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Methods for Improving Thermodynamic Performance of Vapour Compression Refrigeration Systems Using Nano Mixed Ecofriendly Refrigerants in Primary Circuit and Comparsion with Nano Particles Mixed Wih R718 Used in Secondary Evaporator Circuit and Ecofriendly Refrigerants in Primary Circuit for Reducing Global Warming and Ozone Depletion

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ABSTRACT

The use of nano particles mixed refrigerants in a primary circuit in vapour compression refrigeration systems and used of nano particles mixed with R718 in the secondary evaporator circuit was studied in detail and computational system model was developed for solving the non linear heat transfer equations of the system. The effect of brine mass flow rate on the overall evaporator heat transfer rate and first and second law performances of VCRS have been investigated. It was observed that C.O.P enhancement about 8-28 % in the nanoparticles mixed refrigerants in a primary circuit and nanoparticles mixed refrigerants in the R718 and used in a secondary circuit is from 8% to 20% with evaporator heat transfer rate increasing is double as compared without nanoparticles in the secondary circuit due to its thermo-physical properties increases in the system.

Keywords: *Nano Refrigerants in Primary Circuit; Nanorefrigerants in Secondary Circuit; Enhancement in Thermal Performances; Vapour Compression Refrigeration System.*

1.0 Introduction

Now a day's refrigeration based equipment are most important for industrial and domestic applications. Those systems utilize more energy as compared to other appliances.

The refrigeration systems have been severely investigated to reduce the energy consumption.

The nanoparticle based refrigerant gives a superior thermodynamic properties as compaired to the without refrigerant due to increase in the heat transfer performances of base refrigerant in the vapour compression refrigeration systems.

There are several methods for improving the thermal performance of vapour compression refrigeration systems.

Utility of nano particles mixed in the ecofriendly refrigerants and then used as a refrigerant can significantly enhanced its thermal performance and simanteously decreases exergy destruction ratio. Several authors had defined exergy destruction ratio (EDR) based on its input or based on its output in the vapour compression refrigeration systems.

EDR is a ratio of total exergy losses in the system (i.e. which is a sum of total exergy losses in the components in VCR) to the exergy of input (in terms of fuel in terms of compressor work) or a ratio of total exergy losses in the system (i.e. which is a sum of total exergy losses in the components in VCR) to the exergy of input (in terms of product i.e. net exergy due to cooling load). Many types of solid and oxide materials could be used as the nanoparticles to be suspended into the conventional refrigerants.

The nano refrigerant/refrigerant could be better working fluid to be used in the refrigeration and air conditioning system to increase the heat transfer performance of that system and overall system performance and save the energy usage. The effect of the suspended copper oxide (CuO), Titanium Oxide (TiO2), Aluminum Oxide (Al2O3), into the ecofriendly refrigerants (i.e. R134a, R407c and R404a etc.) eco friendly refrigerant enhances its first law performance in terms of coefficient of perform-

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ance. Lots of researches have evaluated the performance of various metallic/ nonmetallic nanoparticle suspended into the conventional fluid to enhance the heat transfer property of base fluid and simple theoretical analysis of suspension of nanoparticle Al2O3 in conventional refrigerants.

On the other hand the thermodynamic performances of vapour compression system in the primary circuit using nano particles mixed ecofriendly refrigerants yet to be analyzed and also be compared with nano particles (i.e. TiO2, CuO) mixed with R718 refrigerant and then used in secondary circuit The effect of changing input parameter of VCRS using nanorefrigerant is on thermodynamic performance is also investigated.

Thus, the use of nanoparticles in refrigeration systems is a new, innovative way to enhance the efficiency and reliability in the refrigeration systems.

Elcock [1] observed by conducting experiments regarding the use of TiO2 nanoparticles as additives in the refrigeration system to enhance the solubility of the mineral oil with the hydro fluorocarbon (HFC) refrigerant by prepairing a mixture of HFC134a and mineral oil with TiO2 nanoparticles and found the better performance by returning more lubricant oil to the compressor with similar performance to systems using HFC134a.

E. Halimic [2] carried out experimental study on the boiling heat transfer characteristics of R22 refrigerant with Al2O3 nanoparticles and found the nano particles performance and save the energy usage.

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Lots of researches have evaluated the performance of various metallic/ nonmetallic nanoparticle suspended into the conventional fluid to enhance the heat transfer property of base fluid and simple theoretical analysis of suspension of nanoparticle Al2O3 in conventional refrigerants.

On the other hand the thermodynamic performances of vapour compression system in the primary circuit using nano particles mixed ecofriendly refrigerants yet to be analyzed and also be compared with nano particles (i.e. TiO2, CuO) mixed with R718 refrigerant and then used in secondary circuit The effect of changing input parameter of VCRS using nanorefrigerant is on thermodynamic performance is also investigated.

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E. Halimic [2] carried out experimental study on the boiling heat transfer characteristics of R22 refrigerant with Al2O3 nanoparticles and found the nano particles enhances refrigerant heat transfer characteristics with reduced bubble sizes.

Eastman et al.[3] found the pool boiling heat transfer characteristics of R11 refrigerant with TiO2 nanoparticles and observed the heat transfer enhancement to bed reached 20% at a particle loading of 0.01 g/ L. Liu et al. [4] studied the effects of carbon nanotubes (CNTs) on the nucleate boiling heat transfer of R123 and HFC-134a refrigerants and observed that that CNTs increases the nucleate boiling heat transfer coefficients for these refrigerants and found a large enhancements up to 36.6% at low heat fluxes of less than 30 kW/m2.

Jiang et al.[5] observed experimentally the thermal conductivities of carbon nanotube (CNT) nanorefrigerants are much higher than those of CNT–wate nanofluids spherical nanoparticle–R113 nanorefrigerant and found that the smaller the diameter of CNT larger the thermal conductivity enhancement of CNT nano refrigerant. Hwang et al. [6] has found the thermal conductivity enhancement of nanofluids is greatly influenced by thermal conductivity of nano-particles and base fluid due to the thermal conductivity of water based nanofluid with multiwall carbon nano tube has noticeably higher thermal conductivity as compared to the SiO2 nanoparticles for the same base fluid. Yoo et al. [7] had found the surface to volume ratio of nanoparticles is a dominant factor due to surface to volume ratio is increased with smaller sizes of nanoparticles which influence thermal conductivity of nano fluid rather than nanoparticles.

Choi et al. [8] found 150% thermal conductivity enhancement of poly (a-olefin) oil with the addition of multiwalled carbon nanotubes (MWCNT) at 1% volume fraction. Yang [9] observed 200% thermal conductivity enhancement for poly (a-olefin) oil containing 0.35% (v/v) MWCNT and found that the thermal conductivity enhancement was accompanied by a three order of magnitude due to increase in viscosity.

He has also measured the thermal conductivity of a similar copper containing nanofluid, except the base fluid was water and salt was used as a dispersant and found the 70% thermal conductivity enhancement for 0.3% (v/v) copper nanoparticles in water. Eastman et al.[10] had observed 40% thermal conductivity enhancement for ethylene glycol with 0.3% (v/v) copper nano particles (10 nm diameter) by added about 1% (v/v) thioglycolic acid in the dispersion of the nano particles and found a greater thermal conductivity than the same concentration of nanoparticles in the ethylene glycol without the dispersant.

Kang et al.[11] had observed the 75% thermal conductivity enhancement for ethylene glycol with 1.2% (v/v) diamond nanoparticles between 30 and 50 nm in diameter by measuring the thermal conductivity of nanofluids and have found no anomalous results Lee et al. [12] observed the thermal conductivity of nanofluids is greatly affected by pH level and addition of surfactant during nanofluids preparation stage due to better dispersion of nanoparticles is achieved with addition of surfactant such as sodium dodecylbenzenesulfonate and found that the optimum combination of pH and surfactant leads to 10.7% thermal conductivity enhancement of 0.1% Cu/H2O nanofluids. Jiang et al. [13] observed the thermal conductivity of nanofluids also depend on the nanoparticles size and temperature.

Wu et al.[14] found that the pool boiling heat transfer was enhanced at low nanoparticles concentration of TiO2 in R11 but deteriorated under the condition of high nanoparticles concentration. Trisaksrie.al. [15] had investigated TiO2 in HCFC 141(b) in a cylindrical copper tube and found that the nucleate pool boiling heat transfer deteriorated with increasing nanoparticle concentrations especially at higher heat fluxes.

Hao et al. [16] investigated the heat transfer characteristics of refrigerant-based nanofluids flow boiling inside a smooth tube at different nanoparticles concentration, mass fluxes, heat fluxes, and inlet vapor qualities and analyzed the influence of nanoparticles on the heat transfer characteristics of refrigerant-based nanofluid flow boiling inside the smooth tube and also developed correlation for predicting the heat transfer coefficient of refrigerant-based nanofluid and the predicted heat transfer coefficients agree with 93% of the experimental data and found that the heat transfer coefficient of refrigerant-based nanofluid in flow boiling is larger than that of pure refrigerant and the maximum enhancement is about 29.7% when observed with a mass fraction of nanoparticles 0–0.5 wt%. and the reduction of the boundary layer height due to the disturbance of nanoparticles enhances the heat transfer. Hao et al. [17] observed experimentally the nucleate pool boiling heat transfer characteristics of refrigerant/oil mixture with diamond nanoparticles.

The refrigerant was R113 and the oil was VG68 and found the nucleate pool boiling heat transfer coefficient of R113/oil mixture with diamond nanoparticles was larger than that of R113/oil mixture by maximum of 63.4% and the enhancement increases with the increase of nanoparticles concentration in the nanoparticles/oil suspension and decreases with the increase of lubricating oil concentration and developed a correlation for predicting the nucleate pool boiling heat transfer coefficient of refrigerant/oil mixture with nanoparticles which agreed well with the experimental data of refrigerant/oil mixture with nanoparticles.

Wang et al. [18] had conducted experiments for finding the boiling heat transfer characteristics of R22 refrigerant with Al2O3 nanoparticles and observed that the nanoparticles enhanced the refrigerant heat transfer characteristics with reduced bubble sizes that moved quickly near the heat transfer surface.

Li et al.[19] studied the pool boiling heat transfer characteristics of R11 refrigerant with TiO2 nanoparticles and found the heat transfer enhancement reached to a 20% at a particle loading of 0.01 g/L.

Peng et al. [20] studied the influence of nanoparticles on the heat transfer characteristics of refrigerant-based nano fluid flow boiling inside a horizontal smooth tube, and developed a correlation for predicting heat transfer performance of refrigerant based nanofluids by preparing refrigerant based nanofluids, In his experiment, R113 refrigerant and CuO nanoparticles were used and found that the heat transfer coefficient of refrigerant-based nanofluids is higher than that of pure refrigerant, and found the maximum enhancement of heat transfer coefficient to be about 29.7%.Kumar et. al. [21]

Experimentally investigated the effect of concentration of nano Zno ranges in the order of 0.1%,0.3% and 0.5% volume with particle size of 50 nm on various thermodynamic parameters (i.e. COP, suction temperature ,input power and pressure raio with ecofriendly R152a as working fluid in the simple vapour compression refrigeration system and found that maximum COP of 3.56 and 21% reduction of power input with 0.5% volume of of zinc oxide (ZnO) and also found that the Pressure ratio decreases with increase in nano Zno concentration.

Mahbubul et al. [22] studied the thermo-physical properties, pressure drop and heat transfer performance of Al2O3 nano-particles suspended in the ecofriendly refrigerant (R-134a) and viscosity of ecofriendly R-134a refrigerant was investigated.

Lot of researches have been done and going on based on the performance evaluation of various combinations of different types of refrigerant and also nanoparticle behavior on the nanofluid. On the other hand the performance of VCS using nanofluid (with different nanoparticle) for different types of eco friendly refrigerant is yet to be analyzed.

The use nano fluid in VCS (chiller system) is presented in this paper and, the performance evaluation of vapour compression refrigeration system is explored by using new and alternative ecofriendly refrigerants HFO1234yf, HFO1234ze backed by the fact that they are more environments friendly can replaced. R134a, R407c, R404a and R125 in the coming future.

This paper presents following research objectives. Thermodynamic first law comparison and % improvement of simple vapour compression system using three ecofriendly alternative refrigerants.

Thermodynamic analysis in terms of % improvement in first law efficiency and second law efficiency by using exergetic analysis of simple vapour compression system using Al2O3 as nanofluid and comparison of results of performance evaluation in terms of reduction in irreversibility without nanofluid and with nanofluids.

2.0 Results and Discussions

The performances of nano particles mixed with R134a is shown in Table-1 It was observed that as mass flow rate of brine is increases , the the first law efficiency in terms of COP is increases along with increase in second law performance as shown in Table-1(a). Similarly as increase in compressor speed the first lwa efficiency (COP) and second law performance (exergetic efficiency) in also decreases and exergy destruction ratio in terms of total exergy losses in the system to the exergy of product is also increases as shown in Table-1(b) respectively.

Table 1a: Variation of Mass Flow Rate Of Brine in the Eveporator on the Performance of VCRS for Tbi = 25 o C, Twi =25 oC, Nano Al2O3 ϕ- 0.05 (5 % vol.) Mixed with R 134 a in the Primary Circuit

mb kg/s	C.O.P.	EDR	η effective
0.006	3.688	1.422	0.4129
0.007	3.817	1.341	0.4272
0.008	3.925	1.276	0.4394
0.009	4.018	1.223	0.4497
0.010	4.099	1.18	0.4588

Table: 1b. Variation of Compressor Speed on the Performance of VCRS for Tbi = 25 o C, Twi =25 oC, Nano Al2O3 ϕ- 0.05 (5 % vol.) Mixed with R 134 a in the Primary Circuit

N comp. speed (r.p.m.)	C.O.P.	EDR	η effective
2900	3.688	1.422	0.4129
3025	3.652	1.446	0.4088
3150	3.62	1.468	0.4052
3275	3.592	1.487	0.4021
3400	3.569	1.503	0.3995

Table: 1c. Variation of Temperature of Water Flowing in Condenser on the Performance of VCRS for Tbi = 25 o C, Twi =25 oC ,Nano Al2O3 ϕ- 0.05 (5 % vol.) Mixed with R 134 a in the Primary Circuit

T water in °K	C.O.P.	EDR	η effective
298	3.699	1.415	0.4141
300	3.563	1.507	0.3989
302	3.437	1.599	0.3848
304	3.319	1.691	0.3716
306	3.209	1.784	0.3592

Table: 1d. Variation of Temperature of Brine Flowing in Secondary Circuit on the performance of VCRS for Tbi = 25 o C, Twi =25 oC , Nano Al2O3 ϕ- 0.05 (5 % vol.) mixed with R 134 a in the Primary Circuit

T brine in °K	C.O.P.	EDR	η effective
298	3.68	1.428	0.4119
300	3.793	1.355	0.4246
302	3.907	1.286	0.4374
304	4.023	1.221	0.4503
306	4.0994	16.03	0.4634

Similarly the increase in the water flowing in the condender decreases in coefficient of performance and increase in exergy destruction ratio and also decrease in second law performance as shown in Table-1 (c) and the increase in the brine flowing in the evaporator increases in coefficient of performance and decrease in exergy destruction ratio and also increase in second law performance as shown in Table-1 (d) Table-2 shows the % improvement in second law efficiency in terms of exergetic efficiency improvement by using nano particles mixed with R718 in the secondary evaporator circuit. It was also observed that first law efficiency without nano particles using R134a is maximum while by using R1234ze is minimum however second highest is found to be by using. alternate refrigerant R1234yf (GWP=4, and ODP=0) is suitable which can replace R134a in the coming future. It was also observed that without using nano particles, the first law performance by using R1234yf is better than R1234ze for replacing R134a during 2030 due to higher global warming potential of R134a as compared to R1234yf.

Table: 2a. Performance comparison of first law performance in terms of coefficient of performance and % Improvements in first law efficiency of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using Al2O3, as nano material of 10 micron size

Refrigerant	COP with Al2O3 nano	COP without nano	% Improvement in first law efficiency
R1234ze	3.434	3.15	9.01587
R1234yf	3.604	3.276	10.0122
R134a	3.872	3.555	8.91702

Table: 2b. Performance Comparison of First Law Performance in Terms of Coefficient of performance and % Improvements in First Law Efficiency of Vapour Compression Refrigeration System Using Ecofriendly Refrigerant in the Primary Circuit and Water Flowing in the Condenser in Secondary Circuit and Brine Flow in the Secondary Circuit in the Evaporator Using Copper as Nano Material of 10 Micron Size

Refrigerant	COP with copper nano particles	COP without nano	% Improvement in first law efficiency
R1234ze	4.402	3.15	39.746
R1234yf	4.761	3.276	45.32967
R134a	5.923	3.555	66.6104

Table: 2c. Performance Comparison of First Law Performance in Terms of Coefficient of Performance and % Improvements in First Law Efficiency of Vapour Compression Refrigeration System Using Ecofriendly Refrigerant in the Primary Circuit and Water Flowing in the Condenser in Secondary Circuit and Brine Flow in the Secondary Circuit in the Evaporator TiO2 as Nano Material of 10 micron Size

Refrigerant	COP with TiO2 nano	COP without nano	% Improvement in first law efficiency
R1234ze	3.394	3.15	7.810
R1234yf	3.579	3.276	9.24908
R134a	3.823	3.555	7.5387

Table: 2d. Performance comparison of second law performance in terms of coefficient of performance and % Improvements in second law efficiency of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator Al2O3 as nano material of 10 micron size

Refrigerant	Eta_second with nano Al2O3	Eta_Second without nano	% Improvement in second law efficiency
R1234ze	0.2724	0.2406	13.217
R1234yf	0.2925	0.2548	14.796
R134a	0.3215	0.2860	12.4126

Table: 2e. Performance comparison of second law performance in terms of exergetic efficiency and % Improvements in second law efficiency of vapour compression refrigeration system using

ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator copper as nano material of 10 micron size

RefrigerRant	Eta_second with nano copper particles	Eta_second without nano particles	% Improvement in second law efficiency
R1234ze	0.402	0.2406	67.0823
R1234yf	0.421	0.2548	65.22763
R134a	0.4806	0.2860	68.0412

Table: 2f. Performance comparison of second law performance in terms of exergetic efficiency and % Improvements in second law efficiency of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator TiO2 as nano material of 10 micron size

Refrigerant	Eta_second with nano TiO2	Eta_second without nano	% Improvement in second law efficiency
R1234ze	0.2680	0.2406	11.3882
R1234yf	0.2887	0.2548	13.30455
R134a	0.3160	0.2860	10.4895

Table: 2. shows the second law efficiency in terms of exergetic efficiency for thee ecofriendly refrigerants and second law performance improvement while by using three nano particles, in terms of exergetic efficiencyand maximum exergetic efficiency is found by using R134a as ecofriendly refrigerant and second highest is also found by using R1234yf as ecofriendly refrigerant in the primary evaporator circuit. It was also observed that second law performance is better due to 39.13% improvement by using R1234yf as compared to 16.52% improvement by using R1234ze in the primary evaporator circuit.

Table: 2g. Performance evaluation (% Improvements) of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using Al2O3 as nano material of 10 micron size

EDR with Al2O3 nano		EDR without nano	% reduction in EDR
R1234ze	2.670	3.155	15.3724
R1234yf	2.430	2.925	16.923
R134a	2.111	2.496	15.4247

Table: 2h. Performance evaluation (% Improvements) of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using Copper as nano material of 10 micron size

RefrigeEco	EDR with copper	EDR without	% reduction in EDR
Friendlyrefri-gerants	nano	nano	
R1234ze	1.487	3.155	52.8685
R1234yf	1.375	2.925	52.991453
R134a	1.081	2.496	56.6907

Table: 2c. Performance evaluation in terms of EDR (% deprovements) of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using TiO2 as nano material of 10 micron size

RefrigeEco Friendlyrefri-gerants	EDR with TiO2 nano	EDR without nano	% reduction in EDR
R1234ze	2.731	3.155	13.439
R1234yf	2.464	2.925	18.9094
R134a	2.165	2.496	13.2612

Table: 3a. Performance comparison of first law performance in terms of coefficient of performance and % Improvements in first law efficiency of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using Al2O3, as nano material of 10 micron size

Refrigerant	COP with Al2O3 nano	COP without nano	% Improvement in first law efficiency
R1234ze	3.434	3.15	9.01587
R1234yf	3.604	3.276	10.0122
R134a	3.872	3.555	8.91702

Table: 3b. Performance comparison of first law performance in terms of coefficient of performance and % Improvements in first law efficiency of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using copper as nano material of 10 micron size

Refrigerant	COP with copper nano particles	COP without nano	% Improvement in first law efficiency
R1234ze	4.402	3.15	39.746
R1234yf	4.761	3.276	45.32967
R134a	5.923	3.555	66.6104

Table: 3c. Performance comparison of first law performance in terms of coefficient of performance and % Improvements in first law efficiency of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator TiO2 as nano material of 10 micron size

Refrigerant	COP with TiO2 nano	COP without nano	% Improvement in first law efficiency
R1234ze	3.394	3.15	7.810
R1234yf	3.579	3.276	9.24908
R134a	3.823	3.555	7.5387

Table: 4a. Performance evaluation (% Improvements in second law effictiveness) of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using Al2O3 as nano material of 10 micron size

Eco friendly Refri-gerants	Second law effectiveness with Al2O3 nano particles	Second law effectiveness without nano particles	% improve - ment in second law efficiency
R1234ze	0.3844	0.3526	9.0187
R1234yf	0.4035	0.3667	10.03545
R134a	0.4334	0.3980	8.89447

Table: 4b. Performance evaluation (% Improvements in second law effictiveness) of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using Copper as nano material of 10 micron size

Eco friendly Refri-gerants	Second law effectiveness with copper nano particles	Second law effectiveness without nano particles	% improve - ment in second law efficiency
R1234ze	0.5140	0.3526	45.77425
R1234yf	0.533	0.3667	45.3504
R134a	0.5925	0.3980	48.870

Table: 4c. Performance evaluation (% Improvements in second law effictiveness) of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using TiO2 as nano material of 10 micron size

Eco friendly Refri-gerants	Second law effectiveness with copper nano particles	Second law effectivenes s without nano particles	% improve-ment in second law efficiency
R1234ze	0.5140	0.3526	45.77425
R1234yf	0.533	0.3667	45.3504
R134a	0.5925	0.3980	48.870

Table: 5a. Reduction in irreversibility in terms of exergy destruction ratio of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using Al_2O_3 as nano material of 10 micron size

Refrigerant	EDR with Al_2O_3 nano	EDR without nano	% reduction In EDR
R1234ze	1.602	1.836	12.7451
R1234yf	1.479	1.727	14.360
R134a	1.307	1.513	13.615

Table: 5b. Reduction in irreversibility in terms of exergy destruction ratio of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using Al_2O_3 as nano material of 10 micron size

Refrigerant	EDR with copper nano	EDR without nano	% reduction In EDR
R1234ze	0.9457	1.969	51.986
R1234yf	0.8763	2.429	63.9234
R134a	0.6877	1.335	48.4869

Table: 5c. Reduction in irreversibility in terms of exergy destruction ratio of vapour compression refrigeration system using ecofriendly refrigerant in the primary circuit and water flowing in the condenser in secondary circuit and brine flow in the secondary circuit in the evaporator using TiO_2 as nano material of 10 micron size

Refrigerant	EDR with TiO_2 nano	EDR without nano	% reduction In EDR
R1234ze	1.632	1.969	17.1153
R1234yf	1.496	2.429	38.41
R134a	1.337	1.335	0.1498

Table-5(a)-(d) represents the reduction in the irreversibility in terms of exergy destruction ratio in the system and maximum exergy destruction ratio around 25.294% was observed by using R152a and exergy destruction ratio is 22.79% by using R290 hydrocarbon and 23.403% by using R407c as ecofriendly refrigerant. The Reduction in EDR is 20.09% by using R404a, and 21.37% by using R134a. The R1234ze and R1234yf have slightly less reduction in EDR as compaired by using R134a

3.0 Conclusions

In this paper, first law and second law analysis of vapour compression refrigeration systems using multiple evaporators and single compressor and single expansion valve with thirteen ecofriendly refrigerants have been presented. The conclusions of the present analysis are summarized below:

1 The First law efficiency (COP) and Second law efficiency (Exergetic efficiency) of vapour compression refrigeration systems using liquid vapour heat exchanger and multiple evaporator and single compressor and single expansion valve is higher than without liquid vapour heat exchanger for above mentioned ecofriendly refrigerants.
2 The First law efficiency (COP) and Second law efficiency (Exegetic efficiency) of vapour compression refrigeration systems using R717 refrigerant is higher but is has toxic nature can be use by using safety measure for industrial applications.
3 COP and exegetic efficiency for R152a and R600 are nearly matching the same values. are better than that for R125 at 313K condenser temperature and showing higher value of COP and exergetic efficiency in comparison to R125.
4 For practical applications R-134a is recommended because it is easily available in the market has second law efficiency slightly lesser than R-152a which was not applicable for commercial applications.
5 The worst component from the viewpoint of irreversibility is expansion valve followed by condenser, compressor and evaporators, respectively. The most efficient component found to be subcooler. The R-152a has least efficiency defects for 313K condenser temperature.
6 The increase in dead state temperature has a positive effect on exergetic efficiency and EDR, i.e. EDR decreases and exergetic efficiency increases with increase in dead state temperature. Both R-152a and R-600 show the identical trends for exergetic efficiency are nearly overlapping. The exergetic efficiency for R-600 is higher than

that of R-134a for the practical range of dead state temperature considered. The use of nano particles improves the first law and second law performance significantly. The best performance is found using R152a and worst performance is observed using R410a. Due to flammable nature of R290, R600, R600a and R152a

7 Performance evaluation of Vapour compression refrigeration system when calculated nucleate heat transfer coefficient enhancement factor based on Al2O3 nanoparticle mixed in the ecofriendly refrigerant and implement into the program results is to be found as 23% using R134a and 18% when using R407c in the primary circuit. Performance evaluation of Vapour compression refrigeration system when calculated nanorefrigerent property implement into the program based on Al2O3 nanoparticle mixed in the R134a ecofriendly refrigerant is 13% and Al2O3 nanoparticle mixed in the R407c is 9%. Performance evaluation of Vapour compression refrigeration system when nanoparticle into refrigerant oil nanoparticle based on Al2O3 nanoparticle mixed in the ecofriendly R134a refrigerant is 11%

8 The performance of vapour compression refrigeration systems using Al2O3 particles direct mixed in the R134a gives better first law performance than R407c and improvement in the first law performance is 28% using R134a and Al2O3 nano particles mixed with compressor oil and then used is 18.8% and 8% as heat transfer enhancement factor and implement into the refrigerant property and lowest improvement 2.64% when Al2O3 directly mixed with R407c, mixed with compressor oil and then used as refrigerant the primary circuit

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