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First law thermal performance improvement of vapour compression refrigeration using nano materials mixed in R718 in secondary circuit and eco-friendly refrigerant in primary circuit

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Abstract

In past time, HFC refrigerants were used in refrigeration process and they were having a global warming potential at high level. Now, as time change, and due to the modern techniques are coming into existence with the help of them the refrigeration process become more efficient and safe as compare to previous in atmospheric prospective.
The nanotechnologies used in present time in the vapor compression refrigeration system. The nano refrigerant is nothing but the combined form of nano particle with the refrigerant. The nano refrigerant can be formed by two ways (1) by mixing nano particles with refrigerant in gaseous form, (2) by mixing nano particles to lubricant. We will combine different nano particles such as copper, Al2O3having the same diameter and same volume fraction with the R718 in the secondary circuit of evaporator and to study the nature of thermo-physical properties in refrigeration process which improves the first law performance of vapour compression refrigeration system The nano particles like AL2O3, CuO and TiO2 mixed in R718 and used in secondary circuit of evaporator gives better around 95% more improvements in heat transfer coefficient which improves 11.8% to 19.05% first law thermal performances as presented in this paper.

Keywords: Nano Materials, performance improvements, VCR , energy –Exergy analysis, Entropy generation

1. Introduction

Refrigeration is a technology which absorbs heat at low temperature and provides temperature below the surrounding by rejecting heat to the surrounding at higher temperature. Simple 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.

2. Vapour compression refrigeration system

Performance of systems based on vapour compression refrigeration technology can be improved by following.

(i) The performance of refrigerator in term of first law efficiency (COP) which is the ratio of refrigeration effect to the network input given to the system is improved by using nano particles mixed in the ecofriendly refrigerant or mixed in R718 flowing in the secondary circuit of evaporator.

(ii) The COP of vapour compression refrigeration system can be improved either by increasing refrigeration effect or by reducing work input given to the system.

(iii) It is well known that throttling process in vapour compression refrigeration (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 consequence there will be increase in cooling capacity and reduce the size of the evaporator.

(iv) Work input can also be reduced by replacing multi-stage compression or compound compression with single stage compression.

(v) Refrigeration effect can also be increased by passing the refrigerant through sub cooler after condenser to evaporator.

3. Use of Nano materials

The most common refrigerant in current time is R134a in all vapour compression refrigeration systems. But the only problem with this type of refrigerant is they need the large amount of electric power. Now for the time demand we need something new that will be able to replace alternative refrigerant such as R1234yf and R1234ze or with some advanced thermo-physical properties nano materials which increase high heat transfer coefficient, low power consumption in order to make the refrigeration process more effective and efficient to save the environment. The new nano materials mixed in R718 used in secondary circuit of evaporator technology is being introduced in the present investigation and using this nano technology the performance of VCRS improves significantly.

Nano refrigerant is the combination of nano particle to the refrigerant. As compared to alternative refrigerant. The nano particles like AL2O3, CuO and TiO2 mixed in R718 and used in secondary circuit of evaporator gives better around 95% more improvements in heat transfer coefficient.

4. 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 greenhouse gases in 1997[1]. 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 [2].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 [3-6]. Mishra [7] carried out numerical analysis of vapour compression refrigeration system using R134a, R143a, R152a, R404A, R410A, R502 and R507A for finding 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 concluded that evaporator and condenser temperature have significant effect on both COP and exergetic efficiency and also found that R134a gives the better performance while R407C has poor performance in all respect. Kapil chopra [5] have designed domestic refrigerator which was used R134a as ecofriendly refrigerant and also compared the thermal performance of the system with using another ecofriendly refrigerant as hydrogen mixture (i.e. R290/R600a mixture) and found that R290/R600a hydrocarbon mixture gives better performance in terms of higher COP and exergetic efficiency than R134a. They also concluded that highest irreversibility obtained in the compressor compare to condenser, expansion valve and evaporator in the domestic refrigeration system. Mishra [8] analytically found the considerable effect on system irreversibility by change in evaporator and condenser temperatures of two stage vapour compression refrigeration Mishra [9] concluded that there is need for optimizing condenser and evaporator conditions. Mishra [10] carried out energy and exergy analysis of vapour compression refrigeration system using of energy-exergy analysis They also used detailed first law analysis for calculating the coefficient of performance and second law analysis for evaluating irreversibility in terms of various losses occurred in different components of vapour compression cycle using R718 as secondary circuit of evaporator and found improvements in the first law efficiency using ecofriendly R134a refrigerant experimentally..

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: simple vapour compression refrigeration systems using nano material mixed R718 in secondary circuit of evaporator.

5. Results and Discussion

To improve thermal performance of vapour compression refrigeration systems by improving: (i) first law efficiency (ii) second law efficiency (iii) reduction of system defect in components of system which results into the mixing of nano particles in secondary fluid R-718 in the evaporator

circuit and detailed analysis of vapour compression refrigeration systems using ecofriendly refrigerants
Following input values have been selected for finding thermal performance of vapour compression refrigeration system with and without nano fluid in secondary circuit of evaporator.

- Length of Evaporator=0.72m,
- Length of condenser=1.2m,
- Water mass flow rate in condenser=0.008 Kg/sec.
- Inlet temperature of flowing water in condenser $=27^0$C.
- Inlet temperature of flowing brine solution mixed with nano materials in the secondary circuit of evaporator$=27^0$C.
- Inlet Pressure of water in condenser =2 bar.
- Inlet Pressure of brine solution in secondary circuit of evaporator=2 bar
- Inlet pressure of air =1.013 bar, Air temperature =30+273.15 K
- Acceleration due to gravity= 9.81 m/sec^2

Table-1 shows the physical properties of nano materials used in the modelling of vapour compression Refrigeration system (VCRS) and numerical computation have been carried out and performance of vapor compression refrigeration system using eco-friendly refrigerants in the primary circuit and different nano particles mixed in R718 is used in the secondary circuit of evaporators with varying brine mass flow rate are shown in Table-(2).) respectively and it was found that First law efficiency in terms of COP increases with increasing mass flow rate of brine flowing in the secondary circuit of evaporator. For 0.007 kg/sec brine mass flow rate, the first law thermal performance is found as 19.044% using copper nano material and 18.02% using Al2O3 and 11.847% using TiO2 Table- :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-1 Physical properties of nano materials used vapour compression Refrigeration system (VCRS)

Nano materials of 0.00001m size	Cp_nf	Ro_nf	Mu_nf	K_nf	Pr_nf
Copper	2965	1293	0.003653	31.33	0.3457
Al_2O_3	3590	1145	0.003653	16.83	0.7795
TiO2	3558	1155	0.003653	9.727	1.336

Table-2: Effect of Brine mass flow rate in secondary circuit of evaporator on First law thermal performance for Design of vapour compression Refrigeration system (VCRS) using First Method (For different nano particles of 0.00001 m diameter mixed in R718 in the secondary circuit and ecofriendly (R-134a) refrigerant in primary evaporator circuit)

Mass flow rate in Evaporator M_{brine} (Kg/sec)	First law Efficiency / Coefficient of Performance (COP) using Copper	First law Efficiency/ Coefficient of Performance (COP) using Al2O3	Coefficient of Performance Coefficient of Performance (COP) using TiO2	First law Efficiency / Coefficient of Performance (COP) without nano materials
0.007	3.507	3.477	3.295	2.946
0.008	3.58	3.549	3.504	3.013
0.009	3.64	3.604	3.563	3.069
0.010	3.689	3.658	3.612	3.119

6. Conclusions

Extensive numerical studies have been conducted to evaluate thermal performance parameters of a vapour compression refrigeration system with different nanomaterials mixed in R718 which was used in the secondary circuit of evaporator. The conclusions derived out of the present study are
(i) The R134a refrigerant used in evaporator primary circuit with nano-particles mixed in the secondary circuit of evaporator improves first law thermal performance significantly normally (ii) Thermal performance of the vapour compression refrigeration system is higher with R718 mixed with copper nanoparticles as compared to the TiO_2 mixed in R718 used in secondary circuit of evaporator in VCRS (iii) The Al_2O_3 mixed in R718 used in secondary circuit of evaporator in VCRS also gives better performance than using TiO_2 mixed in R718 used in secondary circuit of evaporator in VCRS (iv) The coefficient of performance of the refrigeration system also increases by 11.84% to 19% as compared to without nano particles mixed refrigerant.

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