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Methods for Improving Thermodynamic Performance of Vapour Compression Refrigeration Systems using Thirteen Ecofriendly Refrigerants in Primary Circuit and Tio2 Nano Particles Mixed with R718 used in Secondary Evaporator Circuit for Reducing Global Warming and Ozone Depletion

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ABSTRACT

The methods for improving first law and second law efficiency have been considered in this paper by using water as secondary coolent in evaporator with nano particles such als Al2O3 and TiO2 mixed R718 refrigerant is investigated in this paper. Detailed energy and exergy analysis of multi-evaporators at different temperatures in the vapour compression refrigeration systems have been done in terms of performance parameter for R507a, R125, R134a, R290, R600, R600a, R410a, R407c, R404a and R152a refrigerants.

The numerical computations have been carried out for both systems. The use of nano particles improves the first law and second law performance significantly. The best performance is found using R152a and worst performance is observed using R410a. Due to flammable nature of R290, R600, R600a and R152a The results were compared by using water in secondary circuit with nano refrigerants and without nano particles used and it was found that use of nano particles improves thermal performances.

The first law performance improvement in terms of COP and second law performance in terms of exergetic efficiency (rational efficiency) using TiO2 is better than using Al2O3 with R718 refrigerant in the secondary evaporator circuit.

Keywords: *Performance Improvement Vapour; Compression Refrigeration Systems; Energy and Exergy Analysis; First and Second Law Analysis; Nano Refrigerants*.

1.0 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 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 performance of system. The use of nano particles improves the first law and second law performance significantly. The best performance is found using R152a and worst performance is observed using R410a. Due to flammable nature of R290, R600, R600a and R152a

2.0 Literature Review

Vapour compression refrigeration system based applications make use of refrigerants which are responsible for greenhouse gases, global warming and ozone layer depletion. Montreal protocol was signed on the issue of substances that are responsible for depleting Ozone layer and discovered how much consumption and production of ozone depletion substances took place during certain time period for both developed and developing countries.

Another protocol named as Kyoto aimed to control emission of green house gases in 1997. The relationship between ozone depletion potential and

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global warming potential is the major concern in the field of GRT (green refrigeration technology) so Kyoto proposed new refrigerants having lower value of ODP and GWP. Internationally a program being pursued to phase out refrigerants having high chlorine content for the sake of global environmental problems .Due to presence of high chlorine content ,high global warming potential and ozone depletion potential after 90's CFC and HCFC refrigerants have been restricted. Thus, HFC refrigerants are used nowadays, showing much lower global warming potential value, but still high with respect to non-fluorine refrigerants. Lots of research work has been done for replacing "old" refrigerants with "new" refrigerants Ahamed et al. [1] emphasized on use of hydrocarbons and mixture compressor shows much higher exergy destruction as compared to rest of components in the vapour compression refrigeration system and this exergy destruction can be minimized by using of nanofluid and nanolubricants in compressor. Anand [2] did detailed exergy analysis of 2 ton of refrigeration capacity 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

Arora et al.[3] 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 compared to R404A and R507A and compressor is the worst component and liquid vapour heat exchanger is best component of the system in case of exergy transfer.

Bolaji et al. [4] had done experimentally comparative analysis of R32, R152a and R134a refrigerants in vapour compression refrigerator and concluded that R32 shows lowest performance whereas R134a and R152a showing nearly same performance but best performance was obtained of system using R152a

Chopra et.al (5) carried out analysis of energetic and exergetic based comparison Multiple Evaporators with compound compression and flash intercooler with individual and multiple throttle valves and find out the effect of flash intercooler on second law performances.

Han et al. [6] Under different working conditions experimental results revealed 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.

Mishra et al. [7-9] performed 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 subcooling 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 R404a has poor performance in all respect.

Saravana kumar [10] compared the 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.

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. Researchers did not go through the irreversibility analysis (second law analysis) of followings

(i) Simple VCR with nano particles used as secondary evaporator circuit in the water cooled evaporator
(ii) Detailed analysis of vapour compression refrigeration systems using thirteen ecofriendly refrigerants with effect of nano particles for improving their first and second law performances

This paper mainly deals with effect of nano particles (TiO2 and Al2O3) mixed with R718 refrigerants was used in the water cooled evaporator for improving thermal performance of vapour compression refrigeration systems for keeping evaporator size constant due to enhancing heat transfer coefficient in the evaporator

3.0 Performance Evaluatio

The computation modeling of vapor compression refrigeration systems was carried out with the help of EES for first and second law analysis in terms of energetic analysis i.e. COP (First law analysis) and exegetic analysis in terms of exergetic efficiency, exergy destruction ratio (EDR). In this analysis we assumed negligible pressure losses and heat losses.

The comparative performance for condenser temperature varying between 320K to 330K with increment of 2 and evaporator temperature is varying from 265K to 281 K with increment of 4. The energy and exergy change in vapour compression refrigeration cycle have been calculated for various eco friendly refrigerants such asR125, R507, R-134a, R404a, R410a, R407c R-290 (propane), R600 (butane), R-600a (isobutene) for environmental temperature of 298K. and results are shown The performance of vapour compression refrigeration system using ecofriendly refrigerants in the primary circuit and TiO2 nano particles mixed in R718 is used in the secondary circuit of evaporators are shown in Table-(1). to Table-(3) respectively.and it was found that maximum First law efficiency in terms of COP and maximum second law efficiency in terms of exergetic efficiency using ecofriendly R152a and minimum first and second law performance using R410a. Due to flammable nature of R152a, and R290, R600 and R600a which can be used by considering safety measure gives better performance. The R407c R134a and R404a also gives good performance for replacing R502, R11 and R12 and R22 which produces global warming and ozone depletion performance have been obtained usingR-152a ecofriendly refrigerant and worst performances were found using R-410a ecofriendly refrigerants. Due to flammable nature of R290, R600, R600a and R152a it is recommended that R407c and R134a is suitable for industrial and commercial applications.

Table: 1. Performance Prediction of Vapour Compression Refrigeration System Using TiO2 in R718 in the Secondary Circuit and Ecofriendly Refrigerants in Primary Circuit for Condenser Temperature 48oC and Evaporator Temperature of -5oC

Refrigerant	COP	ETA_II	EDR
R404a	4.36	0.4831	1.694
R410a	2.14	0.2396	6.836
R134a	4.36	0.4880	1.659
R152a	5.169	0.5786	1.143
R507a	4.328	0.4844	1.685
R407c	4.736	0.5301	1.391
R290	4.826	0.5402	1.335
R600	3.605	0.4036	2.429
R600a	4.009	0.4480	1.969
R125	4.03	0.4511	1.949

Table: 2. Variation of Performance Parameters with Condenser Temperature in the Vapour Compression Refrigeration System Using R-134a in Primary Circuit and Water in Secondary Circuit

Condenser temp. (°C)	C.O.P.	η second	EDR
47	2.919	0.3013	0.6987
49	2.825	0.2859	0.7141
51	2.736	0.2713	0.7287
53	2.652	0.2575	0.7425
55	2.572	0.2442	0.7558
57	2.497	0.2316	0.7684

Table: 2. Explaining the variation of condenser temperature with first and second law performance parameters and it was observed that increasing condenser temperature reduces first and second law performances and also increases exergy destruction ratio while Table-3shows the variation of evaporator temperature with first and second law performance parameters. and it was found that first law performance in terms of coefficient of performance and second law efficiency increases and exergy destruction ratio of system decreases

Table: 3. Variation of Performance Parameters with Evaporator Temperature in the Vapour Compression Refrigeration System Using R-134a in Primary Circuit and Water in Secondary Circuit

Evaporator temp. (°C)	C.O.P.	η second	EDR
-8	2.481	0.3105	0.6895
-4	2.767	0.3000	0.7000
0	3.096	0.2854	0.7146
4	3.467	0.2649	0.7451
8	3.880	0.2369	0.7631
12	4.327	0.1998	0.8002

4.0 Conclusions and Recommendations

In this paper, first law and second law analysis of vapour compression refrigeration systems using multiple evaporators and single compressor and single expansion valve with ecofriendly refrigerants in the system and R718 (water used in secondary circuit with and without nano particles mixed with water used as refrigerant) have been presented. The conclusions of the present analysis are summarized below:

1. The First law efficiency (COP) and Second law efficiency (Exergetic efficiency) of vapour compression refrigeration systems using R718 mixed with nano particles gives better performance is than without nano particles used in the secondary circuit of water cooled evaporator for above mentioned ecofriendly refrigerants.
2. The First law efficiency (COP) and Second law efficiency (Exergetic efficiency) of vapour compression refrigeration systems using R152a refrigerant is higher but is has flammable nature similar to hydrocarbons then safety measures to be taken while using R152a or hydrocarbons (R290, R600 and R600a)
3. The first law performance in terms of Coefficient of performance and second law performance in terms of exergetic efficiency improvesusing TiO2 in the secondary evaporator circuit as compared to Al2O3 in the secondary circuit
4. COP and exergetic efficiency for R507a and R134a are nearly matching the same values.are better than that for R125.
5. For practical applications R-407c, R134a and R404a, R125 can be used recommended because it is easily available in the market has second law efficiency slightly lesser than R-152a which was not applicable for commercial applications due to flammable nature and R717 is also toxic nature..
6. The first law performance improvement in terms of COP and second law performance in terms of exergetic efficiency (rational efficiency) using TiO2 is better than using Al2O3 with R718 refrigerant in the secondary evaporator circuit.

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Nomenclature

COP	Coefficient of Performance (Non-Dimensional)
VCR	Vapour Compression Refrigeration
CFC	Chlorofluorocarbon
HCFC	Hydro Chlorofluorocarbon
Q	Rate of Heat Transfer (kW)
W	Work Rate (kW)
T	Temperature (K)
Δ	Efficiency Defect (Non-Dimensional)
Δ	sc Degree of Sub cooling
EP	Exergy Rate of Product (kW)
EV	Expansion Valve
h	Specific Enthalpy (kJ/kg)
P	Pressure (kPa)
IR	Irreversibility (kW)
Ex	Exergy Rate of Fluid (kW)
M	Mass Flow Rate (kg/s)
S	Specific Entropy (kJ/kgK)
EF	Exergy Rate of Fuel (kW)
EL	Exergy Loss Rate (kW)
η	Efficiency (Non-Dimensional)
r	Refrigerant, Space to be Cooled
ex	Exergetic
EP	Evaporator
e	Evaporator
ev	Expansion Valve
c	condenser