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Thermodynamic model analysis of vapour compression refrigeration systems by using ecofriendly refrigerant (R1234yf) in primary circuit and R718 in the secondary circuit by mixing Nano particles (Al_2O_3) for improving thermal efficiencies

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Abstract

Simple thermal model was developed for predicting first law thermal performance in term of coefficient of performance (COP) which is the ratio of refrigeration effect to the network input given to the system of refrigeration system is evaluated. Therefore the coefficient of performance (COP) of vapour compression refrigeration system can be improved either by increasing evaporator load (i.e. Refrigeration effect) or by reducing high grade energy in terms of exergy of fuel (i.e. work input) given to the system.

The constant enthalpy process is also known as throttling process in VCR is an irreversible expansion process causing internal irreversibility computed using entropy changes multiplied by ambient temperature (i.e. reference temperature of 298 K) . In the expansion process, the factors responsible for exergy loss in thermos-syphonic cycle performances. Normally in the throttling process, because of entering the portion of the refrigerant flashing to vapour in evaporator which will not only reduce the cooling capacity but also increases the size of evaporator. This problem can be eliminated by adopting multi-stage expansion where the flash vapors is removed after each stage of expansion as a consequence there will be increase in cooling capacity or reduce the size of the evaporator by using nano refrigerants . This thermal model predicts condenser refrigerant temperature along with evaporator temperature, which is a function of brine mass flow rate and condenser water flow rate & pressure, inlet water temperature and inlet brine temperature & pressure.

Key words: Simple thermal model, Coefficient of Performance, First and second law performances, Nano refrigerants

1. Introduction

The refrigeration is a technology which absorbs heat at low ambient temperature and provides temperature below the surrounding by rejecting heat energy to the surroundings at higher temperature. Simple vapour 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 vapour compression refrigeration 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 system. The systems under vapour compression technology consume huge amount of electricity, this problem can be solved by improving performance of system. The thermal performance of systems based on vapour compression refrigeration technology can be improved by following:

The first law thermal performance of refrigeration system is evaluated in term of coefficient of performance (COP) which is the ratio of refrigeration effect to the net work input given to the system. Therefore the coefficient of performance (COP) of vapour compression refrigeration system can be improved either by increasing evaporator load (i.e. Refrigeration effect) or by reducing high grade energy in terms of exergy of fuel (i.e. work input) given to the system.

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

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can be eliminated by adopting multi-stage expansion where the flash vapours is removed after each stage of expansion as a consequence there will be increase in cooling capacity and reduce the size of the evaporator.

2. Literature Review

Kumar et al. (1989) carried out energy and exergy analysis of vapour compression refrigeration system by the use of exergy-enthalpy diagram. They did first law analysis or energy analysis for calculating the coefficient of performance and exergy analysis for evaluation of various losses occurred in different components of vapour compression cycle using R11 and R12 as refrigerants [1]. Nikolaidis and Probert (1998) studied analytically that change in evaporator and condenser temperatures of two stage vapour compression refrigeration plant using R22 add considerable effect on plant irreversibility. They suggested that there is need for optimizing the conditions imposed upon the condenser and evaporator [2]. Yumrutas et al. (2002) carried out exergy analysis based investigation of effect of condensing and evaporating temperature on vapour compression refrigeration cycle in terms of pressure losses, COP, second law efficiency and exergy losses. Variation in temperature of condenser as well as have negligible effect on exergy losses of compressor and expansion valve, also first law efficiency and exergy efficiency increase but total exergy losses of system decrease with increase in evaporator and condenser temperature [3].

Halimic et al. (2003) is also compared thermal performance of R401A, R290 and R134A with R12 by using in vapour compression refrigeration system, which is originally designed for R12.Due to similar performance of R134a in comparison with R12,R134A can be replaced in the same system without any medication in the system components. But in reference to greenhouse impact R290 presented best results [4]. Cabello et al. (2007) observed the effect of operating parameters on COP, work input and cooling capacity of single-stage vapour compression refrigeration system. There is great influence on energetic parameters due change in suction pressure, condensing and evaporating temperatures [5]

Cabello et al. (2004) effect of condensing pressure, evaporating pressure and degree of superheating was experimentally investigated on single stage vapour compression refrigeration system using R22, R134a and R407C. It was observed that mass flow rate is greatly affected by change in suction conditions of compressor in results on refrigeration capacity because refrigeration capacity depended on mass flow rate through evaporator. It was also found that for higher compression ratio R22 gives lower COP than R407C [6]. Ahamed et al. (2011) suggested the use of hydrocarbons and mixture of hydrocarbons and R134a in vapour compression refrigeration system and found that compressor shows much higher exergy destruction as compared to rest of components of vapour compression refrigeration system and this exergy destruction can be minimized by using of nanofluid and nano lubricants in compressor [7]. Ahamed et al. (2012) carried out the experimental investigation of domestic refrigerator with hydrocarbons (isobutene and butane) by energy and exergy analysis. They reached 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 and found that compressors shows highest system defect (69%) among components of considered system [8]. Spatz and Motta (2004) suggested the replacement of R12 with R410a through experimental investigation of medium temperature vapour 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 [9].

Han et al. (2007) conducted the experiment under different working conditions and found that there could be replacement of R407C in vapour 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 [10].

Getu and Bansal (2008) also optimized the design and operating parameters of like condensing temperature, sub-cooling temperature, evaporating temperature, superheating temperature and temperature difference in cascade heat exchanger R744-R717 cascade refrigeration system. A regression analysis was also done to obtain optimum thermodynamic parameters of same system [11].

Padilla et al. (2010) carried out the exergy analysis of domestic vapour compression refrigeration system with R12 and R413A was done. They concluded that performance in terms of power consumption, irreversibility and exergy efficiency of R413A is better than R12, so R12 can be replaced with R413A in domestic vapour compression refrigeration system [12].

Mohanraj et al. (2009) carried out the experimental investigation of domestic refrigerator they arrived on conclusions that under different environmental temperatures COP of system using mixture of R290 and R600a in the ratio of 45.2: 54.8 by weight showing up to 3.6% greater than same system using R134a, also discharge temperature of compressor with mixture of R290 and R600a is lower in the range of 8.5-13.4 K than same compressor with R134a [13].Bolaji et al. (2011) carried out the experimentally comparative analysis of R32, R152a and R134a refrigerants in vapour 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 [14].

Stanciu et al. (2011) carried out numerical and graphical investigation on one stage vapour compression refrigeration system for studied 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 [15].

Eastman et al. (1996) found the pool boiling heat transfer characteristics of R11 refrigerant with TiO_2 nanoparticles and showed that the heat transfer enhancement reached 20% at a particle loading of 0.01 g/L [16].
Kang et al. (2006) is found 75% thermal conductivity enhancement for ethylene glycol with 1.2% (v/v) diamond nanoparticles between 30 and 50 nm in diameter. Despite these remarkable results, some researchers have measured the thermal conductivity of nanofluids and have found no anomalous results [17].
Liu et al. (2006) found the effects of carbon nanotubes (CNTs) on the nucleate boiling heat transfer of R123 and HFC134a refrigerants. Authors reported that CNTs increase the nucleate boiling heat transfer coefficients for these refrigerants. Authors noticed large enhancements of up to 36.6% at low heat fluxes of less than 30 kW/m2. Thus, the use of nanoparticles in refrigeration systems is a new, innovative way to enhance the efficiency and reliability in the refrigeration system [18].
Elcock (2007) observed that TiO_2 nanoparticles can be used as additives to enhance the solubility of the mineral oil with the hydrofluorocarbon (HFC) refrigerant. Authors also reported that refrigeration systems using a mixture of HFC-134a and mineral oil with TiO_2 nanoparticles appear to give better performance by returning more lubricant oil to the compressor with similar performance to systems using HFC-134a and POE oil [19].
Hindawi (2009) carried out an experimental study on the boiling heat transfer characteristics of R22 refrigerant with Al_2O_3 nanoparticles and found that the nanoparticles enhanced the refrigerant heat transfer characteristics with reduced bubble sizes [20].
Reddy et al. (2012) carried out numerical analysis of vapour compression refrigeration system using R134a, R143a, R152a, R404A, R410A, R502 and R507A and discussed the effect of evaporator temperature, degree of sub-cooling at condenser outlet, superheating of evaporator outlet, vapour liquid heat exchanger effectiveness and degree of condenser temperature on COP and exergetic efficiency. They reported that evaporator and condenser temperature have significant effect on both COP and exergetic efficiency and also found that R134a has the better performance while R407C has poor performance in all respect [21].
Mahbubul et al. (2013) carried out the thermos-physical properties, pressure drop and heat transfer performance of Al_2O_3 nanoparticles suspended in R-134a was investigated .To determine the thermal conductivity and viscosity of the nano-refrigerants for the nanoparticle concentrations of 1 to 5 vol.% existing model was studied . The thermal conductivity of Al_2O_3/R-134a nano-refrigerant increased with the augmentation of particle concentration and temperature however, decreased with particle size intensification. In addition, the results of viscosity, pressure drop, and heat transfer coefficients of the nano-refrigerant show a significant increment with the increase of volume fractions. The frictional pressure drop shows rapid increment of more than 3 vol.% with particle volume fraction, and the pumping power increases with particle concentration similar to pressure drop increment. The pumping power is proportional to the pressure drop of nano-refrigerant. Based on the literature it was observed that researchers have gone through detailed first law analysis in terms of coefficient of performance and second law analysis in term of exergetic efficiency of simple vapour compression refrigeration system with single evaporator. Authors also analyzed the effect of Nano fluids on simple vapour compression cycle in the term of pool boiling, COP, Thermal conductivity etc [22]..
Selladurai and Saravanakumar (2013) compared thermal performance between R134a and R290/R600a mixture on a domestic refrigerator which is originally designed to work with R134a and found that R290/R600a hydrocarbon mixture showed higher COP and exergetic efficiency than R134a. In their analysis highest irreversibility obtained in the compressor compare to condenser, expansion valve and evaporator [23].
Hao et al. (2009) studied the heat transfer characteristics of refrigerant-based Nano fluids flow boiling inside a smooth tube at different nanoparticles concentration, mass fluxes, heat fluxes, and inlet vapor qualities to analyze the influence of nanoparticles on the heat transfer characteristics of refrigerant-based Nano fluid flow boiling inside the smooth tube and presented a correlation for predicting the heat transfer coefficient of refrigerant-based Nano fluid and the predicted heat transfer coefficients agree with 93% of the experimental data and found 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%. it was observed that the reduction of the boundary layer height due to the disturbance of nanoparticles enhances the heat transfer [24].
Hao et al. (2010) investigated experimentally the nucleate pool boiling heat transfer characteristics of refrigerant/oil mixture with diamond nanoparticles. The refrigerant was R113 and the oil was VG68. The results indicate that the nucleate pool boiling heat transfer coefficient of R113/oil mixture with diamond nanoparticles is 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. Authors developed a correlation for predicting the nucleate pool boiling heat transfer coefficient of refrigerant/oil mixture with nanoparticles and it agrees well with the experimental data of refrigerant/oil mixture with nanoparticles [25].
Hwang et al. (2006) observed that the thermal conductivity enhancement of nanofluids is greatly influenced by thermal conductivity of nanoparticles and base fluid. For instance, thermal conductivity of water based nanofluid with multiwall carbon nano tube has noticeably higher thermal conductivity compared to SiO_2 nanoparticles in the same base fluid [26].
Lee et al. (2008) observed Nano fluids thermal conductivity effect by pH level and addition of surfactant during Nano fluids preparation stage. Better dispersion of nanoparticles is

achieved with addition of surfactant such as sodium dodecylbenzene sulfonate and found the optimum combination of pH and surfactant leads to 10.7% thermal conductivity enhancement of 0.1% Cu/H2O Nano fluids [27].

Wang et al. (2006) did an experimental study of the boiling heat transfer characteristics of R22 refrigerant with Al2O3 nanoparticles and found that the nanoparticles enhanced the refrigerant heat transfer characteristics with reduced bubble sizes that moved quickly near the heat transfer surface [28].

Li et al. (2006) observed the pool boiling heat transfer characteristics of R11 refrigerant with TiO2 nanoparticles and showed that the heat transfer enhancement reached 20% at a particle loading of 0.01 g/L [29].

Peng et al. (2009) find out the influence of nanoparticles on the heat transfer characteristics of refrigerant-based Nano fluids flow boiling inside a horizontal smooth tube, and presented a correlation for predicting heat transfer performance of refrigerant based Nano fluids. For the convenience of preparing refrigerant based Nano fluids, R113 refrigerant and CuO nanoparticles were used by the authors. Authors reported that the heat transfer coefficient of refrigerant-based Nano fluids is higher than that of pure refrigerant, and the maximum enhancement of heat transfer coefficient found to be about 29.7% [30].

Kumar and Elansezhian (2014) experimentally analyzed the effect of concentration of Nano Zno ranges in the order of 0.1%, 0.3% and 0.5% v with particle size of 50 nm on various parameters like COP, suction temperature, input power and pressure ratio with 152a as working fluid. In simple vapour compression refrigeration system. They found that maximum COP of 3.56 and 21% reduction of power input was obtained with 0.5% v of ZnO. Pressure ratio decreases with increase in Nano Zno concentration [31]. Xuan and Chen (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 [32]

Jiang et al. (2009) also found the effect of added that thermal conductivity of Nano fluids which depends on the nanoparticles size and temperature [33].

Jiang et al. (2009) found experimentally the thermal conductivities of carbon nanotube (CNT) Nano refrigerants are much higher than those of CNT–water Nano fluids or spherical nanoparticle–R113 Nano refrigerants. Authors reported that the smaller the diameter of CNT larger the thermal conductivity enhancement of CNT Nano refrigerant [34].

Yoo et al. (2007) also found that surface to volume ratio of nanoparticles is a dominant factor that influences the Nano fluids thermal conductivity rather than nanoparticles thermal conductivity. Surface to volume ratio is increased with smaller sizes of nanoparticles [35].

Choi et al. (2001) observed 150% thermal conductivity enhancement of poly (a-olefin) oil with the addition of multiwall carbon nanotubes (MWCNT) at 1% volume fraction [36]. Yang (2006) found a 200% thermal conductivity enhancement for poly (a-olefin) oil containing 0.35% (v/v) MWCNT. It is important to note that this thermal conductivity enhancement was accompanied by a three order of magnitude increase in viscosity [37].

Trisaksri and Wongwises (2009) studied the nano particles TiO_2 mixed in HCFC 1416 in a cylindrical copper tube and found that the nucleate pool boiling heat transfer deteriorated with increasing nanoparticle concentrations especially at higher heat fluxes [38].

Eastman et al. (2001) found a 40% thermal conductivity enhancement for ethylene glycol with 0.3% (v/v) copper nanoparticles (10 nm diameter), although the authors added about 1% (v/v) thioglycolic acid to aid in the dispersion of the nanoparticles. The addition of this dispersant yielded a greater thermal conductivity than the same concentration of nanoparticles in the ethylene glycol without the dispersant [39]. Mastani Joybari et al. (2013) performed experimental investigation on a domestic refrigerator originally manufactured to use of 145g of R134a and concluded the exergetic defect occurred in compressor was highest as compare to other components and through their analysis it has been found that instead of 145g of R134a if 60g of R600a is used in the considered system gave same performance which ultimately result into economic advantages and reduce the risk of flammability of hydrocarbon refrigerants [40].

Wu et al. (2008) found the pool boiling heat transfer was enhancement at low nanoparticles concentration of TiO2 in R11 but deteriorated under the condition of high nanoparticles concentration [41].

Anand and Tyagi (2012) carried out detailed exergy analysis of two ton of refrigeration window air conditioning test rig with R22 as working fluid and reached to the conclusions that irreversibility in system components will be highest when the system is 100% charged and lowest when 25% charged and irreversibility in compressor is highest among system components [42].

Arora and Kaushik (2008) developed numerical model of actual vapour compression refrigeration system with liquid vapour heat exchanger and did energy and exergy analysis on the same in the specific temperature range of evaporator and condenser and concluded that R502 is the best refrigerant compare to R404A and R507A, compressor is the worst and liquid vapour heat exchanger is best component of the system. Jana et al. (2006) computed thermal conductivity of a similar copper containing Nano fluid, except the base fluid was water and laurate salt was used as a dispersant and observed a 70% thermal conductivity enhancement for 0.3% (v/v) cu nanoparticles in water. Researchers did not go through the computation of irreversibility in terms of exergy destruction ratio (EDR) using second law analysis of multiple evaporators systems with multi-stage expansion in vapour compression refrigeration systems. Researchers did not go through computing irreversibility's occurred in the each component in terms of exergy destruction using entropy generation and second law analysis of single and multi-stage vapour compression refrigeration systems by using of Nano fluid in the secondary circuit of evaporator or by using of Nano fluid in the secondary circuit of condenser [43].

To improve thermal performance of vapour compression refrigeration systems (both single and multiple evaporator system) by improving:

According to first law of thermodynamic energetic efficiency /COP is defined as the ratio of net refrigeration effect to the per unit power consumed. First law analysis restricted to calculate only coefficient of performance of the systems and second law efficiency. The concept of exergy was given by second law of thermodynamics. Second law efficiency is the exergy of the heat abstracted in to the evaporators from the space to be cooled and exergy of fuel is actual compressor work input and reduction of system defect by using of nanoparticles in vapour compression refrigeration systems which results into reduction of work input.

Table-1(a) Effect of compressor speed on Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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 Efficiency (COP)	Exergy Destruction Ratio(EDR)	Exergetic Efficiency	Evaporator Temperature (°C)	Condenser Temperature (°C)	Evaporator overall heat transfer coefficient (W/m²K)	Condenser overall heat transfer coefficient (W/m²K)	Evaporator Pressure (bar)
2500	3.631	3.249	0.2353	6.861	325.6	1314.24	708.26	3.731
2600	3.583	3.234	0.2362	6.574	326.0	1312.60	709.11	3.695
2700	3.542	3.219	0.2370	6.310	326.4	1313.30	710.38	3.661
2800	3.507	3.203	0.2379	6.066	326.8	1315.94	712.02	3.631
2900	3.477	3.186	0.2389	5.841	327.1	1320.21	714.01	3.602
3000	3.451	3.169	0.2399	5.631	327.1	1325.84	716.29	3.576

Table-1(b) Effect of compressor speed on Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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 Efficiency (COP)	Condenser Pressure (bar)	Isentropic Efficiency of Compressor	Volumetric Efficiency of Compressor	Condenser Liquid_LMTD	Condenser Vapour_LMTD	Evap-LMTD	Q_Cond_Liquid (W)	Q_Cond_vapour (W)
2500	3.631	14.02	0.7860	0.6537	32.82	16.67	12.91	427.9	34.31
2600	3.583	14.16	0.7924	0.642	33.14	16.83	13.1	434.9	39.85
2700	3.542	14.29	0.7991	0.6409	33.42	16.96	13.27	441.9	35.29
2800	3.507	14.42	0.8060	0.6348	33.67	17.07	13.41	448.8	35.65
2900	3.477	14.55	0.8131	0.6289	33.89	17.17	13.54	455.7	35.93
3000	3.451	14.67	0.8203	0.6232	34.07	17.24	13.65	462.5	36.13

Table-1(c) Effect of compressor speed on Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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 Efficiency (COP)	Exergy Destruction Ratio(EDR)	Exergetic Efficiency	Evaporator Load (W)	Condenser Heat rejected (W)	Compressor Work (W)
2500	3.631	3.249	0.2353	365.40	462.2	100.6
2600	3.583	3.234	0.2362	370.3	469.8	103.3
2700	3.542	3.219	0.2370	375.2	477.2	105.9
2800	3.507	3.203	0.2379	380.1	484..5	108.4
2900	3.477	3.186	0.2389	384.9	491.6	110.7
3000	3.451	3.169	0.2399	389.7	498.6	112.9

Table-1(d) Effect of evaporator Mass flow rate of brine on Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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 Efficiency (COP)	Exergy Destruction Ratio(EDR)	Exergetic Efficiency	Reynold $Number_{\_Brine}$	Re_23	Re_Cap	Rem
2500	3.631	3.249	0.2353	104.3	180907	25045	$1.407X10^6$
2600	3.583	3.234	0.2362	104.3	187581	25451	$1.407X10^6$
2700	3.542	3.219	0.2370	104.3	194088	25858	$1.407X10^6$
2800	3.507	3.203	0.2379	104.3	200428	26265	$1.407X10^6$
2900	3.477	3.186	0.2389	104.3	206601	26671	$1.407X10^6$
3000	3.451	3.169	0.2399	104.3	212608	27074	$1.407X10^6$

Table-2(a) Effect of evaporator Mass flow rate of brine on Performance of Vapour compression Refrigeration System with Nano Particle (Al_2O_3) 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=2.0 Bar

Evaporator Mass flow rate of brine (Kg/sec)	First law Efficiency (COP)	System Exergy Destruction Ratio (EDR)	System Exergetic Efficiency	Condenser Temperature (K)	Evaporator Temperature (°C)	Outlet water Condenser Temperature (°C)	Outlet brine Evaporator Temperature (°C)	System Exergy Destruction Ratio based on input
0.007	3.477	3.186	0.2389	327.1	5.841	41.69	13.86	0.7611
0.008	3.549	3.277	0.2338	327.5	6.583	42.02	15.19	0.7662
0.009	3.609	3.357	0.2295	327.9	7.179	42.29	16.27	0.7705
0.010	3.658	3.427	0.2259	328.2	7.669	42.52	17.18	0.7741

Table-2(b) Effect of evaporator Mass flow rate of brine on thermal Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) mixed with R-718, compressor speed(rpm)=2900, m_{water} (kg/sec)=0.008, $L_{\_eva}$=0.72m, $L_{\_Cond}$=1.2m, $P_{\_brine}$=$P_{_wate}$r=2.0 Bar

Evaporator Mass flow rate of brine (Kg/sec)	First law Efficiency (COP)	Second Law Efficiency/ Exergetic Efficiency	Exergy of product (W)	Exergy of fuel (W)	Isentropic Efficiency of Compressor	Volumetric Efficiency of Compressor
0.007	3.477	0.2389	26.45	110.7	0.8131	0.6289
0.008	3.549	0.2338	26.04	111.4	0.8222	0.6313
0.009	3.609	0.2295	25.68	111.9	0.8297	0.6332
0.010	3.658	0.2259	25,36	108.3	0.8360	0.6349

Table-2(c) Effect of evaporator Mass flow rate of brine on Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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=2.0 Bar

Evaporator Mass flow rate of brine (Kg/sec)	First law Efficienc y (COP)	Evaporator overall heat transfer coefficient (W/m^2K)	Condenser overall heat transfer coefficient (W/m^2K)	Evaporator Pressure (bar)	Condenser Pressure (bar)	Evaporator Load (W)	Condenser Heat rejected (W)	Compressor Work (W)	Exergetic Efficiency
0.007	3.477	1320.21	714.01	3.602	14.55	384.9	491.6	110.7	0.2389
0.008	3.549	1342.87	722.63	3.696	14.70	395.3	502.7	111.4	0.2338
0.009	3.609	1361.93	729.54	3.772	14.83	403.8	511.7	111.9	0.2295
0.010	3.658	1378.26	735.19	3.835	14.93	410.9	516.2	108.3	0.2259

Table-2(d) Effect of evaporator Mass flow rate of brine on thermal performances of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) mixed with R-718, compressor speed (rpm)=2900, m_{water} (kg/sec)=0.008, $L_{\_eva}$=0.72m, $L_{\_Cond}$=1.2m, $P_{\_brine}$=$P_{\_water}$=2.0 Bar

Evaporator Mass flow rate of brine (Kg/sec)	First law Efficiency (COP)	Exergy Destruction Ratio(EDR)	Exergetic Efficiency	Reynold $Number_{\_Brine}$	Re_23	Re_Cap	Re_m
0.007	3.477	3.186	0.2389	104.3	206601	26671	$1.407X10^6$
0.008	3.549	3.277	0.2338	119.2	207155	27703	$1.407X10^6$
0.009	3.609	3.357	0.2295	134.10	207682	28558	$1.407X10^6$
0.010	3.658	3.427	0.2259	149.0	208170	29281	$1.407X10^6$

Table-3(a) Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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)	System Exergy Destruction Ratio based on input	Second Law Efficiency/ Exergetic Efficiency	Exergy of product (W)	Exergy of fuel (W)	Evaporator Temperature (K)	Condenser Temperature (°C)	Outlet water Condenser Temperature (°C)	Outlet brine Evaporator Temperature (°C)
0.007	3.379	0.7726	0.2274	25.53	112.3	6.212	328.7	43.65	14.04
0.008	3.477	0.7611	0.2389	26.45	110.7	5.841	327.1	41.69	13.86
0.009	3.557	0.7517	0.2483	27.16	109.4	5.581	325.9	40.14	13.71
0.010	3.625	0.7440	0.2560	27.73	108.3	5.344	324.9	38.89	13.59

Table-3(b) Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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)	System Exergy Destruction Ratio (EDR)	System Exergetic Efficiency	Evaporator overall heat transfer coefficient (W/m^2K)	Condenser overall heat transfer coefficient (W/m^2K)	Evaporator Pressure (bar)	Condenser Pressure (bar)	Isentropic Efficiency of Compressor	Volumetric Efficiency of Compressor
0.007	3.379	3.398	0.2274	1327.54	692.96	3.649	15.13	0.8198	0.6239
0.008	3.477	3.186	0.2389	1320.21	714.01	3.682	14.55	0.8131	0.6289
0.009	3.557	3.028	0.2483	1315.88	731.28	3.568	14.11	0.808	0.6328
0.010	3.625	2.906	0.2560	1313.34	745.71	3.541	13.76	0.8041	0.6359

Table-3(c) Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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 Load (W)	Condenser Heat rejected (W)	Compressor Work (W)
0.007	3.379	3.398	0.2274	379.4	487.5	112.3
0.008	3.477	3.186	0.2389	384.9	491.6	110.7
0.009	3.557	3.028	0.2483	389.3	494.8	109.4
0.010	3.625	2.906	0.2560	392.7	497.4	108.3

Table-3(d) Performance of Vapour compression Refrigeration System by using HFO-1234yf in the primary circuit and Nano Particle (Al_2O_3) 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)	Condenser Liquid portion LMTD (K)	Condenser Vapour portion LMTD (K)	Evaporator LMTD (K)	$Q_{\_Cond\_Liquid}$ (W)	$Q_{\_Cond\_Vapour}$ (W)
0.007	3.379	35.15	16.82	13.27	451.4	36.02
0.008	3.477	33.89	17.17	13.54	455.7	35.93
0.009	3.557	32.73	17.45	13.74	459.0	35.84
0.010	3.625	31.8	17.68	13.89	461.6	35.75

3. Results and Discussion

Tables-1(a)-(1(d) showing the variation of compressor speed with first and second law Performances of Vapour compression Refrigeration System with Nano Particle (Al_2O_3) mixed with R-718 in the secondary circuit of evaporator and it was observed that when compressor speed is increasing, first law efficiency in terms of COP along with system exergy destruction ratio (EDR), volumetric efficiency of compressor, Evaporator Pressure, Evaporator overall heat transfer coefficient (W/m^2K) Condenser overall heat transfer coefficient (W/m^2K) are decreasing and second law efficiency (i.e exergetic efficiency), compressor isentropic Efficiency, Condenser Pressure , L.M.T.D. of condenser Liquid , L.M.T.D. of condenser Vapour and L.M.T.D. of Evaporator is increasing. The developed model is also predicting unknown the condenser temperature , which is increasing and decreasing evaporator refrigerant temperature. Similarly increasing compressor speed is the increasing condenser liquid and vapour heat and condenser Reynold and Capillary Reynold numbers for constant Reynold number of evaporator refrigerant and brine Reynold numbers. Similarly Table-2(a)-2(d) shows the variation of Evaporator Mass flowrate of brine (Kg/sec) with first and second law Performances of Vapour compression Refrigeration System with Nano Particle (Al_2O_3) mixed with R-718 in the secondary circuit of evaporator and it was observed that when Evaporator Mass flow rate of brine (Kg/sec) is increasing, first law efficiency in terms of COP, compressor isentropic Efficiency along with system exergy destruction ratio (EDR), volumetric efficiency of compressor, Evaporator Pressure, Evaporator overall heat transfer coefficient (W/m^2K) Condenser overall heat transfer coefficient (W/m^2K) are increasing and second law efficiency (i.e. exergetic efficiency), exergy of Product , exergy of fuel, Condenser Pressure , L.M.T.D. of condenser Liquid , L.M.T.D. of condenser Vapour and L.M.T.D. of Evaporator is increasing. The developed model is also predicting unknown the condenser temperature , which is increasing and decreasing evaporator refrigerant temperature. Similarly increasing Evaporator Mass flow rate of brine is the increasing condenser liquid and vapour heat and condenser Reynold and Capillary Reynold number Reynold number of evaporator refrigerant and brine Reynold numbers are also increasing. Tables-3(a)-3(d) shows the variation of Condenser Mass flowrate of brine (Kg/sec) with first and second law Performances of Vapour compression Refrigeration System with Nano Particle (Al_2O_3) mixed with R-718 in the secondary circuit of evaporator and it was observed that when Condenser Mass flow rate of brine (Kg/sec) is increasing, first law efficiency in terms of COP, compressor isentropic Efficiency along with volumetric efficiency of compressor, Evaporator Pressure, Condenser overall heat transfer coefficient (W/m^2K) are increasing and second law efficiency (i.e exergetic efficiency), exergy of Product , exergy of fuel, Condenser Pressure , L.M.T.D. of condenser Vapour and L.M.T.D. of Evaporator is increasing while decreasing system exergy destruction ratio (EDR) and Evaporator overall heat transfer coefficient (W/m^2K), Condenser evaporator Temperatures, outlet water condenser temperature, outlet brine evaporator temperature L.M.T.D. of condenser Liquid . The developed model is also predicting unknown the condenser temperature , which is increasing and decreasing evaporator refrigerant temperature. Similarly increasing Condenser Mass flow rate of condenser water , the decreasing condenser liquid and vapour heat and condenser Reynold and Capillary Reynold number Reynold number of evaporator refrigerant and brine Reynold numbers are also increasing.

4. Conclusion

Following conclusions were drawn

(i) The first law performance in terms of COP is decreased and increased second law efficiency by increasing compressor speed.

(ii) The first law performance in terms of COP and system exergy destruction ratio (EDR) based on output increased and decreased second law efficiency by increasing evaporator mass flow rate of brine,

(iii) The first law performance in terms of COP and second law efficiency is increased and decreased system exergy destruction ratio (EDR) based on output by increasing condenser mass flow rate of water.

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