International Journal of Research in Engineering and Innovation
(IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

Thermodynamic performance enhancement of vapour compression refrigeration systems by using ecofriendly refrigerant (R134a) in primary circuit and R718 in the secondary circuit by mixing Nano particles

R.S. Mishra

Department, of Mechanical production, Industrial and Automobiles Engineering, DTU Delhi-110042, India

Abstract

Lot of literature are available for improving physical properties such as thermal conductivities , specific heat density viscosity of nano fluids. In this paper , Three nano fluid was compared for vapour compressor refrigeration system in which variable speed compressor and water cooled condenser consisting of two parts such as liquid part and vapour part , evaporator in which nano particles mixed with R718 was used in secondary circuit of evaporator for enhanced its thermal first law performance in terms of coefficient of performance(COP). It was observed that by using as three nano particles of 10 micron with concentration volume ratio =0.05 , the evaporator heat transfer coefficient enhanced from 83.97% to 104.91% and in condenser it enhanced up to 9.64% to 11% respectively along with its 17.85 % to 18.83% enhancement of COP using three nano materials. copper oxide. The maximum enhancement was observed in using copper oxide as nano materials and minimum enhancement by using TiO_2.

Keywords: Performance-improvement, Nano Refrigerant, Eco-friendly Refrigerant,

1. Introduction

Green energy is renewable and sustainable. It is renewable because it does not deplete easily and is obviously replenished. Solar, hydro, wind, geo thermal, bio fuels and tidal power are some of the green energy sources that can be used as an alternative to our conventional sources of energy. Specifically the solar energy technologies produce electricity from the energy of the sun. However, the energy recurring from solar through two significant modes of technologies one is solar Photovoltaics and another solar thermal collectors. This article provides a sandwich approach on thermo physical properties of different nanofluids and their applications vapour compression refrigeration system.

2. Heat Transfer enhancement using nano particles

Heat transfer fluids are a crucial parameter that affects the size and costs of heat exchangers. However, the available coolants like water and oils have low thermal conductivities, which put many limitations to the development of heat transfer to achieve high performance cooling. The need for development of new classes of fluids which enhance the heat transfer capabilities attracted the attention of many researchers. In the last few decades, modern nanotechnology developed nanoparticles, which have unique thermal and electrical properties that could help improve heat transfer using nanofluids. A “nanofluid” is a fluid with suspended fine nanoparticles which increases the heat transfer properties compared with the original fluid. Nanofluids are considered a new generation of heat transfer fluids and are considered two-phase fluids of liquid solid mixtures. The efficiency of the fluid could be improved by enhancing its thermal properties, especially the thermal conductivity, and it is expected that the nanofluids will have a greater thermal conductivity than the base fluids.
Most of the study has been carried out for the performance evaluation of vapour compression refrigeration system using energetic analysis, but with the help of first law analysis irreversibility destruction or losses in components of system unable to determined [1], so that second law thermodynamic

Corresponding author: R.S. Mishra
Email Id: rsmishra@dtu.ac.in

analysis is the advanced approach for thermodynamic analysis which gives an additional practical view of the processes. The utility of second law analysis on vapour compression refrigeration systems is well defined because it gives the idea for improvements in efficiency due to modifications in existing design in terms of reducing exergy destructions in the components. The second law exergetic analysis also provides new thought for development in the existing systems. Mishra [1] developed theoretical model of vapour compression refrigeration using eco-friendly refrigerants and observed that the coefficient of performance (COP) of the vapour compression refrigeration system, increases with increasing evaporator in the range of (-20oC to +5oC) temperature for a constant condensing temperature (40oC) and decreases with increasing condenser temperature (30oC to 60oC) for constant evaporator -20oC . Mishra [2] developed theoretical model for computing first law and second law performance of vapour compression refrigeration systems using eco-friendly refrigerant in the primary circuit and Brine water mixed with nano materials in the secondary circuit and found that (i) the use of R407c as ecofriendly refrigerants in the primary circuit and suspended nano particles in water flowing in secondary circuit of evaporator using Al2O3 nano particles is quite adequate improvement in the first law performance around 13.49% (ii) flowing R134a in the primary circuit and improvement is12.60% 11.04% by using R404a and Al2O3 nano particles in first law efficiency in terms of COP.as compared to without nano particles. Similarly second law performance improvement is ranging between 15% to 39.13% using suspended nano particles in brine water. The better second law efficiency is 39.13% improvement due to, by using R1234yf as compared to 16.52% improvement by using R1234ze in the primary evaporator circuit. The reduction in the irreversibility in terms of exergy destruction ratio in the system and maximum exergy destruction ratio around 25.294% was observed by using R152a and exergy destruction ratio is 22.79% by using R290 hydrocarbon and 23.403% by using R407c as ecofriendly refrigerant. The Reduction in EDR is 20.09% by using R404a, and 21.37% by using R134a. The R1234ze and R1234yf have slightly less reduction in EDR as compared by using R134a.

The experimental results of Eastman et al. [2] showed that increase of 60% approximately thermal conductivity of Nano fluid consisting of water and 5 vol % CuO suspended nanoparticles in heating or cooling fluids, can improve heat transfer performance of the fluid significantly due to following reasons may be listed as follows:

1. The suspended nanoparticles increased the surface area and the heat capacity of the fluid.
2. The suspended nanoparticles increased the effective (or apparent) thermal conductivity of the fluid.
3. The interaction and collision among nanoparticles, fluid and the flow passage surface are intensified.
4. The mixing fluctuation and turbulence of the fluid are intensified.

incomplete reaction or stabilization which diminishes the purity of the nanofluid [3].

5. The dispersion of nanoparticles attends the transverse temperature gradient of the fluid.

The numerical computations have been carried out by Mishra [4] for variable compressor speed vapour compression refrigeration systems. It was observed that first law and second law efficiency improved by 25% by mixing copper nano particles in the R-1234yf and 18% improvement using R1234ze eco-friendly refrigerants in the primary circuit of vapour compression refrigeration systems.

Mishra [6] conducted detailed analysis of vapour compression refrigeration systems using thirteen eco-friendly refrigerants and observed that there is a 12% to 19% improvement in the first law efficiency using nano particles mixed with R718 in the secondary evaporator circuit of VCR and suggested that higher improvement occurs using copper particles mixed with R718 and low improvement occurs using TiO2 in R134a .The maximum improvement in the second law thermal performance (exergetic efficiency) of vapour compression refrigeration system by mixing copper nano particles and lowest by suspending TiO2 in R718 in secondary evaporator circuit and various eco-friendly refrigerants in the primary evaporator circuit.

3. Preparation of Nano fluids

Preparation of nanofluids is the first key step to synthesize fluids with improved thermal conductivity. These nanofluids are obtained by suspending nanoparticles in the range of 1–100 nm in conventional regular fluids in suitable volume fractions. Theoretically, when solid particles with high thermal conductivity are added to fluids, the overall thermal conductivity is improved due to the change in flow, heat, transport, and heat transfer features of the liquid. Some of the vital requirements that nanofluid must fulfill are adequate durability, even and stable suspension of particles, no chemical change of particles or fluid, and negligible agglomeration of particles. Several types of particles have been reported in literature to prepare nanofluids, which include nonmetallic particles (SiO2 , SiC , TiO2 , Al2O3 , ZnO , CuO , Fe3O4 , and AlN), metallic particles (Cu , Ag , and Au), and different particle shapes such as carbon nanotubes , nanodroplets , nanofibers , and nanorods. The base fluids commonly used are water, oil, acetone, decene, ethylene glycol, and mineral oil. Two methods have been employed in producing nanofluids which can be classified as single-step and two-step methods [3].

The single-step method involves the preparation of nanoparticles and dispersion of them in the host or base fluid simultaneously. The nanoparticles can be directly prepared via physical vapor deposition technique or liquid chemical method. Therefore, the process of drying, storage, dispersion, and transportation is avoided, so that agglomeration is minimized and, hence, nanoparticle dispersion in the host fluid is improved. The main demerit of this process is that the residue of reactants is left behind in the nanofluid due to

Another shortage in this process is that only low vapor pressure fluids can be used, which limits the application of the method. In the two-step method, which is the most widely used method for preparing nanofluids, the nanoparticles, nanotubes, nanofibers, or nanorods are first produced by chemical vapor deposition, inert gas condensation, or any other technique as a dry powder. The second step involves dispersing this nano powder into the base fluid with the help of intensive magnetic force agitation, ultrasonic agitation, high shear mixing, homogenizing, and ball milling. The two-step method is more economical than the one-step method to produce nanofluids commercially. The main disadvantage of this method is that, due to the high surface area and surface attractively, the nanoparticles tend to agglomerate. The agglomeration of nanoparticles in the fluid results in decreasing the thermal conductivity and increasing the settlement and clogging of microchannels. Therefore, surfactants are widely used to stabilize nanoparticles in the fluids. Nevertheless, this method is suitable for wide range of particles such as oxide particles and carbon nanotubes and it is attractive to industry because it is simple for nanofluid preparation [3].

4. Result and Discussion

Following input data have been considered for numerical computations

Compressor speed (rpm) =2900, mbrine (kg/sec)=0.007(Kg/sec), mwater (kg/sec)=0.008Kg/sec, L_eva=0.72m, L_Cond=1.2m, P_brine=P_water=2.0 bar)

Table -1-2 show, the variation of first law efficiency in terms of coefficient of the system it was found that coefficient of performance of the vapour compression refrigeration system is using nano mixed brine in the secondary circuit of evaporator is increased 18.83% using copper oxide as nano materials along with evaporator heat transfer coefficient around 104.9% and condenser heat transfer coefficient 11%. Similarly by mixing Al_2O_3, the enhancement in the COP 18%, evaporator heat transfer coefficient 96% and condenser heat transfer coefficient 10.47% and lowest performance was found by mixing TiO_2 nano particles in the brine

Table 1: Comparison of thermal performances using R134a as ecofriendly refrigerant in vapour compression Refrigeration System with variation of brine mass flow rate (kg/sec) in the secondary circuit of evaporator

Performance Parameters	Without nano particles mixed R-718	Nano Particle (CuO) mixed with R-718	Nano Particle (Al2O3) mixed with R-718	Nano Particle (TiO2) mixed with R-718
COP_System	2.946	3.507	3.477	3.472
Evaporator heat transfer Coefficient (W/m2K)	673.45	1380.0	1320.21	1239.0
Condenser heat transfer Coefficient (W/m2K)	646.31	717.61	714.01	708.64

Table-2 Comparison of % enhancement in the thermal performances and using R134a as ecofriendly refrigerant in vapour compression Refrigeration System with variation of brine mass flow rate (kg/sec) in the secondary circuit of evaporator

Performance Parameters	% Enhancement using Nano Particle (CuO) mixed with R-718	% Enhancement using Nano Particle (Al2O3) mixed with R-718	% Enhancement using Nano Particle (TiO2)mixed with R-718
COP_System	18.83	18.024	17.854
Evaporator heat transfer Coefficient (W/m2K)	104.91	96.03	83.97
Condenser heat transfer Coefficient (W/m2K)	11.031	10.47	9.64

Similarly table-3 shows the first law performance in terms of coefficient using eight ecofriendly refrigerants in the primary circuit of evaporator and nano Al2O3 mixed brine flowing in the secondary circuit of evaporator, it was found the maximum performance improvement is found by using hydrocarbon R290 and R600a however, lowest performance improvement is found by using R125 refrigerant.

Table-3: First law improvement using Al_2O_3 nano particles mixed in R718 in the secondary circuit of evaporator

Refrigerants	First law efficiency (COP)	% Enhancement
R134a	3.4061	18%
R404a	3.0636	16%
407C	3.1105	17%
R152a	3.34101	18%
R600	3.3401	17%
R600a	3.4663	20%
R290	3.5433	20%
R125	3.0332	15%

Similarly table-3 shows the first law performance in terms of coefficient using eight ecofriendly refrigerants in the primary circuit of evaporator and Nano Al_2O_3 mixed brine flowing in the secondary circuit of evaporator, it was found the maximum performance improvement is found by using hydrocarbon R290 and R600a however, lowest performance improvement is found by using R125 refrigerant.

Table-3: First law improvement using Al2O3 nano particles mixed in R718 in the secondary circuit of evaporator

Refrigerants	First law efficiency (COP)	% Enhancement
R134a	3.4061	18%
R404a	3.0636	16%
407C	3.1105	17%
R152a	3.34101	18%
R600	3.3401	17%
R600a	3.4663	20%
R290	3.5433	20%
R125	3.0332	15%

The maximum improvement in the second law thermal performance (exergetic efficiency) of vapour compression refrigeration system by mixing copper nano particles and lowest by suspending TiO2 in R718 in secondary evaporator circuit and various eco-friendly refrigerants in the primary evaporator circuit.

5. Conclusion

Following conclusions were drawn from present investigations.

1. Using Nano particles mixed in the brine flow in the evaporator, the first law performance in terms of coefficient enhanced significantly due to enhancement in the thermal conductivity of Nano materials
2. The improvement in evaporator heat transfer coefficient is found from 84% to 104.7% while 11% to 9.6% is found in condenser heat transfer coefficient.
3. The highest performance was found using copper oxide mixed Nano in brine while lowest enhancement was found in mixing TiO_2.
4. The maximum first law enhancement is found by using hydrocarbons in VCR by using safety measures because hydrocarbons are flammable while lowest performance is found by using R125 refrigerant

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