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Use of Nano materials for thermodynamic performance improvement of vapor compression refrigeration system using R134a eco-friendly refrigerant

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Abstract

The thermodynamics analysis of modified vapour compression refrigeration system using ecofriendly refrigerants have been presented based on energy and exergy concepts. The modified vapour compression refrigeration system having heat exchanger between two simple vapour compression cycle and this heat exchanger act as super heater for first cycle and condenser for secondary cycle. Numerical computations have been carried out using energy and exergy equations to calculate different parameters for evaluating the system performance of cycle using R134a ecofriendly refrigerant using three types of Nano particles mixed with brine water flowing in the evaporator. From simulation results of modified vapour compression refrigeration systems using different ecofriendly refrigerants gives better thermal performance comparison of these refrigerants when used without Nano particles in modified vapour compression refrigeration system. It was observed that first law efficiency is decreasing as compressor speed increasing and maximum thermal efficiency around 20% higher by using copper Nano particles mixed in the brine water in the evaporator and minimum (15% higher) by using TIO_2 Nano particles of size 0.00001m mixed in the brine water in the evaporator as without mixing Nano particles.

Keywords: Global warming Potential (GWP), Ozone Depletion Potential (ODP), Nano -Materials, Performance Improvement

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. Vapour compression refrigeration system based applications make use of refrigerants which are responsible for greenhouse gases, global warming and ozone layer depletion. Simple vapour compression 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 vapour compression refrigeration system. The systems under vapour compression technology consume huge amount of electricity, this problem can be solved by improving thermal performance of the vapour compression refrigeration system. The thermal Performance of systems based on vapour compression refrigeration technology can be improved by following.

The thermal performance of vapour compression refrigeration system is evaluated in term of first law efficiency known as coefficient of performance (COP) which is the ratio of cooling load in terms of refrigeration effect to the net work input (known as high grade energy) to the system. The first law performance (COP) of vapour compression refrigeration system can be improved either by increasing cooling load capacity (refrigeration effect) or by reducing work input given to the vapour compression refrigeration system. 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 vapour in evaporator which will not only reduce the cooling capacity but also increase the size of evaporator. This problem can be eliminated by adopting multi-stage expansion with flash chamber where the flash vapours is removed after each stage of expansion as a

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consequence there will be increase in cooling capacity and reduce the size of the evaporator.

Work input can also be reduced by replacing multi-stage compression or compound compression with single stage compression. Refrigeration effect can also be increased by passing the refrigerant through sub cooling after condenser and super heating to evaporator outlet.

The modified system is develop combing two simple vapour compression cycles together with a heat exchanger. Secondary cycle is connected with the primary cycle with this heat exchanger. In this modified system, heat exchanger acts as a condenser in the secondary cycle and as a super-heater in the primary cycle. The system contains two evaporators, two compressors, one condenser, two expansion valves and one heat exchanger. Both the evaporators are placed in the location where temperature to be maintained low. In the secondary cycle, evaporator takes the heat from that location and refrigerant evaporated and enters into the compressor. This can be achieved by maintaining appropriate mass flow rates of the refrigerants in both cycles, secondary cycle refrigerant enters into the expansion valve and primary cycle refrigerant enters into the compressor and followed by the basic components of simple vapor compression cycle. Refrigerant flow is maintained in such a way that primary cycle refrigerant temperature is superheated to 20ºc after taking the heat in heat exchanger. Refrigerants considered in both the cycle are R-290, R-600A, R-32 and R-134A one by one. Vapour refrigerant is then compressed to a higher pressure and temperature where the heat exchanger is placed .In the heat exchanger, this refrigerant exchanges heat with the primary cycle vapor refrigerant after it takes the heat in the primary cycle evaporator. The exchanger is designed in such a way that, when the secondary cycle refrigerant leaves the heat exchanger it become condensed liquid by rejecting latent heat and this heat is then taken by the primary cycle refrigerant resulting in increasing its temperature. Refrigerants considered in both the cycle are R-290, R-600A, and R-134a one by one respectively. Condenser temperature is considered for this study is 50°C and evaporator temperature is varied between -10°C to 0°C in a step of 2°C.

2. Literature Review

Jain Vaibhav , Kachhawaha & Mishra R.S. [1] presented a theoretical performance study of a vapor compression refrigeration system with the ecofriendly refrigerants i.e. R134a/R410a/R407c/M20.and developed computational simulation model based on energy and exergy analysis for the investigation of the effects of evaporating temperatures, degree of sub-cooling, dead state temperatures and effectiveness of the liquid vapor heat exchanger on the coefficient of performance, second law efficiency and exergy destruction ratio of the vapour compression refrigeration cycle and found the theoretical investigation, which showed that better performances. Qureshi, et.al [2] carried out, an experimental investigation into the effects, in terms of energy, of employing a dedicated mechanical sub-cooling cycle with a residential 1.5 ton simple vapor compression refrigeration system is presented. A comparative analysis of the experimental cycle performance is conducted with and without the dedicated sub-cooler cycle when the room temperature is kept between 18 and 22^0 C. and found a percentage increase in efficiency due to use of a dedicated sub-cooling loop. Poltker G et.al [3] presented a theoretical study about the effect of condenser sub-cooling on the performance of vapor-compression systems. The thermodynamic properties associated with the relative increase in refrigerating effect, i.e. liquid specific heat and latent heat of vaporization and found that as condenser sub-cooling increases, the COP reaches a maximum as a result of a trade-off between increasing refrigerating effect and specific compression work. Kilicarsln et.al. [4] carried out Experimental investigation and theoretical study of a different type of two-refrigeration system using R-134 as the refrigerant stage vapor compression cascade and observed that the change in water mass flow rate has little effect on the coefficient of performance for single stage and cascade stage refrigeration systems. S.G. Kim,et. Al [5] investigated the performance of an auto-cascade refrigeration system using zeotropic refrigerant mixtures of R744/134a and R744/290. The Performance test and simulation have been carried out for an auto-cascade refrigeration system by varying secondary fluid temperatures at evaporator and condenser inlets. S. Paul, A. Sarkar [6] reviewed the various experimental and theoretical studies carried out around the globe with environment friendly alternative refrigerants such as hydrocarbons (HC), hydrofluorocarbons (HFC) and their mixtures, which are going to be the promising long-term alternatives and observed that the use of "natural" refrigerants (air, CO_2 or ammonia) becomes a possible solution, as a alternatives halogenated refrigerants have adverse environmental impacts such as ozone layer depletion potential and global warming. R.B. Jernaa, Mansouri R.et.al [7] developed thermodynamic model using the Engineering Equation Solver (EES) and parametric study is conducted to investigate the effect of evaporating and ambient temperatures on the energy and exergy efficiencies, the total exergy destruction and the exergy losses in different components of the system and they found that for both refrigerants, no important differences are observed between the energy and the exergy efficiencies. Gang Yan et. al [8] proposed a modified vapor-compression refrigeration cycle (MVRC) system operating with the zeotropic mixture R290/R600a for domestic refrigerator-freezers. In this MVRC system, a phase separator is introduced to enhance the overall system performance .Their simulation results of two cycles in which he found the MVRC can give the most excellent performances in the COP. Alleyne [9] designed the exergetic, (second law), optimal controller for a canonical four-component vapor compression system (VCS). A lumped parameter moving boundary modeling framework is used to model the two heat exchangers in the VCS. A model predictive controller is then designed and implemented in simulation using a dynamic exergy-based objective function and determined the optimal control actions for the VCS to maximize exergetic efficiency while achieving a desired cooling capacity. Yataganbaba Al., et al [10] carried out exergy analysis on a two evaporator vapor compression refrigeration system using R1234yf, R1234ze and R134a as refrigerant computer code was developed by using Engineering Equation Solver (EES-V9.172-3D) software package program. And found that the R1234yf and R1234ze, which are good alternatives to replace R134a concerning their environmental friendly properties.

3. Results and Discussions

Performance Prediction of vapour compression refrigeration systems using nano particles in the brine water of evaporator circuit for following input data
Length of evaporator =0.72 m,
Length of condenser =1.2 m,
Evaporator temperature of brine water inlet = 27^0C,
Condenser temperature of water inlet = 27^0C, Pressure of brine water inlet = 2 (bar),
Pressure of condenser water inlet = 2 (bar),
Mass flow rate of brine= 0.007 (Kg/sec),
Mass flow rate of condenser water= 0.008 (Kg/sec)
From Table-1(a) to Table1(j) As compressor speed increases the first law efficiency in terms of Coefficient of performance (COP) and second law efficiency increases while exergy destruction of the system decreases. Similarly Reynold numbers of liquid portion condenser and condenser vapour portions and Reynold number of evaporation in increases. As compressor speed in increases. The LMTD of Liquid portion condenser and vapour portion condenser and LMTD of evaporator is increases. The isentropic efficiency of compressor is in increases and volumetric efficiency of compressor is decreases as compressor speed is increases.

Table-1(a): The variation of first law efficiency (COP) with compressor speed

Compressor speed (rpm)	Copper nano materials	A_2O_3	TiO_2	Without nano
2500	-----------	3.631	3.582	3.058
2600	-----------	3.583	3.536	3.023
2700	-----------	3.542	3.496	2.993
2800	-----------	3.507	3.462	2.968
2900	3.507	3.477	3.432	2.946
3000	3.58	3.451	3.407	2.928

Table-1(b) :The variation of Second law efficiency with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	0.4064	0.4010	0.3327
2600	-------	0.4011	0.3958	0.3384
2700	--------	0.3665	0.3914	0.3351
2800	--------	0.3926	0.3889	0.3322
2900	0.3926	0.3892	0.3842	0.3298
3000	0.3896	0.3863	0.3814	0.3277

Table-1(c): The variation of system exergy destruction ratio (EDR) with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	1.461	1.494	1.921
2600	-------	1.493	1.526	1.955
2700	--------	1.522	1.555	1.984
2800	--------	1.547	1.581	2.01
2900	1.547	1.569	1.603	2.032
3000	1.567	1.589	1.622	2.051

Table-1(d) :The variation of Evaporator over all heat transfer coefficient (W/m^2K) with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	1314.24	1234.73	677.41
2600	-------	1312.60	1233.02	675.52
2700	-------	1313.30	1233.39	674.3
2800	-------	1315.94	1235.47	673.64
2900	1380.0	1320.21	1239.0	673.45
3000	1386.35	1325.84	1243.72	673.65

Table-1(e) :The variation of Condenser over all heat transfer coefficient (W/m2K) with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	708.26	702.77	639.9
2600	-------	709.11	703.65	641.10
2700	--------	710.38	704.95	642.46
2800	--------	712.02	706.63	644.24
2900	717.61	714.01	708.64	646.31
3000	719.88	716.29	707.95	648.65

Table-1(f): The variation of volumetric efficiency of compressor with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	0.6537	0.652	0.6350
2600	-------	0.642	0.645	0.6289
2700	--------	0.6409	0.639	0.6229
2800	--------	0.6348	0.633	0.6172
2900	0.6299	0.6289	0.627	0.6116
3000	0.6242	0.6232	0.621	0.6061

Table-1(g) :The variation of isentropic efficiency of compressor with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	0.7860	0.7806	0.7209
2600	-------	0.7924	0.7870	0.7269
2700	--------	0.7991	0.7936	0.7331
2800	--------	0.8060	0.8004	0.7395
2900	0.8169	0.8131	0.8074	0.7461
3000	0.8242	0.8203	0.8146	0.7521

Table-1(h) :The variation of LMTD of condenser liquid portion with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	32.82	32.88	34.19
2600	-------	33.14	33.2	34.42
2700	--------	33.42	33.47	34.6
2800	--------	33.67	33.71	34.74
2900	33.87	33.89	33.92	34.85
3000	34.06	34.07	34.09	34.92

Table-1(i) :The variation of LMTD of Condenser vapour portion with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	16.67	16.74	17.72
2600	-------	16.83	16.9	17.58
2700	--------	16.96	17.03	17.95
2800	--------	17.07	17.14	18.03
2900	17.12	17.17	17.23	18.09
3000	17.20	17.24	17.30	18.13

Table-1(j) :The variation of LMTD of Evaporator with compressor speed

Compressor speed (rpm)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
2500	-------	12.91	13.52	20.29
2600	-------	13.1	13.72	20.58
2700	--------	13.27	13.9	20.86
2800	--------	13.41	14.05	21.11
2900	13.10	13.54	14.19	21.35
3000	13.20	13.65	14.31	21.57

From Table-2(a) to Table-2(m) As mass flow rate of brine in the evaporator increases the first law efficiency in terms of Coefficient of performance (COP) and second law efficiency increases while exergy destruction of the system decreases. Similarly Reynold numbers of liquid portion condenser and condenser vapour portions and Reynold number of evaporation in increases. As mass flow rate of brine in the evaporator is increases. The LMTD of Liquid portion condenser and vapour portion condenser is decreases and LMTD of evaporator is increases. The isentropic efficiency of compressor is in increases and volumetric efficiency of compressor is also increases as as mass flow rate of brine in the evaporator

Table-2(a) :The variation of first law efficiency (COP) with evaporator brine mass flow rate for m_water=0.008

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	3.507	3.477	3.432	2.946
0.008	3.580	3.549	3.504	3.013
0.009	3.640	3.609	3.563	3.069
0.01	3.689	3.658	3.612	3.119

Table-2(b): The variation of second law efficiency (Exergetic efficiency) with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	0.3926	0.3892	0.3742	0.3298
0.008	0.4008	0.3922	0.3892	0.3372
0.009	0.4074	0.4039	0.3988	0.3436
0.01	0.4129	0.4094	0.4043	0.3491

Table-2(c): The variation of system exergy destruction ratio (EDR) with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	1.547	1.569	1.603	2.032
0.008	1.495	1.517	1.55	1.965
0.009	1.454	1.476	1.507	1.91
0.01	1.422	1.442	1.473	1.864

Table-2(d): The variation of evaporator overall heat transfer coefficient (W/m2K) with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	1380.0	1320.	1239.0	675.14
0.008	1401.19	1342.8	1263.3	673.45
0.009	1418.86	1361.9	1284.0	772.42
0.01	1433.89	1378.2	1301.9	671.77

Table-2(e): The variation of condenser overall heat transfer coefficient (W/m^2K) with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	717.43	714.0	708.64	630.06
0.008	726.24	722.63	717.26	646.321
0.009	739.12	729.54	724.20	659.6
0.01	738.74	735.2	729.91	670.64

Table-2(f): The variation of volumetric efficiency of compressor with evaporator brine mass flow rate

Mass flow rate of brine (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	6299	0.6289	0.6275	0.6116
0.008	0.6323	0.6313	0.6298	0.6137
0.009	0.6343	0.6332	0.6317	0.6156
0.01	0.6359	0.6349	0.6334	0.6172

Table-2(g): The variation of isentropic efficiency of compressor with evaporator brine mass flow rate

Evaporator mass flow rate of brine (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	0.8169	0.8131	0.8074	0.7461
0.008	0.8261	0.8222	0.8165	0.7545
0.009	0.8117	0.8297	0.8239	0.7617
0.01	0.8078	0.8360	0.8303	0.7679

Table-2(h) :The variation of LMTD of Condenser liquid portion with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	33.87	33.89	33.92	34.85
0.008	33.85	33.86	33.85	34.65
0.009	33.85	33.85	33.85	34.49
0.010	33.86	33.85	33.85	34.38

Table-2(i):The variation of LMTD of Condenser vapour portion with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	17.12	17.17	17.23	18.09
0.008	17.02	17.07	17.13	17.96
0.009	16.95	16.99	17.05	17.85
0.010	16.89	16.93	16.98	17.75

Table-2(j) :The variation of LMTD of evaporator with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	13.10	13.54	14.19	21.35
0.008	13.25	13.67	14.29	21.15
0.009	13.36	13.77	14.37	20.36
0.010	13.45	13.84	14.42	20.79

Table-2(k) :The variation of Capillary Reynold number with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	27097	26671	26047	19832
0.008	28147	27703	27895	19653
0.009	29014	28559	28595	19518
0.010	29743	29281	29281	19414

Table-2(l):The variation of condenser Reynold number with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	206819	206601	206312	210116
0.008	207421	207155	206797	206080
0.009	207985	207682	207269	202919
0.010	208502	208170	208170	200356

Table-2(m): The variation of brine Reynold number with evaporator brine mass flow rate

Evaporator brine mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	104.3	104.3	104.3	334.4
0.008	119.2	119.2	119.2	396.4
0.009	134.1	134.1	134.1	396.0
0.010	149.0	149.0	149.0	395.6

From Table-3(a) to Table3(m) As mass flow rate of water in the condenser increases the first law efficiency in terms of Coefficient of performance (COP) and second law efficiency increases while exergy destruction of the system decreases. Similarly reynold numbers of liquid portion condenser and condenser vapour portions and Reynold number of evaporation in increases. As mass flow rate of water in the condenser is increases. The LMTD of Liquid portion condenser and vapour portion condenser is decreases and LMTD of evaporator is increases. The isentropic efficiency of compressor is in increases and volumetric efficiency of compressor is also increases as As mass flow rate of water in the condenser increases.

Table-3(a): The variation of first law efficiency (COP) with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	------	3.477	3.338	2.822
0.008	3.505	3.549	3.432	2.946
0.009	3.589	3.609	3.510	2.998
0.01	3.659	3.658	3.576	3.041

Table-3(b):The variation of second law efficiency (Exergetic efficiency) with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	--------	0.3892	0.3736	0.3226
0.008	0.3926	0.3973	0.3842	0.3298
0.009	0.4018	0.4039	0.3929	0.3356
0.01	0.4096	0.4094	0.4003	0.3404

Table-3(c) :The variation of of system exergy destruction ratio (EDR) with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	------	1.644	1.677	2.10
0.008	1.547	1.569	1.603	2.032
0.009	1.489	1.511	1.545	1.98
0.01	1.442	1.464	1.448	1.938

Table-3(d): The variation of evaporator overall heat transfer coefficient (W/m^{2}K) with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	--------	1372.2	1245.2	675.14
0.008	1380.0	1342.8	1239.0	673.45
0.009	1375.15	1321.9	1235.0	672.42
0.01	1372.29	1302.0	1233.1	671.77

Table-3(e) :The variation of condenser overall heat transfer coefficient (W/m2K) with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	--------	692.96	688.01	630.06
0.008	717.61	714.01	708.64	646.31
0.009	735.12	731.28	725.28	659.59
0.01	749.75	745.71	739.28	670.64

Table-3(f) :The variation of Volumetric efficiency of compressor with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	------	0.6239	0.6225	0.6075
0.008	0.6299	0.6289	0.6289	0.6116
0.009	0.6338	0.6328	0.6313	0.6146
0.01	0.6369	0.635	0.634	0.617

Table-3(g): The variation of isentropic efficiency of compressor with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	------	0.8198	0.814	0.7513
0.008	0.8169	0.8131	0.807	0.7461
0.009	0.8117	0.8080	0.802	0.7422
0.01	0.8074	0.8041	0.797	0.7392

Table-3(h): The variation of LMTD of Condenser liquid portion with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	--------	35.15	35.35	36.02
0.008	33.87	33.89	33.92	34.85
0.009	32.71	32.73	32.78	33.93
0.01	31.76	31.8	31.87	33.19

Table-3(i): The variation of LMTD of Condenser vapour portion with condenser water mass flow rate

Condenser mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	-------	16.82	16.85	17.76
0.008	17.12	17.17	17.23	18.09
0.009	17.40	17.45	17.51	18.35
0.01	17.64	17.68	17.75	18.57

Table-3(j): The variation of LMTD of evaporator with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	----	13.27	13.92	21.08
0.008	13.10	13.54	14.19	21.35
0.009	13.29	13.74	14.33	21.55
0.01	13.44	13.89	14.54	21.71

Table-3(k): The variation of Re-23 with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	----	211720	211337	206080
0.008	206819	206601	206312	205753
0.009	202749	202581	202366	205575
0.01	199474	199346	199190	205490

Table-3(l): The variation of Re-Cap with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	----	26194	26285	19653
0.008	27097	26671	26047	20486
0.009	26914	26490	25871	21208
0.01	26774	26352	25736	21841

Table-3(m): The variation of Re-brine with condenser water mass flow rate

Condenser water mass flow rate (Kg/sec)	Copper Nano materials	Al_2O_3	TiO_2	Without Nano
0.007	-------	104.3	104.3	396.4
0.008	104.3	104.3	104.3	458.6
0.009	104.3	104.3	104.3	521.1
0.01	104.3	104.3	104.3	583.8

4. Conclusions

Following conclusions were drawn from developed thermal model for vapour compression refrigeration systems using speed variable compressor.

(i) The first law efficiency in terms of coefficient of performance of vapour compression refrigeration system using ecofriendly R134a refrigerant is decreasing as increasing speed of compressor while second law efficiency in terms of exergetic efficiency is decreases.

(ii) The first law efficiency in terms of coefficient of performance is increasing along with increasing volumetric efficiency as increasing brine mass flow rate in the evaporator while exergetic efficiency is decreasing along with increasing isentropic compressor efficiency.

(iii) The first law efficiency in terms of coefficient of performance is increasing along with decreasing volumetric efficiency as increasing water mass flow rate in the condenser while exergetic efficiency is increasing along with decreasing isentropic compressor efficiency

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