International Journal of Research in Engineering and Innovation (IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

ORIGINAL ARTICLE

Comparison of thermodynamic(energy-exergy) performances of VCRS using HFOs & HCFOs ecofriendly low GWP refrigerants with HFC-134a in primary circuit and nano mixed R718 in secondary circuit of evaporator

R. S. Mishra

Department of Mechanical Engineering, Delhi Technological University, Delhi, India

Article Information

Received: 30 Sep 2022
Revised: 25 Nov 2022
Accepted: 05 Dec 2022
Available online: 30 Dec 2022

Keywords:

Nano-fluids
Thermo-physical properties
VCRS
HFOs &HCFO refrigerants

Abstract

This paper mainly deals with nano-refrigerants' effect on their performance improvement due to higher evaporator overall heat transfer coefficient and condenser heat transfer coefficient due to its enhanced boiling heat transfer. The Comparison has been done for using new HFO and HCFO refrigerants with HFC-134a in the primary circuit of the evaporator and brine flow in the secondary circuit of the evaporator and found that by using HFO refrigerants the thermodynamic second law(exergy) performances improved up to 32.34%, 28.99 %, and 27.523 respectively by using CuO, Al2O3and TiO2 nanomaterials respectively in the brine water flowing in the secondary circuit of the evaporator. Similarly, its thermodynamic first law performances improved from 35.84%, 32.52%, and 28.18%. using HFO-1234ze(Z) in primary circuit.

1. Introduction

A nanofluid can be defined as a fluid system in which nanoparticles are dispersed in the base fluid. A nano-refrigerant is a refrigeration fluid used in a refrigeration system in which suspended nanoparticles are well-dispersed in a continuous base refrigerant. It has a very long history that has contributed to developing and enhancing modern refrigeration systems [1]. As with time, when nano-technology started playing significant roles in almost all areas of science and technology, Choi, in the year 1995, introduced to the world a different concept of making nano-refrigerant. The main reason for the study and the research related to nanofluids was to improve the thermal conductivity (k)of various fluids. It has been observed that the thermal conductivity of the base fluid increases significantly with the addition of nanoparticles; by mixing carbon nanotube (CNT) in R-113, the thermal conductivity increased by 105%. The main advantage of using nano-refrigerants is their size which assisted in developing lighter refrigeration systems and less power-consuming compressors, and more energy-efficient systems. Secondly, better boiling heat transfer of nano-refrigerants. It has been experimentally investigated that the boiling heat transfer performance of nano-refrigerants is superior to conventional base refrigerants. A 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, [2]; 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 include lowering of friction

Corresponding author: R. S. Mishra
Email Address: rsmishra@dtu.ac.in
https://doi.org/10.36037/IJREI.2022.6603

coefficient of raw oil by replacing it with nano-oil with effective lubricating properties.

2. Effect of Physical-Properties of nano-materials on the performance on vapour compression refrigeration system

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

2.1 Thermal Conductivity

Many essential research investigations have been conducted on studying the thermal conductivity of water-based nanofluids and nano-refrigerants. The thermal conductivity of CNT-based nano-refrigerants is enhanced compared to the base refrigerants fluid (W. Jiang et al. [3]). In their study, CNT nanoparticles of different aspect ratios were selected to be mixed with R-113 as the base refrigerant. They concluded that conductivity enhancement in the case of CNT-R113 nano-refrigerants was higher compared to CNT-water nano-fluids. They also observed that the larger aspect ratio of CNT nanoparticles improved the conductivity of CNT R-113 nano-refrigerants. Y.J. Hwang et al.[4] carried out experiments to measure the thermal conductivity of different nanofluids in which plain water and ethylene glycol were used as base fluids and MWCNT, silicon oxide(SiO_2), and cupric oxide(CuO) were the nanoparticles dispersed in the water and ethylene glycol(base-fluid). They concluded that the nanofluid's conductivity depended on the constituent nanoparticles' and base fluids' individual thermal conductivity. Moreover, it also depends on factors like the volume fraction of nanoparticles, their size, temperature, the material used for the formulation of the base fluid, pH and the methods used to extract nanoparticles like" Sonication," Philip and Shima,[5]. Hence, it can be seen how the thermo-physical properties of nano-refrigerants play a significant role in the refrigeration system area. This is the only reason that maximum research so far has been conducted on experiments on improving the thermal conductivity, and also been stated that the thermal conductivity of nanofluid improves non-linearly with increasing temperature [6].

2.2 Viscosity

The viscosity of nano-refrigerants is the following important parameter (after thermal conductivity) that has drawn the attention of researchers working in this domain. The incorporation of nanoparticles into the refrigerants increases the viscosity of the resultant nano-refrigerant. This increase eventually increases the pressure differential during the flow. Still, an increase in thermal conductivity and heat transfer coefficient compensates for the effect encountered due to increased viscosity on pressure drop.

Einstein [7] proposed a model for the viscosity of the fluids suspended with nanoparticles. But he never mentioned the effect of the size of the particles used to form the nanofluids. 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 to future research in this area. After that, different flow models were proposed, but none of them explained the role of the size of the particle on viscosity measurements.

A.K.Sharma et al. [8] explained the flow parameters of different time-independent nanofluids and summarized that a significant fraction of nanofluids shows linear dependency on the shear stress with changing rate of shear, i.e., they exhibited Newtonian behavior when loading of particles was increased as far as the shape of the nanoparticles is concerned, spherical shaped nanoparticles show Newtonian behavior. Many researchers also concluded that nano-refrigerants' viscosity might increase with the improvement in their volume fraction.

3. Other thermo-physical properties affect the performance of VCRS.

Boiling and condensation heat transfer plays a significant role for nano-refrigerants. Both these parameters depend on other physical properties apart from conductivity and rheology of nano-refrigerant. Properties like IFT are critical parameters that significantly change a refrigeration system's performance. It was observed by Cheng et al. [9] that the IFT of plain water decreases with the addition of surface active agents in the base fluid & they investigated the IFT of CNT-water nanofluid and observed a 14% increase in the same as compared to that pure water. On the contrary, S. S. Khaleduzzaman et al. [10] postulated that it is challenging to get the IFT variation because of nano-fluids as it can increase or decrease in either way by adding nanoparticles. The other property that is relevant to nano-refrigerants is specific heat capacity.

In their study,I.M. Shahrul, et.al.,[11] : observed that specific heat is a function of the type of nanoparticles and the type of continuous base fluid; therefore, it can either increase or decrease in the case of nanofluids. W. Jiang, G. Ding, and H. Peng, [12-14]: have shown that the thermal conductivity of R113-CNT nano-refrigerants increased by 50% to 104%. The thermal conductivity was measured by the Transient Plane Source (TPS) technique. They have suggested that the aspect ratio to diameter of nano-tubes directly affected the improvement of thermal conductivity and observed that the thermal conductivity of R113-based nano-refrigerants was increased by 20% at a volume fraction of 1%. Almost the same trend was displayed by all the nano refrigerants used in the investigation. H. Peng, et al. [15] worked with the R141b-MWCNT combination and found that anionic, cationic and non-ionic refrigerants controlled the aggregation significantly. I.M. Mahbubul, R. Saidur and M.A. Amalina [15] investigated the rheology of R123/TiO_2 nano-refrigerants and observed a viscosity increase. Also observed that the impact of volume fraction of particles and temperature on thermo physical properties of R141b based nano-refrigerants prepared with

Al2O3. The researchers reported that the thermal conductivity of nano-refrigerants increased with the addition of particle concentration and temperature. S.Ozturk, Y.A. Hassan and V.M. Ugaz, [16] : developed the nano sheets made of graphene MWCNT based on nano-refrigerants. From the experimental data, authors concluded that nanosheets have the unique potential to improve thermal conductivity.

3.1 Pressure Drop Studies in Nano-Refrigerants

The primary purpose of studying the pressure drop is to get over the decrease in efficiency caused by the increase in the viscosity of the nano-refrigerants. Numerous experimental studies have been conducted to investigate single-phase pressure drop phenomena of different fluids formulated with the help of nanoparticles. The increase in pressure drop can lead to the requirement of more power to circulate nano-refrigerant. So far, the desired conclusion on the effects caused by increased pressure drop has yet to be reported. So to design an efficient refrigeration system with nano-refrigerants, more experimental studies are required. H.Peng, et al., [12, 13,] performed the experiments to study the frictional pressure differential properties of CuO; R113 nanoparticle-refrigerant combination. Their studies concluded that the inclusion of nanoparticles in the refrigerant increased pressure drop. Moreover, the frictional pressure differential increased by 20.8% at the molar flux of 100kg/m^2 and a molar fraction of 0.5 wt%. Apart from this, as the vapor quality improved, the flow parameters changed to annular flow, resulting in a pressure differential. H.Peng, et.al.,[14] also worked with the R141b-MWCNT combination and found that the presence of anionic, cationic and non-ionic refrigerants controlled the aggregation significantly. I.M. Mahbubul, R. Saidur and M.A. Amalina [15,17] did experiments with nanoparticles Al2O3 and refrigerant R141b inside a smooth horizontal tube. They observed an improvement in the pressure drop up to 181%. Likewise, Omer A. Alawi et al. [18] performed the experiments with the TiO2 nanoparticle and R123 nano refrigerant, and they observed enhancement in pressure drop by 42.5% at 0.5% volume fraction.

3.2 Boiling heat transfer in nano-refrigerants

In the last few years, researchers have been focusing on studies to enhance the role of nanoparticles on pool boiling and flow boiling heat transfer of nano-refrigerants. Optimizing these two phenomena is possible to improve the heat transfer performance of nano-refrigerants. However, several researchers have published particular studies on boiling processes in nano-refrigerants. K.J. Park and D.Jung, [19], conducted experiments with a 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 up to 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 2007, K. Jung, et.al [20] performed experiments with R-123, R-134a-CNT combination in a plane tube and observed a decrease in the heat transfer coefficient. M.A.Kedzierski and M.Gong, [21]: worked with an R-134a-CuO refrigerant-nanoparticle combination and evaluated an increase in boiling heat transfer in 50 to 275%. D.W. Liu and C.Y. Yang [22] used a 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, [23]: performed experiments with the R141b-Au combination and observed that the heat transfer coefficient was doubled. The researchers performed the experiments in plain copper tube.

K. Bartelt, Y Park and A. Jacobi [24]: worked with the R-134a-CuO refrigerant-nanoparticle combination with polyester (POE) and conducted experiments in horizontal tubes; they manifested an increment in heat transfer coefficient by 42%. K. Henderson, et al., [25]: also performed an R-134a-CuO combination in the same horizontal tubes with POE as a lubricant and observed a development in the heat transfer coefficient by 101 %. H. Peng, et.al, [13] also worked with the R-113-CuO combination and observed that the maximum heat transfer improvement attained was 29.7%. B.Sun and D.Yang, [26,27]: performed experiments with an R-141b-CuO combination and observed that the heat transfer coefficient was increased about 1.14 times. I.M.Mahbubul et al. [28] carried out experiments with an R-134a-Al2O3 variety and observed a significant increment in the heat transfer coefficient.

M.A. Akhavan et al. [29]: did an experiment with R-600-CuO combination with POE as a lubricant and noticed that the heat transfer coefficient might increase up to 63%. The nano-particles present in the base fluid has Brownian movement in addition to weak Vander wall forces and high surface free energy. This phenomenon leads to the cluster formation of nanoparticles, and they get sediment. This will finally impact the performance of nano-refrigerants. S.S.Bi, L.Shi and L.Zhang,[30]: did experiments on the stability of refrigerant-nanoparticle combination of R113, R123, and R141b-TiO2 with surfactant span 80 and found the system was highly stable. L.Lin, H. Peng and G.Ding, [31] worked with TiO_2/NM56/R141b nano-lubricant-refrigerant mixture and found that the presence of lubrication oils prevents aggregation.

M.Xing, R. Wang and J.Yu, [32]: 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 a decrease in the compressor temperature, which is a desirable property in the refrigeration system.

Many researchers [33-35] have also reported that the quantum of work should be increased on nano-refrigerant condensation heat transfer. Oxides of metals such as Al2O3, TiO2 and CuO can be considered 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 nanoparticles in the nano-refrigerants. Likewise, the presence of lubricating oils prevented the aggregation behavior and reported an increase of about 127% in steady-state hydro-dynamic diameter with the use of R-141b nano-refrigerant. So the researchers [36-38] and researchers have also observed an increase in boiling heat transfer by 129% with the use of R-134a nano-refrigerant. Further, there is a requirement for more work to be done on R-134a nano-refrigerant so that cooling can be more than 6%. Using nano-refrigerants results in increasing COP and less power consumption.

4. Results and Discussion

Nano-refrigerants have a promising future with lots of advantages and challenges that should be pursued by researchers working in this field. This paper aims to address such promises, improve the efficiency of nano-refrigerants, and increase their performance. Mishra [36] pointed out that the conductivity ratio of pure refrigerant to Nano refrigerant increases with the concentration of nanoparticles in the host refrigerant. In contrast, Cu nanoparticle-based Nano refrigerants have a higher conductivity ratio than other nanoparticles and have approx. Two times higher than base refrigerant at 5 vol % concentration and the eco-friendly HFC-134a with copper oxide as nanoparticle have the highest Effectiveness factor approx. 3.2 at 5 vol %. The Effectiveness Factor increases with an increasing percentage of volume (vol %), and the copper nanoparticle-based nano refrigerant has the highest convective heat transfer coefficient ratio than other nanoparticles mixed in brine water in the secondary circuit of the evaporator. In response to various environmental conventions, more environmentally friendly refrigeration systems have been investigated in recent years. Two aspects are of particular concern: ecological (ecologically friendly) refrigerants and energy consumption.

Mishra [37] computed the first law and second law analysis of vapour compression refrigeration system with and without Nanoparticles using eco-friendly refrigerants (R134a, R407c, R404a, R1234yf, and R1234ze) and suggested the blend of nanoparticles with ecological refrigerant has a promising future and R1234yf and R1234ze Nano refrigerants have potential to replace R134a and concluded that (i) By using Nano in the HFC-410a gives the worst thermal performance in terms of first law efficiency, second-law efficiency and exergetic efficiency. (ii) The best thermal performance in terms of first-law efficiency is found by using R134a. (iii) By increasing the evaporator temperature, the first law performance (COP) increases. (iv) By increasing condenser temperature, the first law thermal performance (COP) decreases. (v) First and second law efficiency for vapour compression refrigeration system without CuO nanoparticles mixed in R718 in the secondary evaporator circuit and eco-friendly refrigerants in the primary circuit (i.e., R134a and R1234ze) match the same values. However, R1234ze has slightly fewer performances than R134a. (vi) HFO-1234ze eco-friendly refrigerant is better than that for R123yf, showing a 2% to 6% higher value of first law efficiency (i.e., COP). (vii) Both energetic and exergetic increase with the increase in the degree of subcooling (viii) Energetic and exergetic efficiency is greatly affected by changes in evaporator and condenser temperature. (ix) R1234ze is the best among considered refrigerants since it has 218 times lower GWP values than R134a, and R1234ze is eco-friendly and has both ODP and GWP are lowest. The R1234yf and R1234ze can replace R-134a after 2030 due to low global warming potential. The author has not studied the thermodynamic performances using HCFsO (such as R1224yd(Z) and HCFO-1233zd (E) and other HFO refrigerants (such as HFO-1234ze(Z), R1243zf, R1225ye(Z). In this paper, the following input parameters have been taken.

Length of evaporator tube =7m
length of condenser tube =12.5m
a mass flow rate of water flow is 0.008kg/sec
a mass flow rate of brine flow is 0.007kg/sec
condenser water inlet temperature =27°C
brine water inlet temperature =27°C

The thermodynamic performances of vapour compression refrigeration using HFOs and HCFO refrigerants have been carried out in terms of first-law efficiency (COP) and second-law efficiency (Exergy efficiency) and compared with the thermodynamic performances without nanofluid in the secondary circuit using HFC-134a in the primary circuit.

X Table-1 shows the variations of first law performance in terms of coefficient of performance (COP) with different eco-friendly low GWP refrigerants flowing in the primary circuit of the evaporator and R718 fluid flowing in the secondary circuit of the evaporator. It is found that R1234ze(Z) gives the best first-law thermodynamic performance (COP) and is slightly higher than HCFO-1233zd(E) and HCFO-1224yd(Z). However, the lowest first-law performance COP was found using R1234yf in the primary circuit of the evaporator.

Table 1: Effect of ecofriendly refrigerants in the primary circuit on the thermodynamic first law performance(COP) of vapour compression refrigeration system using nano fluid in secondary circuit of evaporator

Ecofriendly Refrigerants	COP without nano material	% Improvement in COP
R1234ze(Z)	3.195	12.698
R1234ze(E)	2.789	-1.622
R1224yd(Z)	3.076	9.206
R1243zf	2.783	-1.834
R1233zd(E)	3.156	11.323
R1225ye(Z)	2.752	-2.928
R1336mzz(Z)	3.071	8.324
R1234yf	2.667	-5.926
R134a	2.835	0.0

Table 2 shows the first law performance variations in the coefficient of performance (COP) with different eco-friendly low GWP refrigerants flowing in the primary circuit of the evaporator and R718 fluid flowing in the secondary circuit of the evaporator. It is found that R1234ze(Z) gives the best first-law thermodynamic performance (COP) and is slightly higher than HCFO-1233zd(E) and HCFO-1224yd(Z). However, the lowest first-law performance COP was found using R1234yf in the primary circuit of the evaporator.

Table 2(a): Effect of ecofriendly refrigerants in the primary circuit on the thermodynamic first law performance(COP) of vapour compression refrigeration system using nano fluid in secondary circuit of evaporator and Comparison of first law performance (coefficient of performance) using different ecofriendly low GWP refrigerants with HFC-134a in VCRS

Ecofriendly Refrigerants	COP using CuO	% improvement in COP	COP using Al_2O_3	% improvement in COP	COP using TiO_2	% improvement in COP
HFO-1234ze(Z)	3.851	35.84	3.757	32.522	3.634	28.18
HFO-1234ze(E)	3.589	26.596	3.564	25.714	3.386	19.43
HCFO-1224yd(Z)	3.762	32.698	3.685	29.982	3.408	20.21
HFO-1243zf	3.588	26.561	3.457	21.940	3.375	19.048
HCFO-1233zd(E)	3.818	34.674	3.746	32.134	3.593	26.74
HFO-1225ye(Z)	3.417	20.529	3.404	20.07	3.365	18.695
HFO-1336mzz(Z)	3.715	31.040	3.685	29.982	3.505	23.633
HFO-1234yf	3.452	21.764	3.429	20.95	3.352	18.236
HFC134a	3.621	27.72	3.602	27.055	3.502	23.527

Table 3 shows the variations of second law (exergy) performance in terms of exergy efficiency with different HFOs and HCFO eco-friendly low GWP refrigerants flowing in the primary circuit of the evaporator and R718 fluid flowing in the secondary circuit of the evaporator. it is found that HFO1234ze(Z) gives best second law exergy performance and slightly higher than HCFO-1233zd(E) and HCFO-1224yd(Z) However the lowest second law(exergy) performance was found by using R1234yf in primary circuit of evaporator.

Table 3: Effect of ecofriendly refrigerants in the primary circuit on the thermodynamic first law performance(COP) of vapour compression refrigeration system using nano fluid in secondary circuit of evaporator and Comparison of first law performance (coefficient of performance) using different ecofriendly low GWP refrigerants with HFC-134a in VCRS

Ecofriendly Refrigerants	Exergy Efficiency using CuO	% improvement in Exergy Efficiency	Exergy Efficiency	% improvement in Exergy Efficiency	Exergy Efficiency	% improvement in Exergy Efficiency
R1234ze(Z)	0.3902	32.344	0.3806	28.990	0.3764	27.523
R1234ze(E)	0.3543	19.804	0.344	16.277	0.3385	14.286
R1224yd(Z)	0.3780	28.082	0.3690	24.939	0.3644	23.332
R1243zf	0.3543	19.804	0.3463	17.01	0.3382	14.181
R1233zd(E)	0.3857	30.772	0.3763	27.489	0.3672	24.310
R1225ye(Z)	0.3493	18.058	0.3415	15.334	0.3325	12.19
R1336mzz(Z)	0.3717	25.882	0.3629	22.808	0.3512	18.722
R1234yf	0.3308	11.596	0.3239	9.186	0.3202	7.894
R134a	0.3587	21.341	0.3504	18.442	0.3305	11.49

Table 4: Effect of ecofriendly refrigerants in the primary circuit on the thermodynamic performances of vapour compression refrigeration system using nano fluid in secondary circuit of evaporator and Comparison of first law performance (coefficient of performance) using different ecofriendly low GWP refrigerants with HFC-134a in VCRS

Ecofriendly Refrigerants	First law Efficiency (COP)	Exergy Destruction Ratio (EDR)	Exergy Efficiency	Compressor Work W_{Comp} "kW"	% Exergy Destruction In comp	% Exergy Destruction in cond.	% Exergy Destruction in valve.	% Total exergy Destruction	% Rational Exergy Efficiency	% error
R1234ze(Z)	3.851	1.563	0.3902	1.234	17.92	30.53	13.8	62.25	37.75	3.255
R1234ze(E)	3.589	1.645	0.3543	1.359	18.37	28.37	19.54	66.28	33.72	4.382
R1224yd(Z)	3.762	1.822	0.3780	1.273	18.39	29.3	15.73	63.42	36.58	3.126
R1243zf	3.588	1.593	0.3543	1.359	18.15	28.37	19.2	65.72	34.28	2.947
R1233zd(E)	3.818	1.863	0.3857	1.248	18.24	29.88	14.56	62.68	37.32	3.203
R1225ye(Z)	3.417	1.788	0.3493	1.378	18.33	27.89	19.99	66.21	33.79	2.922
HFO1336mzz(Z)	3.715	1.69	0.3717	1.295	18.44	28.85	16.74	64.03	35.97	3.075
R1234yf	3.452	2.023	0.3308	1.455	18.40	26.85	22.74	67.99	32.01	2.742
R134a	3.621	1.788	0.3587	1.342	17.82	29.15	18.34	65.31	34.69	3.024

Table 4 shows the thermodynamic performance in terms of first law efficiency (COP), the second law (exergy) efficiency of vapour compression refrigeration system using different low GWP refrigerants (including HFO and HCFO refrigerants flowing in the primary circuit of the evaporator) and R718 fluid flowing in the secondary circuit of evaporator using nano CuO -oxide and found that the first law performance is highest using HFO-1234ze(Z). However, first law thermodynamic performance (COP) using HCFO refrigerants is slightly less than HFO-1234ze(Z) and higher than HFO-1234ze(E), HFO-1225ye(Z), HFO1243zf. The lowest performance was observed using HFO-1234yf. The thermodynamic performances were also compared with HFC-134a, which has a higher global warming potential (GWP). The maximum exergy destruction was observed in the condenser component, and the lowest was observed in the throttle valve of vapour compression refrigeration system using HFO-1234ze(Z) in the primary circuit. Cuo mixed brine water flowing in the secondary circuit of the evaporator of vapour compression refrigeration system. The second law(exergy) performance was compared using both methods, and % error was a maximum of 4.382%, which validates our model.

5. Conclusions and Recommendations

Extensive investigations are necessary to identify the chemical interaction between molecules. More research work is required to do experiments with natural refrigerants. The studies with natural refrigerants such as CO2 and NH3 are still unexplained due to their stability. Stability is a critical parameter that should be studied more. The stability and sustainability of different combinations are required in future research. The wetting characteristics of nano-fluids used in the nano-refrigerants will be studied extensively. The following conclusions are made-

- Using eco-friendly HFO-1234ze(Z) refrigerant with suspended CuO, Al2O3 and TiO2 nanoparticles in the brine water of the secondary circuit of the evaporator in vapour compression refrigeration system, it was found that the first law performance(COP) is enhanced maximum upto is about 35.84%, 32.52%, and 28.18%.
- By Using eco-friendly HFO-1234ze(Z) refrigerant with suspended CuO, Al2O3 and TiO2 (titanium dioxide) nanoparticles in the brine water of the secondary circuit in the evaporator, the second law exergy performance of the system is improved in the range of 32.34%, 28.99 %, respectively.
- R1234ze(Z) gives the best first-law thermodynamic performance (COP) and is slightly higher than HCFO-1233zd(E) and HCFO-1224yd(Z).
- The maximum exergy destruction was observed in the condenser component, and the lowest was observed in the throttle valve of vapour compression refrigeration system using HFO-1234ze(Z) in the primary circuit. Cuo mixed brine water flowing in the secondary circuit of the evaporator of vapour compression refrigeration system.
- The lowest thermodynamic performances were found by using HFO-1234yf in the primary circuit and brine water in the secondary circuit of the evaporator of the vapour compression refrigeration system
- The second law(exergy) performance was compared using both methods and % error was a maximum of 4.382%, which validates both methods.

References

[1] S.U.S. Choi (1995): Enhancing thermal conductivity of fluids with nanoparticles, in Developments and Applications of Non-Newtonian Flows, D. A. Singer and H. P. Wang, Eds., ASME, New York, FED–231/MD-66, 99–105

[2] S.U.S Choi, et.al., (2001): Anomalous thermal conductivity enhancement in nanotube suspensions. Applied Physics Letters, 79(14), 2252-2254.

[3] W. Jiang, G. Ding and H. Peng, (2009): Measurement and model on thermal conductivities of carbon nanotube nanorefrigerants. International Journal of Thermal Sciences. 48(6), 1108–1115

[4] Y.J.Hwang, et.al., (2006): Investigation on characteristics of Thermal conductivity enhancement of nanofluids. Current Applied Physics, 6(6), 1068-1071

[5] J.Philip and P.D.Shima, (2012), Thermal properties of nanofluids. Advances in Colloid and Interface Science 183–184, 30–45.

[6] X.Wang and S.U.S Choi, (1999), thermal conductivity of nanoparticle–fluid mixture. Journal ofThermophysics andHeat Transfer, 13(4), 474–480.

[7] A. Einstein, (1906), Eineneuebestimmung der molekül dimensionen Annalen der Physik, 324(2), 289–306

[8] A. K Sharma, A. K. Tiwari and A.K., A.R Dixit (2016): Rheological behaviour of nanofluids: A review. Renewable and Sustainable Energy Reviews 53, 779-791

[9] L. Cheng, D.Mewes and A.Luke , (2007): Boiling phenomena with surfactants and polymeric additives: a state-of-the-art review. International Journal of Heat and Mass Transfer,50, 2744-2771

[10] S. S. Khaleduzzaman, I.M. Mahbubul, I.M. Shahrul and R. Saidur,(2013}:.Effect of particle concentration, temperature and surfactant on surface tension of nanofluids. International Communications in Heat and Mass Transfer, 49, 110–114.

[11] I.M. Shahrul,et.al, (2014): A comparative review on the specific heat of nanofluids for energy perspective. Renewable and Sustainable Energy Reviews 38, 88–98

[12] Peng, H., et.al, (2009), Heat transfer characteristics of refrigerant-based nanofluid flow boiling inside a horizontal smooth tube. International Journal of Refrigeration 32(6), 1259-1270

[13] Peng, H., et.al, (2009), Measurement and correlation of frictional pressure drop of refrigerant-based nanofluid flow boiling inside a horizontal smooth tube, International Journal of Refrigeration 32(7), 1756-1764

[14] H.Peng, et.al.,(2015), Influences of primary particle parameters and surfactant on aggregation behavior of nanoparticles in nanorefrigerant. Energy, 89, 410-420

[15] I.M. Mahbubul, R. Saidur and M.A. Amalina, (2012) Investigation of Viscosity of R123-TIO2 Nanorefrigerant. International Journal of Mechanical and Material Engineering 7(2), 146–151

[16] S. Ozturk, Y.A. Hassan andV.M. Ugaz, (2013), Graphene-enhanced nanorefrigerants. Nanoscale. 5, 541–547

[17] I.M. Mahbubul, R. Saidur and M.A. Amalina, (2013), Conductivity, viscosity and density of R141b refrigerant based Nanofluid. Procedia Engineering, 56, 310 –315.

[18] A. Omer Alawi, (2015): Measurements and correlations of frictional pressure drop of TiO2/R123 flow boiling inside a horizontal smooth tube, International Communications in Heat and Mass Transfer

[19] K.J.Park and D.Jung, (2007). Enhancement of nucleate boiling heat transfer using carbon nanotubes. International Journal of Heat and Mass Transfer. 50, 4499–4502.

[20] K.J. Park andD.Jung, (2007). Boiling heat transfer enhancement with carbon nanotubes for refrigerants used in building air-conditioning. Energy Buildings. 39(9), 1061–1064.

[21] M. A. Kedzierski and M. Gong, (2009), effect of CuO nanolubricant on R134a pool boiling heat transfer. International Journal of Refrigeration, 32(5), 791-799.

[22] D.W.Liu and C.Y. Yang (2007), Effect of Nano-Particles on Pool Boiling Heat Transfer of Refrigerant 141b. Icnmm200730221, 789–793.

[23] X. F Yang and Z.H. Liu, (2011), Pool boiling heat transfer of functionalized nanofluid under sub- atmospheric pressures. International Journal of Thermal Science, 50(12), 2402-2412.

[24] K. Bartelt, Y Park andA. Jacobi, (2008), Flow-Boiling of R-134a /POE/CuO Nanofluids in a Horizontal Tube. International Refrigeration and Air Conditioning Conference, paper 928, Purdue University

[25] K. Henderson, Y. Park, L.Liu and A. M. Jacobi, (2010): Flow-boiling heat transfer of R-134a-based nanofluids in a horizontal tube. International Journal of Heat and Mass Transfer. 53, 944–951.

[26] B. Sun and D.Yang, (2013), flow boiling heat transfer characteristics of

nano-refrigerants in a horizontal tube. International Journal of Refrigeration38, 206-214.
[27] B. Sun and D.Yang, (2013):Experimental study on the heat transfer characteristics of nanorefrigerants in an internal thread copper tube. International Journal of Heat and Mass Transfer 64, 559–566.
[28] I. M. Mahbubul, R. Saidur and M. A. Amalina, (2013), Influence of particle concentration and temperature on k and viscosity of Al_2O_3/R141b nanorefrigerant. International Communications in Heat and Mass Transfer, 43, 100-104
[29] I. M. Mahbubul, et.al, 2015, Effective ultrasonication process for better colloidal dispersion of nanofluid. Ultrason. Sonochem. 26, 361–369
[30] Akhavan M.A., Sadoughi, M.K., Darzi, M., Fakoor-Pakdaman, M., (2015): Experimental study on heat transfer characteristics of R600a/POE/CuO nano-refrigerant flow condensation. Experimental Thermal and Fluid Science, 66, 46–52.
[31] S.Bi, L. Shi, L and Zhang, (2008): Application of nanoparticles in domestic refrigerators. Applied Thermal Engineering, 28, (pp.1834-1843), Elsevier.
[32] L.Lin, H. Peng and G.Ding, (2016): Experimental research on particle aggregation behavior in nanorefrigerant-oil mixture. Applied Thermal Engineering. 98, 944–953
[33] M.Xing, R.Wang, J.Yu,(2014): Application offullerene C60 nano-oil for performance enhancement of domestic refrigerator compressors. International Journal of Refrigeration 40, 398-403.
[34] R.K. Sabareesh, et.al., (2012): Application of TiO_2 nanoparticles as a lubricant-additive for vapor compression refrigeration systems – an experimental investigation. International Journal of Refrigeration, 35(7), 1989-1996
[35] H. Yoo and H.S.Yang, (2007):Study of thermal conductivity of nanofluids for the application of heat transfer fluids. Thermochimica Acta, 455(1-2), 66–69
[36] J. R., Xue, H.S., et.al, (2006): The interface effect of carbon nanotube suspension on the thermal performance of a two-phase closed thermosyphon. Journal ofApplied Physics 10(10). Paper 104909
[37] R S Mishra, Rahul Jaiswal (2017): Thermo physical property of nano-refrigerant: preparation, thermal characteristics, and applications, International Journal of Research in Engineering and Innovation Vol-1, Issue-3, 163-170
[38] R.S Mishra (2019) Modelling of vapour compression refrigeration system (VCRS) by using alternative refrigerants with CuO and without Nano materials International Journal of Research in Engineering and Innovation Vol-3, Issue-1 (2019), 36-41.

Cite this article as: R. S. Mishra, Comparison of thermodynamic(energy-exergy) performances of VCRS using HFOs & HCFOs ecofriendly low GWP refrigerants with HFC-134a in primary circuit and nano mixed R718 in secondary circuit of evaporator, International Journal of Research in Engineering and Innovation Vol-6, Issue-6 (2022), 381-387. *https://doi.org/10.36037/IJREI.2022.6603*.