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ORIGINAL ARTICLE

Comparison of thermal performance evaluation of VCRS using Brine based and Glycol based fluid nano materials in secondary circuit in evaporator using water cooled condenser

R. S. Mishra

Mechanical Engineering Department, Delhi Technological University, Delhi, India

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Abstract

Methods for to improving the base refrigerant's ability to transfer heat in the VCR system, nanoparticle-based refrigerant offers better qualities. Nanoparticles are used for increasing thermal performances in the VCR n systems. These nano particles could be suspended in a variety of solid and oxide materials. The impact of suspended copper oxide (CuO), titanium oxide (TiO2), and aluminum oxide (Al2O3) on environmentally beneficial HFO and HCFO refrigerants have been investigated. The system thermal model using the NTU approach was developed to solve the nonlinear equations of heat and mass transfer and it was found that the use of ecofriendly refrigerants as the primary fluid in VCR systems and brine / glycol fluid flow in the secondary circuit of evaporator. The results obtained by using developed thermal model have been compared for both secondary fluids mixed with nano materials, to determine the effect of changing performance parameters on the second law performance in terms of the exergy efficiency of the VCR system. Thermal performances of the VCRS nano based two fluids (such as brine based and glycol based nano on system performance have been compared and found that brine fluid mixed nano materials gives better thermodynamic performance than using glycol based nano materials in the secondary circuit and HFO & HCFO refrigerants used I primary circuit.

1. Introduction

Modern refrigeration-based technology is crucial for both household and commercial uses. Comparatively speaking, these systems used more energy than conventional appliances. These systems utilize more energy compare to other appliances. The refrigeration systems have been severely investigated to reduce the energy consumption in many research articles. Hence, nanoparticle based refrigerant has been introduced a superior properties refrigerant that increased the heat transfer performance of base refrigerant of the refrigeration system. This investigation includes the effect of brine fluid mass flow rate in the evaporator and water mass flow rate in the condenser using brine fluid flow and compared with glycol fluid flow in secondary circuit of evaporator and HCFO refrigerants in the primary circuit on COP, and exergy efficiency of the complete system geometry of VCRS.

2. Nano materials for enhancing thermal performances.

The literature review includes a few studies that illustrate the behaviour of nanoparticles, the use of nano fluid in VCR

Corresponding author: R.S. Mishra
Email Address: rsmishra@dtu.ac.in
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systems, and the theoretical analysis and experimental investigation of refrigeration systems based on the first law and second law analysis with various pairs of refrigerants. Jwo et al.'s [2] carried out analytical studies for replacing polyester lubricant and R-134a refrigerant with mineral lubricant and hydrocarbon refrigerant. To improve heat transmission and lubrication, Al_2O_3 nanoparticles are added to the mineral lubricant. Their tests showed that the best materials were R-134a at 60% and Al_2O_3nanoparticles at 0.1 weight percent.In these conditions, the C.O.P. increased by 4.4% while power consumption fell by 2.4%.The experimental study by Henderson et al. [4] studied the flow boiling heat transfer coefficient of nanofluids based on R134a (refrigerant) was carried out in a horizontal tube and found that CuO nanoparticles were well dispersed in R134a and POE oil, and the heat transfer coefficient was significantly higher than it had been with previous R134a/POE oil results.

The effects of single wall carbon nanohorns (SWCNH) and titanium dioxide on the tribological properties of POE oil and the solubility of R134a at various temperatures were investigated in a study of Bobbo et al. [5].

They established,how the addition of nanoparticles can either improve or deteriorate the tribological behaviour of the base lubricant and observed that the solubility was not considerably impacted by the dispersion of nanoparticles. Al_2O_3-R600a nano refrigerant was used as the working fluid in an experimental work on the performance of a home refrigerator Bi et al. [6].demonstrated that the Al_2O_3-R600a system operated normally and effectively in the refrigerator with a 9.6% reduction in energy use and found that the nano refrigerating system had a higher freezing velocity than a system using only pure R600a in a vapour compression device.

According to Lee et al.'s [7] experiment. The nanoparticles could improve the compressor's dependability and efficiency. According to Wang and Xie [8], Al_2O_3 nanoparticles can be used the solubility between mineral oil as additives to improve of hydrofluorocarbon (HFC) refrigerant. The refrigeration systems using R134a and mineral oil combined with Al_2O_3 nanoparticles perform the best when compared to systems using polyol-ester (POE) and R134a because they return more lubricating oil to the compressor.

The refrigerant selected for this investigation is R600a, while the nanoparticle employed is alumina. Isobutane (R600a) is more widely utilised in household freezers due to its higher energy and environmental characteristics.

In the experiment, Heris et al.[9] found the convective heat transfer coefficient through a circular tube while maintaining the temperature of the tube wall for the boundary condition for nano fluids made up of water as the base fluid and Al_2O_3 and CuO oxide nanoparticles. They used a copper tube with a diameter of 6 mm and a length of 1 metre for the experiment. A 32 mm diameter exterior stainless steel tube is used with a copper tube that is 0.5 mm thick. In their experiment, saturated stea in the annuli section of the steel tube and nano fluid flow inside the copper tube provide constant wall temperatures. Water was utilised to cool the test chamber before the fluid is then directed to a heat exchanger. The experimental results show that an increase in the nanofluid's coefficient of heat transmission was not predicted by the homogeneous model (single phase correlation of nanofluid). According to the experimental results, CuO/water and Al_2O_3/water had heat transfer coefficients that were quite similar to those predicted by the homogeneous model, but when the volume percent concentration of nanoparticles was raised, Al_2O_3/water experienced a significantly higher coefficient of heat transfer. They have concluded that a number of variables (i.e. thermal conductivity, nanoparticles movement, suspension technique of nanoparticle nanoparticle diameter,) which influenced on the coefficient of heat transfer of nanofluid.

Y. He et al. [10] conducted research to ascertain how nanofluid behaved in laminar and turbulent flow. Their experiment consists of a heating and cooling equipment, a flow loop, and a monitoring instrument. The test section is made up of a straight copper tube measuring 1830 mm in length, 3.95 mm inside, and 6.35 mm outside. Two flexible silicon rubber heaters were utilised in the experiment to heat the tube. For the continuous heat flux condition in the test portion, they offered a thermally insulated layer. The pressure drop was measured using two pressure transducers. Testing has been done on the effects of Reynolds number, nanoparticle size, and nanoparticle concentration in the base fluid and they got to the conclusion that we can increase the thermal conductivity of the base fluid by floating nanoparticles in the host fluid. Additionally, we can make it better by increasing concentration and reducing particle size which reduced that the pressure drop brought on by the nanofluid was comparable to that of the base fluid. SiO_2 nanoparticle suspension in an EG/water mixture at a 60:40 weight percent ratio was utilised by Kulkarni et al. [11] to study the heat transmission and fluid dynamics capabilities of nanofluids.A copper tube measuring 1.m in length, 3.15 mm in diameter, and 4.75 mm in diameter was used as a test piece for this experiment.

To keep the fluid's intake temperature constant, four counterflow shell and tube heat exchangers were used. The scientists conducted an experiment to examine the effects of growing the concentration of volume nanoparticles and the pressure drop that follows on the convective heat transfer of nanofluid with diameters of 20 nm, 50 nm, and 100 nm in the turbulent area.

Hwang et al. investigated an Al2O3/water-based nanofluid's convective heat transfer coefficient flowing through a 1.8 mm inside diameter circular tube while keeping a steady heat flux for a fully formed laminar regime. Al2O3/water-based nanofluids are produced using a two-step process and from 0.01% to 0.3% of range in volume% concentration

Additionally, the density, viscosity, heat capacity, and thermal conductivity of nanofluids have been measured. They have determined that, in a fully established laminar regime, an increase in the convective heat transfer coefficient occurs at concentrations of nanoparticles between 0.01 and 0.3 vol%, and that, at the same Reynolds number of base fluid, an increase in heat transfer of about 8% is obtained. They found that for the same volume percent concentration of nanoparticles, a heat transfer coefficient enhancement was substantially greater than an in thermal conductivity enhancement. Al_2O_3 nanofluid was placed in a tube with a twisted tape inserted in the flow zone. The evaluation of the friction factor and heat transfer coefficient was studied by Sharma et al. [13]. A 1.5-meter-long test portion with an L/D ratio of 160 was taken into account. To ensure even heating, one Kw was wrapped around the test part.It makes use of 1mm thick by 0.018mm broad metal strips. 5, 10, and 15 twist ratios are determined by applying a 180° twist while maintaining both ends of the test piece in the lathe machine. The results show that adding Al2O3 nanoparticles to the base fluid rather than base water improves the heat transfer coefficient. The heat transfer coefficient was 23.7% higher than that of water at Reynolds number 9000. According to Yu et al., [14], silicon carbide nanoparticles having a diameter of 170 nm and 3.7 vol% suspended in pure water showed an increase in convective heat transfer coefficient of about 50–60% in comparison to the host fluid. Their test section's stainless steel tube has a 2.27 mm inside diameter and an outside diameter of 4.76 mm. Their test setup consists of a closed loop system with a horizontal tube heat exchanger flow metre. They got to the conclusion that the actual value of the heat transfer augmentation for single phase turbulence is 14-32% higher than the planned value. The pressure loss is also found to be slightly lower than that of the Al2O3 water nanofluid.

Torii and Yang [15] investigated the heat transfer coefficient of a suspended diamond nanoparticle into the host fluid while maintaining a constant heat flow. The improvement of the heat transfer coefficient is impacted by changes in the Reynols number. Rea et al. [16] studied viscous pressure loss & heat transfer coefficient for the Al_2O_3/water and zirconia-water nanoparticle based nanofluid flowing loops using 1.0 m-long, stainless steel using vertical heated test segment had a 6.5 mm of outside diameter and an interior diameter of 4.5 mm used in experimental set up. In the test section, which was situated 5 centimetres, 16 centimetres, 44 centimetres, 58 centimetres, 89 centimetres, and 100 centimetres away from the heated inlet area of the testing facility, 8 T type thermocouples were utilised. Measurement of the fluid temperatures two T-type thermocouples of the similar type is located in the channel both before and after the test section and found 17% and 27% enhancement in convective heat transfer coefficients in fully developed organisms. The heat transfer of zirconia-water nanofluid increases by roughly 2% and 3% in the inlet zone at 1.32 vol% and in the fully formed region at 1.32 vol%, respectively. Despite being in good agreement with the predicted model for laminar flow,

Murshed et al. [17] tested TiO2 nanoparticles using spherical and rod-shaped particles improvement of 32.8%.for 15 nm in diameter of the the spherical particles and 10 nm in diameter and 40 nm in length of rod-shaped particles. For the first time, a nonlinear relationship between the volume fraction and conductivity improvement was found here at lower concentrations. This is intriguing in terms of the temperature effect and pure metallic particles. They discovered that rod-shaped particles improved conductivity as more than spherical particles. The enhancement up to 29.7% in the spherical particles with 5%, and enhancement up 32.8% with rod-shaped particles. They attributed this to the larger form factor (n = 6) for rods in the Hamilton-Crosser [18] model compared to spheres (n = 3). Yuan and Li [19] showed that the turbulent heat transfer coefficient initially considerably increased. They found that, at given velocities, the heat transfer coefficient of nano fluids containing 2.0 vol% Cu nanoparticles was up to 40% better than that of host water. The Dittus Boelter correlation was not used to generate the improved experimentally observed nanofluid heat transfer performance in comparison to pure refrigerant.

Recent unpublished study reveals that the importance of particle size, shape, and dispersion becomes crucial in order to enhance heat transmission in nano fluids. The one-step method aims to produce nanofluids with significantly greater effects on heat transmission. It is thus possible to "engineer" exceptionally energy-efficient heat transfer fluids by selecting the nanoparticle material and controlling particle size, shape, and dispersion.

Al_2O_3/R134a nano refrigerant's thermal performance was examined by Mahbubul and Saadah [20]. They considered the homogeneous mass flux of nanorefrigerant in a horizontal, smooth tube when conducting in their study. In comparison to pure refrigerant, the nano-refrigerant's C.O.P. rose by about 15%, thermal conductivity by about 28.8%, dynamic viscosity by about 13.68%, and density by about 11%.

Faulkner et al. [21] carried out experimental studied on fully developed laminar convection heat transfer tests and discovered that CNT-containing water-based nanofluids considerably increase overall heat transmission. First, the heat transfer coefficient of the nanofluids increases along with the Reynolds number. The heat transfer coefficient of the nanofluid was approximately double that of ordinary water at the higher end of the Reynolds number range investigated, and it appears that this advantage will endure as Reynolds numbers increase. In terms of performance, water trails nanofluids with low particle concentrations (1.1 vol%) perform better than those with higher concentrations (2.2 and 4.4 vol%).

Wien and Ding [22], carried out study on laminar flow of nano fluids and exhibited that the nano fluids had extensive entrance length than water and found significantly increase in the heat transfer coefficient of water-based nano fluids containing Al_2O_3 nanoparticles at the entry region. During 2006, several lot of research work have been done on multi-walled carbon nanotubes in water-based nanofluids laminar flow.For carbon nanotubes of 0.5 weight %, the higher convective heat transfer coefficient improvement is beyond 350% at 800 Reynold number due to increasing thermal conductivity. They proposed a number of plausible explanations, such as the thickness of the thermal boundary layer, the effect of carbon nanotubes on particle rearrangement, and the exceptionally high aspect ratio of carbon nanotubes. Lee and others [23] examined the thermal conductivities of micro fluids between 21 and 55°C, the findings were nothing short of amazing. Over this modest temperature increase of 34° C, the thermal conductivity enhancement was more than three times greater. At a 4% particle volume fraction, the enhancement increased from

9.4% to 24.2%, and at a 1% particle volume fraction, it increased from 2.1% to 10.9%. For CuO-water nano fluids, the increase was 6.5% to 29% for a 1% particle-volume fraction and 14% to 36% for a 4% particle fraction. This absolutely puts the phenomenological theory of nanofluids into perspective. In actuality, no theory advanced before the publication of this study could have predicted such a strong temperature effect; as a result, they all disintegrated in the face of this discovery. The experimental study also exposed that at high temperatures, neither the CuO-based nanofluids nor the Al_2O_3-based nanofluids. This clearly shows how the Hamilton-Crosser model and the Al_2O_3 nano fluids work.

Joaquin Navarro et al.'s [24] investigation of the efficacy of an R1234yf-based VCR cycle (system) in place of R134a. They looked assessed the efficiency of VCR systems using the R1234yf and R134a refrigerants under a variety of working situations, both with and without internal heat exchangers, as part of their research. An experimental outcome is attained by using an internal heat exchanger and changing the evaporator and condenser's temperatures and found reduces 13% C.O.P & 6%, cooling cooling capacity Their research shows that switching by using HFO-1234yf instead of HFC-134a.

This paper mainly deals with the comparison of thermal performances using HFO and HCFO in primary circuit of VCR systems and nano mixed brine water flow and glycol flow in secondary circuit of evaporator.

3. Result and Discussion

For nano refrigerant flowing in primary circuit and R718 (water) and glycol based fluid flowing in secondary circuit of VCRS and results are given below.

- Total length of evaporator tube =14.4 m
- Total length of condenser tube =24.4 m
- Inlet water temperature of condenser=300K
- Inlet brine fluid temperature of evaporator=300K
- Dead state temperature =300K
- Mass flow rate of water =0.008Kg/sec
- Mass flow rate of brine water =0.00Kg/sec
- Mass flow rate of glycol =0.00Kg/sec

Use of nanoparticles in glycol fluid flow in secondary circuit of water enhances the thermal (first law efficiency) performance (COP) and second law exergy performance of VCR system shown in table-1(a) to table-1(g) respectively and it was found that first law energy performance (COP) was 34.49% than using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and 19.77 % using HFO-1234yf refrigerants in the primary circuit and glycol mixed CuO nano fluid in secondary circuit. Similarly, second law exergy performance (Exergy Efficiency) was 37.686% than using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and 23.27 % using HFO-1234yf refrigerants in the primary circuit and glycol mixed CuO nano fluid in secondary circuit. While overall evaporator heat transfer coefficient (U_eva) was 112.75% using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and. using glycol mixed CuO nano fluid in secondary circuit and HFO -1234yf 109.57% in the primary circuit. Similarly, overall condenser heat transfer coefficient (U_eva) was 14.42% using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and. using glycol mixed CuO nano fluid in secondary circuit and HFO -1234yf 14.77% in the primary circuit.

Table 1(a): Comparison of thermal performances of VCRS using HCFO-1233zd(E) in primary circuit and with CuO nano mixed brine floe in secondary circuit and without nano fluid t

Performance Parameters	With nano	Without nano	% enhancement
COP	3.893	2.895	34.49
Exergy_Efficiency	0.3975	0.2887	37.6861
$U_{\_Eva}$ ($W/m^{2o}C$)	1395.5	655.7	112.749
$U_{\_Cond}$ ($W/m^{2o}C$)	725.7	623.5	14.42

Table 1(b): comparison of thermal performances of VCRS using HCFO-1224yd(E) in primary circuit and with CuO nano mixed brine flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.793	2.885	31.473
Exergy_Efficiency	0.3875	0.2857	35.632
$U_{\_Eva}$ ($W/m^{2o}C$)	1365.5	645.7	111.476
$U_{\_Cond}$ ($W/m^{2o}C$)	720.7	621.5	15.961

Table 1(c): comparison of thermal performances of VCRS using HCFO-1336mzz(Z) in primary circuit and with CuO nano mixed brine flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.755	2.857	31.432
Exergy_Efficiency	0.3747	0.285	31.474
$U_{\_Eva}$ ($W/m^{2o}C$)	1351.51	645.3	109.44
$U_{\_Cond}$ ($W/m^{2o}C$)	715.8	621.2	14.907

Table 1(d): comparison of thermal performances of VCRS using HFO-1225ye(Z) in primary circuit and with CuO nano mixed brine flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.498	2.847	22.86
Exergy_Efficiency	0.3574	0.285	25.4035
$U_{\_Eva}$ ($W/m^{2o}C$)	1331.90	633.3	110.311
$U_{\_Cond}$ ($W/m^{2o}C$)	701.56	611.4	14.747

Table 1(e): comparison of thermal performances of VCRS using HFO-1243zf in primary circuit and with CuO nano mixed brine flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.558	2.856	24.58
Exergy_Efficiency	0.3731	0.2851	27.359
$U_{\_Eva}$ ($W/m^{2o}C$)	1353.63	643.76	110.27
$U_{\_Cond}$ ($W/m^{2o}C$)	713.5	621.1	14.877

Table 1 (f): comparison of thermal performances of VCRS using HFO-12343ze(E) in primary circuit and with CuO nano mixed brine flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.560	2.858	24.56
Exergy_Efficiency	0.3732	0.2858	30.58
$U_{\_Eva}$ ($W/m^{2o}C$)	1353.93	643.77	110.313
$U_{\_Cond}$ ($W/m^{2o}C$)	713.8	621.2	14.907

Table 1(g): comparison of thermal performances of VCRS using HFO-1234yf in primary circuit and with CuO nano mixed brine flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.398	2.837	19.770
Exergy_Efficiency	0.3543	0.2874	23.270
$U_{\_Eva}$ ($W/m^{2o}C$)	1323.93	631.3	109.567
$U_{\_Cond}$ ($W/m^{2o}C$)	701.56	613.3	14.765

3.1 Thermal performances of VCRS using glycol based secondary circuit

Use of nanoparticles in glycol fluid flow in secondary circuit of water enhances the thermal (first law efficiency) performance (COP) and second law exergy performance of VCR system shown in table-2(a) to table-2(g) respectively and it was found that 15.74% than using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and 10.257 % using HFO-1234yf refrigerants in the primary circuit and glycol mixed CuO nano fluid in secondary circuit. While exergy Efficiency was 19.67% than using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and 15.53 % using HFO-1234yf refrigerants in the primary circuit and glycol mixed CuO nano fluid in secondary circuit. While overall evaporator heat transfer coefficient (U_eva) was 67% using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and. using glycol mixed CuO nano fluid in secondary circuit and HFO -1234yf 62.45% in the primary circuit. Similarly, overall condenser heat transfer coefficient (U_eva) was 8.37% using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and. using glycol mixed CuO nano fluid in secondary circuit and HFO -1234yf 10.49% in the primary circuit

Table 2(a): comparison of thermal performances of VCRS using HCFO-1233zd(E) in primary circuit and with CuO nano mixed glycol flow in secondary circuit and without nano fluid secondary circuit

Performance Parameters	With nano	Without nano	% enhancement
COP	3.334	2.895	15.74
Exergy_Efficiency	0.3455	0.2887	19.67
$U_{\_Eva}$ ($W/m^{2o}C$)	1095.5	655.7	66.997
$U_{\_Cond}$ ($W/m^{2o}C$)	675.7	623.5	8.372

Table 2(b): comparison of thermal performances of VCRS using HCFO-1224yd(E) in primary circuit and with CuO nano mixed glycol flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.314	2.88	15.07
Exergy_Efficiency	0.3421	0.2880	18.78
$U_{\_Eva}$ ($W/m^{2o}C$)	1075.5	650.7	65.207
$U_{\_Cond}$ ($W/m^{2o}C$)	670.5	620.5	8.058

Table2(c): comparison of thermal performances of VCRS using HCFO-1336mzz(Z) in primary circuit and with CuO nano mixed glycol flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.29	2.875	14.435
Exergy_Efficiency	0.3387	0.2878	17.686
$U_{\_Eva}$ ($W/m^{2o}C$)	1065.2	648.4	64.281
$U_{\_Cond}$ ($W/m^{2o}C$)	663.8	619.3	8.26

Table-2(d): comparison of thermal performances of VCRS using HCFO-1225ye(Z) in primary circuit and with CuO nano mixed glycol flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.227	2.839	13.66
Exergy_Efficiency	0.337	0.2878	17.095
$U_{\_Eva}$ ($W/m^{2o}C$)	1032.7	633.3	63.07
$U_{\_Cond}$ ($W/m^{2o}C$)	677.45	613.3	10.45

Table 2(e): comparison of thermal performances of VCRS using HFO-1243zf in primary circuit and with CuO nano mixed brine flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.227	2.839	13.67
Exergy_Efficiency	0.3385	0.2879	17.576
$U_{\_Eva}$ ($W/m^{2o}C$)	1052.7	638.7	64.82
$U_{\_Cond}$ ($W/m^{2o}C$)	663.2	613.3	8.066

Table 2(f): comparison of thermal performances of VCRS using HFO-12343ze(E) in primary circuit and with CuO nano mixed brine flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.228	2.839	13.702
Exergy_Efficiency	0.3386	0.2879	17.61
$U_{\_Eva}$ ($W/m^{2o}C$)	1052.8	638.7	64.83
$U_{\_Cond}$ ($W/m^{2o}C$)	663.3	613.3	3.261

Table-2(g): comparison of thermal performances of VCRS using HFO-1234yf in primary circuit and with CuO nano mixed glycol flow in secondary circuit and without nano fluid in secondary

Performance Parameters	With nano	Without nano	% enhancement
COP	3.128	2.837	10.257
Exergy_Efficiency	0.3321	0.2874	15.553
$U_{\_Eva}$ ($W/m^{2o}C$)	1025.75	631.3	62.452
$U_{\_Cond}$ ($W/m^{2o}C$)	675.45	611.3	10.49

3.2 Comparison between Thermal performances of VCRS using brine based and glycol based secondary circuit

Use of nanoparticles in brine water flow in secondary circuit of water enhances the thermal (first law efficiency) performance (COP) and second law exergy performance of VCR system shown in table-3(a) to table-3(g) respectively and it was found that COP is 16.67 % than using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and 10.25 % using HFO-1234yf refrigerants in the primary circuit and glycol mixed CuO nano fluid in secondary circuit. While exergy Efficiency was 15.05 % than using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and 6.685 % using HFO-1234yf refrigerants in the primary circuit and glycol mixed CuO nano fluid in secondary circuit. While overall evaporator heat transfer coefficient (U_eva) was 67% using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and. using glycol mixed CuO nano fluid in secondary circuit and HFO -1234yf 62.45% in the primary circuit. Similarly, overall condenser heat transfer coefficient (U_eva) was 8.37% using glycol mixed CuO nano fluid in secondary circuit and HCFO -1233zd(E) in the primary circuit and. using glycol mixed CuO nano fluid in secondary circuit and HFO -1234yf 10.49% in the primary circuit

Table3(a): comparison of thermal performance of VCRS with brine mixed CuO nano material with glycol mixed and R1233zd(E) fluid in primary circuit

Performance Parameters	With nano in brine water	With nano in glycol	% enhancement
COP	3.893	3.334	16.67
Exergy_Efficiency	0.3975	0.3455	15.05
U_{Eva} ($W/m^{2o}C$)	1395.5	1095.5	27.442
U_{Cond} ($W/m^{2o}C$)	725.7	675.7	7.399

Table3(b): comparison of thermal performance of VCRS with brine mixed CuO nano material with glycol mixed and R1224yd(Z) fluid in primary circuit

Performance Parameters	With nano in brine water	With nano in glycol	% enhancement
COP	3.793	3.314	14.45
Exergy_Efficiency	0.3875	0.3421	13.27
U_{Eva} ($W/m^{2o}C$)	1365.5	1075.5	26.96
U_{Cond} ($W/m^{2o}C$)	720.7	670.5	7.487

Table 3(c): comparison of Thermal performance of VCRS with HCFO-1336mzz(Z) in primary circuit and brine mixed CuO nano material and with glycol mixed CuO nano fluid

Performance Parameters	With nano in brine water	With nano in glycol	% enhancement
COP	3.755	3.29	16.392
Exergy_Efficiency	0.3747	0.3387	10.63
U_{Eva} ($W/m^{2o}C$)	1351.51	1065.2	26.87
U_{Cond} ($W/m^{2o}C$)	715.8	663.8	7.835

Table 3(d): comparison of Thermal performance of VCRS with brine mixed CuO nano material and with glycol mixed CuO nano fluid

Performance Parameters	With nano in brine water	With nano in glycol	% enhancement
COP	3.498	3.227	8.398
Exergy_Efficiency	0.3574	0.337	6.053
U_{Eva} ($W/m^{2o}C$)	1331.90	1032.7	28.97
U_{Cond} ($W/m^{2o}C$)	701.56	677.45	10.256

Table 3(e): comparison of thermal performance of VCRS with brine mixed CuO nano material and with glycol mixed CuO nano fluid

Performance Parameters	With nano in brine water	With nano in glycol	% enhancement
COP	3.398	3.128	8.632
Exergy_Efficiency	0.3543	0.3321	6.685
U_{Eva} ($W/m^{2o}C$)	1323.93	1025.75	29.07
U_{Cond} ($W/m^{2o}C$)	701.56	675.45	10.287

Table 3(f): comparison of Thermal performance of VCRS with brine mixed CuO nano material and with glycol mixed CuO nano fluid

Performance Parameters	With nano in brine water	With nano in glycol	% enhancement
COP	3.558	3.227	10.25
Exergy_Efficiency	0.3731	0.3385	10.22
U_{Eva} ($W/m^{2o}C$)	1353.63	1052.7	28.59
U_{Cond} ($W/m^{2o}C$)	713.5	663.2	9.76

Table 3(g): comparison of Thermal performance of VCRS with brine mixed CuO nano material and with glycol mixed CuO nano fluid

Performance Parameters	With nano in brine water	With nano in glycol	% enhancement
COP	3.560	3.228	10.285
Exergy_Efficiency	0.3732	0.3386	10.22
U_{Eva} ($W/m^{2o}C$)	1353.93	1052.8	28.603
U_{Cond} ($W/m^{2o}C$)	713.8	663.3	7.613

4. Conclusion

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

- COP of VCR system varying from 34.49 % using CuO nano mixed brine in secondary and using R1233zd(E) primary refrigerant circuit.Use of nano particles enhances
- By using R1233zd(E) refrigerant in primary circuit and CuO nano brine water in secondary circuit of VCRS found highest improvement in thermal performances and overall evaporator heat transfer coefficient.
- The thermal performance of VCR system improves from 10.25 % to to 15.74% by using nano CuO nano mixed glycol in secondary circuit.
- Use of nanoparticles in brine water flow in secondary circuit of water enhances the thermal (first law efficiency) performance (COP) and second law exergy performance of VCR system from 10.28 % to 16.68 % than using glycol

mixed nano fluid in secondary circuit for all HCFO and
- HFO refrigerants in the primary circuit.
- Very low improvement in thermal performance was observed using R1234yf nano refrigerant in primary circuit and VCRS secondary circuit using TiO_2 mixed glycol.

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