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Performance enhancement in vapour compression refrigeration systems using Nano refrigerants-A Review

R.S. Mishra

Department of Mechanical, production, Industrial & Engineering, Delhi Technological University Delhi, India

Abstract

Although the nanorefrigerants have been extensively studied over the years, there still remains is left is the application of Nano refrigerants in the vapour compression refrigeration cycle. This paper presents the effect of nanoparticles on the thermodynamic performance of a refrigeration system. The aim of the present theoretical study is to examine the COP enhancement using three nano materials mixed in the brine flowing in the secondary circuit of evaporator. The performance of these five nano-refrigerants in a vapour-compression refrigeration cycle is evaluated based on three nano materials (with a mass fraction of 0.05%) are mixed in the brine. The effects of the main parameters of the refrigeration cycle, such as the refrigerant type and the effect of sub cooling and superheating on the COP, are investigated for various evaporation and condensation temperatures were investigated

Keywords: Ecofriendly refrigerants, Nano-refrigerants, Performance enhancement, Vapour compression refrigeration system

1. Introduction

The Nanorefrigerants, which are a new class of nanofluids, are mixtures of nanoparticles and refrigerants. They have several potential applications in various fields, such as for refrigeration and air-conditioning systems and heat pumps, among others. Accordingly, adding nanoparticles to conventional refrigerants results in anomalous improvements in the thermophysical properties and heat transfer characteristics of refrigerants, thereby further improving the performance of refrigeration systems.

Sanukrishna S. S., Vishnu A. S., Jose Prakash M [1] prepared R134a-based Nano refrigerant from R134a + CuO/Polyalkylene glycol (PAG) oil Nano lubricant by dispersing copper oxide nanoparticles in the PAG lubricant. The effect of adding nanoparticles was studied in details in relation to the thermal conductivity of lubricants and tribological characteristics of Nano lubricants and evaluated overall performance of a vapour compression refrigeration system with nanorefrigerants. In terms of enhanced heat transfer rate, coefficient of performance, freezing capacity, and reduced power consumption in the the refrigeration system. The thermal conductivity of the Nano lubricant was better than that of the pure lubricant.

2. Literature Review

Experimental results also showed that the low concentrations of CuO nanoparticles suspended in synthetic oil enhanced the tribological properties of the base oil. The Nanofluid consisting of copper nanometer-sized particles dispersed in ethylene glycol has a much higher effective thermal conductivity than either pure ethylene glycol or ethylene glycol containing the same volume fraction of dispersed oxide nanoparticles. J. A. Eastman[2] pointed out that the effective thermal conductivity of ethylene glycol is shown to be increased by up to 40% for a nanofluid consisting of ethylene glycol containing approximately 0.3 vol% Cu nanoparticles of mean diameter <10 nm. The results are anomalous based on previous theoretical calculations that

Corresponding author: R.S. Mishra
Email Id: rsmishradtu@gmail.com

had predicted a strong effect of particle shape on effective nanofluid thermal conductivity, but no effect of either particle size or particle thermal conductivity. Park and Jung [3] carried out an analysis of nucleate boiling of carbon nanotubes (CNTs) with 1% volume fraction mixed with R134a and R123 and found that at the low heat fluxes, the heat transfer enhancement is greater than at high heat fluxes. Kedzierski [4-6] conducted experiment by using rectangular finned surface to investigate the effects of Al_2O_3 nanoparticles on the pool boiling performance of the R134a/polyolester lubricant (RL68H) mixture and found that the use of nanoparticles in R134a/polyolester lubricant enhances the boiling performance up to 113%. Javadi and Saidur [7] studied the use of nanorefrigerants in the refrigeration system which was domestically used to reduce the energy consumption and emissions of greenhouse gasses. The nano material of TiO_2 with mineral oil- in the R134a and $Al_2O_3$with mineral oil in the R134a with mass fractions of 0.06% and 0.1% were used as nanorefrigerants and found that the nanorefrigerant containing TiO_2 nanoparticles of 0.1 wt.% gives the highest energy savings—up to 25%. Dalkilic, A. S. and Wongwises, S [8-9]., theoretical analyzed thermal performance of the vapour-compression refrigeration system in terms of coefficient of performance and also compared with various alternative refrigerants and found that the performance enhanced by using super heating and subcooling so that the working fluid at the condenser outlet should be completely liquid, which is achieved by using superheating in the evaporator /subcooling subcooling in the condenser instead of the no superheating/subcooling arrangement. He also compared the effect of superheating/sub cooling compared to non-superheating/sub cooling using pure and blended refrigerants during various refrigeration cycles and also found the COP improvement using ecofriendly refrigerants. Sun and Yang [10] studied the use of R141b/Cu, R141b/Al, R141b/Al_2O_3, and R141b/CuO Nano refrigerants in a computer-aided test section to investigate the effects of nano material types and vapour quality on flow boiling heat transfer inside a horizontal tube and found that the same mass fraction, the Cu-R141b nanorefrigerant had the highest heat transfer coefficient, and R141b/CuO gives the minimum heat transfer coefficient. Bi et al. [11] studied theoretically the effect of R134a/Al_2O_3 nanorefrigerant in the refrigeration system and found that 23.24%, energy savings by using 0.06 wt. % mixture and 18.30%. Enhancement in COP. Abdel-Hadi et al. [12] investigated the use of Nano refrigerant (R134a/CuO) in the vapour-compression refrigeration system and found that the optimum size and concentration of CuO nanoparticles enhances maximum heat transfer enhancement; and found the optimal values were 25 nm. Subramani and Prakash [13] studied the effect of added nanoparticles Al_2O_3 in ecofriendly R134a refrigerant in the vapour compression refrigeration system and found that there is an enhancement in COP. They also determined the system's COP theoretically for both R134a and R134a/Al_2O_3. They found that the COP of cycles that use R134a increases by 10.11% while the R134a/Al_2O_3 mixture used in the actual refrigeration cycle experimentally while the theoretically COP enhancement ratio was 9.74%. Kumar and Elansezhian [14] experimental studies to discover the effects of nanorefrigerant R134a/Al_2O_3/PAG oil mixture on the vapour-compression refrigeration system. In terms of energy consumption and freeze capacity and found that by using the nanorefrigerant at a 0.2% concentration on Nano refrigerant reduces the energy consumption by 10.32% as compared to the R134a/PAG oil mixture. However, by using use of nanorefrigerant in the vapour compression refrigerant system the COP of system is increases and minimizes the length of the capillary tube because it is also cost effective.. Bartelt et al.[15] studied the flow boiling of CuO nanoparticles dispersed in a mixture of R134a/polyol-easter oil (POE) and found that the nanofluid with 0.5% weight concentration has no effect on heat transfer enhancement while 1% mass fraction displays 42–82% improvement in heat transfer and a 2% mass fraction showed 50–101% heat transfer enhancement. Jwo et al. [16] studied the potential of Al_2O_3 nanoparticles as additives to R12/MO refrigerant and found that by using the nano refrigerant at 0.1 wt.% showed a higher compression ratio as compared to R12. Trisaksri and Wongwises [16] studied the nucleate pool boiling of nanorefrigerant using R141b/TiO_2 at low concentrations, including 0.01%, 0.03%, and 0.05% by volume and their results showed that by increasing the particle volume concentration decreases the boiling heat transfer coefficient. Henderson et al. [17] investigated the heat transfer performance of R134a and R134a/polyester mixtures with nanoparticles during boiling flow conditions in a horizontal tube. The R134a/SiO_2nanorefrigerant having volume concentrations of 0.5% and 0.05% was tested to determine the effects of nanoparticles. It was found that by using nanofluids leads to a decrease in convective boiling heat transfer coefficient (around 55%) as compared to pure R134a. and also conducted experiments with R134a/POE mixtures having CuO nanoparticles with volume fractions of 0.02%, 0.04%, and 0.08% and also observed that R134a/CuO/POE Nano-refrigerant with a volume fraction of 0.02% has no significant enhancement in heat transfer while the volume fractions of 0.04% and 0.08% caused considerable heat transfer enhancement as high as 52% and 76%, respectively. Several studied were carried by Peng et al. [18] investigated the influence of the concentration of the flow boiling characteristics of the R113/CuO Nano refrigerant inside a horizontal tube at 0.1 wt.%, 0.2 wt.%, and 0.5 wt.% nanoparticle concentrations. A correlation predicted the heat transfer enhancement of the R113/CuO Nano refrigerant. It was found that dispersing nanoparticles in R113 refrigerant enhances the flow boiling heat transfer of the nanofluid, and the maximum heat transfer enhancement is 29.7%. Peng et al.[19] investigated the influence of mass fraction on the pressure drop of R113/CuO Nano fluid flow boiling inside a horizontal tube and concluded that by dispersing nanoparticles in R113 pure refrigerant increases the pressure drop; the maximum enhancement in pressure drop was 20.8%. Peng et al. [20] investigated the effects of nanoparticle size (i.e. three different average diameters) on nucleate pool boiling heat transfer characteristics of the mixture of refrigerant R113, ester oil VG68, and Cu nanoparticles and their results showed that the nanoparticles with an average diameter of 20 nm give higher heat transfer enhancement (up to 23.8%) compared to other nanoparticle sizes such as 50 nm and 80 nm. Peng et al. [21] investigated the nucleate pool boiling heat transfer characteristics of R113/CNT/oil nano-refrigerant. The results showed that the R113/oil mixture with CNTs increased nucleate pool boiling heat transfer coefficient up to 61% compared to the R113 oil mixture. Peng et al. [22] carried out the experimental study to determine the nucleate pool boiling heat transfer characteristics of R113/VG68 oil with diamond nanoparticles and observed that the usage of diamond nanoparticles in R113/VG68 oil mixture increased the nucleate pool boiling heat transfer coefficient up to 63.4%. Sabareesh et al. [23] studied the potential of R12/TiO2/mineral oil nanorefrigerant to improve the COP of a vapor-compression refrigeration system. And found that the usage of nanorefrigerant in the vapor-compression refrigeration system (instead of the R12/MO mixture) decreases compressor work by 11% while the COP increases. Moreover, the nanoparticle is likely dispersed in the lubricant and is not dispersed in the gas phase. Therefore, the influence of the nanoparticle on heat transfer in a heat exchange depends on how much oil is discharged from the compressor and circulates with the refrigerant in the cycle. It is, therefore, necessary to consider the oil circulation ratio and the concentration of the nanoparticle in the cycle. The reduction of power consumption of the compressor by improvement of lubrication as reported by several investigators..

3. Results and Discussion.

The following numerical input parameters wer taken [24]**.**
Compressor speed (rpm) =2900,
m_{brine}=0.007(Kg/sec), m_{water}=0.008Kg/sec, Length of evaporator tube (L_{eva}) =0.72m, Length of compressor tube L_{Cond}=1.2m, P_{brine}=P_{water}=2.0 bar **.** Water flow in the condenser tube = 27^0C Brine flow in the evaporator tube = 27^0C
Theoretical study on vapour compression refrigeration system usingR134a ecofriendly refrigerant in the primary circuit of evaporator in which nano particles size of 10 nm were mixed in the brine is flowing at a rate of 0.007 kg/sec to 0.01 kg/sec in the secondary circuit of evaporator was carried out. In the vapour compression refrigerant system, the water cooled condenser was used at a flow rates variation from 0.007 kg/sec to 0.01 kg/sec of condenser tube length 1.2 m and evaporator length of 0.72 m and found that at a flow rate of brine is 0.007 kg/sec and water flow rate in condenser is also 0.007 kg/sec, the first law performance in terms of COP is enhanced up to 18.83% using copper nano particles to 17.85% using TiO2 nano particles in brine flow in the evaporator . Similarly evaporator heat transfer coefficient is also enhanced up to 104.9 % using copper Nano material and around 84% using TiO2 nano particles in brine flow in the evaporator. However little enhancement were found around 11% using CuO and 9.64% by using TiO2 Nano particles.

4. Conclusion

Following conclusions were taken:

- The effect of adding the three nano refrigerants CuO, Al2O3 and TiO2nanoparticle to different refrigerants for improving first law performance in terms of COP and significant enhancement in the evaporator and condenser heat transfer coefficients.
- COP results were found to be higher at 5°C in the superheating in the evaporator /subcooling in the condenser as compared to the non-superheating/non sub-cooling in the condenser case.
- Vapour compression refrigeration working with Nano-refrigerants had a higher COP improvement in superheating/subcooling conditions over non-superheating/subcooling. R600 and R600a/Al2O3 nano-refrigerants had the highest COP under all conditions.
- The performance improvement of the Compression vapour refrigeration system by applying a nanoparticle is mainly due to heat transfer enhancement in heat exchangers

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