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

ORIGINAL ARTICLE

Performances evaluation of VCR system using HFO &HCFO refrigerants in primary and Nano mixed brine flow in secondary circuits

R. S. Mishra

Department of Mechanical, Production, industrial and Automobiles Engineering, Delhi Technological University, Delhi, India

Article Information

Received: 09 May 2023
Revised: 15 July 2023
Accepted: 03 Aug 2023
Available online: 06 Aug 2023

Keywords:

Thermodynamic performances
VCRS
HFO refrigerants
Energy-exergy analysis

Abstract

This paper mainly deals with the effect of HFO refrigerants of ultra-low GWP on their first and second law performances. Comparison has been done for using low global warming potential three HFC-134a refrigerant in the primary circuit of the evaporator and brine flow with Nano materials and without Nano materials in the secondary circuit of the evaporator using and found that by using HFO-1234ze(Z) refrigerant gives best the thermodynamic (energy-exergy) performances enhanced up to 30.05%, 25.25%, and 20.27% respectively by using CuO, $Al_2O_3$and TiO_2 nanomaterials respectively in the brine water flowing in the secondary circuit of the evaporator.

1. Introduction

When a refrigeration system uses a VCR cycle to collect heat from a low-temperature system and discharge it to a higher temperature system, the refrigerant acts as the heat-carrying medium. The first refrigerant used was a blend of salt and natural ice. The VCR system was introduced in 1834, and its refrigerants included ammonia, sulphur dioxide, methyl chloride, and carbon dioxide. The most widely utilised halo-carbon or organic refrigerants are methane (CH4) and ethane (C2H6) chloro-fluoro derivatives. Chloro-fluoro-carbon (CFC) refrigerants are fully halogenated refrigerants that contain chlorine (Cl) atoms in their molecules. These CFC refrigerants include R11, R12, R13, R113, R114, and R115. The term "hydro-chloro-fluorocarbon" (HCFC) refrigerants" refers to gases that have hydrogen (H) atoms in their molecules. HCFC refrigerants include those found in R22 and R123. Hydro-fluoro-carbon (HFC) refrigerants are the name for refrigerants that have no chlorine atoms in their molecules. HFC refrigerants include R134a and R152a, among others. The term "hydrocarbon (HC) refrigerants" refers to refrigerants without chlorine or fluorine atoms in their molecules. These HC refrigerants include R290, R600a, and others and it was discovered that the fluorine (F) atom in the refrigerant molecules makes them more advantageous physiologically. The depletion of this layer in the upper atmosphere, which permits dangerous ultraviolet rays from the sun to penetrate through the atmosphere and reach the earth's surface causing skin cancer, is thought to be caused by the chlorine (Cl) atom in the molecules of the refrigerants. The ozone layer's thinning has been related to chlorofluorocarbon (CFC) refrigerants. Their ozone depletion potential (ODP) varies in intensity. The halo-carbon refrigerants have a global warming effect on the environment in addition to the ozone depletion effect, which could result in significant environmental changes. A 1987 international agreement known as the Montrel Protocol

Corresponding author: R. S. Mishra
Email Address: rsmishra@dtu.ac.in
https://doi.org/10.36037/IJREI.2023.7402

mandated the phase-out of halogenated chlorofluorocarbon (CFC) refrigerants with a high propensity to deplete the ozone layer, including R11, R12, R13, R113, R114, and R502. Since its ODP is one-twentieth that of R11 and R12, the hydro-chloro-fluorocarbon (HCFC) refrigerant R22 is not covered under the original Montreal Protocol. But it must be phased out due to high GWP. However, R22 is now proven to be more useful as it is used not just in R22 applications that already exist, but also in significant capacity air conditioning installations using screw or centrifugal compressors to replace R11. A substitute for fully halogenated chlorofluorocarbon (CFC) refrigerants is offered by the hydrocarbon (HC) and hydro-fluorocarbon (HFC) refrigerants. because they have no chlorine at all. They have the lowest ODP as a result. Refrigerants. Even hydro-chloro-fluoro-carbon (HCFC) refrigerants, which also include some hydrogen (H) and chlorine (Cl) atoms, have far lower ODP; however, hydro-fluoro-carbons (HFCs) may be slightly combustible due to their hydrogen (H) content. The quantity of H atoms in the molecules affects how flammable they are. Hydrocarbons in their purest form are quite combustible.

1.1 Substitutes for chloro-fluoro-carbon (CFC) refrigerants for VCR systems [1]

Currently, the following substitutes are available for replacement. CFC refrigerants

- The HCFC refrigerant R123 (CF_3CHCl_2) in place of R11 (CCl_3F).
- The HFC refrigerant R134a (CF_3CH_2F) & R152a (CH_3CHF_2) in place of R12.
- The HFC refrigerant R143a (CH_3CF_3) & R125 (CHF_2 CF_3) in place of R502 (a mixture of R22 & R115)
- The HC refrigerants, propane (R290), C3H8 and R600a (C4H10) may also be used in place of R12.

1.2 The use of HFOs and HCFOs to replace chlorofluorocarbon (HFC) refrigerants

As a result, HFCs that do not harm the ozone layer were created to take the place of HCFCs. In Japan, businesses first switched from CFC to HCFC and then, later, to HFC refrigerants out of concern for the environment, ahead of other nations and before the Montreal Protocol's deadline for regulation.

HFC refrigerants are safe and dependable because they don't damage the ozone layer and aren't combustible or highly toxic. However, HFC has a high GWP. As a result, a fresh initiative to enact legal restrictions on HFCs was launched [2].

Adrián Mota-Babiloni [2] carried out an analysis of the feasibility of R454C and R455A, two new low global warming potential (GWP of 148) refrigerants, in VCRS as alternatives to R404A for warm countries and found that the R454C and R455A will be the most viable low GWP options to perform a direct replacement of R404A due to similar uniqueness and found experimental results show that the cooling capacity of the reserves is slightly lower than R404A, being the Coefficient of Performance (COP) of the new mixtures 10–15% higher than that of R404A, especially at more increased condensation. The EU F-gas Regulation was formed in 2006, and under the Montreal Protocol on compounds that degrade the ozone layer, a proposal to phase down HFCs was released under the direction of the United States. The "Act on Rational Use and Proper Management of Fluorocarbons" (often referred to as the "Fluorocarbon Emission Control Law") replaced the "Law Concerning the Recovery and Destruction of Fluorocarbons. As a result of these new initiatives, and it went into force in Japan in April 2015. Regarding the international landscape, the Parties to the Montreal Protocol decided to phase down HFCs (Kigali Amendment) at their 28th Meeting of the Parties (MOP-28) in October 2016 in Kigali, Rwanda.

On a CO_2 equivalent basis, it was resolved that the industrialised nations should gradually cut back on their production and consumption of HFCs by 10% by 2019, 40% by 2024, then 70% by 2029, and finally 85% by 2036. On the other side, poorer nations would need to delay reducing HFC production and consumption by roughly 10 to 13 years.

All parties are obligated to reduce HFCs over a 30-year period as a whole. This transitional strategy is comparable to earlier attempts to reduce HCFCs. The Kigali Amendment has led to a steady strengthening of the Fluorocarbon Emission Control Law requirements in Japan. The government proposed adding centrifugal chillers to the list of products that must use lower GWP refrigerants, which equipment makers must comply with, in December 2017. From 2025 on, makers of centrifugal chillers must limit GWP values to 100 or less. To attain low-GWP values, the characteristics of refrigerants must eventually alter. Despite having a very low GWP, so-called natural refrigerants can have drawbacks. For instance, ammonia is very poisonous and highly flammable, whereas hydrocarbons are highly flammable. Hydrofluoroolefins (HFOs) with a carbon-carbon double bond have recently been developed as another contender for a low-GWP refrigerant in an effort to overcome these obstacles. HFOs have a limited atmospheric lifetime and a low GWP because they break down when they are exposed to ultraviolet radiation. However, as a natural trade-off for lowering GWP, compounds frequently become combustible because the stability of the molecules is lowered to quicken the rate of disintegration. We can conclude that non-flammability is not always attained in the quest to obtain low GWP, despite the fact that numerous types of low GWP refrigerants have been produced for various refrigeration and air conditioning equipment. However, food items are frequently stored in a distinct compartment and at a different temperature in applications like big hotels, food storage facilities, and food processing plants. The systems used in vapour compression technology use a lot of electricity; however, this issue can be resolved by increasing system performance.

1.3 Use of Nano refrigerants in VCR systems

Fluid used in refrigeration systems with nanoparticles that are suspended and evenly disseminated in a continuous base refrigerant. Due to improvements in the thermodynamic energy and exergy capabilities, it has a very lengthy history and has helped build and improve modern refrigeration systems. The thermal conductivity of water-based nano-fluids and nano-refrigerants has been the subject of numerous important research efforts. When compared to base refrigerants fluid, CNT-based nano-refrigerants have greater thermal conductivity (W. Jiang et al. [3]). Additionally, R-134a-CuO was combined with POE as a lubricant in the same horizontal tubes by K. Henderson et al. [4], and they discovered a 100% improvement in heat transfer coefficient. The amount of nanoparticles in the host refrigerant causes the conductivity ratio of pure refrigerant to nano refrigerant to rise. In eco-friendly HFC-134a with copper oxide as the nanoparticle, the Cu nanoparticle-based nano refrigerants have the highest effectiveness factor and have a better conductivity ratio than other nanoparticles at a concentration of 5%. The efficiency factor rises as the volume percentage (vol%) rises, and the secondary circuit of the evaporator's copper nanoparticle-based nano refrigerant has the highest convective heat transfer coefficient ratio of all the nanoparticles combined with brine water. In recent years, new eco-friendly refrigeration systems have been researched at various environmental conventions by taking into account two factors: ecological and energy consumption. coefficient.

2. Thermodynamic analysis of VCR systems refrigeration

The four basic parts of the single-stage vapour compression system are the evaporator, expansion valve, condenser, and compressor. Technology is based on the rejection of heat to the environment at higher temperatures and absorption of heat at low temperatures. Systems for refrigeration that use vapour compression use a lot of electricity. By enhancing the system's performance settings, this problem can be solved. As a result, the following can be done to enhance the thermodynamic performances of approaches based on vapour compression refrigeration technology. The two primary factors used to calculate the performance of refrigeration systems are first law efficiency (Coefficient of performance) and second law efficiency (Exergy Efficiency). The power consumption of the compressor can be reduced or the cooling effect can be increased to improve the performance coefficient. The cooling effect can be increased by the use of multi-stage throttling. On the other side, adding multi-stage compression and a flash chamber can increase the compressor's power consumption. These two aspects work together to enhance the vapour compression system's overall performance. It is explained that the irreversibility of system components results from large temperature variations between the system and its surroundings. Since energy losses are what cause the system performance to deteriorate, irreversibility should be measured in the cycle to optimise system performance. While exergy analysis can be used to quantify the exergy losses in VCR systems, the coefficient of performance (COP) is frequently employed to calculate the performance of vapour compression systems. However, COP offers no information regarding thermodynamic losses in the system components. With an increase in the temperature difference between a system's environment and itself, energy losses rise. Exergy is the usable or available energy, and when energy is lost, exergy is also lost within the system. Exergy losses are excellent for enhancing system performance and better utilising the energy input provided to the system, which is advantageous for the environment and the economics of energy technology.

This technique can boost the use of green energy. Using environmentally friendly refrigerants (R134a, R407c, R404a, R1234yf, and R1234ze), Mishra [5] calculated the first law and second law analysis of VCR systems with and without nanoparticles and suggested that blends of HFOs with nanoparticles have a bright future.

HFC-134a might be replaced by nanorefrigerants, but Mishra [5] discovered that they had the worst thermal performance in terms of first-law efficiency, second-law efficiency, and exergy efficiency. By utilising nanotechnology in the HFC-410a, it has been determined that R1234ze(Z) provides the best thermal performance in terms of first-law efficiency.

Many researchers [6,7,8] 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.

The ultra-low GWP HFO and HCFO refrigerants behave under the first and second laws of thermodynamics. Utilising brine flow with nanomaterials and without nanomaterials in the secondary circuit of the evaporator and low global warming potential three HFC-134a refrigerant in the primary circuit of the evaporator, respectively

3. Results and Discussion

In this paper, the following input parameters have been taken.

Table-1: Input data used in VCR System

S.No.	Description	Value with unit
1	Length of evaporator tube	0.72m
2	Length of condenser tube	1.25m
3	Mass flow rate of water flow	0.006 to 0.010 kg/sec
4	Mass flow rate of brine flow	0.006 to 0.010 kg/sec
5	Condenser water inlet temp	27°C
6	Brine water inlet temperature	27°C

The thermodynamic performance of vapour compression refrigeration have been evaluated using low GWP HFC refrigerants in the primary circuit of evaporator and nano mixed brine water was flowing in the secondary circuit of evaporator and thermodynamic first law (energy) performance improvement along with refrigerants are shown in Table-2(a) and second law (exergy) performance using copper oxide (CuO) nano material shown in Table-2(b) respectively.

.

3.1 Performance evaluation of VCRS using eco-friendly refrigerant in primary circuit and nano particle missed with R718 in secondary circuit of evaporator

we considered nanoparticles mixed with R718 in the secondary circuit and eco-friendly HCFOs and HFOs and HFC refrigerants in the primary circuit and conclude the performance of VCRS using nano materials mixed with brine water is enhanced significantly as compared without nano materials. Fig.1 shows the thermodynamic energy performance in terms of COP of vapor compression refrigeration system using HFO and HCFO refrigerants and it was found that best cop was observed by using HFO-1234ze(Z) in the primary circuit and lowest COP was found by using HFC-407c. However, the COP of HCFO1224yd(Z) and HCFO-1233zd(E) is slightly lower than using HFO-1234ze(Z) and higher than using HFO-1336mzz(Z). Although the COP of R134a is higher than HFO-1234ze(E), HFO-1243zf and HFO-1225ye(Z) and lower than HCFO-1233zd(E) and HCFO-1224yd(Z)

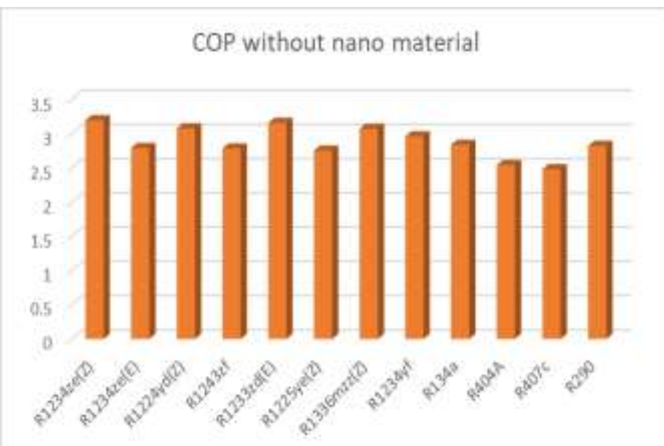

Figure 1: COP of VCRS using eco-friendly refrigerant in the primary circuit and R718 without nanoparticles in secondary circuit

From Fig. 1, it is found that the first law efficiency of efficiency (of low ODP/GWP refrigerant. R1234ze and R1234yf has best 1st law efficient compared to R134a. In future, both refrigerants can take place of R134a as they have 218 times lower GWP value that R134a.although other refrigerants R1225ye(Z) & R1243zf has lower COP. In the coming yers it is necessary to remove high GWP refrigerant as per Kyoto protocol then HFO and HCFOs, and HC-290, HC-600a, HFC-152a, HFC-245fa and R32 will be the best choice to replace R134a. similarly the first law efficiency in terms of COP of VCR system using HCFO and HCFO refrigerants as compared with HFC-134a is also shown in Fig. 2 respectively. Fig.3 Shows the percentage improvement in COP of VCRS using eco-friendly refrigerant in the primary circuit along with CuO+R718 mixed nanofluid in secondary circuit and it was found that highest (35.85%) improvement was observed by using HFO-1234ze(Z) and lowest (20.53%) improvement in first law performance was found by using HFO-1225ye(Z).

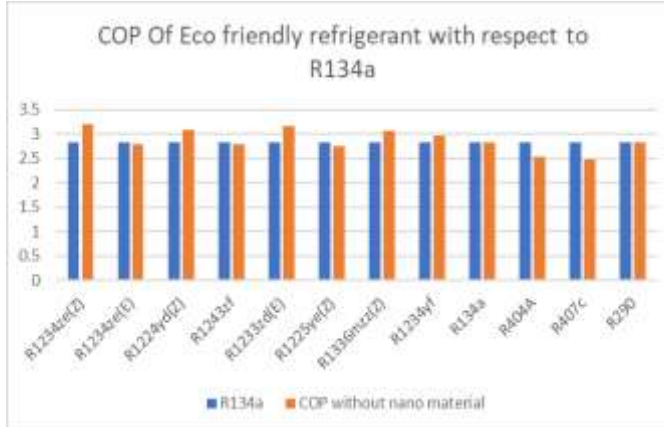

Figure 2: First law efficiency in terms of COP of VCR system using HCFO and HCFO refrigerants as compared with HFC-134a

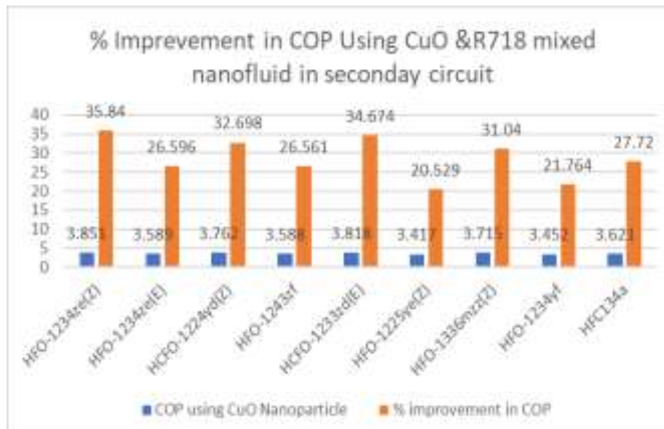

Figure 3: First law efficiency in terms of COP of VCR system using HFOs and HCFOs & HFCs refrigerants using CuO nano materials

Similarly Fig. 4 Shows the first law performance (COP)of VCRS using eco-friendly refrigerant in the primary circuit and Al_2O_3+R718 mixed nanofluid in secondary circuit and it was found that highest(32.5%) improvement was observed by using HFO-1234ze(Z) and lowest (20.07%) improvement in first law performance was found by using HFO-1225ye(Z) Fig. 5 Show the first law efficiency (COP) of VCRS using eco-friendly refrigerant in the primary circuit and TiO_2+R718 mixed nanofluid in secondary circuit. From Fig 3, to Fig 5, it is concluded that the HFO-1234ze(Z) gives the best thermodynamic first law performance with CuO nanoparticle as the COP of VCRS was improved around 35.85 % compared with, & without nanoparticle in secondary circuit. Fig. 6 Shows the percentage improvement in second law efficiency (exergy efficiency) of VCR System using eco-friendly refrigerant in the primary circuit along with CuO+R718 mixed nanofluid in secondary circuit and it was found that highest (32.34%) improvement was observed by using HFO-1234ze(Z) and lowest (11.6%) improvement in second law performance (exergy efficiency) was found by using HFO-1234yf.

Figure 4: First law performance (COP) of VCRS using eco-friendly refrigerant in the primary circuit and Al_2O_3+R718 mixed nanofluid in secondary circuit.

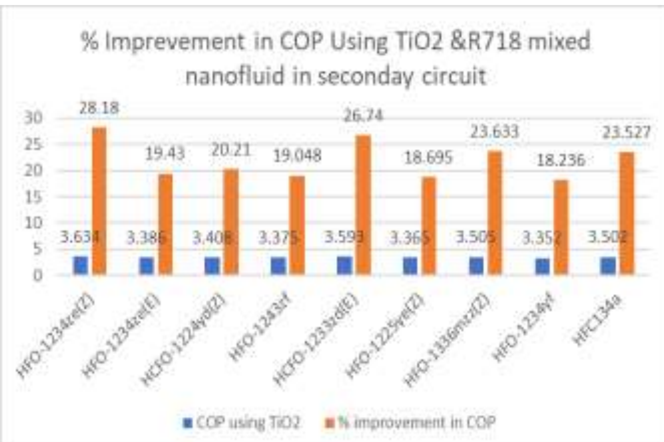

Figure 5: First law efficiency (COP) of VCRS using eco-friendly refrigerant in the primary circuit and TiO_2+R718 mixed nanofluid in secondary circuit

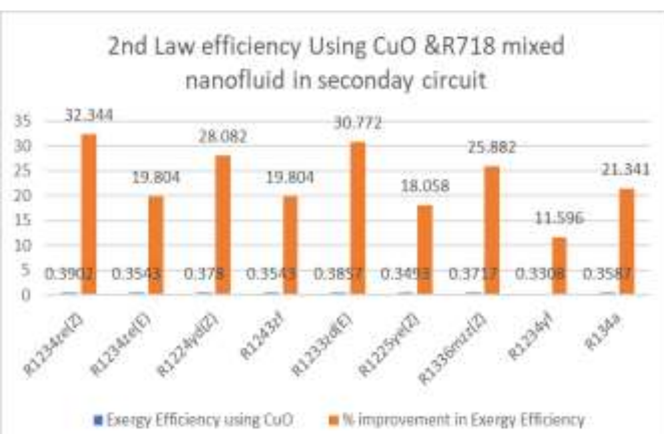

Figure 6: Second Law (exergy efficiency) performance of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit

Similarly, Fig.7 Shows the exergy performance of VCRS using eco-friendly refrigerant in the primary circuit and Al_2O_3+R718 mixed nanofluid in secondary circuit and it was found that the highest (29%) improvement in exergy efficiency was observed by using HFO-1234ze(Z) and lowest (9.19%) improvement in second law performance was found by using HFO-1234yf. Similarly, Fig. 8 Shows the second law (exergy efficiency) performance of VCRS using eco-friendly refrigerant in the primary circuit and TiO_2+R718 mixed nanofluid in secondary circuit and it was found that the highest (27.52%) improvement was observed by using HFO-1234ze(Z) and lowest (7.9%) improvement in second law exergy performance was found by using HFO-1234yf.

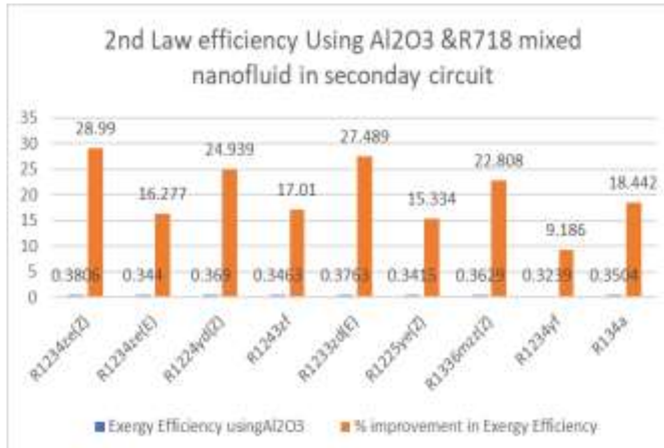

Figure 7: Second Law (exergy efficiency) performance of VCRS using eco-friendly refrigerant in the primary circuit and Al2O3+R718 mixed nanofluid in secondary circuit.

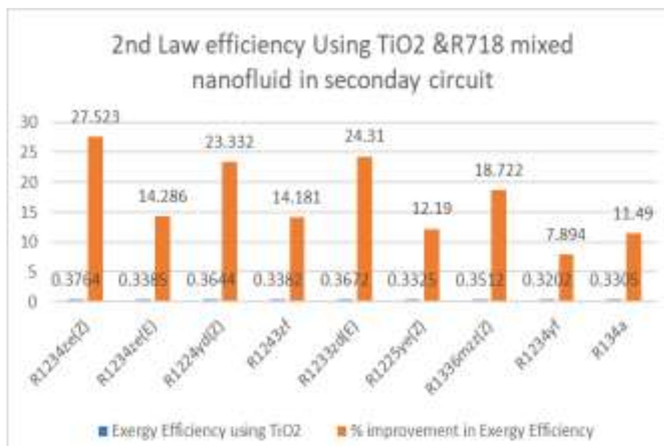

Figure 8: Second law (exergy efficiency) performance of VCRS using eco-friendly refrigerant in the primary circuit and TiO_2+R718 mixed nanofluid in secondary circuit

Fig. 9 Show the Compressor work of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit and it was found that lowest exergy destruction was using HFO-1234ze(Z) is lowest and highest by using HFO-1234yf.

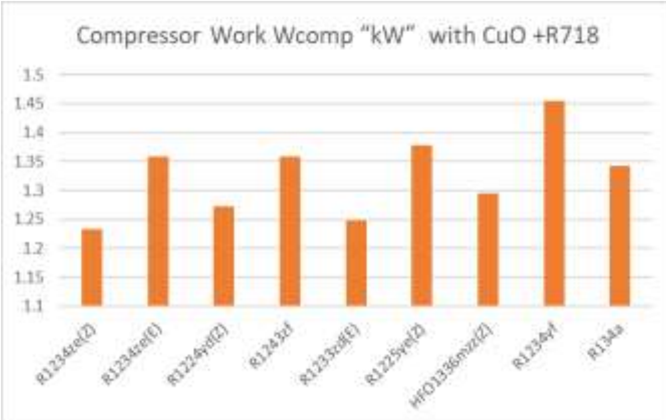

Figure 9: Compressor work of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit.

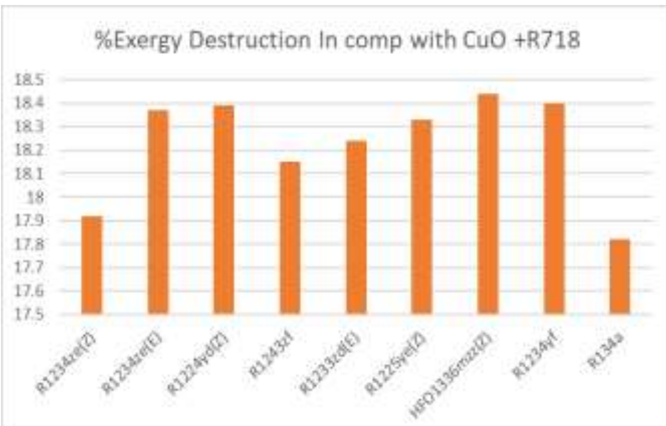

Figure 10: Percentage of Exergy Destruction in Compressor of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit.

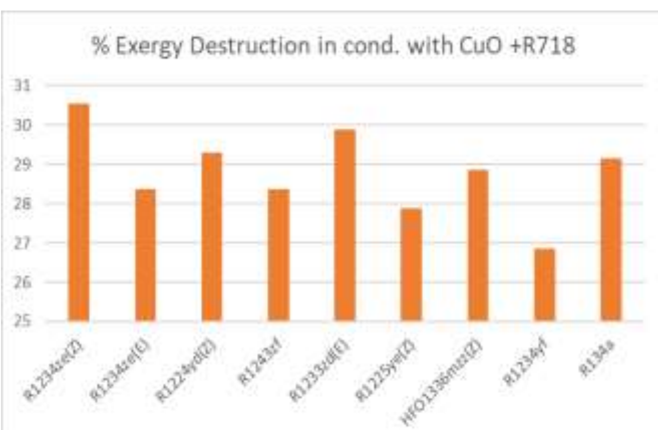

Figure 11: Exergy Destruction percentage in Condenser of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit.

Fig. 10 Shows the % Exergy Destruction in Compressor of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit and it was found that lowest exergy destruction was using HFO-1234ze(Z) is lowest and highest by using HFO-1234yf. Fig. 11 Shows the % Exergy Destruction in Condenser of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit and it was found that lowest exergy destruction was using HFO-1234ze(Z) is lowest and highest by using HFO-1234yf. Fig. 12 Show the % Exergy Destruction in Valve of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718. mixed nanofluid in secondary circuit and it was found that lowest exergy destruction was using HFO-1234ze(Z) and lowest is highest by using HFO-1234yf.

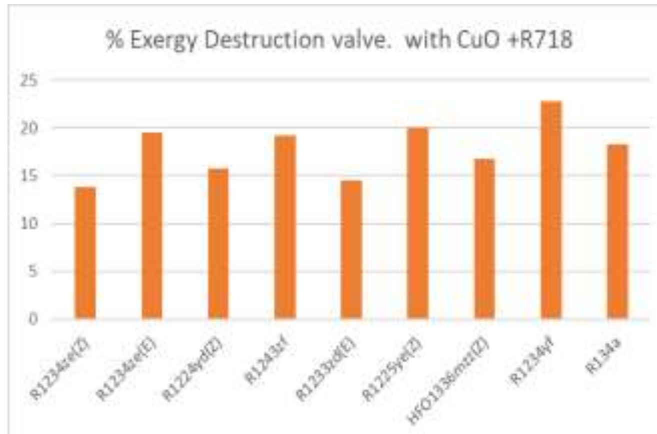

Figure 12: Exergy Destruction percentage in Valve of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit.

Fig. 13 Show the Total Exergy Destruction of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit and it was found that lowest exergy destruction was using HFO-1234ze(Z) is lowest and highest by using HFO-1234yf.

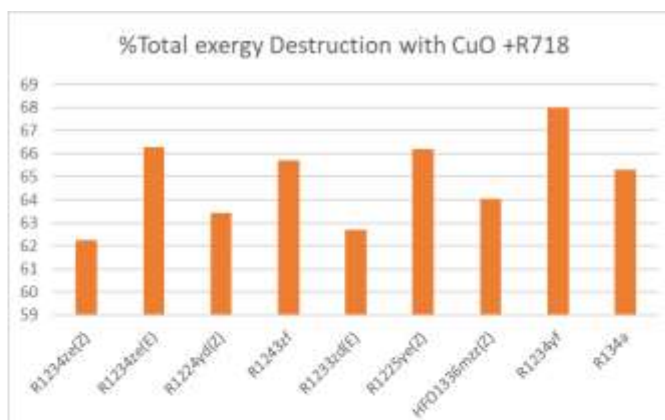

Figure 13: Total Exergy Destruction(percentage) of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in secondary circuit.

Similarly, Fig. 14 Shows the Rational Exergy efficiency of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in the secondary circuit and it was found that highest rational exergy efficiency was found by using HFO-1234ze(Z) and lowest by using HFO-1234yf.

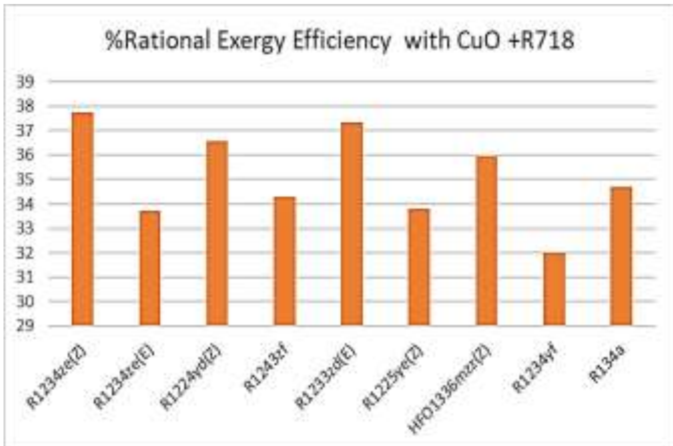

Figure 14: Rational Exergy efficiency(percentage) of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718 mixed nanofluid in the secondary circuit.

4. Conclusions

The following conclusions are made.

- Thermodynamic first law (energy) performance of VCR System using eco-friendly HFC refrigerants suspended with CuO, Al_2O_3 and TiO_2 nanoparticles in the brine water of the secondary circuit of the evaporator in VCR System, it was found that the first law performance(COP) is enhanced up to maximum 35%
- Thermodynamic second law (exergy) performance of VCR system using eco-friendly HFC refrigerants suspended with CuO, Al_2O_3 and TiO_2 nanoparticles in the brine water of the secondary circuit of the evaporator in VCR system, it was found that the first law performance(COP) is enhanced maximum upto is about improved up to 33%, 26.5%, and 25.8% respectively
- Thermodynamic first law (energy) performance of VCR system by using eco-friendly blends of HFO &HCFO refrigerants with suspended CuO, Al_2O_3 and TiO_2 (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 22.5%, 20.25%, 17%, respectively.
- Thermodynamic second law (exergy) performance of VCR system using eco-friendly HFC refrigerants suspended with CuO, Al_2O_3 and TiO_2 nanoparticles in the brine water of the secondary circuit of the evaporator in VCR system, it was found that the first law performance(COP) is enhanced maximum upto is about improved up to 25.5%, 21.8%, and 16.9% respectively as compared with HFC-134a
- The Exergy Destruction in compressor (percentage), Exergy Destruction in condenser (percentage), Exergy Destruction in Valve (percentage), and total exergy destruction (percentage) of VCRS using eco-friendly refrigerant in the primary circuit and CuO+R718. mixed nanofluid in secondary circuit and it was found that lowest exergy destruction was using HFO-1234ze(Z) and lowest is highest by using HFO-1234yf. However lowest exergy destruction was found in evaporator by using all HFOs, HCFOs and HFC refrigerants.

References

[1] R. S. Mishra / International journal of research in engineering and innovation (IJREI), vol 7, issue 1 (2023), 1-5.
[2] Adrian Mota Babiloni, et.al [2018] experimental drop in replacement of R404a for warm countries using low GWP mixtures of R454C and R455A, International Journal of refrigeration, 91, DOI: 10.1016/j.ijrefrig. 2018.05.018.
[3] W. Jiang, G. Ding and H. Peng, (2009): Measurement and model on thermal conductivities of carbon nanotube nano refrigerants. International Journal of Thermal Sciences. 48(6), 1108–1115
[4] K. Henderson, Y. Park, L.Liu and A. M. Jacobi, (2010): Flow-boiling heat transfer of R-134a-based nano fluids in a horizontal tube. International Journal of Heat and Mass Transfer. 53, 944–951.
[5] R.S Mishra (2019) Modelling of VCR 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.
[6] M.Xing, R.Wang, J.Yu,(2014): Application of fullerene C60 nano-oil for performance enhancement of domestic refrigerator compressors. International Journal of Refrigeration 40, 398-403.
[7] R.K. Sabareesh, et.al., (2012): Application of TiO2 nanoparticles as a lubricant-additive for vapor compression refrigeration systems – an experimental investigation. International Journal of Refrigeration, 35(7), 1989-1996
[8] 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.

Cite this article as: R. S. Mishra, Performances evaluation of VCR system using HFO &HCFO refrigerants in primary and Nano mixed brine flow in secondary circuits, International Journal of Research in Engineering and Innovation Vol-7, Issue-4 (2023), 152-158. https://doi.org/10.36037/IJREI.2023.7402.