International Journal of Advance Research and Innovation
Vol. 4(2), Apr-Jun 2016, pp. 85-90
Doi: 10.51976/ijari.421613

Article Info
Received: 20 Jan 2016 | Revised Submission: 10 Feb 2016 | Accepted: 28 Feb 2016 | Available Online: 15 Mar 2016

Methods for Improving Thermodynamic Energy and Exergy 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 energy and exergetic efficiency have been considered in this paper by using water as secondary coolent in evaporator with nano particles ofAl2O3 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 energy and exergy performance significantly. The best thermodynamic performance is found using R152a and worst performance is observed using R410a.

Due to flammable nature of R290, R600, R600a and R152a , the R134a is recommended for domestic applications. 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 significantly The energy performance improvement in terms of COP and exergetic 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; Vapor Compression Refrigeration Systems; Energy and Exergy Analysis; Nano Refrigerants Sustainable Technologies; Green Technologies; Sustainable Development, Alternative Refrigerants; Eco Friendly Refrigerants; Reduction in Global Warming; Reduction in Ozone Depletion.*

1.0 Introduction

The exploitation of the vast natural resources through progressive development of science, engineering and technology that has brought about the vast changes in the civilization and society from the stone age to the present high technology era. In facts, the mad race for industrialization and economic development has resulted in over exploitation of natural resources, leading to a situation where the two worlds of mankind- the biosphere, lithosphere and hydrosphere of his inheritance and the techno sphere of his creation, are out of balance with each other, indeed on a collision path. To facilitate optimal utilization of finite natural resources for ensuring a sustainable benefit steam for better quality of life on the one hand and to simultaneously keep in mind the conservation of natural resources on the other hand, it is essential that the technology conservation process must be made as efficient as possible.

Therefore sustainable economic development depends on the careful choice of technologies and judicious management of resources for productive activities to satisfy the changing human needs without degrading the environment or depleting the natural resources base. The efforts under the Montreal protocol to protest the OZONE layer, the alternative refrigerants have been proposed as a substitutes for ozone depleting substances. HFCs (Hydrofluoro carbons) PFCs (Perfluro carbons) have zero ODP

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potential but they are producer of green house gases and are subjected to limitation and reduction commitments under UNFCC(United Nations Framework Convention on Climate change). With the entry into force of Kyoto protocol on 16th February 2005 developed countries have already planning and implementing rational measures intended to contribute towards meeting green house gas reduction targets during the first commitment period of Kyoto protocol (2008-2012). The countries have also started together with developing countries to size up projects that qualify under Kyoto clean development mechanism. As what lies beyond 2012.

All Governments will work together over next few years to decide on future intergovernmental action on the climate change. In this light, it is vital that there should be continuous work on the replacement options for ozone depleting substances in way that serve the aim of the Montreal protocol and UNFCC alike. In the developing countries the conversion of CFCs to alternate is still a major issue. In this paper the first law and second law analysis of various eco friendly refrigerants have been carried out which will help in deciding about the path to be followed to satisfy Montreal and Kyoto protocol.

1.1. Appropriate vapor compression refrigeration technology

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 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. R-22 is the refrigerant used for window type air conditioning systems long back.

Due to Montreal protocol and Kyoto protocol and the provision of 1990 clean air act specifying phasing out the use of R-22 by the year 2030 due to ozone depleting potential around 0.055 as compared to the alternate refrigerants which have zero ozone depleting potential (ODP) and zero global warming potential (GWP).and some other alternate refrigerants which have less ODP & GWP. This paper , energy (first law) analysis and second law (exergy)analysis of vapor compression refrigeration systems have been carried out in terms of performance parameters such as COP, EDR, Exegetic efficiency, percentage of exergy destruction in components (i.e. condenser, compressor, throttle valve and evaporator) to total exergy destruction in the system for air conditioning system of 1.5 ton capacity for seven eco-friendly refrigerants such as (R-134a, R-404a, R-407C, R-502, propane(R-290), isobutene(R-600a), butane (R-600)).

These performance parameters have been evaluated for varying condenser temperatures in the range from 303 K to 333K and evaporator temperatures in the range from 253 to 278K of 1.5 ton capacity of vapor refrigeration systems by using eco friendly refrigerants.

It was observed that R-290 (zero ODP & zero GWP) and R-600 (butane of zero ODP and zero GWP) and R-600a (isobutene of zero

ODP and zero GWP) are best alternatives if its flammable problem will mitigate and the next option are R-134a (of zero ODP and 1300 GWP), R-407c(of zero ODP and 1530), R-404a (zero ODP and 3260 GWP)and R-410a (of zero ODP & 1730 GWP) for R-22 refrigerant but it needs the some modification in the existing design of components of vapor refrigeration systems (i.e. larger size of compressors in case of R-134a , which increases the cost of the vapor compression refrigeration system .

1.2. Use of multiple evaporators vapor compression refrigeration systems

Vapor 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 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. 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.

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

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 vapor compression refrigeration system and this exergy destruction can be minimized by using of nano-fluid and nano-lubricants 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 vapor compression refrigeration system with liquid vapor 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 vapor 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 vapor 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 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. 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 vapor compression refrigeration system with single evaporator. Researchers did not go through the irreversibility analysis (second law analysis) of followings

- Simple VCR with nano particles used as secondary evaporator circuit in the water cooled evaporator
- Detailed analysis of vapor compression refrigeration systems using thirteen eco friendly 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 vapor compression refrigeration systems for keeping evaporator size constant due to enhancing heat transfer coefficient in the evaporator

3.0 Performance Evaluation of Vapor Compression Refrigeration Systems

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 in Table (1-3) respectively.

The performance of vapor compression refrigeration system using eco-friendly 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 eco friendly 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

Table 1: Performance Prediction of Vapor Compression Refrigeration System Using Tio2 in R718 in the Secondary Circuit and Eco Friendly 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 Vapor 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 Vapor 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

The thermodynamic performance have been obtained using R-152a eco-friendly refrigerant and worst performances were found using R-410a eco-friendly 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.

4.0 Conclusions

In this paper, first law and second law analysis of vapor compression refrigeration systems using multiple evaporators and single compressor and single expansion valve with eco-friendly 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 vapor 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 eco friendly refrigerants
2. The First law efficiency (COP) and Second law efficiency (Exergetic efficiency) of vapor 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 improves using 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.

References

[1] Ahamed, et.al. A review on exergy analysis of vapor compression refrigeration system. Int J Renewable and sustainable energy reviews, 15, 2011, 1593-1600

[2] Anand et.al, Exergy analysis and experimental study of a vapour compression refrigeration cycle.Int J Therm Anal Calorim, 110, 2012, 961-971

[3] Arora, et.al. Theoretical analysis of a vapour compression refrigeration system with R502, R404A and R507A. Int J Refrigeration, 31, 2008, 998-1005

[4] B.O. Bolaji et.al, Comparative analysis of performance of three ozone-friends HFC refrigerants in a vapor compression refrigerator. Int J Sustainable Energy & Environment, 2, 2011, 61-64

[5] Chopra et.al., Energetic and Exergetic Based Comparison Multiple Evaporators with Compound Compression and Flash Intercooler with Individual or Multiple Throttle Valves International Journal of Advance Research & Innovations, 1, 2013, 73-81

[6] Han, et.al, Cycle performance study on R32/R125/R161 as an alternative refrigerant to R407C. Int J Applied Thermal Engineering, 27, 2007, 2559-2565

[7] Mishra et.al, Methods for improving thermal performances of vapour compression Refrigeration system using eleven ecofriendly refrigerants, ISTE conference on "Technological Universities and Institutions in New Knowledge Age: Future Perspectives and Action plan" ISTE paper NO:149pp-9, at Delhi Technological University on September 5-6, 2013

[8] Mishra, Irriversibility Analysis of Multi-Evaporators Vapour Compression Refrigeration Systems Using New and Refrigerants: R134a, R290, R600, R600a, R1234yf, R502, R404a and R152a and R12, R502, International Journal of Advance Research & Innovations International Journal of Advance Research & Innovations, 1, 2013, 180-193

[9] Mishra, Thermodynamic performance evaluation of multiple evaporators, single compressor, single expansion valve and liquid vapour heat exchanger in vapour compression refrigeration systems using thirteen ecofriendly refrigerants for reducing global warming and ozone depletion, International Journal of Advance Research & Innovations(IJARI-Vol-1), ISSN No: 2347-3258, PP-163-171

[10] Mishra, Thermodynamic performance evaluation of multiple evaporators, single compressor, single expansion valve and liquid vapour heat exchanger in vapour compression refrigeration systems using thirteen ecofriendly refrigerants for reducing global warming and ozone depletion" International Research Journal of Sustainable Science & Engineering (Monthly Peer Review Journal , IRJSSE, 2(3), 2014, 1-10

[11] R. Saravanakumar, V. Selladurai-Exergy analysis of a domestic refrigerator using eco-friendly R290/R600a refrigerant mixture as an alternative to R134a.Int J Therm Anal Calorim.2013

Nomenclature

COP	coefficient of performance (non-dimensional)
VCR	vapour compression refrigeration
CFC	chlorofluorocarbon
HCFC	hydrochlorofluorocarbon
Q	rate of heat transfer (kW)
W	work rate (kW)
T	temperature (K)
Δ	efficiency defect (non-dimensional)
ΔTsc	degree of subcooling
EP	exergy rate of product (kW)
EV	Expansion Valve
EP	Evaporator Subscript
E	evaporator
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
ev	expansion valve
c	condenser