International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-04, Issue-08, Nov 2018

Experimental Analysis of a Refrigeration system using Al_2O_3/CuO/TiO_2/ZnO-R1234yf Nanofluids as refrigerant

[1]T.Coumaressin, [2]K.Palaniradja, [3]N. Alagumurthi

[1]Research scholar, [2,3]Professor, [1,2,3]Department of Mechanical Engineering, Pondicherry Engineering College, Puducherry, INDIA

ABSTRACT - Thermal systems like refrigerators and air conditioners consume large amount of power and causes harm to nature. Refrigeration and air conditioning systems have become inseparable from modern life as they have become a part of comfort. Today's energy scenario insists us to control the energy consumption in every possible way. Since refrigeration systems have become more important for people's daily life and consume more power and it is essential to develop energy efficient refrigeration and air-conditioning systems with nature friendly refrigerants. Nano fluids are emerging thermo fluids, which when mixed with pure refrigerant at certain ratio is said to improve the heat transfer coefficient of the refrigerant and hence improves the performance of the Vapor compression refrigeration system. Hydrofluoric-olefins especially HFO-1234yf have zero ozone depletion and very low global warming potential and hence we are expecting HFO as a next generation refrigerants. In addition to that theoretically investigate the influence of Al_2O_3 /TiO_2/CuO and ZnO nano particles on the heat transfer characteristics and performance of refrigerant based nanofluid flow through the vapour compression refrigeration system. The heat transfer coefficient and performance of the system were evaluated by using TK Solver, using nano concentration 0 to 1%.The experimental results shows that the heat transfer coefficient of refrigerant based nanofluid is higher than that of pure refrigerant and also coefficient of performance is higher than the existing system.

INDEX TERMS: Aluminum oxide, copper oxide, Titanium oxide and zinc oxide, nano refrigerant, heat transfer coefficient, COP, TK solver

I. INTRODUCTION

HFO-1234yf is the first in a new class of refrigerants acquiring a global warming potential (GWP) rating one 335th that of R-134a (and only 4 times higher than carbon dioxide, which can also be used as a refrigerant but which has properties significantly different from those of R134A, especially requiring operation at around 5 times higher pressure) and an atmospheric lifetime of about 400 times shorter. It was developed to meet the European directive 2006/40/EC that went into effect in 2011 requiring that all new car platforms for sale in Europe use a refrigerant in its AC system with a GWP below 150.HFO-1234yf, which has a 100-year GWP of 4, could be used as a "near drop-in replacement" for R-134a, the current product used in automobile AC systems, which has a 100-year GWP of 1430. This means that automakers would not have to make significant modifications in assembly lines or in vehicle system designs to accommodate the product. HFO-1234yf has the lowest switching cost for automakers among the currently proposed alternatives, although the initial cost of the product is much higher than that of R-134a. The product could be handled in repair shops in the same way as R-134a, although it would require different, specialized equipment to perform the service. One of the reasons for that is the mild flammability of HFO-1234yf. Another issue affecting the compatibility between HFO-1234yf and R-134a-based systems is the choice of lubricating oil. The current lubricating oil is showing signs of damage to plastic and aluminum, and issues with health, including mouth dryness, rashes, and sore throat, among other effects. Shortly after confirmation from automakers that HFO-1234yf would be adopted as a replacement of R-134a automotive air-conditioning refrigerant, Honeywell and DuPont announced that they will jointly build a manufacturing facility in Changshu, Jiangsu Province, China to produce HFO-1234yf which is now in operation. In addition, Honeywell is building a new plant in Geismar, Louisiana, USA to produce the new refrigerant as well.Although others claim to be able to make and sell HFO-1234yf, Honeywell and DuPont hold most or all of the patents registered for HFO-1234yf.On July 23, 2010, General Motors announced that it will introduce HFO-1234yf in 2013 Chevrolet, Buick, GMC and Cadillac

 DOI : 10.18231/2454-9150.2018.1055

models in the U.S.Although the product is classified slightly flammable by ASHRAE, several years of testing by SAE proved that the product could not be ignited under conditions normally experienced by a vehicle. In addition several independent authorities evaluated the safety of the product in vehicles and some of them concluded that it was as safe to use as R-134a, the product in use in cars today. In the atmosphere, HFO-1234yf degrades to trifluoroacetic acid which is a mildly phytotoxic strong organic acid with no known degradation mechanism in water. In case of fire it releases highly corrosive and toxic hydrogen fluoride and the highly toxic gas carbonyl fluoride..BMW, and VW-Audi agreed with Mercedes and left the SAE R-1234yf CRP Team, stating that the performed tests are not sufficient to fully judge the safety of their vehicles. The German Automakers have been leaning towards carbon dioxide refrigerant which is safer for both passengers and the environment. Following Mercedes claims that the new refrigerant was unsafe, Germany's Kraftfahrt-Bundesamt (Federal Motor Transport Authority) ran a series of tests. The Authority concluded that while the substance was potentially more hazardous than previously used R-134a, it did not comprise a serious danger. However the German Automakers disagree with their findings, and test procedures. Following other independent and in house testing, General Motors still plans to transition all new models to the new refrigerant by 2018. Chrysler announced that they would continue the transition to R1234yf as well.

Nanofluids are a new class of fluids which promise to significantly enhance thermal, rheological and tribological properties of technological fluids. They are obtained by dispersing solid nanoparticles (diameter <100 nm) made by metallic oxides, metals, carbon nano tubes etc. In common fluids such as water, glycol, oils and refrigerants.Nanofluids are dilute liquid suspensions of nanoparticles with at least one of their principal dimensions smaller than 100 nm. From previous investigations, Nano fluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water.Nano fluids are prepared by suspending nano sized particles (1-100nm) in conventional fluids and have higher thermal conductivity than the base fluids. Nano fluids have the following characteristics compared to the normal solid liquid suspensions.

i) Higher heat transfer between the particles and fluids due to the high surface area of the particles.
ii) Better dispersion stability with predominant Brownian motion.
iii) Reduces particle clogging.
iv) Reduced pumping power as compared to base fluid to obtain equivalent heat transfer.
v) Metal oxide nano fluids like aluminum oxide,copper oxide, Titanium oxide and zinc oxide are mixed with base R1234yf refrigerant and are analysed using TK Solver to calculate and plot the characteristic curves. The performance of the system using nano refrigerant was Calculated and also compare the coefficient of performance of the refrigeration system.

Metal oxide nano fluids like aluminum oxide,copper oxide, Titanium oxide and zinc oxide are mixed with base R1234yf refrigerant and are analysed using TK Solver to calculate and plot the characteristic curves. The performance of the system using nano refrigerant was Calculated and also compare the coefficient of performance of the refrigeration system.

II. LITERATURE SURVEY

Jitendra Kumar et al. Discussed about various refrigerants, due to Montreal protocol CFC and HCFC are banned and by Kyoto Protocol HFC are also banned in future so there need for new refrigerant which have low GWP and OZP. He viewed HFO-1234yf has thermal characteristics that are very similar to R-134a, so no major modifications to the A/C system are necessary. Better yet, HFO-1234yf has a global warming potential of only 4, compared to 1200 for R-134a, allowing it to meet the European requirements for a GWP of less than 150.

Mendoza-Miranda et al experimentally analyzed of R1234yf as a drop-in replacement for R134a in a vapor compression system and he concluded the cooling capacity obtained with R1234yf in a R134a vapor compression system is about 9% lower than that obtained with R134a in the studied range. When using R1234yf, the system values of COP about 19% lower than those obtained using R134a.

Karber et al he found that R-1234yf is more suitable than R-1234ze to replace R-134A and he two refrigerator setup for refrigerant. In Refrigerator 1 and 2, R-1234yf had 2.7% and 1.3% higher energy consumption than R-134a this indicates that R-1234yf is a suitable for replace R-134a.In Refrigerator 1 and 2, R-1234ze had 16% and 5.4% lower energy consumption than R-134a. Thus R-1234ze might not be suitable for drop-in replacement.

Barbara Minor et al. conclude that HFO-1234yf has excellent potential as a new low global warming refrigerant for automotive air conditioning and potentially for stationary applications. It has excellent environmental properties which can have a long term favorable impact on climate change and meet current and future climate regulations. Significant toxicity tests have been completed with encouraging results. It is compatible with existing R-134a technology which can allow for a smooth and cost effective transition. The mild flammability properties of HFO-1234y have shown its high potential for use in direct expansion applications, pending completion of risk assessments.

 DOI : 10.18231/2454-9150.2018.1055

Thomas J. Leck he evaluate that HFO-1234yf as a Potential Replacement for R-134a in Refrigeration Applications. This paper presents results of work to develop a Martin Hou equation of state model for calculation of thermo physical properties of this new molecule. And he conclude that the vapor pressures are essentially the same at about 40 ºC. At lower temperatures the vapor pressure of HFO-1234yf is higher than that of R-134a, and above 40 ºC the HFO-1234yf drops to less than that of R-134a.

Katsuyuki Tanaka et al. he studied the thermodynamic properties of hfo-1234yf and he concluded that the critical temperature, the critical density and the critical pressure were determined to be 367.85 ± 0.01 K, 478 ± 3 kg/m^3, 3382 ± 3 kPa, respectively. The acentric factor was determined to be 0.280 by the vapor-pressure correlation.

Pravin K. Katare et al that he compare assessment for drop in replacement of R134a in domestic refrigerator and he finalized that the energy efficiency of HFOs is somewhat low, mixtures of medium GWP fluids such as R32 and low GWP refrigerants such as R1234yf may be the working fluids of choice in the immediate future. After the experimental work for thermo physical properties and transport properties are progress, more reliable equation of state will be developed. As the author's opinion, it is too difficult to find the next generation refrigerant from pure substances. The best combination among HFCs, HFOs, and HCs should be expected in the next generation.

Chi-Chuan Wang he provides an overview about the two-phase heat transfer performance for HFO-1234yf which is made to substitute R-134a. Based on the limited information, it is found that the nucleate boiling heat transfer coefficient (HTC) and convective boiling HTC for HFO-1234yf are comparable to R-134a provided q=200 kWm^2.Thecritical heat flux for HFO-1234yf is about 20–40% lower than that of R-134a.

III. OBJECTIVES

The main aim of the Paper is to evaluate and assess new refrigerants (HFO-R1234yf) performances as a drop in replacements for the common high global warming potential refrigerants. To develop a mathematical model for a system and to perform the heat transfer analysis using the TK solverand also the performance curves for R1234yf refrigerants.

Additionally, to increase the thermo physical properties of the refrigeration system the nano particles (Al_2O_3, CuO, and TiO_2 & ZnO) were added with R1234yf refrigerant.To evaluate the heat transfer coefficients for the different concentrations of Nano particles and to come up with an optimized Nano concentration to maximize the heat transfer coefficient, this in turn increases the refrigeration effect and to compare the COP curves of nano refrigerants with pure refrigerant (HFO).

IV. OBJECTIVES

Thermo physical properties of Nano refrigerant

The thermal conductivity of refrigerant based nanofluid is calculated by Hamilton – Crosser equation (Hamilton and crosser, 1962).

$$K_{rn} = K_r\left(\frac{K_n+2K_r-2\varphi(K_r-K_n)}{K_n+2K_r+\varphi(K_r-K_n)}\right) \quad (1)$$

Where,

K_{rn}– Thermal conductivity of nano refrigerant
K_r - Thermal conductivity of pure refrigerant
K_n - Thermal conductivity of nano particle
φ - Particle volume fraction of nano particle

The dynamic viscosity of nano refrigerant is calculated by Brinkman equation (Brinkman, 1952). The Dynamic viscosity of nano refrigerant is as given below,

$$\mu_{rn} = \mu_r \frac{1}{(1-\varphi)^{2.5}} \quad (2)$$

Where,

μ_r– Viscosity of pure refrigerant
φ – Particle volume fraction

The specific heat capacity of Nano refrigerant is calculated by Pak-cho equation (Pak and Cho, 1998). The specific heat of Nano refrigerant is as given below.

$$C_{p-rn} = (1-\varphi)C_{p-r} + \varphi C_{p-n} \quad (3)$$

Where,

φ – Particle volume fraction
C_{p-r} – Specific heat of refrigerant
C_{p-n} – Specific heat of Nano particle

Convective heat transfer coefficient of Nano refrigerant is given by the following relation (Dr.Saidur et al, 2013)

$$h_{c-rn} = \frac{Nu \times K_{rn}}{D_i}$$

This equation can be written as,

$$h_{c-rn} = 0.023\left[\frac{G^4 \times C_{p-rn}{}^2 \times k_{rn}{}^3}{D_i \times \mu_{rn}{}^2}\right]^{\frac{1}{5}} \quad (4)$$

The volume fraction of Nano particles used in the above given equations can be obtained using the below relation (Haopeng et al, 2009)

$$\varphi = \frac{\omega\rho_r}{\omega\rho_r+(1-\omega)\rho_n} \quad (5)$$

Where,

ω - Mass fraction of nano particle
ρ_r - Density of pure refrigerant
ρ_n - Density of nano particle

The relation for mass fraction of Nano particle is given below (Haopeng et al, 2009)

$$\omega = \frac{M_n}{M_n+M_r} \quad (6)$$

Where,

M_n – Mass of Nano particles
M_n – Mass of pure refrigerant

Mathematical Model for Performance of a Refrigeration system

 DOI : 10.18231/2454-9150.2018.1055

Mass of water in the evaporator vessel

m = Density of water × Volume of water

$$m = \rho \times \frac{\pi}{4} \times D^2 \times h \quad \text{Kg/sec} \qquad (7)$$

Where,

ρ - Density of water
D – Diameter of vessel
h – Height of water in vessel

Heat absorbed from Evaporator Vessel,

Refrigeration effect = $\frac{mc_p(T_i - T_f)}{dT}$KW (8)

Where,

T_i – Initial temperature of water
T_f – Final temperature of water
C_p – Specific heat of water
dT – Duration of experiment in sec

Work done by the compressor

Compressor Work = $\frac{3600}{E} \times \frac{5}{t}$ KW (9)

Where,
E – Energy meter constant
T – Time taken for 5 Flickering of the Energy meter disc

Coefficient of performance

Coefficient of performance of the refrigeration $(COP)_{actual}$

$$COP_{actual} = \frac{Refrigeration\ effect}{Work\ done} \qquad (10)$$

Theoretical COP of a vapour compression refrigeration system is given by

$$COP_{Theo} = \frac{H_4 - H_2}{H_1 - H_4} \qquad (11)$$

Where,
H_1 – Enthalpy of refrigerant at the outlet of compressor
H_3=H_2 – Enthalpy of refrigerant at the inlet of evaporator.
H_4 – Enthalpy of refrigerant at the outlet of evaporator

4. Experimental Set up

The Experimental refrigeration setup was fabricated with following components. A hermetically sealed compressor, a forced type fool condenser , an expansion valve and an evaporator containing water. Experiment was conducted using the above setup using pure R1234yf refrigerant and also Nanorefrigerants.

Figure 1 Vapour compression refrigeration system

V. RESULT AND DISCUSSION

5.1Thermo-physical properities of Nano refrigerants

Heat transfer coefficient

 DOI : 10.18231/2454-9150.2018.1055

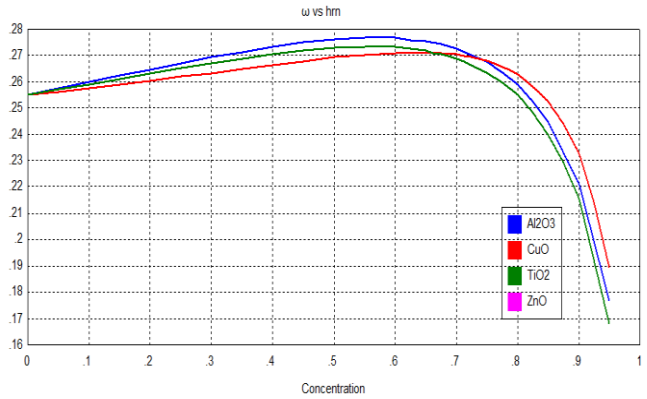

Figure2 Nano concentration Vs Heat transfer coefficient

The above graph shows the Variation of the evaporating heat transfer coefficient for different values of nanoparticles concentrations. It is noticed that the variation of the evaporating heat transfer coefficient is increases with the increase of nanoparticle concentration. Also the heat transfer coefficient increases upto 0.55% nanoparticles concentration and then decreases. The heat transfer coefficient for nanoparticles free refrigerant, 0% concentration shows the lowest value and then increases with almost constant rate upto 0.55% nanoparticles concentration.

Thermal conductivity

The above graph shows the variation between the different nanoparticles concentration and the thermal conductivity of different nano refrigerant. It is found that the thermal conductivity of the different nano refrigerants are increases with the different nanoparticles concentration. Also the thermal conductivity of the different nano refrigerants are same upto 0.55% , after that increases with the increase for nanoparticle concentration. Among these Al_2O_3nano refrigerant gives the higher thermal conductivity than the other nano refrigerants.

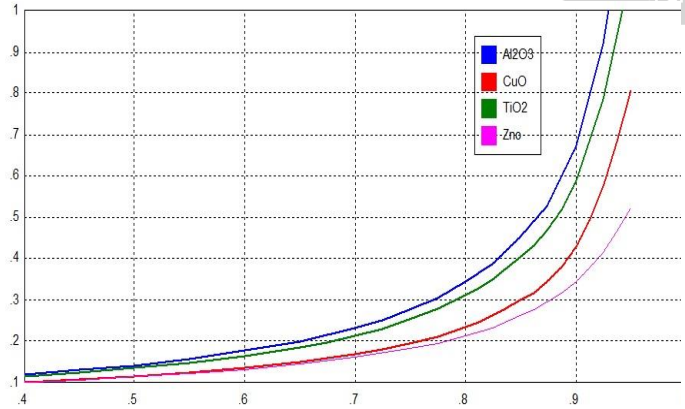

Figure 3 Nano concentration Vs Thermal conductivity

Specific heat capacity

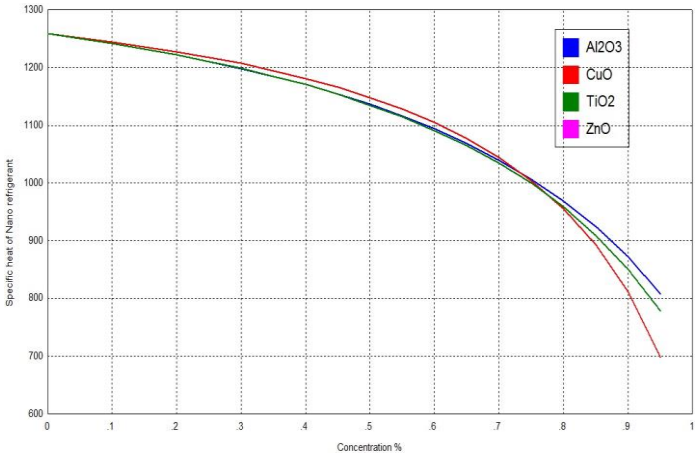

Figure4 Nano concentration Vs Specific heat

The above graph shows the variation of the different nanoparticles concentration and specific heat capacity of different nano refrigerants. It is noticed the specific heat capacity is decreases with the increases the nano particle concentration. Among these CuOnano refrigerant specific heat capacity value is higher than the other nano refrigerants with the different nanoparticles concentration.

Dynamic viscosity

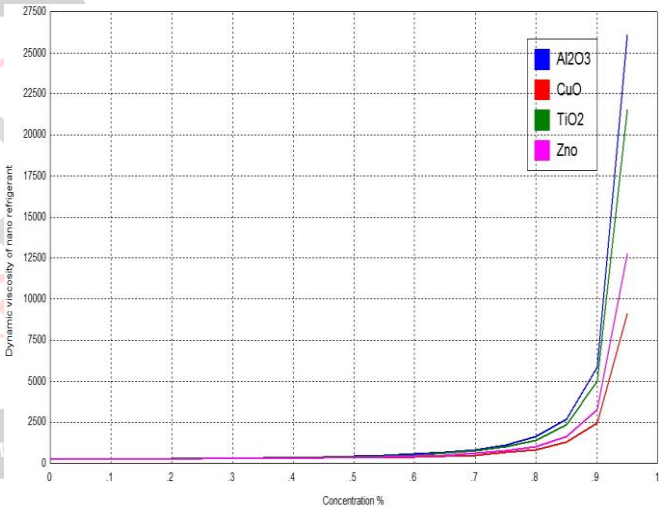

Figure 5 Nano concentration Vs Dynamic viscosity

The above graph shows the variation between the different nanoparticles concentration and the Viscosity of different nano refrigerant. It is found that the Viscosity of the different nano refrigerants increases with the different nanoparticles concentration. Also the Viscosity of the different nano refrigerants are same up to 0.55% , after that increases with the increase for nanoparticle concentration. Among these Al_2O_3nano refrigerant gives the higher Viscosity than the other nano refrigerants.

5.2 Performance of Refrigerant Pure R134a and Nano Refrigerant

The parameters obtained from the experiment conducted on vapour compression refrigeration system using pure R1234yf refrigerant are used to calculate the performance of the system with nano refrigerant of various composition

 DOI : 10.18231/2454-9150.2018.1055

and the coefficient of performance for different nano refrigerant combinations

Table 1 Performance of Nano refrigerant

Refrigerants	Compressor Work(KW)	Refrigeration Effect(KW)	Actual COP	Theoretical COP
Pure R1234yf	0.1172	0.3251	2.774	8.516
Nano Al_2O_3+ R1234yf	0.1197	0.4251	3.552	9.017
Nano CuO + R1234yf	0.1278	0.4251	3.325	8.875
Nano TiO_2 + R1234yf	0.1223	0.4001	3.272	8.726
Nano ZnO + R1234yf	0.125	0.3751	3.001	8.608

5.3 Compression work for refrigerant with and without Nanofluids

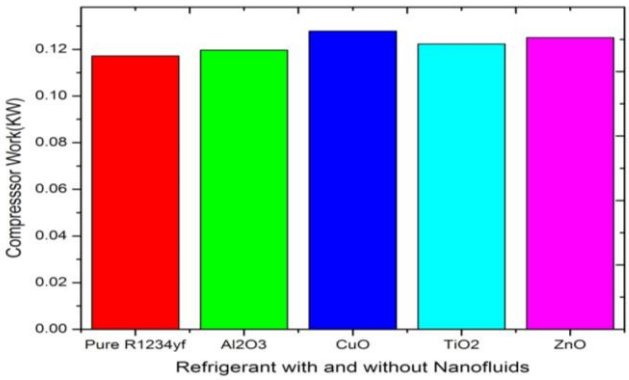

Figure6 Comparision of compressor work for different Nanofluids

The above figure gives the comparision of compressor work for Refrigerant with and without Nanofluids. Compression work is slightly higher the Nanorefrigerant when compared to pure refrigerant beacause of to incresed the volume flow rate of refrigerant by adding nanofluids to refrigerant. But compared to other Nanorefrigerant Al_2O_3 Nano refrigerant is less power consumption by approximately 7%.

5.4 Refrigeration work for refrigerant with and without Nanofluids

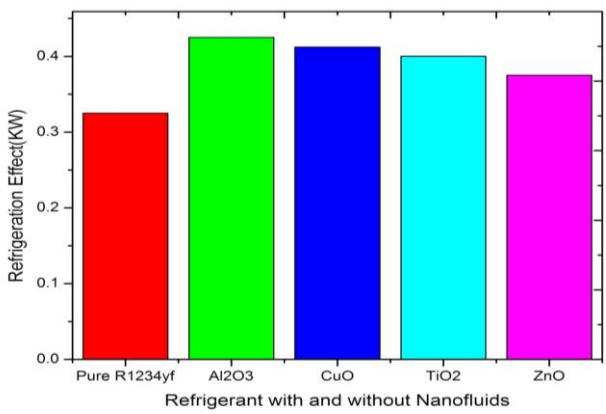

Figure7 Comparision of Refrigeration Effect for different Nanofluids

The above figure gives the comparision of Refrigeration Effect for Refrigerant with and without Nanofluids. Refrigeration Effect of Al_2O_3 Nanorefrigerant is higher when compared to pure refrigerant and also other Nanorefrigerants beacause of Higher thernmal conductivity and higher heat transfer coefficient by adding nanofluids to refrigerant. When compared to other Nanorefrigerant Al_2O_3 Nano refrigerant is Higher refrigeration effect by approximately 10%.

5.5 Coefficient of performance for refrigerant with and without Nanofluids

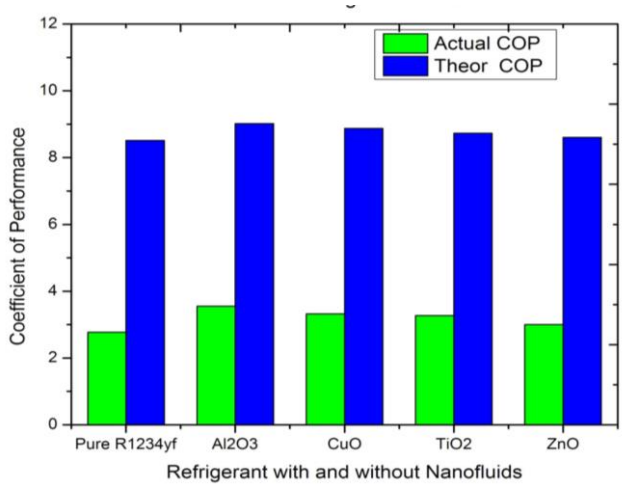

Figure 8 Comparision of Coefficient of Performance for different Nanofluids

The above figure gives the comparision of Coefficient Performance for Refrigerant with and without Nanofluids. Coefficient of Performance of Al_2O_3 Nanorefrigerant is higher when compared to pure refrigerant and also other Nanorefrigerants beacause of Higher Refrigeration effect and higher heat transfer Properities by adding nanofluids to refrigerant. When compared to other Nanorefrigerant Al_2O_3 Nano refrigerant is high Performance by approximately 28%.

VI. CONCLUSION

This paper gives Aluminum oxide, copper oxide, Titanium oxide and zinc oxide nano fluids are used with R1234yf refrigerant in vapor compression refrigeration system. Nanofluids are directly inserted into the refrigerant in the liquid line after the compressor .Using TK solver to evaluated the thermo physical Properties of the Nano refrigerant and Comparison curves were plotted. Fron the Comparsion cureves gives higher values of Al_2O_3 Nanorefrigerant when compared to other Nano refrigerant at 0.55 conentration.The performance of the system is also calculated and found the coefficient of performance to be higher when using aluminum oxide nanofluids compared to others by 28% and also reduced power cosumption by 7%

 DOI : 10.18231/2454-9150.2018.1055

beacause of increaed volumeflow rate through theRefrigeration system.

REFERENCE

[1] Jitendra Kumar Verma, Ankit Satsangi, Vishal Chaturani, A Review of Alternative to R134a (CH3CH2F) Refrigerant, International Journal of Emerging Technology and Advanced Engineering, 2013.

[2] J. Navarro-Esbrý´, J.M. Mendoza-Miranda , A. Mota-Babiloni , A. Barraga´n-Cervera, J.M. Belman-Flores, Experimental analysis of R1234yf as a drop-in replacement for R134a in a vapor compression system, International journal on refrigeration- 36(2013).

[3] Chi-Chuan Wang, An overview for the heat transfer performance of HFO-1234yf, Renewable and Sustainable Energy Reviews 19(2013).

[4] Yukihiro Higashi, Iwaki Meisei, Iino, Chuodai, Thermophysical properties of HFO-1234yf AND HFO-1234ze(E) International Symposium on Next-generation Air Conditioning and Refrigeration Technology, 2010, Tokyo, Japan.

[5] Katsuyuki Tanaka C and Yukihiro Higashi, Thermodynamic Properties of HFO-1234yf (2, 3,3,3-Tetrafluoropropene).

[6] Kyle M. Karber, Experimental Performance of R-1234yf as a Dropin Replacement for R-134a in Domestic Refrigerators, International Refrigeration and Air Conditioning

[7] Conference, 2012.

[8] Barbara Mino, HFO-1234yf Low GWP Refrigerant Update, International Refrigeration and Air Conditioning Conference, 2008.

[9] Thomas J. Leck, Evaluation of HFO-1234yf as a Potential Replacement for R-134a in Refrigeration Applications, 3rd IIR Conference on Thermophysical Properties and Transfer Processes of Refrigerants, Boulder, CO, 2009.

[10] Pravin.K.Katare, Comparative assessment for drop in replacement of R134a in domestic refrigerator, International Journal of Advanced Engineering and Global Technology, 2014.

[11] K. Nagalakshmi, G. Marurhiprasad Yadav, The Design and Performance Analysis of Refrigeration System Using R12 & R134a Refrigerants, Internaitonal Journal of Engineering Research and Applications 2014.

[12] Choi SUS. In: Singer DA, Wang HP, editors. Development and application of non-Newtonian flows, vol. FED 231. New York: ASME; 1995. p. 99–105.

[13] R. Krishna Sabareesh,N. Gobinath, V. Sajithb, Sumitesh Das, C.B. Sobhan, Application of TiO2 Nanoparticles as a Lubricant-Additive for Vapour compression Refrigeration systems-An Experimental Investigation, Int. J. Refri., 35(7):1989,Nov

[14] Yohan Lee,Dong-gyuKang, Dongsoo Jung, Performance of virtually non-flammable azetropic HFO1234yf/HFC134a mixture for HFC134a applications, Int. J. Refrigeration, 36(4) : 1203 June 2013.

[15] Yohan Lee,Dong-gyu Kang,Dongsoo Jung, Performance of virtually non-flammable azetropic HFO1234yf/HFC134a mixture for HFC134a applications, Int. J. Refrigeration, 36(4) : 1203 June 2013

[16] Alawi, O.A.; Sidik, N.A.C.; Mohammed, H.A. A comprehensive review of fundamentals, preparation and applications of nanorefrigerants. Int. Commun. Heat Mass Transf. 2014, 54, 81–95.

[17] Celen, A.; Çebi, A.; Aktas, M.; Mahian, O.; Dalkilic, A.S.; Wongwises, S. A review of nanorefrigerants: Flow characteristics and applications. Int. J. Refrig. 2014, 44, 125–140

[18] Vaishali P. Mohoda etl, A Review on Heat Transfer Enhancement Using Nanoparticles Suspended With Refrigerants/Lubricating Oils in Refrigeration Systems , International Journal of Innovative and Emerging Research in Engineering Volume 2, Special Issue 1 MEPCON 2015

[19] Juan Carlos Valdez Loaiza,Frank Chaviano Pruzaesky,Jose Alberto Reis parise, A numerical Study on the Application of Nanofluids in Refrigeration Systems,Int. Refri. And Air-condtn. Conference, paper 1145, July 12-15,2010

[20] Eastman JA, Choi US, Thompson LJ, Lee S. Enhanced thermal conductivity through the development of nanofiuids. Mater Res Soc Symp Proc 1996;457:3–11.

[21] Pawel K. P., Jeffrey A.E. and David G.C., Nanofluids for thermal transport. Materials Today, 2005. pp. 36-44

[22] Liu M-S, Lin MC-C, Huang I-Te, Wang C-C. Enhancement of thermal conductivity with CuO for nanofluids. Chem Eng Technol 2006;29(1):72–7

[23] Elcock D. Potential impacts of nanotechnology on energy transmission applications and needs. Environmental Science Division, Argonne National Laboratory; November 2007.

[24] Gupta H.K, Agrawal G.D, Mathur J.,,An overview of Nanofluids: A new media towards green environment, International Journal of environmental sciences volume 3, no 1, 2012

 DOI : 10.18231/2454-9150.2018.1055