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Modeling of variable speed compressor vapour compression refrigeration system using ecofriendly refrigerants and nano refrigerants and water cooled condenser-evaporator with experimental validation

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Abstract

Lots of researches have been done and going on based on the performance evaluation of various metallic/ nonmetallic nanoparticle suspended into the conventional fluid to enhance the heat transfer property of base fluid. Also some theoretical analysis of suspension of nanoparticle Al_2O_3 in conventional refrigerant. On the other hand the performance of vapour compression cycle based chiller facility using nano refrigerant yet to be analyzed with different type, concentration and diameter of nanoparticle. Such as TiO_2, CuO nanoparticle suspension into conventional refrigerant with different concentration and diameter have been analyzed by several investigators and also effect of variation of concentration and nanoparticle diameter on the first and second law performance of vapour compression refrigeration system is presented. The effect of changing input parameter of VCRS using nano refrigerant also affecting significantly the evaporative heat transfer coefficient and very little condor heat transfer coefficient. The idea of Suspension nanoparticle into conventional refrigerant and theoretical analysis of VCRS using nano-refrigerant is proposed after going through extensive literature review presented in this paper.

Keywords: VCRS, First & Second Law Performance, Nano Materials, Energy-Exergy Analysis

1. Introduction

Theoretical and experimental investigation of refrigeration systems based on first law and second law analysis using refrigerants.is carried out. Chopra, [1] investigated the exergy analysis of vapour compression refrigeration system with R134a R407Cand R410A. In their study they have calculated the effect of varying evaporator temperature of the C.O.P. of VCS for different types of ecofriendly refrigerant and also the effect of varying evaporator temperature on the exergetic efficiency of VCS. Chopra [2] developed a computational model for computing a coefficient of performance (COP), energy destruction, exergetic efficiency and energy defects for R502, R404A, and R507A of detailed energy analysis on actual vapor compression refrigeration cycle. It has been done for evaporator and condenser temperature in the range of 50^0C to 0^0C and 40^0C to 55^0 C respectively. He found that R507A is better substitute to R502 than R404A. The efficiency defects in condenser are highest and lowest in liquid vapour heat exchanger for the refrigerants considered. Choi, S. U. S, [3] investigated thermal properties and rheological behavior of water based Al_2O_3 nano fluid as a heat transfer fluid and found that Thermal conductivity and convective heat transfer of nano fluid increases as mass concentration of nano fluid increases. Jwo et.al, [4] presented the Effect of different nano particle shapes on shell and tube heat exchanger using different baffle angles and operated with nano fluid, in his study he has analyze the effect of nanoparticle volume fraction on overall heat transfer coefficient and entropy generation & heat transfer rate and found that as well as we increase the volume fraction of nano particle the overall heat transfer coefficient generation & heat transfer rate increases and

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entropy generation decreases. Simulation result has been plotted for the same. Lee K, Hwang [5] in his experimental measured on heat transfer coefficient using Al_2O_3 /water nano fluid in an air finned heat exchanger concluded the overall heat transfer coefficient of Fe_2O_3/water nano fluids in compact air cooled heat exchanger using LMTD technique under laminar flow regime. Joaquin Navarro, Francisco, Angel, [6] carried out thermal modelling analysis of vapour compression refrigeration system and found that the influence of an internal heat exchanger on the performance of a vapour compression system using R1234yf as replacement for R134a and compare the energy performance of vapour compression system using ecofriendly refrigerants,R134a and R1234yf, and found that the presence of an internal heat exchanger results, reductions in cooling capacity and COP between 6 and 13% , when R134a is replaced by the R1234yf. Although the presence of an Internal heat exchanger reductions between 2 and 6%. Murshed S. M. S., K. C. Leong, and C. Yang [7] in this study Comparison of convective heat transfer coefficient and friction factor of TiO_2 nano fluid flow in tube with twisted tape inserts' determined the heat transfer coefficient and friction factor of TiO_2/water nano fluid up to 3.0% volume concentration at an average temperature of 30°C and a significant enhancement of 23.2 % in heat transfer coefficient is observed at 1.0% concentration for flow in tube. An increase in the nanofluid concentration to 3.0% decreased heat transfer coefficient to value lower than water for flow in tube and with tape inserts. A thermal system with tape inserts of twist ration 15 and 1.0% TiO_2 concentration gives maximum advantage ratio, if pressure drop is considered along with enhancement in heat transfer coefficient. Hao Peng et.al [8] in his study on Heat transfer and flow characteristics of Al_2O_3 water nanofluid in a double tube heat exchanger and evaluated that the viscosity, relative viscosity of nano fluid at different mass fraction and sizes of nano particles and found that viscosity, Nusselt no. increases as mass fraction and size of nano particles. And observed that the, for a given refrigerating mass faction of nanoparticles, viscosity, Nusselt no. Reynolds No. increase of base fluid. Henderson et al. [9] evaluated the performance parameters of a vapour compression refrigeration system with different lubricants including nano lubricants and concluded that (i) R134a refrigerant and mineral oil mixture with nano particles worked normally (ii) Freezing capacity of the refrigeration system is higher (iii) The power consumption of the compressor reduces by 25% when the nano lubricant (iv) The coefficient of performance of the refrigeration system also increases by 33% with nano refrigerant (v) the energy enhancement factor in the evaporator is 1.53. Juan Carlos et al [10] investigated the use of nano fluids as secondary coolants in vapor compression refrigeration systems using different nanoparticles (Cu, Al_2O_3, CuO and TiO_2) for different volume fraction and particle diameters. Simulation results have shown that, for a given refrigerating capacity, evaporator area and refrigerant-side pressure drop are reduced when: (i) the volume fraction of nanoparticles increase; (ii) the diameter of nanoparticles decrease. Also, nano fluid side pressure drop and, consequently, pumping power, increase with nanoparticle volume fraction and decrease with nanoparticle size. Henderson et al. [9] Measured enhanced thermal conductivity of Cu-water Nano fluid using secondary circuit of evaporator and observed that the rate of heat transfer is increases with increasing flow rate and also its concentration. By nanoparticle dispersed into de-ionized base fluid a better enhancement is achieved. Xuan Y [10]. Investigated the nanoparticle collision and deposition in the surface investigated the base fluid should possess high prandle number, and get enhanced heat transfer rate by minimize particle-particle and particle-wall collision. Viscous dissipation effect is important of narrow channel, because Nusselt number high for high aspect ratio channel. Wang RX, Xie HB [11] studied experimentally the heat transfer coefficient and friction factor of a nano fluid consisting of water and 0.2 vol. % TiO_2 flowing a double pipe heat exchanger. They investigated the effects of the flow Reynolds number and the temperature of the nano fluid and the temperature and flow rate of the heating fluid on the heat transfer coefficient and flow characteristics. Their results showed that the convective heat transfer coefficient of nano fluid is slightly higher than that of the base liquid by about 6 -11%. The heat transfer coefficient of the nano fluid increased with an increase in the mass flow rate of the hot water and nano fluid.

Lee K, Hwang YJ, [12] Studied about the relation between thermal resistance-size of nanoparticle and found that the thermal resistance is directly proportional to the size of the nanoparticle. The maximum reduction of thermal resistance by using 10 nm sized particles, because particle size is increasing the wall temperature also increases. Due to sized particle suitable for enhanced heat transfer rate. Thermal resistance is decreases with increasing heat and concentration of Nano particle.

Murshed S. M. [13] numerically studied heat transfer characteristics of double-tube helical heat exchangers using nano fluids under laminar flow conditions. CuO and TiO_2 nano particles with diameters of 24 nm dispersed in water with volume concentrations of 0.5–3 vol. % were used as the working fluid. The overall heat transfer coefficient ratio was higher at higher nanoparticle concentrations. In other words, the overall heat transfer coefficient ratio was higher when the probability of collision between nanoparticles and the wall of the heat exchanger were increased under higher concentration, confirming that nano fluids. Wen, D., and Y. Ding (2004) [13] investigated convective heat transfer co efficient of diamond based Nano fluid by using heat tube apparatus and showed the heat transfer coefficient is increases with increasing concentration and Reynolds number of Nano fluid. I.M. Mahbubul, A. Saadah [14] investigated heat transfer enhancement and flow characteristic of Al_2O_3-Water Nano fluid using micro channel heat sink. The dimension of test section is 5x5 mm and 50W heat is applied and found heat transfer is enhanced at high Reynolds number and high concentration of Nano fluid, because at high Reynolds number wall temperature is decreases and pressure drop is increased. Y. He, [15] investigated the thermal performance of air-water heat exchanger using TiO_2Nano fluid. And found that the heat transfer coefficient is increases with increasing Reynolds number at constant volume of friction up to 0.6%. D.P. Kulkarni [16] investigated heat transfer and fluid dynamic performance of nano fluids of silicon dioxide (SiO2) nanoparticles suspended in a 60:40 (% by weight) ethylene glycol and water (EG/water) mixture and observed increase in heat transfer coefficient due to nano fluids for various volume concentrations and loss in pressure was observed with increasing nanoparticle volume concentration. S.Z. Heris, et.al. [17] investigated the flow and heat transfer characteristic of spiral pipe heat exchanger using different type of Nano fluid with different concentration as Al_2O_3 water, TiO_2-water, CuO-water Nano fluid with 1%, 1% and 3% concentration respectively. And observed that the heat transfer enhanced 28% at 0.8% concentration of Nano fluid, due to, increased shear stress of Nano fluid. Bobbo S. et.al, [18] Investigated the friction factor and heat transfer rate of CuO Water and Al_2O_3 water and observed that the increase of Nusselt number with increasing the Reynolds number and concentration decreases the friction factor of Nano fluid. As compared the CuO-water and better enhancement as Al_2O_3 water Nano fluids by using CuO-water Nano fluid. Mishra [19-20] observed the overall heat transfer coefficient of nano fluids increases significantly with prandle number. For both nano fluids the overall heat transfer coefficient increases with nanoparticle concentration compared to the base fluid. The experimental results for the Nusselt number of Al_2O_3/water and TiO_2/water nano fluids and Results show that at 0.5 vol. % of Al_2O_3. Nano particles and at 0.3 vol. % of TiO_2 nanoparticles. Considerable enhancement in convective heat transfer coefficient of the nano fluids as compared to the base fluid, ranging from 2% to 50%. Moreover, the results indicated that with increasing nanoparticles concentration and nano fluid temperature, the convective heat transfer coefficient of nano fluid increases. The Nano fluid shows greater heat transfer coefficient compare with water and increase the inlet liquid temperature decreases the overall heat transfer coefficient. The increasing mass flow rate of brine increases Re and overall heat transfer coefficient.

2. Result and Discussion

The main heading should be A computational program has been developed to solve nonlinear equation of vapour compression refrigeration cycle by considering same performance parameter of the VCRS model (i.e. variation of mass flow rate of brine from 0.006 kg/sec to 0.010 kg/sec for fixing 0.008 condenser water flow rate , mass flow rate of water in condenser from 0.006 to 0.010kg/sec by fixing 0.008 kg/sec of brine mass flow rate at pressure of 2 bars , with 0.000010 m nano particle size mixed in the brine water, the theoretical analysis has been done using EES software for nano fluid (nanoparticle mixed with R718) flowing in secondary circuit and eco friendly refrigerant in primary circuit of VCRS and results are given below.

Table 1 shows the enhancement in C.O.P using different R-404a ecofriendly refrigerant of VCRS and maximum COP is found 14.8% using Cuo nano particles 10.7% using TiO2 and 11.5% using Al_2O_3 for 5% of Volume Fraction (ϕ). Although by varying Volume Fraction (ϕ) the first law performance is increased from 3.8% to 11.5% using Al_2O_3 and 2.6% to 10.5% and 5.2% to 14.8% using Cuo nano materials as compared without nano particles mixed in the brine water flowing in the secondary circuit of evaporator

Table 1: Enhancement in C.O.P using different nano refrigerant of Vapour compression Refrigeration System [21]

Refrigerant		R404a	
Nano particle	Volume Fraction (ϕ)	C.O.P.	% Enhancement
	0	2.379	-
Al_2O_3.	0.01	2.47	3.8%
	0.02	2.524	6.1%
	0.03	2.536	6.6%
	0.04	2.558	7.5%
	0.05	2.653	11.5%
TiO_2	0.01	2.44	2.6%
	0.02	2.498	5.0%
	0.03	2.548	7.1%
	0.04	2.594	9.0%
	0.05	2.634	10.7%
CuO	0.01	2.502	5.2%
	0.02	2.572	8.1%
	0.03	2.63	10.6%
	0.04	2.683	12.8%
	0.05	2.73	14.8%

Table 2 shows the enhancement in C.O.P using different R-407c ecofriendly refrigerant of VCRS and maximum COP is found 14.8% using CuO nano particles 10.7% using TiO_2 and 11.5% using Al_2O_3 for 5% of Volume Fraction (ϕ). Although by varying Volume Fraction (ϕ) the first law performance is increased from 2.9% to 9.4% using TiO_2 and 3.2% to 9.9% Al_2O_3 and 4.4% to 12.1% using Cuo nano materials as compared without nano particles mixed in the brine water flowing in these condary circuit of evaporator.

Table: 2 Enhancement in second law using different nano refrigerant of Vapour compression Refrigeration System [21]

Refrigerant		R407C	
Nano particle	Volume Fraction (ϕ)	C.O.P.	% Enhancement
	0	2.556	-
Al_2O_3	0.01	2.637	3.2%
	0.02	2.702	5.7%
	0.03	2.755	7.8%
	0.04	2.787	9.0%
	0.05	2.808	9.9%
TiO_2	0.01	2.629	2.9%
	0.02	2.685	5.0%
	0.03	2.733	6.9%
	0.04	2.765	8.2%
	0.05	2.795	9.4%
CuO	0.01	2.669	4.4%
	0.02	2.748	7.5%
	0.03	2.806	9.8%
	0.04	2.842	11.2%
	0.05	2.864	12.1%

Table 3 shows experimentally the enhancement in C.O.P using different R-404a ecofriendly refrigerant of VCRS and maximum COP is found 3.817 using CuO and 3.691 using TiO_2 and 3.748 using Al_2O_3. Similarly as volume fraction (ϕ) is increased the first law performance is increased maximum using R134a and minimum as using ecofriendly refrigerant R404a. The % improvement is found in Table-4 from 21.3% in case of Volume Fraction (ϕ) is 1% to 35.4% using R-134a and CuO as nano material and 16.6% to 30.9 % using TiO_2 and 22.8% to 32.9% using Al_2O_3.

Table: 3 Enhancement in C.O.P using different nano refrigerant of Vapour Compression Refrigeration System [22]

Refrigerant		R134a	R404A	R407c
Nano particle	Volume Fraction (ϕ)	C.O.P.	C.O.P.	C.O.P.
	0	2.82	2.379	2.556
CuO	0.01	3.421	2.47	2.637
	0.02	3.604	2.524	2.702
	0.03	3.701	2.536	2.755
	0.04	3.717	2.558	2.787
	0.05	3.817	2.653	2.808
TiO_2	0.01	3.287	2.44	2.629
	0.02	3.488	2.498	2.685
	0.03	3.603	2.548	2.733
	0.04	3.666	2.594	2.765
	0.05	3.691	2.634	2.795
Al_2O_3	0.01	3.464	2.502	2.669
	0.02	3.616	2.572	2.748
	0.03	3.681	2.63	2.806
	0.04	3.725	2.683	2.842
	0.05	3.748	2.73	2.864

Table-4, showing the enhancement in first law efficiency in terms of COP using different ecofriendly refrigerants of Vapour Compression Refrigeration System and maximum COP is found 14.8% using ecofriendly R404a refrigerant and Cuo nano particles, 10.7% using TiO_2 and 11.5% using Al_2O_3 for 5% of Volume Fraction (ϕ). Although by varying Volume Fraction (ϕ) the first law performance is increased from 3.2% to 9.9% using ecofriendly R407c refrigerant and Cuo nano particles and from 2.9% to 9.4% using R407c and TiO_2 as nano particles and 3.2% to 9.9% Al_2O_3 as compared to without nano particles mixed in the brine water flowing in these condary circuit of evaporator

Table: 4 Show % enhancement in C.O.P using different nanorefrigerant of Vapour Compression Refrigeration System [23]

Refrigerant		R134a	R404A	R407c
Nano particle	Volume Fraction (ϕ)	% Enhance ment	% Enhance ment	% Enhance ment
	0	-	-	-
CuO	0.01	21.3%	3.8%	3.2%
	0.02	27.8%	6.1%	5.7%
	0.03	31.2%	6.6%	7.8%
	0.04	31.8%	7.5%	9.0%
	0.05	35.4%	11.5%	9.9%
TiO_2	0.01	16.6%	2.6%	2.9%
	0.02	23.7%	5.0%	5.0%
	0.03	27.8%	7.1%	6.9%
	0.04	30.0%	9.0%	8.2%
	0.05	30.9%	10.7%	9.4%
Al_2O_3	0.01	22.8%	5.2%	4.4%
	0.02	28.2%	8.1%	7.5%
	0.03	30.5%	10.6%	9.8%
	0.04	32.1%	12.8%	11.2%
	0.05	32.9%	14.8%	12.1%

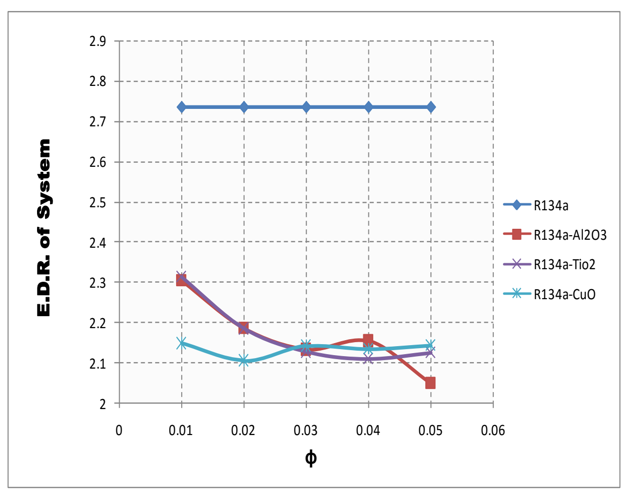

Figure: 1 Variation of Exergy destruction ratio with volume fraction (ϕ) of Vapour Compression Refrigeration System with R134a using different nano particles [24]

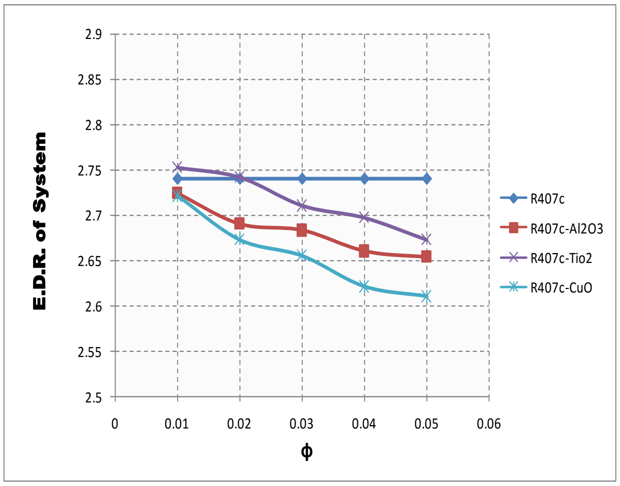

Figure: 2 Variation of Exergy Destruction ratio with volume fraction (ϕ) of Vapour Compression Refrigeration System with R407c using different nano particles [24]

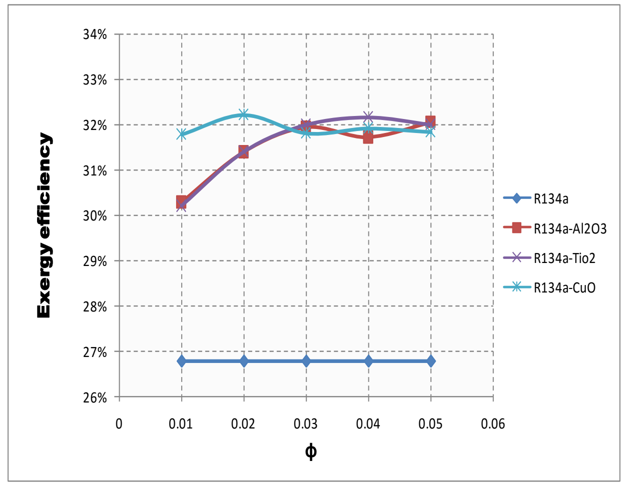

Figure: 4 Variation of Exergy Efficiency with volume fraction (ϕ) of Vapour Compression Refrigeration System with R134a using different nano particles [25]

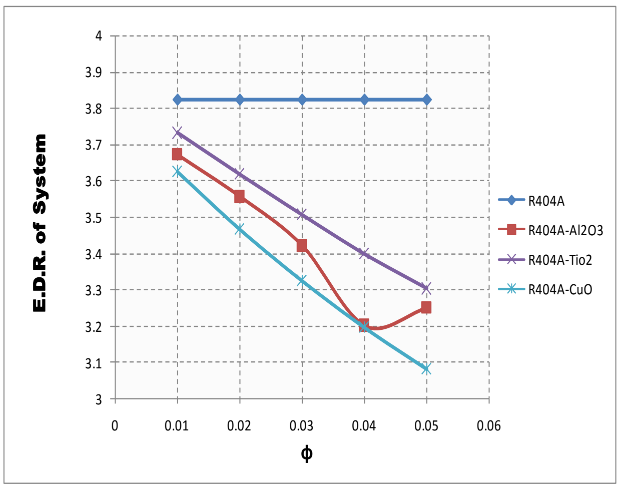

Figure: 3 Variation of Exergy destruction ratio with volume fraction (ϕ) of VCRS with R404A using different nano particles [24]

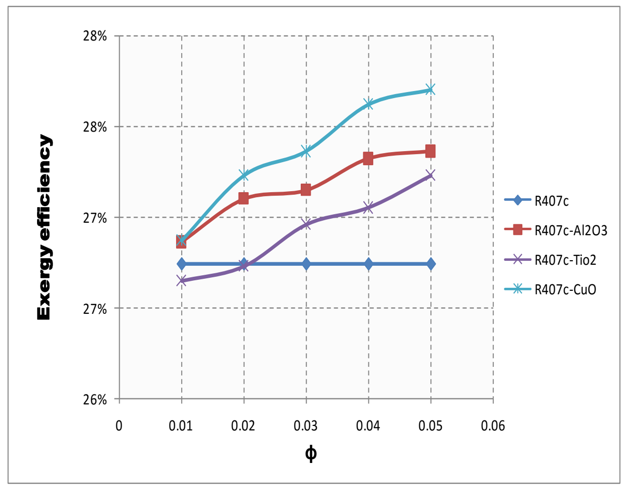

Figure: 5 Variation of Exergy Efficiency with volume fraction (ϕ) of Vapour Compression Refrigeration System with R407c using different nano particles [25]

Fig 1-3 shows that the Exergy .Destruction Ratio (EDR) of VCRS (i.e. which is a ratio of exergy losses in the system to the exergy of output is decreasing as volume fraction ratio is increasing) and will reduce by using nano fluid (nanoparticle based nano refrigerant) and thus improving second law efficiency

The Effect of nanoparticle volume fraction (ϕ) on the second law efficient using R134a as ecofriendly refrigerants in primary circuit of evaporator and with three type of nano materials of 0.000010(m) diameter is shown in Fig-4. As volume fraction Ratio is increasing from 0.01 to 0.05, the exergetic efficiency is increased.

Similarly The Effect of nanoparticle volume fraction (ϕ) on the second law efficiency using R407c and R404a as ecofriendly refrigerants in primary circuit of evaporator and with three type of nano materials of 0.000010(m) diameter is shown in Fig-5-6 respectively. As volume fraction Ratio is increasing from 0.01 to 0.05, the exergetic efficiency is also increasing sharply. The similar trend is also observed in case of using nano materials.

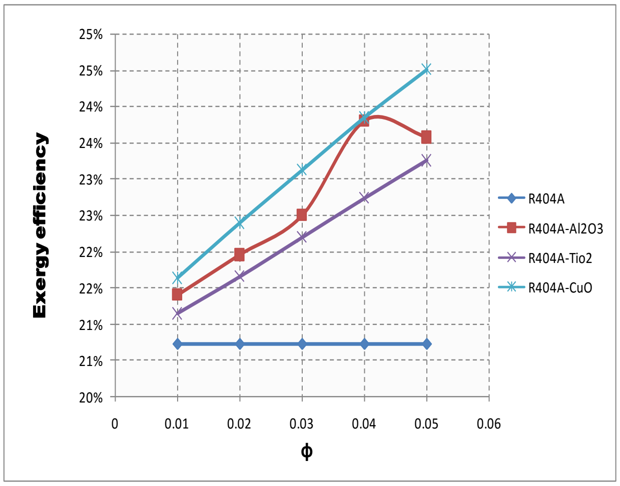

Figure: 6 Variation of Exergy Efficiency with volume fraction (ϕ) of Vapour Compression Refrigeration System with R404A using different nano particles [25]

It was observed that the 2nd Law efficiency will increase by using nano refrigerant. 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 32%. A computational program has been developed to solve nonlinear equation of vapour compression refrigeration cycle Considering same geometric parameter of the VCRS model theoretical analysis has been done using EES software for nano fluid (nanoparticle mixed with R718) flowing in secondary circuit and eco friendly refrigerant in primary circuit of VCRS and Theoretical result of eight different ecofriendly refrigerants and using Al_2O_3 at 5 vol % nano fluid in secondary circuit as obtained from model is shown in Table-5.

Table 5 Enhancement in C.O.P in Vapour Compression Refrigeration System using Al_2O_3at 5 vol % nano fluid in Secondary circuit [26]

For Al_2O_3at volume fraction of 5 vol %		
Refrigerant	First law efficiency C.O.P.	% Improvement in first law efficiency (C.O.P.)
R134a	3.406	17.98%
R404A	3.0635	16.00%
R407c	3.110488	17.20%
R-152a	3.4102	18.00%
R-600	3.3402	17.20%
R-600a	3.466	19.90%
R-125	3.033016	14.80%
R-290	3.54312	19.70%

3. Conclusions

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

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

References

[1] Kapil Chopra .V.Sahni and R.S Mishra (2013)*Energetic and Exergetic Based Comparison Multiple Evaporators with Compound Compression and Flash Intercooler with Individual or Multiple Throttle Valves International Journal of Advance Research & Innovations (IJARI-Vol-1) ISSN No: 2347-3258, pp-73-81.

[2] Kapil Chopra .V.Sahni .R.S Mishra*(2014) "Thermodynamic Analysis of Multiple evaporators vapour compression Refrigeration Systems with R-410a, R290, R1234yf, R502, R404a, R152a and R134a " International Journal of Air conditioning and Refrigeration (Ms. No: IJACR-D-13-00043R1) , Paper Vol-22 No-1, 145-158.

[3] Choi, S. U. S. (1995). Enhancing thermal conductivity of fluids with nanoparticles, in *Developments and Applications of Non-Newtonian Flows* FED–31/MD-66:99–105.

[4] Jwo et.al, 2009. Effect of nano lubricant on the performance of Hydrocarbon refrigerant system. J. Vac. Sci. Techno. B, Vol.27, No. 3, pp. 1473-1477.

[5] K.S. Hwang, S.P. Jang, S. U. S. Choi, (2009) Flow and convective heat transfer characteristics of water-based Al_2O_3 nanofluids in fully developed laminar flow regime, Int. J. Heat Mass Transf. 52 193-199.

[6] Joaquin Navarro, Francisco, Angel, (2013). Experimental analysis of internal heat exchanger influence on vapour compression system performance working with R1234yf as drop in replacement of R134a. Applied thermal Engineering, 59, 153-161.

[7] Murshed S. M. S., K. C. Leong, and C. Yang (2005). Enhanced thermal conductivity of TiO_2-water based nanofluids, *Int. J. Therm. Sci.*, 44: 367–373.

[8] Hao Peng et.al., (2010). Nucleate pool boiling heat transfer characteristics of refrigerant/oil mixture with diamond nano parti cles. International Journal of Refrigeration, Vol.33, pp. 347-358.

[9] Henderson et al. (2010) Experimental analysis on the flow boiling heat transfer of R134a based nanofluids in a horizontal tube. IJHMT , Vol. 53, pp. 944-951.

[10] Xuan, Y., and Q. Li (2003). Investigation on convective heat transfer and flow features of nanofluids, *J. Heat Transfer*, 125: 151–155.

[11] Wang RX, et.al. [2003.] A refrigerating system using HFC134a and mineral lubricant appended with N- TiO_2(R) as working Fluids. In: Proceedings of the 4th international symposium on HAVC, Tsinghua University.

[12] Lee K, Hwang YJ, [2009]Performance evaluation of nano-lubricants of fullerene nanoparticles in refrigeration mineral oil. Curr Appl Phys;9:128–131.

[13] Wien, D., and Y. Ding (2004). Experimental investigation into convective heat transfer of nanofluids at the entrance region under laminar flow conditions, *Int. J. Heat Mass Transfer*, 47: 5181–5188.

[14] I.M. Mahbubul , A.Saadah (2015) Thermal performance analysis of Al_2O_3 R134a nanorefrigerant , international journal of heat and mass transfer 85 1034-1040.

[15] Y. He, (2007) Heat transfer and flow behavior of aqueous suspensions of TiO_2 nanoparticles (nanofluids) flowing upward through a vertical pipe, Int. J. Heat Mass Transf. 50 2272-2281.

[16] D.P. Kulkarni, (2008) Convective heat transfer and fluid dynamic characteristics of SiO_2-ethylene glycol/water nanofluid, Heat Transf. Eng. 29 (12) 1027-1035.

[17] S.Z. Heris, S.G. Etemad, M.N. Esfahany(2006), Experimental investigation of Al_2O_3 nanofluids laminar flow convective heat transfer, Int. Commun. Heat Mass Transf. 33 529535.

[18] Bobbo S. et.al, (2010). Influence of nanoparticles dispersion in POE oils on lubricity and R134a solubility. International Journal of Refrigeration, Vol.33, pp. 1180-1186.

[19] Lee K, Hwang YJ, Cheong S, Kwon L, Kim S, Lee J. Performance evaluation of nano-lubricants of fullerene nanoparticles in refrigeration mineral oil. Curr Appl Phys 2009;9:128–131.

[20] R.S. Mishra (2015) Irreversibility Reduction in Vapour Compression Refrigeration Systems Using Al_2O_3 Nano Material Mixed in R718 as Secondary Fluid s" International journal of Advance Research and Innovation Vol-3, Issue 2 (June-2015), pp. 321-327.

[21] R. S. Mishra (2015) "Performance Evaluation of Ecofriendly Refrigerants in the Low Temperature Circuit in Terms of First Law and Second Law Efficiency of Three Stages Cascade Vapour Compression Refrigeration of Biomedical Applications" International journal of Advance Research and Innovation Vol-3, Issue 2 (June-2015), pp. 332-339.

[22] R.S.Mishra (2015) Methods for Improving Thermodynamic Performance of Vapour Compression Refrigeration Systems Using Nano Mixed Ecofriendly Refrigerants in Primary Circuit and Comparsion with Nano Particles Mixed Wih R718 Used in Secondary Evaporator Circuit and Ecofriendly Refrigerants in Primary Circuit for Reducing Global Warming and Ozone Depletion, International journal of Advance Research and Innovation Vol-3, Issue 2 (June-2015), pp. 433-439.

[23] R. S. Mishra(2015) Modeling of Natural Convection Non Reversible Single Pass Pressurized and Non Pressurized Solar Hot Water Systems for Domestic Applications" International journal of Advance Research and Innovation , ISSN. No:2347 – 3258, Vol-3, Issue 3 (Sept-2015), pp. 451- 458.

[24] R. S. Mishra(2015) " Energy-Exergy Performance Comparison of Vapour Compression Refrigeration Systems using Three Nano Materials Mixed in R718 in the Secondry Fluid and Ecofriendly Refrigerants in the Primary Circuit and Direct Mixing of nano Materials in the Refrigerants" International journal of Advance Research and Innovation Vol-3, Issue 3 (Sept-2015), pp. 471-477.

[25] R. S. Mishra(2015) "Vapour Compression Refrigeration Technology for Sustainable Development" International journal of Advance Research and Innovation Vol-3, Issue 4 (Dec-2015)

[26] R. S. Mishra (2015) Thermodynamic performance comparison using HFO-1234yf and hfo-1234ze in the high temperature cascade refrigeration systems and ecofriendly refrigerants in low temperature applications, International journal of Advance Research and Innovation Vol-3, Issue 4 (Dec-2015).

[27] R. S. Mishra(2015) Energy-exergy performance comparison of vapour compression refrigeration systems using three nano materials mixed in r718 as secondry fluid and r-1234yf and r-1234ze ecofriendly refrigerants in the primary circuit International journal of Advance Research and Innovation Vol-3, Issue 2 (June-2015), pp. 321-327

[28] R.S. Mishra (2013) "Irriversibility Analysis of Multi-Evaporators Vapour Compression Refrigeration Systems Using New and Refrigerants: R134a, R290, R600, R600a, R1234yf,R502, R404a and R152a and R12, R502" International Journal of Advance Research & Innovations International Journal of Advance Research & Innovations (IJARI-Vol-1) , ISSN No: 2347-3258 , PP-180-193.