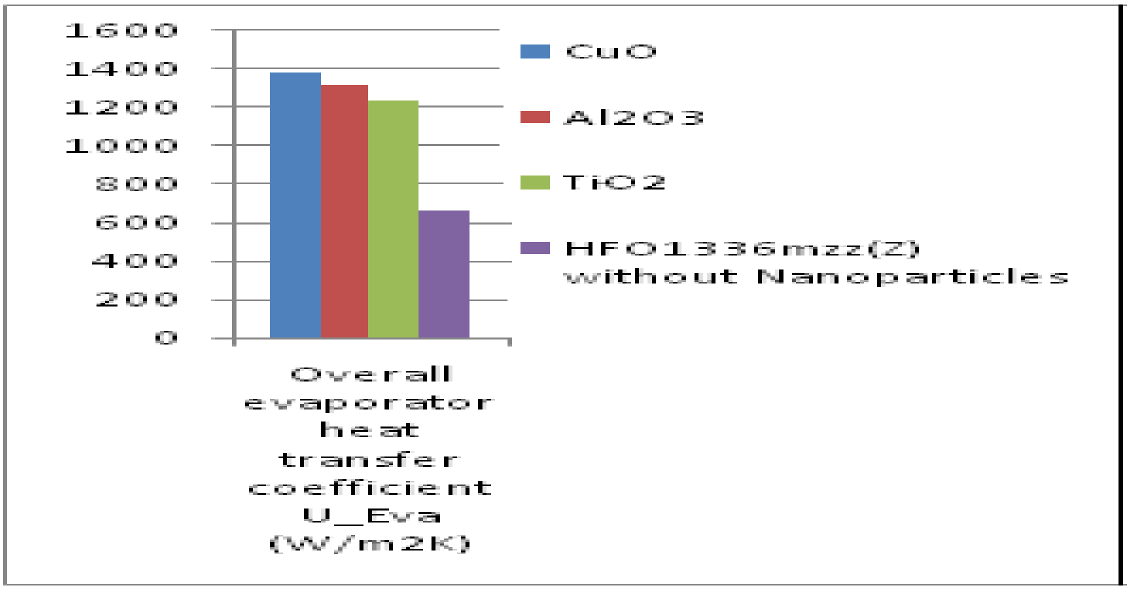

Fig. 10: Variations in Overall evaporator heat transfer coefficient of VCRS by using HFO1336mzz(Z) ecofriendly refrigerant.

Fig-10 shows the variations in Overall evaporator heat transfer coefficient of VCRS by using HFO1336mzz(Z) ecofriendly refrigerantin primary circuit and by using different Nano materials mixed with in R718 fluid flowing in secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. By comparing results of system's properties with-and- without Nanoparticles, Overall evaporator heat transfer coefficient of VCRS was observed by using CuO and lowest by using TiO2. It has also been found that enhancement in Overall evaporator heat transfer coefficient is by using CuO, Al2O3, and TiO2 is about130.1%, 117.29%, and 97.5%.

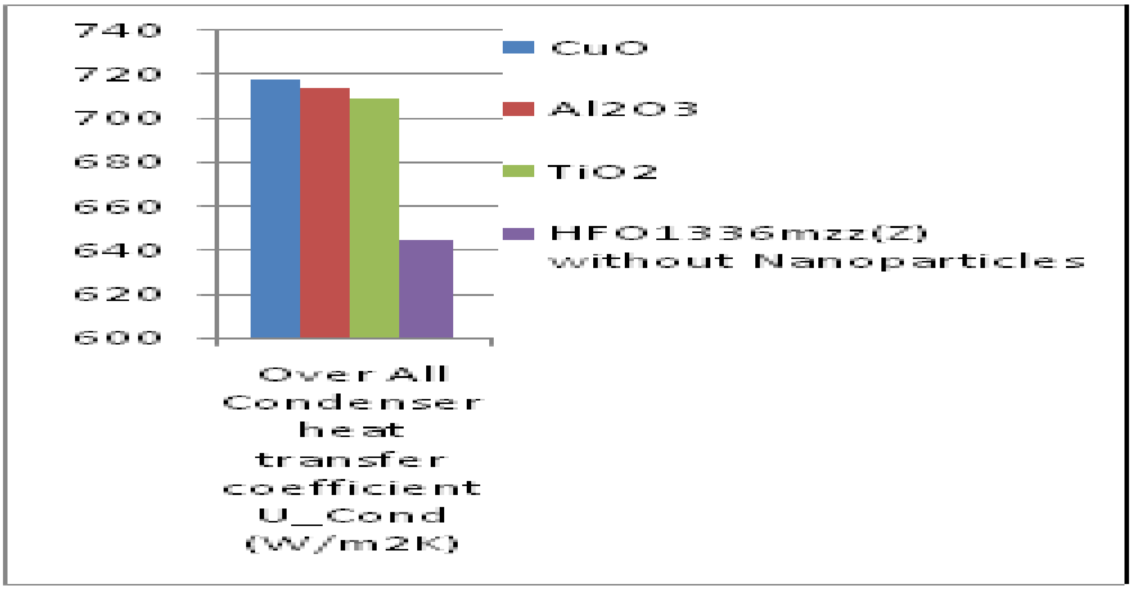

Fig. 11: Variations in Overall condenser heat transfer coefficient of VCRS by using HFO1336mzz(Z) ecofriendly refrigerant

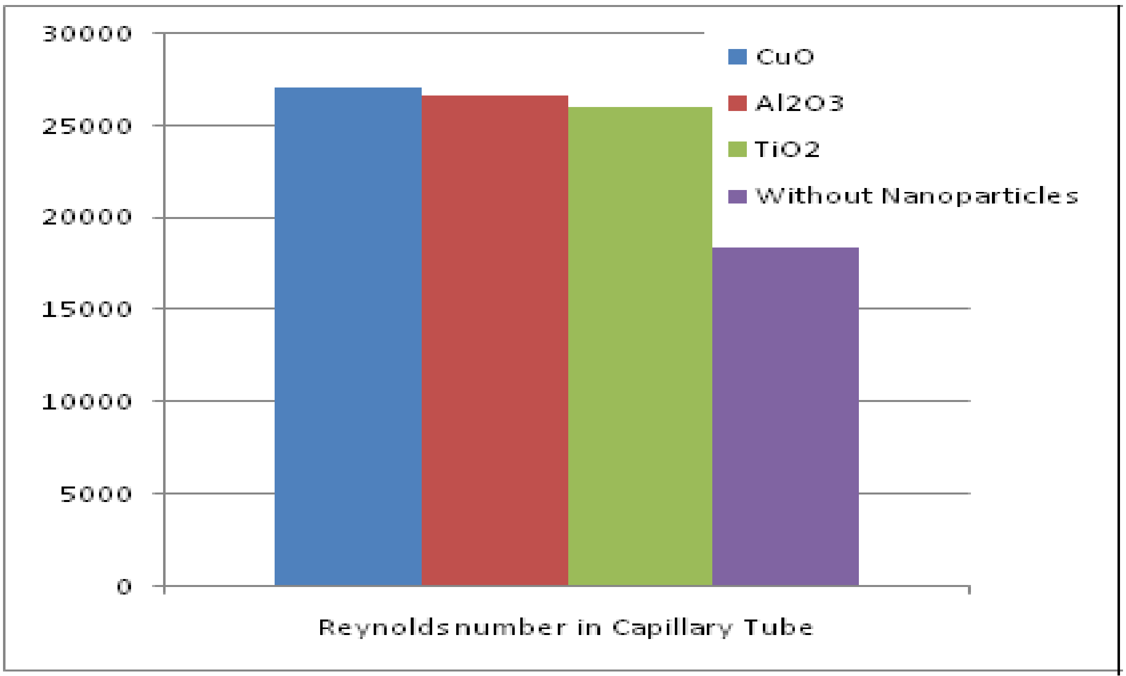

Fig. 12: *Variations of Reynolds numbers in Capillary Tube with Nano materials in VCRS*

Fig-11 shows the variations in Overall condenser heat transfer coefficient of VCRS by using HFO1336mzz(Z) ecofriendly refrigerantin primary circuit and by using different Nano materials mixed with in R718 fluid flowing in secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. By comparing results of system's properties with-and- without Nanoparticles, Overall condenser heat transfer coefficient of VCRS was observed by using CuO and lowest by using TiO2. It has also been found that enhancement in Overall condenser heat transfer coefficient is by using CuO, Al2O3, and TiO2 is about 10.5.%, 9.9%, and 9.23%.

Fig-12 shows the variations of Reynolds number in capillary tube by using different Nano materials mixed with in R718 fluid flowing in the secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. By comparing results of system's properties with-and- without Nanoparticles, higher Reynolds number was observed by using copper oxide and lowest by using TiO2. It has also been found that enhancement in Reynolds number by using CuO, Al2O3, and TiO2 is about 48 %, 45.7% and 42.3%.

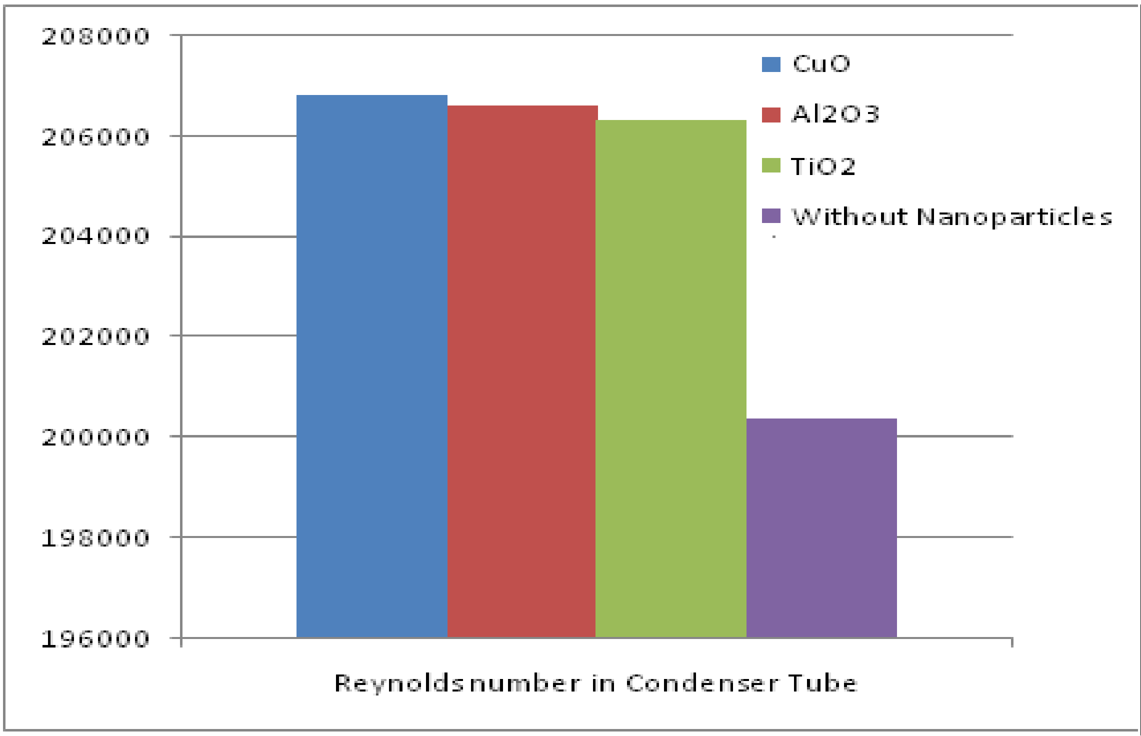

Fig.13: Variations of Reynolds numbers in Condenser tube with Nano materials in VCRS

Fig-13: shows the variations of Reynolds number in condenser tube by using different Nano materials mixed with in R718 fluid flowing in the secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. By comparing results of system's properties with-and- without Nanoparticles, higher Reynolds number was observed by using copper oxide and lowest by using TiO2. It was found that there is a enhancement in Reynolds numbers. It was found that there is enhancement in Reynolds number for condenser tube by using CuO, Al2O3, and TiO2 is about 3.2%, 3.11%, and 2.96%.

From Fig-14 it was found that all the nano-particles gives same Reynolds number when they were immersed in brine flow 1%-5% variation

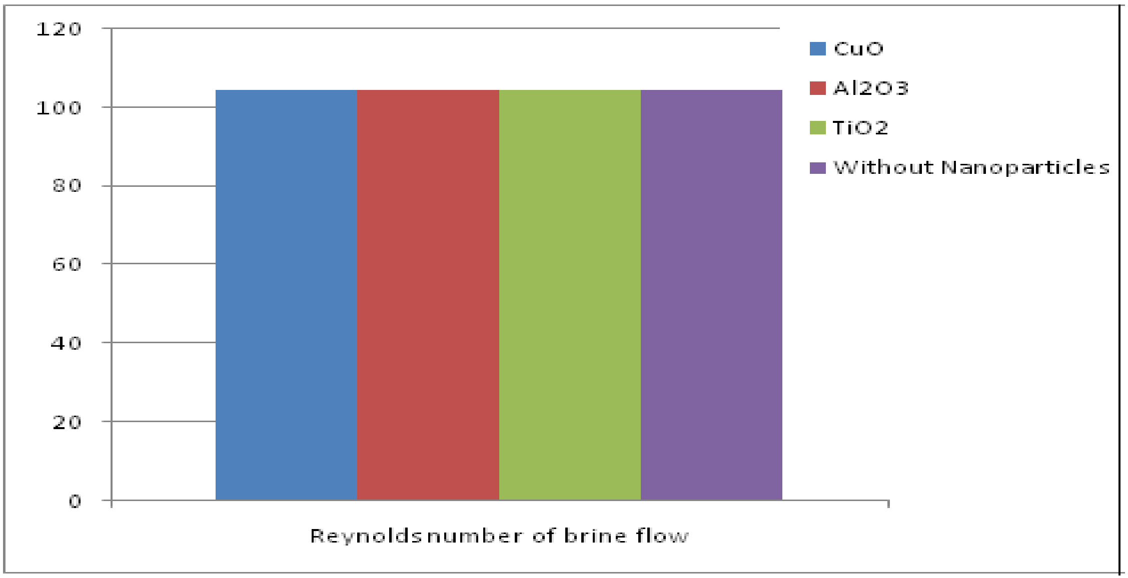

Fig. 14: Variations of Reynolds number of brine flow with Nano materials in VCRS

CONCLUSION

Extensive experimental investigations are necessary to identify the chemicals interaction between molecules. More research works are required to do experiments with natural refrigerants. The studies with natural refrigerants such as CO_2 and NH_3 are still unexplained due to stability. Stability is a key parameter that should be studied more. Stability and sustainability of different combinations are required in the future research. The wetting characteristics of nano-fluids that are to be used in the nano-refrigerants are to be studied extensively. Following conclusions are made-

1. Using ecofriendly refrigerants with suspended CuO, Al2O3 and TiO2 nano particles in the simple refrigeration system it was found that the first law performance(COP) is enhance maximum upto is about 18.5%, 17.5%, and 15.95%,
2. By using ecofriendly refrigerants with suspended CuO, Al2O3 and TiO_2 (Titanium dioxide) nano-particle the second law exergetic erformance of the system is improved in the range of 15.9%, 14.45%, and 12.95 respectively.
3. By using ecofriendly refrigerants with suspended CuO, Al2O3 and TiO_2 (Titanium dioxide) nano-particle the enhancement in Overall evaporator heat transfer coefficient is by using CuO, Al2O3, and TiO2 is about130.1%, 117.29%, and 97.5%.
4. By using ecofriendly refrigerants with suspended CuO, Al2O3 and TiO_2 (Titanium dioxide) nano-particle the enhancement in Overall evaporator heat transfer coefficient is by using CuO, Al2O3, and TiO2 is about130.1%, 117.29%, and 97.5%.
5. Using ecofriendly refrigerants with suspended CuO, Al2O3 and TiO_2 (Titanium dioxide) nano-particle the enhancement in Overall condenser heat transfer coefficient is by using CuO, Al2O3, and TiO2 is about 10.5.%, 9.9%, and 9.23%.
6. Using ecofriendly refrigerants with suspended CuO, Al2O3 and TiO_2 (Titanium dioxide) nano-particle the enhancement in Reynolds number for condenser tube by using CuO, Al2O3, and TiO2 is about 3.2%, 3.11%, and 2.96%.
7. Using ecofriendly refrigerants with suspended CuO, Al2O3 and TiO_2 (Titanium dioxide) nano-particle the enhancement in Reynolds number in capillary tube by using different Nano materials mixed with in R718 fluid flowing in the secondary circuit of evaporator and HFO1336mzz(Z) fluid flowing in primary circuit of evaporator. The enhancement in Reynolds number in capillary tube by using CuO, Al2O3, and TiO2 is about 48 %, 45.7% and 42.3%.

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