IJREI

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

ISSN (Online): 2456-6934

ORIGINAL ARTICLE

Thermal performances of VCRS using HFO refrigerants in primary circuit and glycol based nano fluid in secondary circuit of evaporator

R.S. Mishra

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

Article Information

Received: 09 Sep 2023
Revised: 23 Oct 2023
Accepted: 22 Nov 2023
Available online: 30 Nov 2023

Keywords:

Thermal performance
Cascaded VCRS
HFO and HCFO refrigerant
Exergetic performances

Abstract

Numerous studies have been carried out to evaluate the thermal performances of low global warming potential (GWP) refrigerants, including hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs), in the primary circuit of the evaporator and glycol with nano fluid using CuO, Al_2O_3 , and TiO_2 in secondary circuit of evaporator also results in variations in exergetic efficiency. The comparison were made between brine fluid flow nano fluid and glycol with nano fluid using CuO, Al_2O_3 , and TiO_2 in secondary circuit of evaporator also results in variations in exergetic efficiency and It was found that R718 is mostly utilized in the secondary circuit of the evaporator using nanomaterials CuO, Al_2O_3 , and TiO_2 about 15.7%, 12.57%, and 11.5%, respectively as compared with without nano fluids.. Among the eco-friendly refrigerants studied, HCFO-1223zd(E) exhibits superior first law performance under comparable operating conditions compared to HCFO1224yd(Z). Furthermore, in the primary circuit, employing HFO1336mzz(Z) in the evaporator leads to enhanced performance compared to HFO 1243zf, HFO 1234yf, HFO 1225ye(Z). The lowest thermal performances were found by using HFO-1234yf with glycol based nano fluid in secondary circuit of evaporator. The first law efficiency (COP) is improved by using nanomaterials CuO, Al_2O_3 , and TiO_2 about 10.26%, 8.35%, and 6.4%, respectively. Improvements in the second law efficiency were observed in the condenser tube through the utilization of CuO, Al_2O_3 , and TiO_2 nanoparticles, resulting in enhancements of approximately 9.6%, 6.5%, and 5.5%, respectively.

1. Introduction

A significant part of the modern lifestyle we lead today involves refrigeration. It can be used for many things in both home and business settings. Most of these systems function according to the work-based cycle principle of a vapor compression refrigeration system. Natural refrigerants have been utilized for many years in several applications, including CFCs, HCFCs, HFCs, HCs, and their mixes. It has been discovered that several of these refrigerants pose a serious environmental risk, depleting the ozone layer and raising the possibility of global warming. Since that discovery, scientists have been trying to create new refrigerants that improve the efficiency of current systems while simultaneously addressing the previously listed environmental concerns. One of these more recent innovations in refrigeration systems is the application of nanofluids. A nanofluid is made with nanoparticles, which are only measurable at the nanoscale. Because of their enhanced thermophysical qualities, nano refrigerants—a colloidal suspension of nanoparticles in the base refrigerant—have steadily emerged as one of the most promising and effective heat transfer fluids in various thermal engineering applications. The performance and dependability of a domestic refrigerator with nanoparticles in the working fluid were experimentally investigated [1]. Shengshan Bi [2,3] used mineral oil with TiO2 nanoparticle mixtures instead of

Corresponding author: R.S. Mishra
Email Address: rsmishra@dtu.ac.in
https://doi.org/10.36037/IJREI.2023.7605

Polyolester (POE) oil. Requiring 26.0% less energy with 0.1% mass fraction, TiO2 nanoparticles perform better than the HFC134a. Senthilkumar Alagarsamy et al. [4] conducted studies at varying concentrations by combining two different nanoparticles, such as ZnO and SiO2, in a vapour compression refrigeration system using R600a with ZnO and SiO2 hybrid nano lubricants. On such compressor power consumption, cooling capacity, and coefficient of performance using hybrid nano lubricants, and found more than 42% improvement in the system's performance coefficient experimentally, along with an increase in cooling capacity and a decrease in compressor power consumption by using 40 g of R600a refrigerant and 0.4 g/L of ZnO/SiO2 and Additionally, 0.6 g/L ZnO/SiO2 with 60 g of R600a refrigerant. A. Baskaran [4] experimentally examined the effectiveness of R134a-ZrO2 nano refrigerants at a concentration of 0.2 g/l in a domestic refrigerator without altering the constituent parts. After charging 140 g of R134a and 0.2 g/L of ZrO2 nanoparticles with a 1–10 nm particle size, studies were conducted to examine the refrigerator's performance. Venkataiah S. and Gudimalla Sthithapragna[5] investigated the impact of nanoparticles (e.g., TiO2, Al2O3, CuO, SiO2, ZnO, ZrO2, ZnO/SiO2, diamond, etc.) on thermal performance of refrigeration systems by taking into account several parameters (e.g., pressure drops during suction and discharge, refrigeration effect, power consumption, and COP) using standard refrigerants. Nanofluid is a novel fluid with unique properties that finds application in a wide range of industrial heat transfer processes. Seboka Gobane, et.al.[6] used four mixtures of nanofluid samples at four different volume concentrations. The two-step method of dispersing nanoparticles into Jatropha oil was responsible for the largest increase in thermal conductivity for CuO-Jatropha oil nanofluids. The thermal conductivity of CuO-Jatropha oil nanofluids was determined by considering three factors: temperature, volume concentration, and volume concentrations of the mixture of nanoparticles. The increase in thermal conductivity and viscosity was influenced by nanoparticles at temperatures ranging from 298 to 323 K, according to the results. The invention of nano refrigerants has significantly raised the productivity of refrigeration systems. Nanorefrigerants have exceptional thermal, rheological, and heat transfer properties. Thermal conductivity, viscosity, Coefficient of Performance (COP), and energy savings were evaluated theoretically for volume concentrations of 0.5, 1, 2, and 3 vol% in R134a and R152a refrigerants using Single-Walled Carbon Nanotubes (SWCNTs) nanoparticles. 11 Z. Said, S. Rahman, and M. Sohail [7] discovered that the remarkable heat conductivity of nanoparticles caused the enhancement in the Coefficient of Performance for both nano refrigerants. Compared to R134a-based nanorefrigerants, R152a-based nanorefrigerants have demonstrated the highest coefficient of performance values. Compared to base refrigerant R152a, the R152a-based nano refrigerant showed a maximum increase in Coefficient of Performance of 1.43%. A thorough investigation of nano refrigerants was performed by Omer A. Alawi, et.al. [8]. Studied found surface tension, specific heat, density, and viscosity of nano refrigerants are important physical properties that affect nucleate pool boiling, convective flow boiling, and condensation and concluded that heat transfer was enhanced and the heat transfer coefficient increased as the mass fraction of nanoparticles in the refrigerant increased. The literature claims that pure refrigerants have lower heat conductivities than nano refrigerants. The power consumption was reduced by 2.4%, while the performance coefficient increased by 4.4%. The performance of a refrigerator with a 0.1% mass fraction of TiO2 nanoparticles was 26.1% better than that of a refrigerator with an HFC134a and POE oil system. The performance of vapor refrigeration systems by using R-134a in the primary circuit and Al2O3 water-based nanofluid in the secondary circuit by thermal modeling was investigated by Mishra [9]. The model extracts information about secondary fluid, like the size of nanoparticles, compressor speed, and geometric conditions, to predict the output of the secondary fluid, like operating pressure, temperature, power consumption, and overall system performance. According to the results obtained from the simulation investigation, the system's performance can be enhanced by approximately 17–20%; the design of components like compressor, evaporator, condenser, and throttle valve can be done.R. S. Mishra and RK Jaiswal [10] investigated the impact on the coefficient of performance (COP) and the thermophysical characteristics of various nanoparticles added to eco-friendly HFCs and their blended refrigerant mixtures. The experimental findings demonstrate that, compared to base refrigerant, the specific heat of nano-refrigerant is slightly lower. However, the thermal conductivity, dynamic viscosity, and density of nano-refrigerant (different nanoparticles such as Cu, Al2O3, CuO, and TiO2 with eco-friendly refrigerant R134a, R407c, and R404a) increased by approximately 15 to 24%, 20%, and 12 to 34%, respectively. Furthermore, the Al2O3/R134a Nano refrigerant has the highest COP at 35%. R404a and R407c show improvements in COP of roughly 3 to 14% and 3 to 12%, respectively, when using different nanoparticles. [11] Mahbubul I.M. et al. [11,12] investigated the effects of temperature and volume on the viscosity of R123-TiO2 nano refrigerant at temperatures ranging from 5°C to 20°C and with a maximum volume concentration of 2% of nanoparticles. Investigations have also been conducted into the impact of pressure drop with increasing viscosity. According to the investigation, the viscosity of the nano refrigerant reduces with rising temperatures and increases in proportion to increasing volume concentrations of nanoparticles. Furthermore, as volume concentrations intensify, pressure drops increase noticeably. As a result, modest volume concentrations of nano refrigerant are advised to improve refrigeration system performance. Numerous studies have been carried out to evaluate the performance of low global warming potential (GWP) refrigerants, including hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs), in both the primary and secondary circuits of the evaporator. The impacts of adding various nanoparticles combined with eco-friendly refrigerant and analyzing their effects on the coefficient of performance (COP) were researched by R. S. Mishra [13] found in comparison to base refrigerant, the thermal conductivity, dynamic viscosity, and density of Nano-refrigerant (different nanoparticles, such as CuO, Al2O3, and TiO2) increased by approximately 15%, 20%, and 13%, respectively, in comparison to base refrigerant R134a, R407c, and R404A.

2. Results and Discussion

Thermal performances of VCRS using HFCO refrigerants in the primary circuit have been investigated and results have been presented in the tables -1 to table-2 respectively.

Table-1(a) to table-1(c) showed the evaluation of thermal design performance parameters of vapour compression refrigeration system using HCFO-1233zd(E) refrigerants in primary circuit and glycol based three nano fluids in secondary fluid circuit of evaporator and It has been observed that glycol based fluid is mainly utilized in the secondary circuit of the evaporator gives lower thermal performances than using Brine fluid flow secondary circuit of evaporator. The first law tand second law thermal performances using copper oxide is better than using Al_2O_3 and TiO_2 nano fluid.

Table-1(a) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HCFO-1233zd(E) refrigerants in primary circuit and glycol based CuO nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HCFO-1233zd(E)	COP with CuO Nano	COP without Nano	% improvement
1	COP	3.334	2.895	15.7
2	Exergy Efficiency	0.3455	0.2887	19.7
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1095.5	655.7	67.0
4	$U_{\_Cond}$ ($W/m^{2o}C$)	675.7	623.5	8.37

Table-1(b) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HCFO-1233zd(E) refrigerants in primary circuit and glycol based Al_2O_3 nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HCFO-1233zd(E)	COP with Al_2O_3 Nano	COP without Nano	% improvement
1	COP	3.259	2.895	12.57
2	Exergy Efficiency	0.33275	0.2887	15.257
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1072.25	655.7	63.527
4	$U_{\_Cond}$ ($W/m^{2o}C$)	663.109	623.5	6.353

Table-1(c)Evaluation of thermal design performance parameters of vapour compression refrigeration system using HCFO-1233zd(E) refrigerants in primary circuit and glycol based TiO_2 nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HCFO-1233zd(E)	COP with TiO_2 Nano	COP without Nano	% improvement
1	COP	3.192	2.895	10.257
2	Exergy Efficiency	0.3298	0.2887	11.527
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1046.02	655.7	59.527
4	$U_{\_Cond}$ ($W/m^{2o}C$)	650.65	623.5	4.353

Table-2(a) to table-2(c) showed the evaluation of thermal design performance parameters of vapour compression refrigeration system using HCFO- low GWP 1224yd(Z) refrigerants in primary circuit and glycol based three nano fluids in secondary fluid circuit of evaporator and It has been observed that glycol based fluid is mainly utilized in the secondary circuit of the evaporator gives lower thermal performances than using Brine fluid flow secondary circuit of evaporator. The first law tand second law thermal performances using copper oxide is better than using Al_2O_3 and TiO_2 nano fluid. Among the eco-friendly refrigerants studied, in tables-1 & tables-2 HCFO1223zd(E). showed superior first law performance under comparable operating conditions R1224yd(Z). Thermal performances of VCRS using HFCO refrigerants in the primary circuit have been investigated and results have been presented in the tables -3 to tables-8 respectively. Furthermore, in the primary circuit, employing HFO1336mzz(Z) in the evaporator leads to enhanced performance compared to R1243zf, R1234yf, R1225ye(Z), and R-134a. Although slightly inferior performances as compared to HCFO-1233zd(E).

Table-2(a) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HCFO-1224yd(Z)refrigerants in primary circuit and glycol based CuO nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HCFO-1224yd(Z)	COP with CuO Nano	COP without Nano	% improvement
1	COP	3.314	2.88	15.07
2	Exergy Efficiency	0.3420	0.2880	18.87
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1075.5	650.7	65.2
4	$U_{\_Cond}$ ($W/m^{2o}C$)	670.5	620.9	8.06

Table-2(b)Evaluation of thermal design performance parameters of vapour compression refrigeration system using HCFO-1224yd(Z)refrigerants in primary circuit and glycol based Al_2O_3 nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HCFO-1224yd(Z)	COP with Al_2O_3 Nano	COP without Nano	% improvement
1	COP	3.240	2.88	12.527
2	Exergy Efficiency	0.3282	0.2880	16.253
3	$U_{\_Eva}$ (W/m^{2o}C)	1049.271	650.7	61.253
4	$U_{\_Cond}$ (W/m^{2o}C)	658.68	620.9	6.153

Table-2(c) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HCFO-1224yd(Z)refrigerants in primary circuit and glycol based TiO_2 nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HCFO-1224yd(Z)	COP with TiO_2 Nano	COP without Nano	% improvement
1	COP	3.1543	2.88	9.527
2	Exergy Efficiency	0.31954	0.2880	10.953
3	$U_{\_Eva}$ (W/m^{2o}C)	1016.74	650.7	56.253
4	$U_{\_Cond}$ (W/m^{2o}C)	646.89	620.9	4.253

2.1 Thermal Performances of VCRS using nano fluid in secondary circuit and HFO refrigerants in the primary circuit.

The introduction of low GWP refrigerants with R-178 in the secondary circuit of the evaporator resulted in apparent variations in first-law performances, both in terms of improvement and decrement. Incorporating nanomaterials with HFO-1336mzz(Z) as substitutes for R134a yields notable enhancements in second-law efficiency, with improvements of 14.45% using CuO, 12.76% Al2O3, and 9.76% using TiO2, respectively. As shown in Table-3(a) to Table-3(c) respectively. Similarly, exergy efficiency is also improved by using nanomaterials in the glycol-based fluid in the secondary fluid as 17.7% using CuO, 15.76% Al2O3, and 9.76% using TiO2, respectively. Similarly, the overall heat transfer coefficient of the evaporator was enhanced from 64.3% using CuO, 61.95% Al2O3, and 61.16% using TiO2, respectively, as shown in table-3(a) to tables3-(c) respectively. The compressor's isentropic efficiency is highest when using CuO and lowest with TiO2 in conjunction with HFO1336mzz(Z). Similarly, the compressor's volumetric efficiency follows the same trend: highest with CuO and lowest with TiO in combination with HFO1336mzz(Z). Integrating nanomaterials, specifically CuO, Al2O3, and TiO2, significantly improves first-law efficiency, registering approximately 18.5%, 17.5%, and 15.95%, respectively. Using CuO, Al2O3, and TiO2 for condenser tube enhancements also results in variations in exergetic efficiency, with improvements of about 7.1855%, 5.97%, and 4.95%, respectively. Additionally, the overall evaporator heat transfer coefficient is highest when utilizing CuO and lowest with TiO2 combined with HFO1336mzz(Z).

Table-3(a) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1336mzz(Z) refrigerants in primary circuit and glycol based CuO nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HFO-1336mzz(Z)	COP with CuO Nano	COP without Nano	% improvement
1	COP	3.29	2.875	14.44
2	Exergy Efficiency	0.3387	0.2878	17.7
3	$U_{\_Eva}$ (W/m^{2o}C)	1065.2	648.4	64.28
4	$U_{\_Cond}$ (W/m^{2o}C)	663.8	619.3	7.1855

Table-3(b)Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1336mzz(Z) refrigerants in primary circuit and glycol based Al_2O_3 nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HFO-1336mzz(Z)	COP with Al_2O_3 Nano	COP without Nano	% improvement
1	COP	3.242	2.875	12.76
2	Exergy Efficiency	0.3330	0.2878	15.76
3	$U_{\_Eva}$ (W/m^{2o}C)	1050.15	648.4	61.95
4	$U_{\_Cond}$ (W/m^{2o}C)	656.27	619.3	5.97

Table-3(c) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1336mzz(Z) refrigerants in primary circuit and glycol based TiO_2 nano fluid in secondary fluid circuit of evaporator

S .No.	Performance Parameters for HFO-1336mzz(Z)	COP with TiO_2 Nano	COP without Nano	% improvement
1	COP	3.156	2.875	9.76
2	Exergy Efficiency	0.3159	0.2878	9.76
3	$U_{\_Eva}$ (W/m^{2o}C)	1048.85	648.4	61.06
4	$U_{\_Cond}$ (W/m^{2o}C)	645.286	619.3	4.95

The first law performances (COP), both in improvement and decrement. Incorporating nanomaterials with HFO- 1243zf as substitutes for R134a yields notable enhancements in second law efficiency, with improvements of 13.65% using CuO, 11.7% Al2O3, and 9.7% using TiO2, shown in Table-4(a) to Table-4(c) respectively. Similarly, exergy efficiency is also improved by using nanomaterials in the glycol-based fluid in the secondary fluid as 17.7% using CuO, 15.9% Al2O3, and 9.62% using TiO2, respectively. Integrating nanomaterials, specifically CuO, Al2O3, and TiO2, significantly improves heat transfer rates in evaporators, registering increments of approximately 64.82%, 60.96%, and 59.56%, respectively. Using CuO, Al2O3, and TiO2 for condenser tube enhancements also results in variations in exergetic efficiency, with improvements of about 8.07%, 2.69%, and 2.39%, respectively. Additionally, the overall evaporator heat transfer coefficient is highest when utilizing CuO and lowest with TiO2 in combination with HFO- 1243zf.

Table-4(a) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1243zf refrigerants in primary circuit and glycol based CuO nano fluid in secondary fluid circuit of evaporator

S. No.	for HFO-1243zf	COP with CuO Nano	COP without Nano	% improvement
1	COP	3.227	2.839	13.66
2	Exergy fficiency	0.3385	0.2879	17.6
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1052.7	638.7	64.82
4	$U_{\_Cond}$ ($W/m^{2o}C$)	633.2	613.3	8.066

Table-4(b)Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1243zf refrigerants in primary circuit and glycol based Al_2O_3 nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HFO-1243zf	COP with Al_2O_3 Nano	COP without Nano	% improvement
1	COP	3.176	2.875	11.872
2	Exergy Efficiency	0.3337	0.2878	15.92
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1022.54	648.4	60.096
4	$U_{\_Cond}$ ($W/m^{2o}C$)	629.8	619.3	2.69

Table-4(c) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1243zf refrigerants in primary circuit and glycol based TiO_2 nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HFO-1243zf	COP with TiO_2 Nano	COP without Nano	% improvement
1	COP	3.115	2.875	9.72
2	Exergy Efficiency	0.3156	0.2878	9.62
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1019.54	648.4	59.56
4	$U_{\_Cond}$ ($W/m^{2o}C$)	627.97	619.3	2.392

The improvement in COP, of VCRS by Incorporating nanomaterials with HFO- 1234ze(E) as substitutes for R134a yields notable enhancements in second law efficiency, with improvements of 13.7% using CuO , 11.9% Al_2O_3, and 9.79% using TiO_2, respectively shown in Table-5(a) to Table-5(c) respectively. Similarly exergy efficiency is also improved by using nano materials in the glycol based fluid in the secondary fluid as 17.6% using CuO , 15.94% Al_2O_3, and 8.26% using TiO_2, respectively. The integration of nanomaterials, specifically CuO, Al_2O_3, and TiO_2 , leads to significant improvements in heat transfer rates in evaporator registering increments of approximately 64.83%, 60.37%, and 59.75%, respectively. The use of CuO, Al_2O_3, and TiO_2 for condenser tube enhancements also results in variations in exergetic efficiency, with improvements of about 8.15%, 2.9%, and 2.6%, respectively. Additionally, the overall evaporator heat transfer coefficient is highest when utilizing CuO and lowest with TiO_2in combination with HFO-1234ze(E).

Table-5(a) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1234ze(E)refrigerants in primary circuit and glycol based CuO nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HFO-1234ze(E)	COP with CuO Nano	COP without Nano	% improvement
1	COP	3.228	2.839	13.7
2	Exergy Efficiency	0.3386	0.2879	17.6
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1052.7	638.3	64.83
4	$U_{\_Cond}$ ($W/m^{2o}C$)	663.3	613.3	8.153

Table-5(b) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1234ze(E)refrigerants in primary circuit and glycol based Al_2O_3 nano fluid in secondary fluid circuit of evaporator

S. No.	Performance Parameters for HFO-1234ze(E)	COP with Al_2O_3 Nano	COP without Nano	% improvement
1	COP	3.177	2.839	11.90
2	Exergy Efficiency	0.3338	0.2879	15.94
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1024.3	638.3	60.37
4	$U_{\_Cond}$ ($W/m^{2o}C$)	631.2	613.3	2.917

Table-5(c) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1234ze(E)refrigerants in primary circuit and glycol based TiO_2 nano fluid in secondary fluid circuit of evaporator.

S. No.	Performance Parameters for HFO-1234ze(E)	COP with TiO_2 Nano	COP without Nano	% improvement
1	COP	3.117	2.839	9.79
2	Exergy Efficiency	0.3158	0.2879	8.266
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1020.3	638.3	59.75
4	$U_{\_Cond}$ ($W/m^{2o}C$)	629.27	613.3	2.604

The enhancement in COP of VCRS by Incorporating nanomaterials with HFO-1225ye(Z) as substitutes for R134a yields notable enhancements in second law efficiency, with improvements of 13.67% using CuO, 13.66% Al2O3, and 8.9% using TiO2, shown in Table-6(a) to Table-6(c) respectively. Similarly, exergy efficiency is also improved by using nanomaterials in the secondary fluid's glycol-based fluid as 17.096% using CuO, 9.97% Al2O3, and 8.96% using TiO2, respectively. Integrating nanomaterials, specifically CuO, Al2O3, and TiO2, significantly improves heat transfer rates in the evaporator, registering increments of approximately 63.07%, 59.97%, and 58.9%, respectively. Using CuO, Al2O3, and TiO2 for condenser tube enhancements also results in variations in exergetic efficiency, with improvements of about 8.07%, 5.4%, and 3.7%, respectively. Additionally, the overall evaporator heat transfer coefficient is highest when utilizing CuO and lowest with TiO2 combined with HFO-1225ye(Z).

Table-6(a) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1225ye(Z) refrigerants in primary circuit and glycol based CuO nano fluid in secondary fluid circuit of evaporator.

S. No.	for HFO-1225ye(Z)	COP with CuO Nano	COP without Nano	% improve-ment
1	COP	3.227	2.839	13.66
2	Exergy Efficiency	0.3370	0.2878	17.095
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1032.7	633.3	63.07
4	$U_{\_Cond}$ ($W/m^{2o}C$)	677.45	613.3	8.066

Table-6(b) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1225ye(Z) refrigerants in primary circuit and glycol based Al_2O_3 nano fluid in secondary fluid circuit of evaporator.

S. No.	for HFO-1225ye(Z)	COP with Al_2O_3Nano	COP without Nano	% improve-ment
1	COP	3.1628	2.839	11.76
2	Exergy Efficiency	0.3165	0.2878	9.976
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1013.128	633.3	59.976
4	$U_{\_Cond}$ ($W/m^{2o}C$)	646.45	613.3	5.405

Table-6(c) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1225ye(Z) refrigerants in primary circuit and glycol based TiO_2 nano fluid in secondary fluid circuit of evaporator.

S. No.	Performance Parameters for HFO-1225ye(Z)	COP with TiO_2 Nano	COP without Nano	% improve-ment
1	COP	3.084	2.839	8.976
2	Exergy Efficiency	0.3158	0.2878	9.72
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1006.8	633.3	58.9
4	$U_{\_Cond}$ ($W/m^{2o}C$)	636.11	613.3	3.72

Incorporating nanomaterials in VCRS using HFO-1234yf as substitutes for R134a yields notable enhancements in COP second law efficiency, with improvements of 10.26% using CuO, 6.49% using Al2O3, and 5.5% using TiO2, shown in Table-7(a) to Table-7(c) respectively. Similarly, exergy efficiency is also improved by using nanomaterials in the secondary fluid's glycol-based fluid as 9.55% % using CuO, 6.49% using Al2O3, and 5.49% using TiO2, respectively. Integrating nanomaterials, specifically CuO, Al2O3, and TiO2, significantly improves heat transfer rates in the evaporator, registering increments of approximately 62.45%, 56.49%, and 54.49%, respectively. Similarly, the overall condenser heat transfer coefficient exhibits the same trend, with CuO yielding the highest coefficient and TiO yielding the lowest when paired with HFO1234yf, and glycol is mainly used in the secondary circuit of the evaporator, are 10.5%, 2.75%, and 2.012 %.

Table-7(a) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1234yf refrigerants in primary circuit and glycol based CuO nano fluid in secondary fluid circuit of evaporator.1225ye(Z)

S. No.	Performance Parameters for HFO-1234yf	COP with CuO Nano	COP without Nano	% improve-ment
1	COP	3.128	2.837	10.257
2	Exergy Efficiency	0.3321	0.2874	9.55
3	$U_{\_Eva}$ ($W/m^{2o}C$)	1025.75	631.3	62.45
4	$U_{\_Cond}$ ($W/m^{2o}C$)	675.45	611.3.9	10.5

Table-7(b) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1234yf refrigerants in primary circuit and glycol based Al_2O_3 nano fluid in secondary fluid circuit of evaporator.

S. No.	Performance Parameters for HCFO-1234yf	COP with Al_2O_3 Nano	COP without Nano	% improve-ment
1	COP	3.074	2.837	8.35
2	Exergy Efficiency	0.306	0.2874	6.49
3	$U_{\_Eva}$ ($W/m^{2o}C$)	987.92	631.3	56.49
4	$U_{\_Cond}$ ($W/m^{2o}C$)	628.10	611.3.9	2.749

Table-7(c) Evaluation of thermal design performance parameters of vapour compression refrigeration system using HFO-1234yf refrigerants in primary circuit and glycol based TiO_2 nano fluid in secondary fluid circuit of evaporator.

S. No.	Performance Parameters for HCFO-1234yf	COP with TiO_2 Nano	COP without Nano	% improve-ment
1	COP	3.0183	2.837	6.39
2	Exergy Efficiency	0.3032	0.2874	5.49
3	U_{Eva} ($W/m^{2o}C$)	975.29	631.3	54.49
4	U_{Cond} ($W/m^{2o}C$)	623.6	611.3.9	2.012

3. Conclusions

The thermal performances of the vapour compression refrigeration system with different HFO & HCFO refrigerants in the primary circuit and Gylcol based fluid in the secondary circuit of the evaporator with suspended nanoparticles in the circuit have been evaluated and it was found that three factors (mass flow rate of brine, compressor speed and water flow rate in the condenser strongly affecting system thermal performance enhancement (COP), heat transfer characteristics, and solubility of nanorefrigerants into the base refrigerant . The following conclusions were drawn

- Using nanorefrigerants requires lower power consumption; however, nano refrigerants in secondary circuits increase the evaporator and condenser heat transfer rates in vapour compression refrigeration systems.
- Using CuO nano refrigerants maximizes the heat transfer coefficient of thermal evaporators.
- The system's overall coefficient of performance (COP) and freezing capacity can be improved by including nano refrigerants. CuO and HCFO-1233zd(E) refrigerants are higher than HCFO-1224yd(Z) is used in this combination.
- When nano refrigerants with the same input parameters as HFO refrigerants are used in the system, heat transfer rates and system efficiency (first and second law) can be significantly increased utilizing R1336mzz(Z). at the same time, HFO-1234yf in the primary circuit yields the lowest performances.
- When comparing the thermal system performance under identical input settings, the brine flow nanofluid significantly outperformed the glycol-based nanofluid.

References

[1] Bi, S., [2007] Performance study of a domestic icebox victimisation R134a/mineral oil/nano-TiO_2 as operating fluid,‖ ICR07-B2-346, 2007.

[2] Bi, S., Shi, L., Zhang (2008) Application of nanoparticles in domestic refrigerators. Applied Thermal Engineering, 28, (pp.1834-1843) Elsevier. https://doi.org/10.1016/j.applthermaleng.2007.11.018

[3] Senthilkumar Alagarsamy[2020] Experimental investigation of ZnO / SiO_2 hybrid nano-lubricant in R600a vapour compression refrigeration system, material today proceedings 45(2), DOI:10.1016/j.matpr.2020.10.180

[4] A. Baskaran,[1]N. Manikandan,[2]JuleLeta Tesfaye,[2,3]N. Nagaprasad, [2022], Investigation on the Performance of Domestic Refrigerator with Zirconium Oxide-R134a Nanorefrigerant,Volume 2022 | ArticleID 3668458. https://doi.org/10.1155/2022/3668458, published 18th March 2022

[5] Venkataiah S., and Gudimalla Sthithapragna [2022], Comprehensive evaluation of nano refrigerants: A review, Materials Today Proceedings 72(5), September 2022, DOI:10.1016/j.matpr.2022.09.094

[6] Seboka Gobane, T. Dama, Nasim Hasan, and E. Yanmaz [2023] Characterization of Copper Oxide–Jatropha Oil Nanofluid as a Secondary Refrigerant, Journal of Nanomaterials, Volume2023 https://doi.org/10.1155/2023/7612959.

[7] Z. Said, S. Rahman, and M. Sohail [6] Nano-refrigerants and nano-lubricants in refrigeration: Synthesis, mechanisms, applications, and challenges, Applied Thermal Engineering,Volume 233, October 2023, 121211.

[8] Omer A. Alawi and coworkers [2014]. Omer A. Alawi, Nor Azwadi Che Sidik, H.A. Mohammed, "A comprehensive review of fundamentals, preparation and applications of nanorefrigerants", International Communications in Heat and Mass Transfer 54, page no. 81–95, 2014.

[9] Mishra, R.S [2014] Methods for Improving Thermal Performance of Vapour Compression Refrigeration System Using Twelve Eco Friendly Refrigerants in Primary Circuit and Nanofluid (Water-Nano Particles Based) in Secondary Circuit. International Journal of Emerging Technology and Advanced Engineering, International Journal of Emerging Technology and Advanced Engineering, Volume 4, Issue 6, June 2014

[10] R. S. Mishra, Rahul Kumar Jaiswal,[2019] " Thermal Performance Improvements of Vapour Compression Refrigeration System Using Eco Friendly Based Nanorefrigerants in Primary Circuit", International Journal of Advance Research and Innovation, Volume 3, Issue 3, Page no. 524-535, 2019

[11] Mishra, R.S (2020) Methods for enhancing energetic-exergetic performances of vapour compression refrigeration system using HFO-1336mzz(Z) refrigerant through Nano materials mixed with R-718 fluid in secondary circuit of evaporator. International Journal of Advance Research and Innovation, 4(3),143-148

[12] I.M. Mahabubul, R. Saidur and M.A. Amalina (2012), Investigation of Viscosity of R123-TIO_2 Nano refrigerant, International Journal of Mechanical and materials Engineering, vol. 7. No. 2. 146-151.

[13] I.M. Mahbubul, S. A. Fadhilah, R. Saidur, K. Y. Leong, M. A. Amalina, [2013] Thermo physical properties and heat transfer, Performance of Al2O3/R-134a Nano refrigerants, International Journal of Heat and Mass Transfer, Vol. 57, 100-108.

***Cite this article as*:** R.S. Mishra, Thermal performances of VCRS using HFO refrigerants in primary circuit and glycol based nano fluid in secondary circuit of evaporator, International Journal of Research in Engineering and Innovation Vol-7, Issue-6 (2023), 253-259. *https://doi.org/10.36037/IJREI.2023.7605*.