TO STUDY THE BEHAVIOUR OF NANOREFRIGERANT IN VAPOUR COMPRESSION CYCLE- A REVIEW

Satnam Singh[1], Kapil Sharma[2], Kundan Lal[3], Naveen Mani Tripathi[4]

[1]PG Student, School of Mechanical Engineering, Thapar University Patiala, Punjab, India
[2]Assistant Professor, School of Mechanical Engineering, Lovely Professional University (LPU), Phagwara, Punjab, India
[3]Assistant Professor, School of Mechanical Engineering, Thapar University Patiala, Punjab, India
[4]Research Scholar (Ph. D. student) Department of Mechanical Engineering, Ben-Gurion University of Negev, Beer-Sheva, Israel

Abstract

Nanofluid is an advanced kind of fluid, which contain nanometer sized (10^{-9} m) solid particles that are known as nanoparticles. Nanoparticles enhance the property of normal fluid. In past five years, nanorefrigerant has become the input for large number of experimental and vapour compression systems because of shortage of energy and environmental considerations. The conventional refrigerants have major role in global warming and depletion of the ozone layer. Therefore, there is need to improve the performance of vapour compression refrigeartion system with the help of using suitable refrigerant. Nearly all the works carried out in relation with nanofluids in vapour compression is regarding their applications in systems like domestic refrigerators and industrial purposes etc. The present paper investigate the performance of the nanorefrigerant in vapour compression cycle and the challenges of using nanorefrigerants in vapour compression cycle.

Keywords: *Nanofluids, nanoparticles, nanometer, nanorefrigerants, vapour compression, ecofriendly, domestic refrigerator*

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1. INTRODUCTION

Efficient working of living and nonliving things depends on the condition of physical environment to a great extent. So that demand for the refrigeration and air conditioning is increasing day by day. Temperature, pressure, air motion and humidity are important physical environmental variables that keep on changing throughout the year at any particular location. Vapour compression refrigeration cycle is one of the different refrigeration cycles available for use. This system is mainly used for domestic as well as for industrial purposes such as conditioning of residence, hotels, hospitals and automobiles etc. Energy crises is a major issue all over the world so it is required to reduce its consumption. Refrigeration and air conditioning plays a vital role in the field of energy consumption. To reduce its consumption by the refrigeration systems it is necessary to have efficient systems and their proper operation. To obtain this purpose some change in the refrigeration system or fluid flowing in the system (refrigerant) is required. For economic system now a days most of the refrigerator's use conventional Vapour Compression cycle along with the heat exchanger, which increases the coefficient of performance (COP) of the system.

The COP of a refrigeration system mainly depends on the compressor work and refrigeration effect. R134a is most widely used alternate refrigerant as a replacement of R12 in domestic refrigeration equipments. According to Arora and domkundwar [14] the global (GWP) and (ODP) of R134a be 400 and 0.0 respectively. Whereas, GWP and ODP of R12 are 3700 and 0.93 respectively, which are much higher than of R134a, therefore we can say that R134a proved to be the best alternative refrigerant. The addition of nanoparticles to the present refrigerants result in the improvement of the thermo physical properties and heat transfer characteristics of the refrigerants, in this manner performance of the refrigeration system is enhanced to some great extent [1]. Likewise, the addition of nanoparticles in Polyol-ester (POE) oil, increases the system efficiency, which is used for lubrication in compressor. According to Kumar et al. Suspended nanoparticles like Al_2O_3 in lubricating oil in the compressor work without choking and also it provide better performance by recirculating more lubricant oil [2].

Shengshan et al. [1] Studied the efficiency of domestic refrigerator with mineral oil lubricant and TiO_2 with R134a The presence of nano CuO of particle size 15 to 70 nm in the R134a refrigerant improves the evaporating heat transfer co-efficient. The results showed decrease in 26.1%, power consumption. Ching-Song Jwo et al. studied the handling of alumina naoparticles in R134a based refrigeration arrangement. The results revealed that the thermal conductivity started to improve to some extent, when the temperatures were taken as 20°C to 40°C [2]. As a new type fluid called nanofluid has gained increased interest. Nanorefrigerant is a kind of nanofluid and the host fluid of nanorefrigerant is a refrigerant. The thermal conductivity of nanorefrigerant should be studied in order to increase the efficiency or performance of refrigeration systems. The stability of nanorefrigerant should be known in order to keep the nanorefrigerant's long-term operation in the system. The nanopowders would diffuse and enter the fluid in the system. So the electrical conductivity of nanofluid in the system will increase because of the nanopowder's high electrical conductivity. The nanofluid's electrical conductivity should be researched to ensure the insulating properties of system.

2. EXPERIMENTAL INVESTIGATIONS

2.1 Use of Nanofluids in Refrigeration and Air Conditioning

There are lots of inputs and outputs parameters in the field of refrigeration and air conditioning. These parameters of refrigerants are related with each other when we use in vapour compression refrigeration system. We can use nanofluids in the vapour compression system to enhance the thermal conductivity in various components like condenser, evaporator, hermetically sealed compressors and semi hermetically sealed compressors. The efficiency of the system depends upon the properties of the refrigerant. Normally R600a, R22, R600 and R134a are used in refrigeration system as a refrigerant. The capacity to heat transfer is not so good and hence it will lead to increase in energy consumption. [8].

2.2 Preparation of Nanolubricants

The first initial step in any experimental work is the preparation of nanorefrigerants. Special conditions are like even, stable suspension with slight agglomeration of particles, and nil alteration of chemical properties of the fluid are required. There are two methods to prepare nanofluids one step and two step methods. [1].Figure 1 shows the prepared nanofluid lubricant.

Fig -1: Nanofluid lubricant

2.3 Experimental Setup

To study a refrigeration system test rig for the same was designed and fabricated. The test rig comprises of a air-cooled condenser, thermostatic expansion valve, evaporator and compressor. The compressor used usually is a hermetically sealed reciprocating type compressor. The evaporator is constructed in the shape of a cylindrical spiral coil and is fully immersed in water and it is made of copper. A twisting coil finned tube heat exchanger is used as the condenser. The condenser is cooled with the help of a fan. Figure 2 shows the Experimental setup[1].


Fig -2: Experimental setup

3. VAPOUR COMPRESSION CYCLE PERFORMANCE TEST

A performance test is conducted for 150 gm. of pure R134a arrangement which is treated as the foundation for comparison with other. Nano Al2O3 –R134a with 0.2% strength was used in the experimental setup and the tests were performed under the same working conditions. In order to obtain accurate results each test was run for 3 to 4 times. These tests were also performed with refrigerants mass of the order of 150gm., 180 gm. and 200gm. In Figure 3 the variation of coefficient of performance with capillary tube length is studied. Variation of the pressure drop with time is studied and plot has been shown in figure 4.

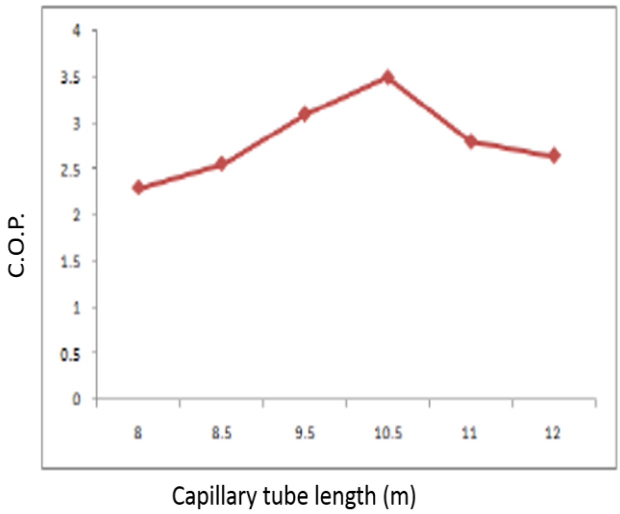

Fig -3: Variation of COP with capillary tube length

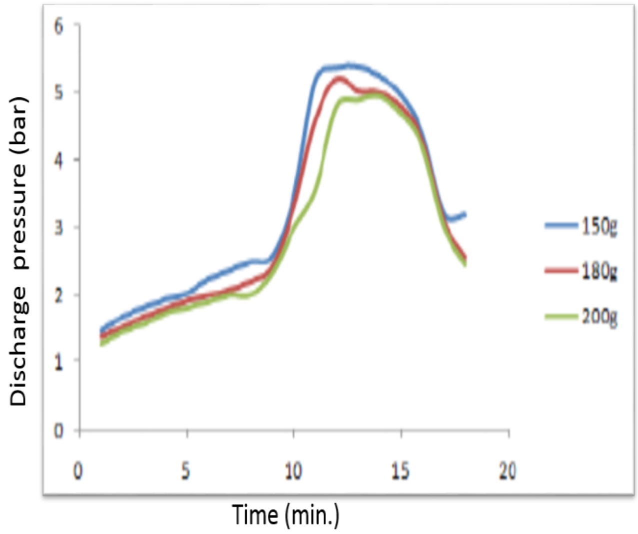

Fig -4: Variation of Discharge pressure with time

An investigational job was done on the nano-refrigerant. Results obtained from this shows that with the use of nanorefrigerant we have large increase in the efficiency of the system. TiO_2-R600a nano-refrigerant was used in the system. The outcomes of this experimental study showed that TiO_2-R600a nano-refrigerants work usually. The refrigerator performance was better than the pure R600a system, with 9.6% less energy used with 0.5 g/L TiO_2-R600a nano-refrigerant. Thus, TiO_2-R600a nano-refrigerant work properly. [5] Theoretical analysis shows heat transfer increase by 53% when nanorefrigerant is used. Peng et al. (2009) have reported that the energy enhance factor is in the range 1.17–1.63. Experiment conducted by R saidur et.al [6] in a domestic refrigerator with R134a/mineral oil with TiO_2 shows improvement. The energy saved by 26.1% with 0.1% vol fraction. [7] Some investigators studied the effect of nanoparticle when mixed with the refrigerant. Some studies carried out on the nanofluids. The results revealed that the addition of nanoparticles increases the critical heat flux. Bi et al. [9] found that there is decrease in the energy consumption and enhancement in the freezing capacity. Lee et al. [10] examined the coefficient of friction of the mineral oil mixed along with 0.1 vol. % fullerene nanoparticles, and the outcomes showed that the friction coefficient decreases by 90%, which shows that nanoparticles improves the efficiency. Wang and Xie [11] found that TiO_2 nanoparticles could be utilized as additives in mineral oil and hydro fluorocarbon (HFC) refrigerant. Results revealed reduction in power consumption by 11.5% when the nanolubricant is used. The R600a refrigerant and mineral oil mixture with nanoparticles worked normally [8]. The COP of the refrigeration system increase by 19.6 % when POE oil is replaced with the nanorefrigerant. [12]. If compared to their corresponding base-fluid, nanofluids present an evident improvement in the thermal conductivity, viscosity and density, as now reported in a number of research papers and reviews [13]. Heat transfer in nanofluids (laminar or turbulent flow; natural or forced convection; single phase, pool boiling, nucleate boiling or critical heat flux) has also been investigated worldwide. For the purpose of the present simulation, i.e., single-phase forced convective flow, literature results concluded that, in general, conventional pressure drop correlations still apply to nanofluids, whereas new correlations for the Nusselt number, or even new heat transfer mechanism, must be sought. More specifically, the study on their use as heat transfer fluids in vapour compression cycles is still incipient. An exploratory simulation was carried out by Loaiza et al [14], who numerically studied the use of nanofluids as secondary fluids (i.e., heat transfer fluids exchanging heat with the refrigerant in the evaporator) in vapour compression refrigeration systems. The present paper improves the model from Loaiza et al. [16] by allowing more realistic situations to be predicted (for example, variable condensing and evaporating pressures, to be determined as a result of operational and fluid conditions, including nanofluid characteristics).A simulation model was developed for the performance prediction of a vapor compression heat pump using nanoscale colloidal solutions (nanofluids) as condenser coolants. The model was intended for a liquid-to-liquid heat pump, with reciprocating compressor, thermostatic expansion valve and counter-flow condenser and evaporator. The compressor is characterized (input data) by its swept volume, shaft speed and isentropic and volumetric efficiencies curves, and the expansion device, by the evaporator superheat. The condenser is divided into three zones, desuperheating, condensing and subcooling. Likewise, the evaporator is divided into the boiling and superheating zones. The heat exchangers are characterized (input data) by their geometry (inner and outer tube diameters and length). Operational input data also include condenser sub cooling and heat transfer fluids (condenser and evaporator) mass flow rates and inlet thermodynamic states. A computational program was developed to get solution for non-linear system of algebraic equations. Solution of the system provides the cycle overall thermal performance, as well as condensing and evaporating pressures and the thermodynamic states of refrigerant and heat transfer fluids at all points of the cycle. Preliminary results were obtained for the simulation of a 19 kW nominal capacity water-to-water/(H_2O-Cu nanofluid) heat pump. A 5.4% increase in the heating coefficient of performance, for a typical operating condition, was predicted for a nanoparticle volume fraction of 2% [15].

The increase of viscosity for TiO_2-R123 nanorefrigerants in respect of volume concentrations have been plotted. It shows increase in viscosity with the increase of volume concentrations. Other two experimental works about viscosity of nanofluid have compared with this result. Duangthongsuk and Wongwises (2009) investigated the viscosity of nanofluid for TiO2 with water. The authors found that viscosity of nanofluid increases with the increase of volume concentrations. The increment rate is linear but not fully straight line or constant rate. It may have happened because of the experimental setup, mixture/stability of nanofluid and also particle size, shape or agglomeration. Chen et al. [20] studied the viscosity of nanofluid for TiO_2 with Ethylene glycol and found viscosity increases accordingly with the intensification of volume fractions.

However, in their studies, the increment rate is very high and almost linear trend. The authors reported large agglomeration of nanoparticles on the suspensions. [18]

It was observed that the nanofluid-side pressure drop and, pumping power, increase with nanoparticle volume fraction and decrease with nanoparticle size. Results from a typical case-study indicated an evaporator area reduction, with the use of nanofluids as secondary coolant, if compared to the conventional base fluid (H_2O) [14] Eastman et al. (2001) [16] found that a 40 % rise in the thermal conductivity of a liquid is possible by inserting nanoparticles of volume fraction 0.4 % [17].

4. CHALLENGES

In the following section the probable challenge for the application of nano refrigerants in vapour compression cycle are mentioned.

1. High cost.
2. Instability and agglomerating.
3. Pumping power
4. Pressure drop.
5. Erosion and corrosion of components.
6. Very less data is available.

5. CONCLUSION

Nanorefrigerants are superior fluids containing nano-sized particles. Nanorefrigerants are used to enhance system performance in vapour compression. This paper presented a review on the performance of the nanorefrigerants Based vapour compression system. The experimental studies revealed that the performance of such systems gets improved by using nano refrigerants. It is observed that using a nanorefrigerant or nanofluid with higher concentration is not true always. Therefore, it is recommended that the nanorefrigerants in different concentration should be tested. It is worth to carry out an investigational work on the effect of different types of nanorefrigerant with different base refrigerant under the variable conditions of compressor pressure ratio, evaporator and condenser parameters like pressure temperature, pressure drop. There is a lot of scope of using nano refrigerant as lubricating oil in vapour compression cycle and in vapour absorption system.

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BIOGRAPHIES

Mr. Satnam Singh, PG Student, Thapar University, Patiala (Punjab).

Mr. Kapil Sharma, Assistant professor (A.P.) in Mechanical Engineering Department at Lovely Professional University, Jalandhar (Punjab).He has two and half years of teaching experience. He has published one paper in international journal.

Mr. Kundan Lal is working as Assistant Professor in Mechanical Engineering Department at Thapar University, Patiala. His research area is heat transfer, refrigeration and air conditioning, fluid mechanics and nanofluidics. He has been a faculty member since last eleven years. He has guided about fifteen ME thesis and has around eleven research papers in International and National Journals.

Mr. Naveen Mani Tripathi, Research Scholar (Ph. D. student) Department of Mechanical engineering, Ben-Gurion University of Negev, Beer-Sheva, Israel.