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Thermodynamic analysis of vapour compression refrigeration system with mixing of TiO_2 nano material in HFO refrigerants for replacing HFC-134a

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Abstract

In recent years, the climate change and environmental damage caused by the greenhouse gases have attracted increased attention to the environmental protection. Currently the refrigeration systems are widely using R11, R12, R22 & R502 as refrigerants. These refrigerants have chemical substances that damage the ozone layer and generates greenhouse effect. Montreal protocol requires for developed countries to completely phase out these refrigerants in 2010, and developing countries to phase out in 2020. Although R22 to be phaseout before 2030. R-134a, R404a, R407c & R410A is a substitute of R11, R12, R22 & R502 as refrigerants. The ODP of R22 is zero and the GWP value is 1924.The F-gas regulations are ended by the European Union in 2014, stipulate that refrigerators and freezers for home use, and those for business use, which contain HFCs and whose GWP value are above 150, are banned from market since January 1st 2015 and January 1st 2022 respectively. The new refrigerants (R1234yf & R1234ze), are environmental friendly refrigerants, with zero ODP value. The GWP value of R1234yf is 4, while GWP value of R1234ze is 6. The HFO refrigerants have a short atmospheric lifetime and its latent heat is small and its evaporation pressure and thermal conductivity is low, which will lead to a decline in system coefficient .of performance. The several methods were developed for enhancement in first law performance (COP) of vapour compression refrigeration systems. By using nano mixed refrigerants enhances first and second law performances. This paper mainly deals with optimal of utilization of TiO_2 in HFO-1234yf and R1234ze. The effect evaporator and condenser temperatures on compressor efficiencies have been discussed.

Keywords: Thermodynamic performances, Energy-exergy Analysis, Eco friendly refrigerants, TiO_2 Nano- material

1. Introduction

The second law analysis (i.e. exergy Computation) is widely accepted as a useful tool for obtaining overall performances of any system for finding various exergy losses occurred in its components Exergy analysis also helps in taking account the important engineering decisions regarding design parameters of a system by finding maximum exergy destruction using entropy generation principle. A conventional exergetic analysis reveals irreversibilities within each component of a vapour compression refrigeration systems. Exergetic analysis provides the tool for a clear distinction between energy losses to the environment and internal irreversibilities in the process because exergy analysis is a methodology for the evaluation of the performance of devices and processes, and examining the exergy at different points in a series of energy-conversion steps. With this information, efficiencies can be evaluated, and the process steps having the largest losses (i.e., the greatest margin for improvement) can be identified. For these reasons, the modern approach uses the exergy analysis in the vapour compression refrigeration systems, which provides a more realistic view of the process and a useful tool for engineering evaluation Many researchers have carried out exergy studies of different thermal energy conversion systems describing various approach for exergy analysis and its usefulness for improving existing designs by reducing exergy destruction in a more simple and effective manner. Samuel yana mota [1] mainly focused on a thorough evaluation of the R22 replacement options for the medium temperature refrigeration applications and also included thermodynamic cycle performances. Comparison test of heat transfer and pressure drop characteristics, system performance comparisons, safety issues, determination of the environmental impact of refrigerant selection and three potentials alternatives to R22

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were HFC (404A and R-410A) and HC (R-290) [1]. Syed Mohammad Said et.al, [2] had assessed theoretical performances of HCFC123, HFC134a, CFC11, and CFC12 as coolants. For a specific amount of desired exergy, more compression work is required for HCFC123 and HFC134a than for CFC11 and CFC12. The differences are not very significant at high evaporation temperatures and hence HCFC123 and HFC134a should not be excluded as alternative coolants and found optimum evaporation temperature for each condensation temperature which yields the highest exergetic efficiency. The exergetic assessment of the coolants HCFC123, HFC134a, CFC11, and CFC12 had done and found that the value of exergetic efficiency decreases with increasing the evaporator temperature. The highest exergetic efficiency occurs at the optimum evaporation temperature. Exergetic efficiency was decreased by 9.24, 12.03, 5.66, 13.78, 20.92, 9.53, 11.34 and 13.04% in R-134a, R-143a, R-152a, R-404A, R-407C, R-410A, R-502 and R-507A, respectively.

Yumrutas et. al [3] investigated of the effects of the evaporating and condensing temperatures on the pressure losses, exergy losses, second law of efficiency, and the COP of a vapour compression cycle. Dincer [4] asserts that conventional energy analysis, based on the first law of thermodynamics, evaluates energy mainly on its quantity but analysis that are based on second law considers not only the quality of energy, but also quantity of energy. Bejan[5] developed, thermodynamic model by using heat transfer irreversibility and showed that the exergetic efficiency decreases as evaporator temperature decreases. Mishra R.S.[6] carried out thermodynamic analysis of multi-evaporators single compressor and single expansion valve and liquid vapour heat exchanger(LVHE) in vapour compression refrigeration systems using thirteen ecofriendly refrigerants for reducing global warming and ozone depletion and concluded that the use of liquid vapour heat exchanger enhances the first law performance in terms of COP and second law performance in terms of exergetic efficiency is 20%. Jarall [7] proposed a theoretical and experimental analysis by using R1234yf in a small refrigeration system for performance comparison with R134a about the energetic characteristics of the refrigeration cycle with the refrigerants R134a and R1234yf and found that HFO-R1234yf could be alternative for replacing HFC-134a. The results showed a lower COP, smaller cooling capacity and lower compressor efficiency for R1234yf.

To explore its thermodynamic properties, applicability, compatibility, stability and safety in automotive air-conditioning systems, Ming Li [8] carried out experimental results are compared with R134a in the same conditions and found that HFO-1234yf could be an ideal alternative for R134a. Samaneh Daviram , et.al [9] is simulated automotive air conditioning system by considering HFO-1234yf (2,3,3,3-tetrafluoropropene) as the drop-in replacement of HFC-134a for finding thermal performance characteristics of system including COP and cooling capacity with changing different parameters. The simulated air conditioning system consists of a multi-louvered fin and flat-plate type evaporator, a wobble-plate type compressor, a mini-channel parallel-flow type condenser and a thermostatic expansion valve. The thermodynamic properties of the refrigerants are extracted from the REFPROP 8.0 software, and a computer program is developed for for finding thermal performances using thermodynamic analysis. In the theoretical analysis , the two different conditions have been considered for the cycle analysis. For the first state, the cooling capacity is taken as constant, and for the second state the fixed refrigerant mass flow rate is consideredAprea C, [10] Thermal analysis from a thermodynamic point of view, is carried out for evaluating the possible advantage of adopting a suction/liquid heat exchanger and developed a simplified criterion for also validating for many working fluids such as chlorofluorocarbon (CFC)s, hydrochlorofluorocarbon (HCFC)s and substitutes on the basis of their thermodynamic properties. The criterion is also presented in a graphical form using given two R502 and R32 examples Ming Li, et.al. [10] carried out Exergy analysis of automotive air-conditioning systems and found that useful exergy and energy outputs are 5.9% less than HFC-134a and found the input variables have significant effects on thermal efficiency and exergetic efficiency and found that the maximum exergy loss is due to condenser Lazarus Godson , B. Raja and D Mohan lal [11] observed that the colloidal mixture of nano-sized particles in a base fluid, called nanofluids, tremendously enhances the heat transfer characteristics of the original fluid, and is ideally suited for practical applications due to its marvelous characteristics. He has explained the unique features of nanofluids, such as enhancement of heat transfer, improvement in thermal conductivity, increase in surface volume ratio, Brownian motion, etc. and summarized the recent research in experimental and theoretical studies on forced and free convective heat transfer in nanofluids, their thermo-physical properties and their applications, and identifies the challenges and opportunities for future research. Dongsheng Wen , Guiping Lin Kai Zhang [12] reported the research carried out on nanofluids has progressed rapidly since its enhanced thermal conductivity and concluded that research on heat transfer applications of nanofluids with the aim of identifying the limiting factors so as to push forward their further development. Gabriela Huminic [13] studies theoretical & experimental results for the effective thermal conductivity, viscosity and the Nusselt number for the enhancement of the convection heat transfer in heat exchangers using nanofluids and explained the application of nanofluids in various types of heat exchangers: plate heat exchangers, shell and tube heat exchangers, compact heat exchangers and double pipe heat exchangers. .M.N. Pantzali, AA Mouza, S.V. Paras [14] investigated the efficiency of nanofluids as coolants. In the testing of nanofluids, he has found that the systematic measurements confirmed that the thermophysical properties of the base fluid are considerably affected by the nanoparticle addition. For a a typical nanofluid, namely a 4% CuO suspension in water, is selected and its thermal performance in a plate heat exchanger (PHE) is obtained experimentally. The new experimental data confirmed that besides the physical properties, the type of flow inside the heat exchanging equipment also affects the efficiency of a nanofluid as coolant. The fluid viscosity seems also to be a crucial factor for the heat exchanger performance. It is concluded that in industrial heat exchangers, where large volumes of nanofluids are necessary and turbulent flow is usually developed, the substitution of conventional fluids by nanofluids seems inauspicious. Mishra et al. [15] experimentally evaluated the performance of a vapour compression refrigeration system by using Cu, Al_2O_3,CuO and TiO_2 based nano refrigerants in the primary circuit. The experimental results showed that the C.O.P of the system using Al_2O_3/R134a nano refrigerant was enhanced by 35% which was highest among all other nano refrigerant. Sabareesh et al. [16] experimentally investigated 17% increase in COP by using 0.01% by volume concentration TiO2 nano fluid in VCRS as a lubricant additive. Sajadi A.R. et.al. [17] experimentally investigated turbulent convective heat transfer coefficient and pressure drop of TiO2 dispersed in water nano fluid in the circular tube and also compared experimental results with correlation of Nusselt number and not concluded that how much (%) convective heat transfer coefficient increased. Huang Dan , et.al. [18] observed the effect of hybrid nano fluid mixture Al_2O_3 in the plate heat exchanger and found that convective heat transfer coefficient is increased as compared without nano fluid. Zeinali S Heris et.al [19] experimentally investigated the convective heat transfer increasement in the laminar flow forced convection heat transfer due to increase in the thermal conductivity of nano fluid due to nano particle fluctuations present in that fluid. Shengshan Bi et al. [20] found performance improvement reduction in power consumption upto 25% by mixed mineral oil TiO2 as the lubricant with refrigerant R600a. Subramani & Prakash [21] found improvement in performance by using Al_2O_3 at 0.06% weight in the mineral oil. Kumar et al. [18] found improvement in COP by 19.6% and reduction in power consumption by 11.5%. Due to enhancement in heat transfer coefficient using nanofluid Al_2O_3 & R600a/mineral oil as working fluid in a domestic refrigerator. Abbas et al. [22] performed the analysis of an air conditioning system by using a concentration of 0.01-0.1wt% of CNT Polyester oil with refrigerant R134a and found 4.2% enhancement in the COP was enhanced by using CNT particles concentration of 0.1% by weight. Hussen [23] showed the conventional refrigeration system performance improved with nano-refrigerant. Compressor work decreases by about 13% and system C.O.P. increases by about 12%.The above investigators have not studied in detail regarding performances of the vapour compression refrigeration systems in which nano refrigerants was circulated in the whole system. Therefore present investigation take care the overall system thermal performances in terms of first law efficiency (COP) and second law efficiency/ exergetic efficiency and various efficiencies of compressor used in the system.

2. Result and Discussion

2.1 Effect of condenser mass flow rate on thermal performances by mixing TiO_2 nano particles in the ecofriendly HFC-1234yf in the vapour compression refrigeration system

Table-1(a) shows the variation of condenser mass flow rate of water of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant with thermal performances and it is found that condenser mass flow rate increases , the first law efficiency in terms of COP is increases and exergy destruction ratio of the system is decreases while second law efficiency is increases. Similarly evaporator convective overall heat transfer coefficient is decreases while condenser overall heat transfer coefficient is increases.

Table-1(a) Performance of vapour compression refrigeration system using R1234yf with Nano Particle (TiO_2) mixed with R-718, compressor speed (rpm) =2900, m_{brine} (kg/sec)=0.007, $L_{\_eva}$=0.72m, $L_{\_Cond}$=1.2m, P_brine=P_water=2.0 Bar

Condenser Mass flow rate of water (Kg/sec)	First law Efficiency (COP)	Exergy Destruction Ratio(EDR)	Exergetic Efficiency	Evaporator overall heat transfer coefficient (W/m^{2}K)	Condenser overall heat transfer coefficient (W/m^{2}K)
0.007	3.379	0.6218	0.3782	1327.54	692.96
0.008	3.477	0.6108	0.3892	1320.21	714.01
0.009	3.557	0.6018	0.3982	1315.88	731.28
0.010	3.625	0.5942	4058	1313.34	745.71

Table-1(b) Effect of evaporator Mass flow rate of brine on thermal performances and overall heat transfer coefficients of Vapour compression Refrigeration System using R1234yf with Nano Particle (TiO_2) mixed with R-718, compressor speed(rpm)=2900, m_{water} (kg/sec)=0.008, $L_{\_eva}$=0.72m, $L_{\_Cond}$=1.2m, P_brine = P_water P_brine =2.0 Bar

Evaporator Mass flow rate of brine (Kg/sec)	First law Efficiency (COP)	Exergy Destruction Ratio(EDR)	Exergetic Efficiency	Evaporator overall heat transfer coefficient (W/m^{2}K)	Condenser overall heat transfer coefficient (W/m^{2}K)
0.007	3.477	0.6108	0.3892	1320.21	714.01
0.008	3.549	0.6027	0.3973	1342.87	722.63
0.009	3.609	0.5961	0.4039	1361.93	729.54
0.010	3.658	0.5926	0.3974	1378.26	735.19

Table-1(b) shows the variation of evaporator mass flow rate of brine (Kg/sec) of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant with the thermal performances and it is found that evaporator mass flow rate of brine (Kg/sec) increases , the first law efficiency in terms of COP is increases and exergy destruction ratio of the system is decreases while second law efficiency is increases. Similarly evaporator convective overall heat transfer coefficient is decreases while condenser overall heat transfer coefficient is increases.

Table-1(c) Effect of compressor speed on Performance of Vapour compression Refrigeration System using R1234yf with Nano Particle (TiO_2) mixed with R-718, m_{brine} (kg/sec)=0.007, m_{water} (kg/sec)=0.008, $L_{\_eva}$=0.72m, $L_{\_Cond}$=1.2m, P_brine=P_water=2.0 Bar

Speed of Compressor (R P M)	First law Effi. (COP)	System Exergy Destruction Ratio based on exergy of fuel	Second Law Efficiency/ Exergetic Efficiency	Exergy of product (W)	Exergy of fuel (W)
2500	3.631	0.5936	0.4064	23.68	100.6
2600	3.583	0.5989	0.4011	24.41	103.3
2700	3.542	0.6035	0.3965	25.11	105.9
2800	3.507	0.6074	0.3926	25.79	108.4
2900	3.477	0.6108	0.3892	26.45	110.7
3000	3.451	0.6137	0.3863	27.09	112.9

Table-1(c) shows the variation of compressor speed with thermal performances of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant, it is found that compressor speed increases, the first law efficiency in terms of COP is decreases and exergy destruction ratio of the system is increases while second law efficiency is decreases. Similarly exergy of product is increases along with exergy of fuel (in terms of electrical power required to run compressor) is increases

2.2 Effect of condenser mass flow rate on thermal performances by mixing TiO_2 nano particles in the ecofriendly HFC-1234yf in the vapour compression refrigeration system

Table- 2(a): Variation of thermal performance (First law efficiency (COP) and Exergetic efficiency) of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant with variation of Condenser temperature using TiO_2 mixed R1234yf for evaporator temp=268 K

Condenser Temperature (K)	COP	Rational EDR	Exergetic Efficiency
328	1.971	0.7848	0.2152
323	3.394	0.6962	0.3034
318	4.430	0.6157	0.3842
313	5.382	0.5272	0.4728
308	6.479	0.4165	0.5835

Table-2(a) shows the variation of condenser temperature with compressor performances, it is found that condenser temperature increases, first law performance in terms of COP is decreases the exergy destruction ratio is increases while exergetic efficiency is decreases. Table-2(b) shows the variation of condenser temperature with compressor performances, it is found that condenser temperature increases, the pressure ratio is increases and isentropic efficiency is decreases and volumetric efficiency of compressor is also decreases.

Table- 2(b): Variation of pressure ratio, isentropic Compressor efficiency and volumetric compressor efficiency of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant with variation of Condenser temperature using TiO_2 mixed R1234yf for evaporator temp=268 K

Condenser Temperature (K)	Pressure Ratio (r_p)	Isentropic Compressor Efficiency	Volumetric Compressor Efficiency
328	6.461	0.8198	0.5523
323	5.744	0.8432	0.6722
318	5.088	0.8648	0.7272
313	4.490	0.8646	0.7554
308	3.947	0.9029	0.7736

2.3 Effect of condenser temperature on thermal performances by mixing TiO_2 nano particles in the ecofriendly HFC-1234ze in the vapour compression refrigeration system

Table- 2(c): Variation of thermal performance (First law efficiency (COP) and Exergetic efficiency) of vapour compression refrigeration system using ecofriendly HFO-1234ze refrigerant with variation of Condenser temperature using TiO_2 mixed R1234ze for evaporator temp=268 K

Condenser Temperature (K)	COP	Rational EDR	Exergetic Efficiency
328	1.971	0.8913	0.1087
323	3.394	0.7320	0.2680
318	4.430	0.6160	0.3804
313	5.382	0.5095	0.4905
308	6.479	0.3867	0.6133

Table-2(c) shows the variation of condenser temperature with variation of thermal performances (i.e. first and second law performances in terms of COP , Rational exergy destruction ratio and exergetic efficiency) of vapour compression refrigeration system using ecofriendly HFO-1234ze refrigerant and it is found it is found that condenser temperature increases , first law performance in terms of COP is decreases the exergy destruction ratio is increases while exergetic efficiency is decreases.

Table- 2(d): Variation of pressure ratio, isentropic compressor efficiency and volumetric compressor efficiency) of vapour compression refrigeration system using ecofriendly HFO-1234ze refrigerant with variation of Condenser temperature using TiO_2 mixed R1234ze for evaporator temp=268 K

Condenser Temperature (K)	Pressure Ratio (r_p)	Isentropic Compressor Efficiency	Volumetric Compressor Efficiency
328	7.312	0.7892	0.5426
323	6.451	0.8176	0.5738
318	5.669	0.8436	0.6040
313	4.961	0.8673	0.6334
308	4.269	0.8819	0.6619

Table-2(d) shows the variation of condenser temperature with compressor performances of vapour compression refrigeration system using ecofriendly HFO-1234ze refrigerant, it is found that condenser temperature increases, the pressure ratio is increases and isentropic efficiency is decreases and volumetric efficiency of compressor is also decreases.

2.4 Effect of evaporator temperature on thermal performances by mixing TiO_2 nano particles in the ecofriendly HFC-1234yf in the vapour compression refrigeration system

Table- 3(a): Variation of evaporator temperature with thermal performances (First law efficiency (COP) and Exergetic efficiency) of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant with variation of evaporator temperature using TiO_2 mixed R1234yf for condenser temp=48^0C.

Evaporator Temperature (K)	COP	EDR	Rational EDR	Exergetic Efficiency
263	2.958	2.838	0.7398	0.2606
264	3.22	2.497	0.7141	0.2859
265	3.488	2.28	0.6952	0.3048
266	3.65	2.137	0.6812	0.3188
267	3.832	2.041	0.6712	0.3288
268	4.002	1.976	0.6640	0.3360
269	4.162	1.933	0.6591	0.3409
270	4.317	1.907	0.6560	0.3440
271	4.471	1.892	0.6542	0.3458
272	4.624	1.887*	0.6536*	0.3464*
273	4.78	1.889	0.6539	0.3461
274	4.939	1.898	0.6549	0.3451
275	5.105	1.913	0.6567	0.3433
276	5.276	1.934	0.6591	0.3409
277	5.456	1.960	0.6622	0.3378
278	5.642	1.994	0.6660	0.3340
283	6.762	2.274	0.6946	0.3054

Table-3(a) shows the variation of evaporator temperature with thermal performances (i.e. in terms of first law performance (COP) and second law performance (exergetic efficiency) and exergy destruction ratio) of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant. It was found that the evaporator temperature is increases the first law performance (COP) of vapour compression refrigeration system is increases while exergy destruction ratio of vapour compression refrigeration system is decreases up to a optimum value and then started increases. Similarly exergetic efficiency of the system is increases as evaporator temperature is increases up to a optimum point and then decreases. The optimum value of evaporator temperature is found to be 272K (i.e. -1ºC) by using HFC-1234yf.

Table- 3(b): Variation of evaporator temperature with pressure ratio, isentropic Compressor Efficiency and volumetric compressor efficiency of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant with variation of evaporator temperature using TiO_2 mixed R1234yf for evaporator temp=268 K

Evaporator Temperature (K)	Pressure Ratio (r_p)	Isentropic Compressor Efficiency	Volumetric Compressor Efficiency
263	6.558	0.8160	0.5653
264	6.322	0.8238	0.5737
265	6.096	0.8313	0.5819
266	5.879	0.8385	0.5895
267	5.673	0.8454	0.5977
268	5.475	0.8520	0.6052
269	5.285	0.8584	0.6127
270	5.104	0.8645	0.6199
271	4.930	0.8703	0.6270
272	4.763	0.8759	0.6339
273	4.604	0.8813	0.6407
274	4.451	0.8865	0.6473
275	4.304	0.8915	0.6538
276	4.163	0.8962	0.6602
277	4.028	0.9008	0.6664
278	3.898	0.9052	0.6725
283	3.322	0.9249	0.7015

Table-3(b) shows the variation of evaporator temperature with rational exergy destruction ratio (which is a ratio of total exergy destruction exergy (losses in the system was sum of exergy destruction in components to the exergy of fuel was evaluated based on exergy of fuel (i.e. total electrical power required for running compressor) of vapour compression refrigeration system using ecofriendly HFO-1234yf refrigerant and it was also observed that when evaporator temperature is increasing the rational EDR was decreasing. The isentropic compressor efficiency and volumetric efficiency is also increases with increasing evaporator temperature.

Table- 3(c): Variation of evaporator temperature with thermal performances (First law efficiency (COP) and Exergetic efficiency) of vapour compression refrigeration system using ecofriendly HFO-1234ze refrigerant with variation of evaporator temperature using TiO_2 mixed R1234ze for condenser temp=48 ^{0}C.

Evaporator Temperature (K)	COP	EDR	Rational EDR	Exergetic Efficiency
263	1.754	8.97	0.8997	0.1003
264	2.34	4.796	0.8285	0.1725
265	2.818	3.414	0.7734	0.2266
266	3.216	2.751	0.7334	0.2666
267	3.55	2.378	0.7039	0.2961
268	3.836	2.15	0.6826	0.3174
269	4.086	2006	0.6673	0.3327
270	4.310	1.913	0.6587	0.3433
271	4.56	1.854	0.6497	0.3503
272	4.711	1.819	0.6453	0.3547
273	4.899	1.80	0.6429	0.3571
274	5.085	1.795*	0.6422*	0.3578*
275	5.272	1.799	0.6427	0.3573
276	5.462	1.812	0.6444	0.3556
277	5.658	1.832	0.6469	0.3531
278	5.681	1.859	0.6503	0.3497
283	7.049	2.119	0.6794	0.3206

Table-3(c) shows the variation of evaporator temperature with thermal performances (i.e. in terms of first law performance (COP) and second law performance (exergetic efficiency) and exergy destruction ratio) of vapour compression refrigeration system using ecofriendly HFO-1234ze refrigerant. It was found that the evaporator temperature is increases the first law performance (COP) of vapour compression refrigeration system is increases while exergy destruction ratio of vapour compression refrigeration system is decreases up to a optimum value and then started increases. Similarly exergetic efficiency of the system is increases as evaporator temperature is increases up to a optimum point and then decreases. The optimum value of evaporator temperature to be 272K (i.e. 1^{o}C) by using HFC-1234ze respectively.

Table- 3(d): Variation of evaporator temperature with pressure ratio, isentropic Compressor Efficiency and volumetric compressor efficiency with variation of evaporator temperature of vapour compression refrigeration system using ecofriendly HFO-1234ze refrigerant using TiO_2 mixed R1234ze for evaporator temp=268 K

Evaporator Temperature (K)	Pressure Ratio (r_p)	Isentropic Compressor Efficiency	Volumetric Compressor Efficiency
263	7.452	0.7841	0.540
264	7.161	0.7938	0.5497
265	6.884	0.803	0.5592
266	6.62	0.8118	0.5684
267	6.369	0.8202	0.5773
268	6.129	0.8283	0.5860
269	5.90	0.8359	0.5944
270	5.682	0.8433	0.6026
271	5.473	0.8504	0.6106
272	5.274	0.8571	0.6184
273	5.083	0.8636	0.6260
274	4.901	0.8697	0.6335
275	4.727	0.8757	0.6407
276	4.561	0.8813	0.6478
277	4.401	0.8868	0.6547
278	4.249	0.892	0.6614
283	3.577	0.9151	0.6931

Table-3(d) shows the variation of evaporator temperature with rational exergy destruction ratio (which is a ratio of total exergy destruction exergy (losses in the system was sum of exergy destruction in components to the exergy of fuel was evaluated based on exergy of fuel (i.e. total electrical power required for running compressor) of vapour compression refrigeration system using ecofriendly HFO-1234ze refrigerant and it was also observed that when evaporator temperature is increasing the rational EDR was decreasing. The isentropic compressor efficiency and volumetric efficiency is also increases with increasing evaporator temperature.

3. Conclusions

Following conclusions were drawn while using ecofriendly HFO1234yf and HFO-1234ze and HFC-134a ecofriendly refrigerants by mixing TiO_2 refrigerants

- Thermal performances of vapour compression refrigeration using HFO-1234ze refrigerant by mixing TiO_2 nano particles is reduced as compared to TiO2 mixed HFO-1234yf refrigerant.
- The first law efficiency (COP) increases with increasing evaporator temperature
- The exergetic efficiency is increases with increasing evaporator temperature up to a certain temperature where exergetic efficiency, second law efficiency becomes optimum (i.e. maximum) and then started decreases with increasing evaporator temperature.
- The optimum value of evaporator temperature is found to be 274K (i.e. 1^{o}C) while in case of optimum second law efficiency, the evaporator temperature to be 271K (i.e. -2 ^{o}C) using HFC-134a
- The optimum value of evaporator temperature is found to be 272K (i.e. 1^{o}C) while in case of optimum second law efficiency, the evaporator temperature to be 269K (i.e. -4 ^{o}C) by using HFC-1234yf respectively
- The optimum value of evaporator temperature is found to be 274K (i.e. 1^{o}C) while in case of optimum second law efficiency, the evaporator temperature to be 272K (i.e. -41^{o}C) by using HFC-1234ze respectively.
- Exergy destruction ratio (EDR) is decreasing while increasing evaporator temperature.
- Exergy destruction ratio (EDR) is also increases with increasing condenser temperature.
- The volumetric efficiency for R1234yf and R1234ze is 4% and 5% lower compared with R134a.
- The first law efficiency (COP) values are about 8% lower

for R1234ye and 11% lower for R1234ze than those obtained using R134a while mixing TiO_2

- The best first law performances (COP) and exergetic efficiency were found using R290 hydrocarbon and R407c which is higher than R134a.
- Refrigerants R134a R404a and R507a give similar trends in their first law efficiency (COP), second law efficiency, exergetic efficiency and exergy destruction ratio, compressor efficiency, isentropic efficiency and volumetric efficiency with slightly variations.
- HFO-1234yf, R125 and R600a gives similar trends with slightly variation, however lower than R134a.
- Nano mixed R1234ze gives lower performance as compared with nano mixed HFO-1234yf
- The worst performances were found by using R410a, R236fa
- Super worst first and second law performances were observed by using Al2O3 mixed in R245fa, R123 refrigerants.
- The isentropic compressor efficiency and volumetric efficiency is also increasing with increasing evaporator temperature and it has optimum value at 274K (i.e. 1^{o}C).
- first law efficiency (COP) decreases with decreasing condenser temperature
- Similarly, isentropic efficiency and volumetric efficiency decreases by increasing condenser temperature.

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