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Performance of Vapour Compression Refrigeration System Using Nanoparticles: A Review

Vinayak Kamble[1], Ankush Panare[2], Sachin Patil[3], Swapnil Gore[4], Omkar Raut[5], [*]U. N. Patil[6]

[1] U. G. Student, Department of Mechanical Engineering, DYPCET, Kolhapur
[2] U. G. Student, Department of Mechanical Engineering, DYPCET, Kolhapur
[3]U. G. Student, Department of Mechanical Engineering, DYPCET, Kolhapur
[4]U. G. Student, Department of Mechanical Engineering, DYPCET, Kolhapur
[5]U. G. Student, Department of Mechanical Engineering, DYPCET, Kolhapur
[*]Corresponding Author: U. N. Patil, Assistant Prof., Department of Mechanical Engineering, DYPCET, Kolhapur.

Abstract

In this paper, nanoparticle-based refrigerant has been used to increase the heat transfer performance of base refrigerant in the vapor compression refrigeration system. Many types of solid and oxide materials could be used as the nanoparticles to be suspended into the conventional/non-conventional refrigerants.

The objective of this work is to study the performance of a vapor compression refrigeration system with and without nano refrigerant. R134a is most widely adopted alternate refrigerant in refrigeration equipment, such as domestic refrigerators and air conditioners. This refrigerant heat transfer capacity is not so good and increase power consumption. Due to these limitation nanoparticles are enhanced with the refrigerant and increases the heat transfer capacity and reduces the power consumption. The experimental studies indicate that the air conditioning system with nano refrigerant works normally. It is found that the coefficient of performance is increased and the power consumption reduces when refrigerant is replaced by a mixture of refrigerant and Al2o3 nanoparticles. According to the thermodynamics equations the COP of vapor compression refrigeration systems depend on compressor work consumption and refrigeration effect. The nano particles when added to ordinary refrigerants improve thermophysical properties and heat transfer characteristics of base fluid due to their high thermal conductivity when suspended to base fluid.

Keywords: *Nanoparticles, Coefficient of performance.*

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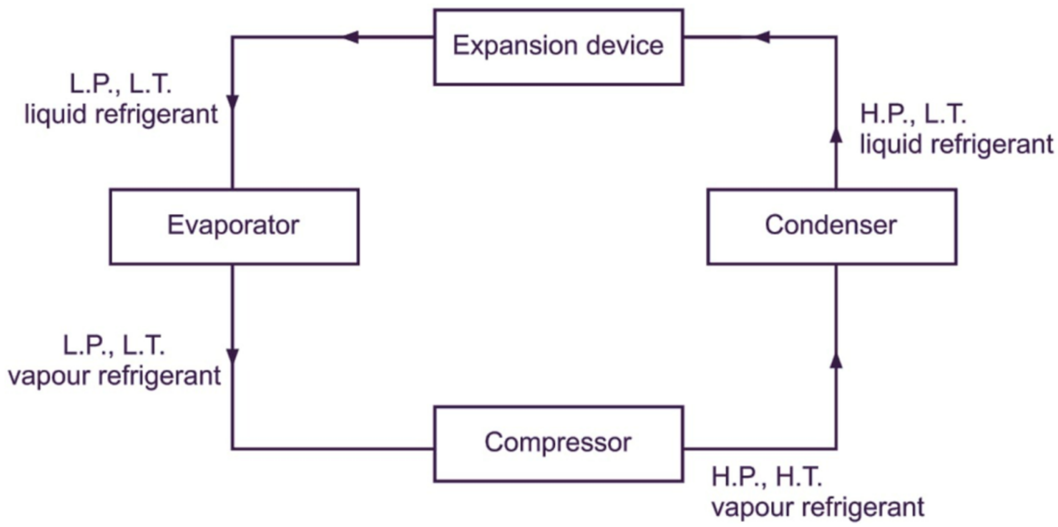
1. INTRODUCTION

Thermal systems like refrigerators and air conditioners consume large amount of electric power. So it is necessary to develop energy efficient refrigeration and air conditioning systems. The rapid advances in nanotechnology have led to emerging of new generation heat transfer fluids called nanofluids. Nanofluids are prepared by suspending nano sized particles (1-100nm) in conventional fluids and have higher thermal conductivity than the base fluids. Nanoparticles have the following characteristics compared to the normal solid liquid suspensions. i) higher heat transfer between the particles and fluids due to the high surface area of the particles ii) better dispersion stability with predominant Brownian motion iii) reduces particle clogging iv) reduced pumping power as compared to base fluid to obtain equivalent heat transfer. Addition of nanoparticles changes the boiling characteristics of the base fluids. Nanoparticles can be used in vapor compression refrigeration systems because of its remarkable improvement in thermo-physical and heat transfer capabilities to enhance the performance of vapor compression refrigeration systems. The purpose of this is to report the results obtained from the experimental studies on vapor compression refrigeration system. In the present study the refrigerant selected is R134a and the nanoparticle is aluminum Oxide.

Most refrigerant undergo a series of evaporation compression condensation and expansion process absorbing heat from a lower-temperature reservoir and releasing it to a higher temperature reservoir in such a way that the final state is equal in all respects to the initial state. It is said to have undergone a closed refrigeration cycle. When air or gas undergoes a series of compression, heat release, throttling, expansion, and heat absorption processes, and its final state is not equal to its initial state, it is said to have undergone an open refrigeration cycle. Both vapour compression and air or gas expansion refrigeration cycles are discussed.

Thermal conductivity is a significant property by which Nano particles are being selected for application in Nano refrigerant applications. The heat transfer coefficient and heat transfer in the VCRS system are dependent on thermal conductivity and properties such as Nano concentration, particle size and flow rate. In addition, the viscosity of Nano particles imbedded fluid affects the pressure drop and hence the heat transfer of Nano fluid. Addition of Nano particles reduces the specific heat and increases density. Also, an increase in dynamic viscosity brings about decrease in convective heat transfer coefficient and frictional pressure drop therefore compressor pumping power increases.



1. Compressor
The low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve and it is compressed isentropically to a high pressure and temperature and discharged into the condenser through the delivery or discharge valve.

2. Condenser
The condenser consists of coils of thin copper pipe in which the high pressure and temperature vapour refrigerant is cooled and condensed by the process of forced convection. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium
which is normally air or water.

3. Receiver
The function of the receiver vessel is to store the condensed vapour-liquid mixture at high temperature and pressure and supply pure liquid refrigerant to the expansion valve so as to get better throttling and controlling effect.

4. Expansion Valve
It is also called throttle valve and the function of this valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporized in the evaporator at the low pressure and temperature.

5. Evaporator
An evaporator usually consists of coils of copper pipe in which the liquid-vapour refrigerant at low pressure and temperature is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.

II. HISTORICAL DEVELOPMENTS

Choi (1995) conceived the novel concept of nanofluids by making use of particles sizes in the order of 1 to 100 nm. Research on heat transfer enhancement by adding nanoparticles has had mixed results since then. Gains & losses of heat transfer have been reported. Main factors, which influence the results, are nanoparticle material, nanoparticle concentration, nanofluid preparation methods & testing consistency. In last decade, the number of published articles mentioning nanoparticles has increased significantly in refrigeration field.

III. NANOPARTICLES

In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport properties. Nanoparticles are between 1 and 100 nanometers ($1x10^{-9}$ and 1×10^{-7} m) in size. Tubes and fibers with only two dimensions below 100 nm are also nanoparticles. Novel properties that differentiate particles from bulk material typically develop at a critical length scale of 100 nm. They are made from ceramics, metals & metal oxides.

IV. EFFECT OF NANOPARTICLES ON THE COP, EFFICIENCY OF COOLING AND POWER CONSUMPTION OF VCR

Thermal conductivity is a significant property by which Nano particles are being selected for application in Nano refrigerant applications. The heat transfer coefficient and heat transfer in the VCRS system are dependent on thermal conductivity and properties such as Nano concentration, particle size and flow rate. By suspending nanoparticles in working fluid results in improved thermal conductivity of fluid and hence improvement in freezing speed. This is one of the most important key parameter for improving the performance of system. In VCR system the nanoparticles can be added to lubricant of compressor.

V. P. Pode et. Al. [1] carried out an investigation using Cuo nanoparticles in base refrigerant (R134a). The result was the comparison of nano-particles with base fluid R134a and without nano particles. In this paper they found that the COP of refrigeration system with nanoparticles is increased by 4-5%.

Ohunakin et al. [2] worked on performance of SiO2, TiO2, and Al2O3 Nano lubricants in household refrigerator system using liquefied Petroleum Gas (LPG) as working fluid. TiO2, SiO2 and Al2O3 nanoparticles were dispersed in a mineral oil in the LPG as the working fluid. The performances such as power consumption, viscosity and thermal conductivity at the compressor discharge and suction, the pull-down time was also considered. The result revealed that Nano lubricant-based LPG had a lower temperature with a pull-down time of 180 min. Moreover, SiO2 and TiO2 led to 12% and 13% reduction in power consumption respectively in comparison with the base LPG refrigerant. Also, there were improvement in the cooling COP, the COP of SiO2 and TiO2 Nano particles in LPG are higher than of pure LPG with 2.06% and 2.97% respectively, while a drop in COP of 2.91% was experienced with Al2O3 Nano particles in LPG at steady state. In the experiment, Al2O3 Nano lubricant as not suitable for LPG due to an increase in power consumption compared to the base LPG refrigerant.

Kumar and Singh [3] worked on ZnO Nano particles effect on a mixture of hydrocarbon made up of 50% R290 and 50% R600a in a vapour compression system. The nanoparticles were introduced via the lubricant oil in the compressor using different percentage by weight of ZnO/R290/R600a Nano refrigerant. The outcome showed that energy consumption of the system was reduced by 7.8% using ZnO/R290/R600a Nano refrigerant of 0.2 -1.0 wt% range of Nano concentration. The COP of the system also increased by 46% compared to base refrigerant (R290/R600a)

.K. Srividya et al. [4] paper investigated performance analysis of VCR system using TIO2 nano particles in lubricant. Christian J.L Hermes, (2014) [5], reports a study on reduction of refrigeration charge in vapour compression refrigeration system with a liquid to suction heat exchanger the analysis was carried out for different refrigerant and it was found that reduction of refrigerant charge depends on thermodynamic properties of refrigerant and working conditions.

Manzoor Hadi et al. [6] paper presented the preparation and property analysis Cuo-R134a and increament of 16.06% in COP while using Nano refrigerant. The decrement of 13.79% in power consumption for one tonne of refrigeration. They usage of nano refrigerant is great alternative to present refrigerant. In experiment is conducted by considering a domestic refrigerator which works on refrigerant R143a, in this paper the nano refrigerant CuO with concentration 1.6% is taken.

Vikram khandare et al. [7] experimental results indicated that the freezing capacity was improved and power consumption was reduced when three nano particles (Al2o3, Cu, SiC) issued as a nano refrigerant. The nanoparticles added to the R600a at different proportions such as 0.5%, 1.0%, and 1.5%. In this project they use R134a as a base refrigerant and R600a as a nano refrigerant. Ravinder kumar et al. [8] studied the effect of nanoparticles on performance characteristic of refrigeration cycle. They review studies related to Al2O3 and CuO, TiO2 nanoparticles. N. Subramani et al. [9] reported that by using the POE oil the power consumption of compressor reduced by 25% when the nanolubricant. And the coefficient of performance of the refrigeration system also increased by 33% when they conventional POE oil is replaced with nanorefrigerant. The energy enhancement factor in the evaporator by 1.53.

Niraj raja and Avinash khanderao et al. [10] investigated experimentally the performance of vapor compression refrigerant system using nanorefrigerant (Al2O3). They investigated that nano refrigerant (R134a+ Al2O3 0.5gm/L concentration & 50-60nm size) with evaporative condenser recorded the highest COP among all other combination of refrigerant. On the basis of the above-mentioned literature survey it is observed that addition of nanoparticles in the base refrigerant or lubricating oil can enhance the thermos-physical properties of working fluid.

V. CONCLUSION

The studies on the nanoparticles are summarized in this review. A research work presented in this paper, following conclusion have been drawn

1. Use of nanoparticles enhances thermal performances of vapour compression refrigeration system using nano particles in the refrigeration system.
2. For use of nanoparticles in refrigeration more research is needed.
3. Maximum enhancement in performance was observed using R134a/ Al2O3 nano refrigerant in primary circuit and water in secondary circuit of VCRS.
4. Lowest enhancement in performance was observed using R134a/TiO2 nano refrigerant in primary circuit and water in secondary circuit of VCRS.

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