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

Methods for improving thermodynamic performances of vapor compression refrigeration systems

R.S. Mishra

Department of Mechanical, Production, Industrial and Automobiles Engineering, Delhi technological University, Delhi, India

Abstract

The refrigerant R134a widely used in vapour compression refrigeration and air conditioning systems. It has zero ozone depilation potential factor (ODP) but have 1360 global warming potential (GWP) and their interaction with heat radiation. It is necessary to minimize the global warming, by changing R134a with the ones that are not depleting the ozone layer and very little in Global Warming Potential (GWP). In this paper, Two HFO refrigerants (i.e. R1234yf & R1234ze) are used as an alternatives refrigerant to.R134a. The method for improving thermodynamic performances of vapour compression refrigeration systems have been discussed in detail and thermal model was developed for computing thermodynamic performances and found that the super heating in evaporator and sub-cooling in condenser improves thermodynamic performances. The variation in evaporator temperature, condenser temperature, effectiveness of heat exchanger significantly effecting the first and second law performances. The theoretical model shows that, HFO refrigerants give slightly less thermodynamic performances than that of R134a used in vapour compression refrigeration systems can replaceHFC-134a in near future. The numerical computations show that the HFO-1234ze (has zero ODP and six GWP) has 0.8575% less second law efficiency than HFC-134a while HFO-1234yf (has zero ODP and four GWP) gives 5.6757 % lower first and second law performances than using R134a in vapour compression refrigeration systems.

Keywords: Thermodynamic analysis, HFO refrigerants, Performance improvement, Vapour compression refrigeration system

1. Introduction

Refrigeration is a technology which absorbs heat at low temperature and provides temperature below the surrounding by rejecting heat to the surrounding at higher temperature. Simple vapor compression refrigeration system which consists of four major components compressor, expansion valve, condenser and evaporator in which total cooling load is carried at one temperature by single evaporator but in many applications like large hotels, food storage and food processing plants, food items are stored in different compartment and at different temperatures. Therefore there is need of multi evaporator vapor compression refrigeration system. The systems under vapor compression technology consume huge amount of electricity, this problem can be solved by improving performance of system. Performance of systems based on vapor compression refrigeration technology can be improved by following:

(i) The performance of refrigerator is evaluated in term of COP which is the ratio of refrigeration effect to the net work input given to the system. The COP of vapor compression refrigeration system can be improved either by increasing refrigeration effect or by reducing work input given to the system.

(ii) It is well known that throttling process in VCR is an irreversible expansion process. Expansion process is one of the main factors responsible for exergy loss in cycle performance because of entering the portion of the refrigerant flashing to vapor in evaporator which will not only reduce the cooling capacity but also increase the size of evaporator.

Kumar et al. [1], carried out energy and exergy analysis of vapor compression refrigeration system using R11 and R12 as refrigerants by the using of exergy-enthalpy diagram and found that the first law analysis (energy analysis) for calculating the coefficient of performance and exergy analysis for calculating various losses occurred in different components of vapor compression cycle. Nikolaidis and Probert [2], studied analytically thermal performances that changing with evaporator

Corresponding author: R.S. Mishra
Email Address: hod.mechanical.rsm@dtu.ac.in
http://doi.org/10.36037/IJREI.2019.3501

and condenser temperatures of two stage vapor compression refrigeration plant using R22 and found considerable effect on plant irreversibility and concluded that there is need for optimizing the conditions imposed upon the condenser and evaporator. Yumrutaset al.[3], carried out exergy analysis by considering the effect of condensing and evaporating temperature on vapor compression refrigeration cycle for computing pressure losses, COP, second law efficiency and exergy losses in the various components and found that the variation in temperature of condenser have negligible effect on exergy losses of compressor and expansion valve. Halimic et al. [4], compared performance of R401A, R290 and R134A with R12 by using in vapor compression refrigeration system and found similar performance of R134a and R290 in comparison with R12 and concluded that the R134A can be replaced in the same system without any modification in the system components. Xuan and Chen [5],(2004) presented in this manuscript about the replacement of R502 by mixture of HFC-161.Through experimental study it was found that mixture of HFC-161 gives same and higher performance than R404A at lower and higher evaporative temperature respectively on the vapor compression refrigeration system designed for R404A.

Cabello et al.[6-7], experimentally found the effect of condensing pressure, evaporating pressure and degree of superheating on single stage vapor compression refrigeration system using R22, R134a and R407C.and found that the mass flow rate is greatly affected by change in suction conditions of compressor which results refrigeration capacity because refrigeration capacity depended on mass flow rate through evaporator and also observed the higher compression ratio of R22 gives lower COP than R407C. Cabello et al. [7], studied about the effect of operating parameters on COP, work input and cooling capacity of single-stage vapor compression refrigeration system. There is great influence on energetic parameters due change in suction pressure, condensing and evaporating temperatures. Spatz and Motta [8], focused on replacement of R12 with R410a through experimental investigation of medium temperature vapor compression refrigeration cycles. In terms of thermodynamic analysis, comparison of heat transfer and pressure drop characteristics, R410a gives best performance among R12, R404a and R290a. Bolaji et al. [9], had done experimentally comparative analysis of R32, R152a and R134a refrigerants in vapor compression refrigerator. They reached to the conclusions that R32 shows lowest performance whereas R134a and R152a showing nearly same performance but best performance was obtained of system using R152a. Padilla et al. [10, 16], carried out the exergy analysis of domestic vapor compression refrigeration system using R12 and R413A and concluded that performance in terms of power consumption, irreversibility and exergy efficiency of R413A is better than R12. Therefore R12 can be replaced by R413A in domestic vapor compression refrigeration system. Ahamed et al. [11]emphasized on use of hydrocarbons and mixture of hydrocarbons and R134a by using exergy analysis in vapor compression refrigeration system and found that compressor shows much higher exergy destruction as compared to rest of components of vapor compression refrigeration system and this exergy destruction can be minimized by using of nano fluid and nano-lubricants in compressor. Ahamed et al [12], had performed experimental investigation on domestic refrigerator using hydrocarbons (isobutene and butane) by energy and exergy analysis. They concluded to the results that energy efficiency ratio of hydrocarbons comparable with R134a but exergy efficiency and sustainability index of hydrocarbons much higher than that of R134a at considered evaporator temperature.

Stanciu et al. [13], carried out numerical computation of single stage vapor compression refrigeration system using following refrigerants (R22, R134a, R717, R507a, R404a) in terms of COP, compressor work, exergy efficiency and refrigeration effect. Effect of sub cooling, superheating and compression ratio was also studied on the same system using considered refrigerants and present system optimization when working with specific refrigerant. Han et al. [14] carried out experimental investigations under different working conditions revealed that there could be replacement of R407C in vapor compression refrigeration system having rotor compressor with mixture of R32/R125/R161 showing higher COP, less pressure ratio and slightly high discharge compressor temperature without any modification in the same system. Selladurai and Saravana kumar [15] also compared the performance of a domestic refrigerator using R134a and R290/R600a mixture and found that R290/R600a hydrocarbon mixture showed higher COP and exergetic efficiency than R134a and found that the highest irreversibility occurred in the compressor as compared to condenser, expansion valve and evaporator. Anand and Tyagi [16], carried out detailed exergy analysis of 2TR window air conditioning test rig using R22 and found that the irreversibility in system components will be highest when the system is 100% charged and lowest when 25% charged and also found the irreversibility in compressor is highest among system components. Based on the literature it was observed that the investigators have gone through detailed first law analysis in terms of coefficient of performance and second law analysis in term of exergetic efficiency of simple vapor compression refrigeration system with single evaporator.

(i) The irreversibility analysis or second law analysis of vapor compression refrigeration systems using liquid vapor heat exchanger.

(ii) Researchers did not go through detailed analysis for irreversibility and second law analysis of single stage vapor compression refrigeration systems using HFO refrigerants by considering the effect of sub cooling of condenser and super heating of evaporator.

2. Results and Discussions

Following numerical values have been chosen for numerical computation for validation of thermal model.

Condenser temperature = 40°C

Evaporator temperature = -40°C

Load on Evaporator = 3.567 “kW”

Compressor efficiency=100%

Refrigerant used: R12

Ambient Temperature =40°C.

The computed results are shown in Table-1(a). It is clear that computed values by thermal model matches well with the reference values as shown in Table-1(a) respectively.

Table 1(a): Validation of results using R12 in vapor compression refrigeration system

Performance Parameters	Results obtained by Model	Ref [19]
COP	1.976	1.97
$COP\__{Carnot}$	2.913	2.9125
Mass flow Rate "Kg/sec)	0.03698	0.0370
Work done by compressor "kW"	1.78	1.781
Second law efficiency	0.6783	0.6760
Irreversibility/ Lost Work "kW"	0.5735	0.5730
Q_Eva "kW"	3.5167	3.5167
Exergy_ Product "kW"	1.207	1.20
Exergy_Fuel "kW"	1.78	1.781
Compressor Efficiency (%)	100 %	100%

The numerical computations have been carried out for dead state temperature of 298K with the following input data have been chosen by using HFO refrigerant for reducing global warming and ozone depletion.

Condenser temperature = 40^{o}C
Evaporator temperature = -40^{o}C
Load on Evaporator = 3.567 "kW"
Compressor efficiency=100%
Refrigerant Used: R1234yf
Ambient Temperature =27^{o}C.
The computed results are shown in Table-1(b).

Table 1 (b): Computed results obtained by Model in vapor compression refrigeration system for $T\_{Ambient}$= 298 K

Performance Parameters	R1234yf	R1234ze	R134a
$COP\__{Actual}$	1.344	1.449	1.505
$COP\__{Carnot}$	3.583	3.583	3.583
Mass flow Rate "Kg/sec)	0.04261	0.03506	0.2987
Workdone by compressor	2.616	2.427	2.337
Second law efficiency	0.3751	0.4062	0.4198
Q_Eva"kW"	3.5167	3.5167	3.5167
Exergy_Product "kW"	0.9811	0.9811	0.9811
Exergy_Fuel "kW"	2.616	2.427	2.337
Compressor Efficiency (%)	80 %	80%	80%

The computed results also obtained for following ecofriendly refrigerants as shown in Table-1(c) and it is clear that performance using HFO-1234yf refrigerant is lower than while using HFC-134a refrigerant for 80% and 100% compressor efficiency.

Table 1(c): Computed results obtained by model in vapor compression refrigeration system for $T\_{Ambient}$= 298 K, T_{Cond} =313K, T_Eva=233K

Performance Parameters	R1234yf	R134a
COP	1.881	1.505
$COP\__{Carnot}$	3.583	3.583
Mass flow Rate "Kg/sec)	0.04261	0.2987
Work done by compressor"kW"	2.093	1.87
Second law efficiency	0..4688	0.5247
Q_Eva"kW"	3.5167	3.5167
Exergy_Product "kW"	0.9811	0.9811
Exergy_Fuel "kW"	2.616	2.337
Compressor Efficiency (%)	100 %	100%

The performance of vapor compression refrigeration system for 10^{0}C of sub-cooling in condenser and 10^{0}C of super heating in evaporator for 80% of heat exchanger effectiveness using fifteen ecofriendly refrigerants is shown in Table-2 (a) to Table-2(b) respectively. The following numerical values have been considered for numerical computation of performance parameters of the vapor compression refrigeration system.

Table-2(a) & Table-2(b) shows the thermal performances variation with changing eco-friendly refrigerants in the vapor compression refrigeration system. It is clear that the first law efficiency in terms of coefficient of performance of R141b is highest and R125 is lowest. The COP of R245fa is higher than R134a and R236fa. The first law efficiency of HFO-1234yf is 5.6757% lower than HFC-134a and HFO-1234ze has less than 1% lower (around 0.8575%) cop than using R134a. . Similarly second law efficiency of vapor compression refrigeration system using R141b is highest and R407c is lowest. While power consumption by compressor is lowest using R227ea and highest by using M32. Similarly exergy of product is highest using R32 and system exergy destruction ratio based on exergy of product is highest by using R125 and lowest by using R123. It is clear that second law efficiency of vapor compression refrigeration system using HFO-1234ze is nearly approaching to the second law efficiency of vapor compression refrigeration system using R134a and second law efficiency of vapor compression refrigeration system using HFO-1234yf is slightly lower (around 5.67034%) by replacing R134a. and 0.85668% lower by using HFO-1234ze for replacing R134a.

Table-3(a) and Table-3(b) show the thermal performance variation with variation of evaporator temperature in the vapor compression refrigeration system using HFO-1234yf refrigerant and it is found that as evaporator temperature is increasing, the first law efficiency (COP_{VCRS}) is increasing while second law efficiency is decreasing and exergy destruction ratio based on exergy of product (System EDR) and also rational EDR is decreasing. Similarly exergetic efficiency is also decreasing along with increasing system EDR Table-4(a) and Table-4(b) show the thermal performance variation with variation of condenser temperature in the vapor compression refrigeration system using HFO-1234yf refrigerant and it is found that as condenser temperature is increasing, the first law efficiency(COP_{VCRS}) is decreasing while second law efficiency is also decreasing and exergy destruction ratio based on exergy of product (System EDR) and also rational EDR is increasing creasing. Similarly exergetic efficiency is also decreasing along with increasing system EDR. Table-5(a) and Table-5(b) show the thermal performance variation with variation of effectiveness of heat exchanger and it is clear that first law efficiency in terms of coefficient of performance and second law efficiency and exergetic efficiency of vapor compression refrigeration system is increasing as effectiveness of heat exchanger is increasing. Similarly exergy destruction ratio based on exergy of product (EDR_System) and Rational EDR (exergy destruction ratio based on exergy of fuel) is decreasing. Table-6(a) shows the thermal performance variation with variation of super heating temperature in evaporator in the vapor compression refrigeration system using HFO-1234yf refrigerant and it is clear that first law efficiency in terms of coefficient of performance of vapor compression refrigeration system is increasing and second law efficiency as sub cooling temperature increasing (i.e. super heating takes place at higher temperature than the evaporator temperature). Similarly exergy destruction ratio based on exergy of product (System EDR) and rational EDR (exergy destruction ratio based on exergy of fuel system) is decreasing as super heating temperature is increasing. Table-6(b) shows the thermal performance variation with variation of sub-cooling temperature in condenser in the vapor compression refrigeration system using HFO-1234yf refrigerant and it is clear that first law efficiency in terms of coefficient of performance of vapor compression refrigeration system is increasing and second law efficiency as sub cooling temperature increasing (i.e. subcooling takes place at lower than condenser temperature) .Similarly exergy destruction ratio based on exergy of product (System EDR) and rational EDR (exergy destruction ratio based on exergy of fuel system) is decreasing as subcooling temperature is increasing.

Table-2(a): Thermodynamic performances of vapor compression refrigeration system using ecofriendly refrigerants

Parameters	R134a	R1234yf	R1234ze	R245fa	R236fa	M32	R227ea
$COP_{\_Actual}$	2.449	2.31	2.428	2.588	2.372	2.369	2.146
System $EDR_{Second\ Law}$	1.296	1.434	1.315	1.172	1.371	1.373	1.62
Second law Efficiency	0.4356	0.4109	0.4319	0.4603	0.4218	0.4214	0.3817
Rational $EDR_{Second\ Law}$	0.5644	0.5891	0.5681	0.5397	0.578	0.5786	0.6183
W_Comp(kW)	55.86	44.69	49.98	55.62	42.68	102.5	32.91
Exergy_Product (kW)	24.33	18.36	21.53	25.6	18.05	43.19	12.56
Exergy_Fuel (kW)	55.86	44.69	49.8	55.82	42.78	102.5	32.91
Exergetic Efficiency	0.1289	0.1232	0.1283	0.1314	0.1261	0.1254	0.1169
System EDR	6.755	7.12	6.795	6.438	6.931	6.974	7.552

Table-2(b): Thermodynamic performances of vapor compression refrigeration system using ecofriendly refrigerants

Parameters	R143a	R152a	R141b	R410a	R404a	R407c	R125	R123
$COP_{\_Actual}$	2.20	2.577	2.769	2.307	2.121	2.089	1.99	2.668
System $EDR_{Second\ Law}$	1.554	1.181	1.031	1.437	1.651	1.692	1.825	1.107
Second law Efficiency	0.3916	0.4585	0.4925	0.4101	0.3772	0.3715	0.3340	0.4745
Rational $EDR_{Second\ Law}$	0.6084	0.5416	0.5075	0.5896	0.6228	0.6285	0.646	0.5255
W_Comp(kW)	54.41	88.90	66.54	67.86	47.89	69.29	37.58	50.11
Exergy_Product (kW)	21.31	40.15	32.77	27.85	18.07	25.13	13.30	23.78
Exergy_Fuel (kW)	54.41	88.90	66.54	67.86	47.89	69.29	37.58	50.11
Exergetic Efficiency	0.1190	0.1338	0.1441	0.1231	0.1156	0.1137	0.1101	0.1374
System EDR	7.403	6.473	6.088	7.121	7.65	7.794	8.801	6.279

Table-3(a): Effect of evaporator temperature on thermodynamic performances of vapor compression refrigeration system using HFO-1234yf refrigerant

$T_{\_EVA}$ (K)	COP_{Actual}	System $EDR_{Second\ Law}$	Second law Efficiency	Rational $EDR_{Second\ Law}$	Exergetic Efficiency	System EDR	Rational EDR
253	2.31	1.434	0.4209	0.5791	0.1232	7.12	0.8768
258	2.656	1.428	0.4118	0.5882	0.1231	7.125	0.8769
263	3.075	1.444	0.4092	0.5908	0.1222	7.186	0.8778
268	3.590	1.489	0.4018	0.5982	0.1201	7.325	0.8799
273	4.237	1.578	0.388	0.6120	0.1166	7.579	0.8834
278	5.072	1.74	0.3649	0.6351	0.1108	8.029	0.8892
283	6.191	2.048	0.3281	0.6719	0.1014	8.86	0.8986

Table-3(b): Effect of evaporator temperature on thermodynamic performances of vapor compression refrigeration system using HFO-1234yf refrigerant

$T_{\_EVA}$ (K)	Exergy_input/ $W_{\_Compressor}$ "kW"	$Q_{\_Evaporator}$ "kW"	$COP_{\_Actual}$	$Exergy_{\_Product}$ "kW"	Second law Efficiency	System $EDR_{Second\ Law}$	Exergetic Efficiency	System EDR
253	44.69	103.2	2.31	18.36	0.4209	1.434	0.1232	7.12
258	40.18	106.7	2.656	16.55	0.4118	1.428	0.1231	7.125
263	35.84	110.2	3.075	14.66	0.4092	1.444	0.1222	7.186
268	31.66	113.6	3.590	12.72	0.4018	1.489	0.1201	7.325
273	27.63	117.1	4.237	10.72	0.388	1.578	0.1166	7.579
278	23.75	120.5	5.072	8.666	0.3649	1.74	0.1108	8.029
283	20.0	123.8	6.191	6.563	0.3281	2.048	0.1014	8.86

Table- 4(a) : Effect of condenser temperature on thermodynamic performances of vapor compression refrigeration system using HFO-1234yf refrigerant

T_{Cond} (K)	COP_{Actual}	System $EDR_{Second\ Law}$	Second law Efficiency	Rational $EDR_{Second\ Law}$	Exergetic Efficiency	System EDR	Rational EDR
333	1.755	2.203	0.3122	0.6878	0.09933	9.067	0.90067
328	2.015	1.79	0.3585	0.6415	0.1109	8.021	0.8891
323	2.310	1.434	0.4109	0.5891	0.1232	7.12	0.8768
318	2.649	1.22	0.4712	0.5288	0.1364	6.331	0.8636
313	3.047	0.8451	0.5420	0.4580	0.1509	5.628	0.8491
308	3.525	0.5954	0.6268	0.3232	0.1668	4.994	0.8332
303	4.111	0.3677	0.7311	0.2699	0.1846	4.416	0.8154
298	4.854	0.1582	0.8634	0.1366	0.2048	3.883	0.7952

Table- 4(b) : Effect of condenser temperature on thermodynamic performances of vapor compression refrigeration system using HFO-1234yf refrigerant

T_{Cond}(K)	Exergy_input/ $W_{Compressor}$ "kW"	$Q_{Evaporator}$ "kW"	COP_{Actual}	$Exergy_{Product}$ "kW"	Second law Efficiency	System $EDR_{Second\ Law}$	Exergetic Efficiency	System EDR
333	50.31	88.31	1.755	15.71	0.3122	2.203	0.09933	9.067
328	47.56	95.86	2.015	17.05	0.3585	1.79	0.1109	8.021
323	44.69	103.2	2.310	18.36	0.4109	1.434	0.1232	7.12
318	41.70	110.5	2.649	19.65	0.4712	1.22	0.1364	6.331
313	38.58	117.6	3.047	20.91	0.5420	0.8451	0.1509	5.628
308	35.33	124.5	3.525	22.15	0.6268	0.5954	0.1668	4.994
303	31.96	131.4	4.111	23.36	0.7311	0.3677	0.1846	4.416
298	28.45	138.1	4.854	24.56	0.8634	0.1582	0.2048	3.883

Table- 5(a) : Effect of effectiveness of liquid vapor heat exchanger on thermodynamic performances of vapor compression refrigeration system using HFO-1234yf refrigerant

Effectiveness of Heat Exchanger	COP_{Actual}	System $EDR_{Second\ Law}$	Second law Efficiency	Rational $EDR_{Second\ Law}$	Exergetic Efficiency	System EDR	Rational EDR
0.50	2.253	1.496	0.4007	0.5993	0.1207	7.282	0.8793
0.55	2.262	1.485	0.4024	0.5976	0.1212	7.254	0.8788
0.60	2.272	1.475	0.4041	0.5959	0.1216	7.227	0.8784
0.65	2.281	1.464	0.4058	0.5942	0.1220	7.20	0.8780
0.70	2.291	1.454	0.4075	0.5925	0.1224	7.173	0.8776
0.75	2.30	1.444	0.4092	0.5908	0.1228	7.146	0.8772
0.80	2.31	1.434	0.4109	0.5891	0.1232	7.12	0.8768

Table-5(b) : Effect of effectiveness of liquid vapor heat exchanger on thermodynamic performances of vapor compression refrigeration system using HFO-1234yf refrigerant

Effectiveness of Heat Exchanger	Exergy_input/ $W_{Compressor}$	$Q_{Evaporator}$	COP_{Actual}	$Exergy_{Product}$	Exergetic Efficiency	System EDR	Exergetic Efficiency	System EDR
0.50	44.69	100.7	2.253	17.91	0.4007	1.496	0.1207	7.282
0.55	44.69	101.1	2.262	17.98	0.4024	1.485	0.1212	7.254
0.60	44.69	101.5	2.272	18.06	0.4041	1.475	0.1216	7.227
0.65	44.69	102.0	2.281	18.14	0.4058	1.464	0.1220	7.20
0.70	44.69	102.4	2.291	18.21	0.4075	1.454	0.1224	7.173
0.75	44.69	102.8	2.30	18.29	0.4092	1.444	0.1228	7.146
0.80	44.69	103.2	2.31	38.36	0.4109	1.434	0.1232	7.12

Table- 6(a): Effect of super heating of condenser on thermodynamic performances of vapor compression refrigeration systemusing HFO-1234yf refrigerant

Super Heating Temperature	COP_{Actual}	System $EDR_{Second\ Law}$	Second law efficiency	Rational $EDR_{Second\ Law}$	Exergetic Efficiency	System EDR	Rational EDR
10	2.31	1.434	0.4109	0.5891	0.1232	7.12	0.8768
9	2.306	1.438	0.4102	0.5896	0.1229	7.136	0.8771
8	2.303	1.441	0.4096	0.5904	0.1227	7.153	0.8773
7	2.30	1.445	0.4090	0.5910	0.1224	7.17	0.8776
6	2.296	1.449	0.4082	0.5916	0.1221	7.187	0.8779
5	2.293	1.452	0.4078	0.5922	0.1219	7.204	0.8781
4	2.289	1.456	0.4072	0.5928	0.1216	7.222	0.8784

3	2.286	1.459	0.4066	0.5934	0.1214	7.240	0.8786
2	2.283	1.462	0.4061	0.5939	0.1211	7.257	0.8789
1	2.281	1.465	0.4057	0.5943	0.1209	7.274	0.8791
0	2.278	1.468	0.4052	0.5948	0.1208	7.269	0.8792

Table- 6(b): Effect of sub cooling of condenser on thermodynamic performances of vapor compression refrigeration system using HFO-1234yf refrigerant

Sub-cooling Temperature	COP_{Actual}	System $EDR_{Second\ Law}$	Second law efficiency	Rational $EDR_{Second\ Law}$	Exergetic Efficiency	System EDR	Rational EDR
15	2.649	1.122	0.4712	0.5288	0.1364	6.331	0.8636
14	2.577	1.182	0.4584	0.5416	0.1337	6.481	0.8663
13	2.507	1.242	0.4460	0.5540	0.1310	6.635	0.8690
12	2.44	1.305	0.4439	0.5661	0.1283	6.793	0.8663
11	2.374	1.368	0.4222	0.57781	0.1257	6.954	0.8743
10	2.310	1.434	0.4109	0.5891	0.1232	7.12	0.8768
9	2.248	1.501	0.3998	0.6002	0.1206	7.29	0.8794
8	2.187	1.570	0.3891	0.6109	0.1181	7.465	0.8819
7	2.129	1.641	0.3786	0.6214	0.1157	7.645	0.8843
6	2.071	1.714	0.3684	0.6316	0.1132	7.83	0.8868
5	2.015	1.79	0.3585	0.6415	0.1109	8.021	0.8891
4	1.961	1.867	0.3488	0.6512	0.1085	8.217	0.8915
3	1.908	1.947	0.3393	0.6607	0.1062	8.419	0.8938
2	1.856	2.030	0.3301	0.6699	0.1039	0.8628	0.8961
1	1.805	2.115	0.3210	0.6790	0.1016	8.844	0.8984
0	1.755	2.203	0.3122	0.6878	0.09933	9.067	0.90067

3. Conclusions

The following conclusions were drawn from present investigation

- First law efficiency in terms of coefficient of performance of R141b is highest and R125 is lowest.
- The COP of R245fa is higher than R134a and R236fa.
- The first law efficiency of HFO-1234yf is 5.6757% lower than HFC-134a and HFO-1234ze
- HFO-1234ze has less than 1% lower (around 0.8575%) first law efficiency than by using R134a.
- The second law efficiency of vapor compression refrigeration system using HFO-1234yf is slightly lower (around 5.67034%) by replacing R134a.
- The second law efficiency of vapor compression refrigeration system using HFO-1234ze is slightly lower (around 0.86%) for replacing R134a
- The first law efficiency (i.e. coefficient of performance) and second law efficiency and exergetic efficiency of vapor compression refrigeration system is increasing as effectiveness of heat exchanger is increasing.
- Exergy destruction ratio based on exergy of product (EDR_{System}) and Rational EDR (exergy destruction ratio based on exergy of fuel) is decreasing.
- As evaporator temperature is increasing, the first law efficiency(COP_{VCRS}) is increasing while second law efficiency is decreasing
- The exergy destruction ratio based on exergy of product (System EDR) and also rational EDR is decreasing.
- Exergetic efficiency is also decreasing along with increasing system EDR when evaporator temperature.
- As condenser temperature is increasing, the first law efficiency(COP_{VCRS}) is decreasing while second law efficiency is also decreasing
- The exergy destruction ratio based on exergy of product (System EDR) and also rational EDR is increasing creasing as condenser temperature is increasing. Exergetic efficiency is also decreasing when condenser temperature is increasing along with increasing system EDR.

References

[1] S.Kumar, M.Prevost, R.Bugarel [1989], Exergy analysis of a vapor compression refrigeration system. Heat Recovery Systems & CHP.Vol-9:page-151-157.

[2] C. Nikolaidis, D. Probert [1998], Exergy method analysis of a two-stage vapor-compression refrigeration-plants performance. Int J Applied Thermal Engineering vol- 60, page-241-256.

[3] RecepYumrutas, Mehmet Kunduz, Mehmet Kanoglu[2002]Exergy analysis of vapor compression refrigeration systems. Exergy, An International Journal.; 2:266-272.

[4] E. Halimic, D. Ross, B. Agnew, A. Anderson, I. Potts. A comparison of the operating performance of alternative refrigerants. Int J Applied Thermal Engineering.2003; 23:1441-1451.

[5] Yongmei Xuan, GuangmingChen.[2007]Experimental study on HFC-161 mixture as an alternative refrigerant to R502. Applied Thermal Engineering, vol. 27, pp. 2559-2365,

[6] R. Cabello, J. Navarro-Esbrı, R. Llopis, E. Torrella. [2007]Analysis of the variation mechanism in the main energetic parameters in a single-stage vapour compression plant. Int J Applied Thermal Engineering.; 27:167-176

[7] R.Cabello a, E.Torrella b, J.Navarro-Esbr. [2004]Experimental evaluation of a vapour compression plant performance using R134a, R407C and R22 as working fluids. Int J Applied Thermal Engineering.; Vol-24, page-1905-1917.

[8] Mark W. Spatz, Samuel F. Yana Motta.[2004] An evaluation of options for replacing HCFC-22 inmedium temperature refrigeration systems. Int J Refrigeration.; Vol-27:page-475-483.

[9] B.O. Bolaji, M.A. Akintunde, T.O. Falade. [2011]Comparative analysis of performance of three ozone-friends HFC refrigerants in a vapor compression refrigerator. Int J Sustainable Energy & Environment.; 2:61-64.

[10] M. Padilla, R. Revellin, J. Bonjour [2010] Exergy analysis of R413A as replacement of R12 in a domestic refrigeration system. Int J Energy Conversion and Management, Vol-51:page-2195-2201.
[11] J.U Ahamed, R.saidur, H.H Masjuki, M.A Sattar- [2012], An analysis of energy, exergy and sustainable development of a vapour compression refrigeration system using hydrocarbon, International journal of Green energy.Vol-9:page-707-717.
[12] J.U. Ahamed, R. Saidur, H.H.Masjuki, [2011], A review on exergy analysis of vapor compression refrigeration system. Int J Renewable and sustainable energy reviews. 15:1593-1600.
[13] Camelia Stanciu, Adina Gheorghian, DorinStanciu, AlexandruDobrovicescu- Exergy analysis and refrigerant effect on the operation and performance lomits of a one stage vapour compression refrigeration system.Termotehnica.2011;1:36-42.
[14] H.O. Spauschus.[1988] HFC 134a as a substitute refrigerant for CFC 12. Int J of Refrigeration. 11:389-392.
[15] Qiyu Chen,R.C Prasad. Simulation of a vapour compression refrigeration cycles HFC134A and CFC12.Int Comm.Heat Mass Transfer.1999; 26:513-521.
[16] M. Padilla, R. Revellin, J. Bonjour. Exergy analysis of R413A as replacement of R12 in a domestic refrigeration system. Int J Energy Conversion and Management.2010; 51:2195-2201.
[17] R.Saravanakumar, V.Selladurai [2013] Exergyanalysis of a domestic refrigerator using eco-friendly R290/R600a refrigerant mixture as an alternative to R134a.Int J Therm Anal Calorim.
[18] S Anand, S.K. Tyagi [2012] Exergy analysis and experimental study of a vapour compression refrigeration cycle. Int. J. Therm. Anal. Calorim. , Vol-110, Page-961-971.
[19] C.P Arora [2010] Thermodynamics, Tata McGraw Hill New Delhi, page-499-501.

Cite this article as: R.S. Mishra, Methods for improving thermodynamic performances of vapor compression refrigeration systems, International Journal of Research in Engineering and Innovation Vol-3, Issue-5 (2019), 291-297, http://doi.org/10.36037/IJREI.2019.3501