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Enhancement of COP using Nanoadditives in Domestic Refrigerator

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ABSTRACT

The performance of refrigerator is evaluated in term of COP which is the ratio of refrigeration effect to the net work input given to the system. The COP of vapour compression refrigeration system is improved either by (i) increasing the refrigeration effect in terms of cooling load capacity or (ii) by reducing compressor work input given to the vapour compression refrigeration system, Work input can be reduced by multi-stage compression or compound compression instead of single stage compression. Refrigeration effect can be increased by passing the refrigerant through sub cooler after condenser to evaporator. These methods have their own advantages and limitations.

The use of additives in the lubricant to improve the performance of the compressor and, at the same time, enhance the heat transfer performance of the condenser and evaporator, represents a new type of energy saving technology. Comparing the use of nanoparticles to modify the organic surface with traditional lubricant additives, the former is more environmentally friendly and gives better heat transfer performance. This work aims to concentrate on experimental study on the effect of nanoparticles in vapour compression refrigeration system. Initial step is develop the vapour compression system. In this study the nanoparticles of SiO2 (15-20 nm) are to be used as additive in refrigerant and lubricating oil. Nanoparticles of SiO2 are to be added in the refrigerant and in lubricant to prepare the nanorefrigerant and mineral oil with volume fraction 0.1, 0.2 and 0.3% by mass. Experimentation results shows that COP of experimental system for 0.1 %, 0.2% and 0.3% of refrigerant are increased by 3.77%, 6.70% and 9.86% respectively. Results shows that COP of experimental system for 0.1 %, 0.2% and 0.3% of lubricant are increased by 6.97%, 9.90% and 12.68% respectively.

Keywords— **Nanofluid, Vapour compression refrigeration system, Refrigerant, COP enhancement.**

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I. INTRODUCTION

Energy shortages and global warming are key problems that may restrict sustainable development of human society. Energy conservation and reduction of emissions are effective ways of solving the problems of energy shortages and global warming. Energy consumption by refrigerators is growing year by year, due to the rapid increase of their production and use. Therefore, the energy efficiency of refrigerators has to be improved. At present, the refrigeration industry is working towards a balance between environmental protection and energy saving. In terms of environmental protection, the previous use of fluorine and chlorine hydrocarbon refrigerants (CFCs), such as R12, as the working fluid in refrigerator compressors is being replaced by more environmental benign refrigerants such as R600a and R134a, since these have less destructive effects on the ozone layer.

The heat transfer performance of various thermal devices may be augmented by active and passive techniques. One of the passive techniques is the addition of ultrafine particles (called nanoparticles) to the common heat transfer fluids so that the thermal transport properties of the prepared suspension (called nanofluid) will be enhanced as compared to the base fluid. Nanorefrigerants are a special type of nanofluids which are mixtures of nanoparticles and refrigerants and have a broad range of applications in diverse fields for instance refrigeration, air conditioning systems, and heat pumps. In this paper, work is performed in order to clarify effect of nanorefrigerant properties (such as nanoparticle type, size and concentration) on heat transfer compared to pure refrigerant.

In this study the nanoparticles of SiO2 (15-20 nm) are to be used as additive in refrigerant and lubricating oil. Nanoparticles of SiO2 are to be added in the refrigerant to prepare the nano refrigerant and mineral oil with volume fraction 0.1, 0.2 and 0.3% by mass.

Experimentation results shows that COP of experimental system for 0.1 %, 0.2% and 0.3% of refrigerant are increased by 8%, 12% and 15% respectively.

II. LITERATURE REVIEW

Bi and Shi (2007) [1] studied the energy consumption of a refrigerator using the R134a/TiO2 mixture as working fluid, experimentally. Results showed that using nanofluid leads to lowering the energy consumption of the system by about 7%.

Bi et al. (2008) [2] researched the domestic refrigerator performance which uses R134a as the working fluid and TiO2/Al2O3 nanoparticle-addicted mineral oil as the lubricant instead of POE oil, experimentally. Energy consumption of the system with 0.1% mass fraction TiO2 nanofluid was 26.1% lower than the POE oil state. Al2O3 addicted nanofluid also showed nearly the same performance. Their results also showed that using the mixture of nanoparticle-mineral oil mixture instead of POE oil will increase system efficiency.

Jwo et al. (2009) [3] conducted studies on a refrigeration system replacing R-134a refrigerant and polyester lubricant with a hydrocarbon refrigerant and mineral lubricant. The mineral lubricant included added Al2O3 nanoparticles to improve the lubrication and heat-transfer performance. Their studies show that the 60% R-134a and 0.1 wt % Al2O3 nanoparticles were optimal. Under these conditions, the power consumption was reduced by about 2.4%, and the coefficient of performance was increased by 4.4%.

Padmanabhan and Palanisamy (2012) [4] intended to increase COP and the energy efficiency of a vapor-compression refrigeration system by using the mixture of refrigerant, TiO2, and lubricant (mineral oil (MO) and Polyolester (POE) oil). They used R134a, R436A, (R290/R600a-56/44-wt. %) and R436B (R290/ R600a-52/48-wt. %) as refrigerant. They investigated irreversibility at different processes. The COP of vapor-compression refrigeration systems using R134a/TiO2/MO nanorefrigerant showed a higher COP value when compared to R436A/TiO2/ MO and R436B/TiO2/MO nanorefrigerant. The COPs of vapor compression refrigeration systems using both R436A/POE oil and R436B/POE oil mixtures were higher when paralleling the R134a/POE oil mixture. In addition, it is observed that the energy efficiency of the R134a/TiO2/MO mixture was lower than the R436A/TiO2/MO and R436B/TiO2/MO/mixtures at lower air temperatures inside the freezer.

Henderson et al. (2010) [5] conducted an experimental analysis on the flow boiling heat transfer of R134a based nanofluids in a horizontal tube. They found excellent dispersion of CuO nanoparticle with R134a and POE oil and the heat transfer coefficient increases more than 100% over baseline R134a/POE oil results.

Bi et al. (2011) [6] conducted an experimental study on the performance of a domestic refrigerator using TiO2-R600a nanorefrigerant as working fluid. They showed that the TiO2-R600a system worked normally and efficiently in the refrigerator and an energy saving of 9.6%.

Sendil kumar and Elansezhian (2012) [7] conducted an experimental study on the performance of a domestic refrigerator using Al2O3-R134a nanorefrigerant as working fluid. They found that the Al2O3-R134a system performance was better than pure lubricant with R134a working fluid with 10.30% less energy used with 0.2%V of the concentration used and also heat transfer coefficient increases with the usage of nano Al2O3.

Krishna Sabareesh et al (2012) [8] conducted an experimental study on the performance of a domestic refrigerator using TiO2 - R12 nanorefrigerant as working fluid. They found that the freezing capacity increased and heat transfer coefficient increases by 3.6 %, compression work reduced by 11% and also coefficient of performance increases by 17% due to the addition of nanoparticles in the lubricating oil.

Reji kumar and Sridhar (2013) [9] conducted an experimental study on the performance of a domestic refrigerator using R600a/mineral oil/nano-Al2O3 as working fluid nanorefrigerant as working fluid. They found that the refrigeration system with nano-refrigerant works normally. It is found that the freezing capacity is higher and the power consumption reduces by 11.5 % when POE oil is replaced by a mixture of mineral oil and Aluminium oxide nanoparticles.

T. Coumaressin and K. Palaniradja (2014) [10] conducted an experimental study on the performance of a domestic refrigerator using CuO-R134a nano-refrigerant as working fluid. The experimental studies indicate that the refrigeration system with nanorefrigerant works normally. Heat transfer coefficients were evaluated using FLUENT for heat flux ranged from 10 to 40 kW/m2, using nano CuO concentrations ranged from 0.05 to 1% and particle size from 10 to 70 nm. It is found that the evaporating heat transfer coefficient with the increase of CuO concentration up to 0.55% then decreases. At 0.55% concentration the evaporating heat transfer coefficient has its highest value for all values of heat flux.

Meibo Xing et al. (2014) [11] worked on a fullerene C60 nano-oil & he found that C60 nano-oil is proposed as a promising lubricant to enhance the performance of domestic refrigerator compressors. The stability of fullerene C60 nanoparticles dispersed in a mineral oil and the lubrication properties of the nano-oil were investigated experimentally.

The applications of the nano-oil with the specific concentration of 3 g/l to two domestic refrigerator compressors were examined by compressor calorimeter experiments. The results shows the COPs of two compressors were improved by 5.6% and 5.3%, respectively, when the nano-oil was used instead of pure mineral oil.

Concluding Remarks:

- Based on the literatures, it has been found that the thermal conductivities of nanorefrigerant are higher than traditional refrigerants.
- Adding nanoparticles to the refrigerant enhanced the heat transfer and that the heat transfer coefficient increased with increased nanoparticle mass fraction. With increased quality, the heat transfer coefficient of nanorefrigerant increases.
- It has been observed that heat transfer enhancement can be achieved from a minimum value of 21% to a maximum value of 27.5% using nanorefrigerant compared to traditional refrigerants.
- Energy consumption can be reduced by using nanorefrigerant.
- As a result of some investigations, it is reported that the freezing speed and COP in cooling devices is increased by adding nanoparticles to the refrigerants.

Several literatures have indicated that there is significant increase of nanofluids pressure drop compared to base fluid.

III. DESIGN AND DEVELOPMENT OF EXPERIMENTAL SETUP

Layout of experimental set up is shown as below for the stated objective of the experimentation. Following test setup is design for the purpose to carried out the testing of nanoadditives in domestic refrigerator in comparison with conventional refrigerant.

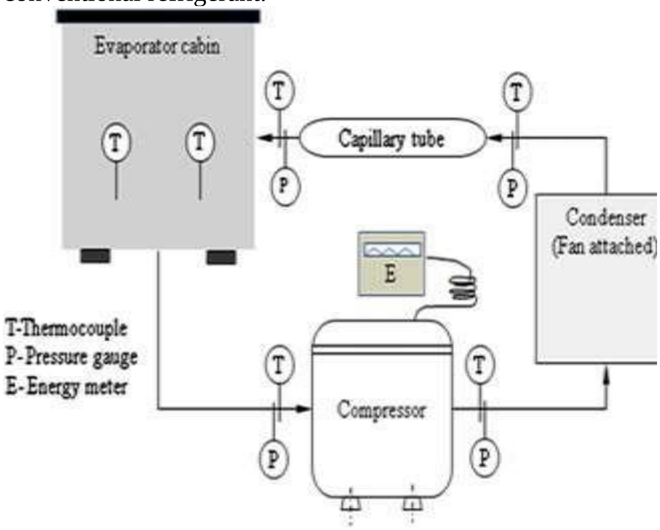

Figure 3.1 Schematic of the experimental apparatus

Preparation of Nanofluid

Nanoparticles of SiO_2 are added to refrigeration system by adding them into the refrigerant R134a. The preparation and stability of this mixture is very important. The refrigerant R134a is in a vapour state so it is difficult to mix the nanoparticles in refrigerant. The nanoparticle is added in the refrigerant by the following procedure

1. Find out the amount of refrigerant R134a is circulated in the system. Before charging the system weight the mass of R134a cylinder and charge the setup by R134a up to limit that air bubbles will totally remove from the rotameter.
2. After charging the setup once again weights the cylinder of R134a we will get amount of mass or volume entered in the system.
3. Weigh the mass of SiO_2 nanoparticles on a digital electronic balance for 0.1% of weight of refrigerant.
4. Vibrate the mixture by using an ultrasonic vibrator for 3 hrs and get the well-dispersed SiO_2 nanorefrigerant.
5. Repeat the above steps for preparing the dispersion of 0.2%, 0.3% nanoparticles in refrigerant R134a.

Testing Methodology

Tests are conducted on experimental setup initially by mixing of nanoparticles in refrigerant and then by mixing of nanoparticle in compressor oil with different mass concentrations. The steps by steps procedures of each test are as below.

1. First take the reading of air conditioning test rig without any mixing of nanoparticles i.e. at 0% mixing of nanoparticle.
2. Preparation of nanorefrigerants i.e. mixing of nanoparticle in the refrigerant R134a.
3. Mixture is then placed on mixing platform like magnetic stirrer to dispersion of nanoparticle in the refrigerant.
4. Evacuating the system with the help of vacuum pump and again charging the setup with the nanorefrigerant. (R134a & Sio2).
5. While charging the setup make sure that amount of refrigerant introduced in the system is equal to that of previous one.
6. Take the reading after charging the set up, the operating procedure is explained in the next chapter.
7. Similar reading can be taken for different concentration.
8. Preparation of nanolubricant i.e. mixing of nanoparticles in the compressor oil.
9. Mixture is place on the ultrasonic vibrator for 3 hrs for uniform dispersion of nanoparticles into the oil.
10. Again evacuating and charging of setup is done with the help of vacuum pump.
11. Taking the reading after each charging
12. Repeat the procedure for different mass concentration.

Formulae Used

1. Refrigerating Effect

$$R.E = m_w \, Cp \, \Delta T/15\times 60$$

2. Compressor Work

$$W_c = \frac{impulse\ (10)\times 3600}{time\ required\ for\ 10\ impulse\times 750}$$

3. Actual coefficient of performance

$$C.O.P = \frac{R.E}{\text{Compressor Work}}$$

IV. RESULTS AND DISCUSSION

Following graph shows the performance of Vapour compression system in case of COP when Nanopowder added in refrigerant and lubricant.

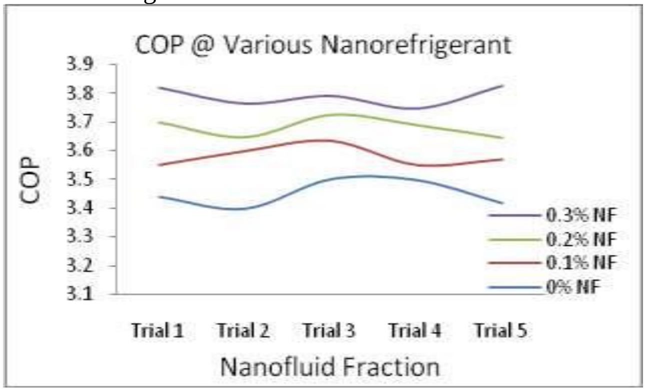

Fig 4.1 COP of Refrigerant at various Fraction of Nanorefrigerant

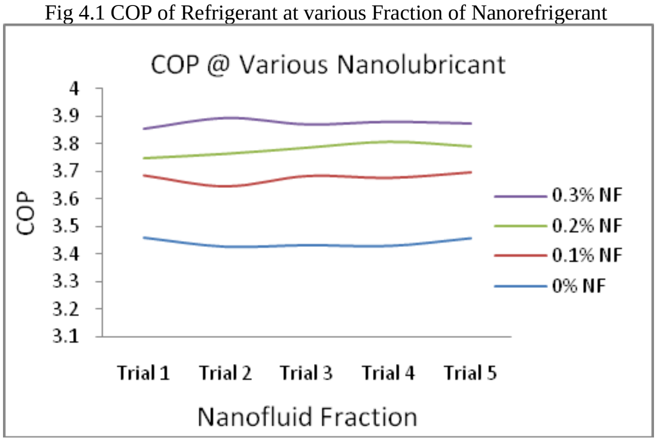

Fig 4.2 COP of Refrigerant at various Fraction of Nanolubricant

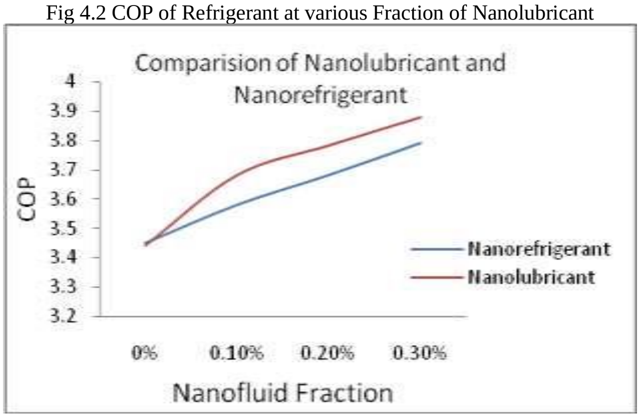

Fig 4.3 Comparison of COP of Nanorefrigerant and Nanolubricant

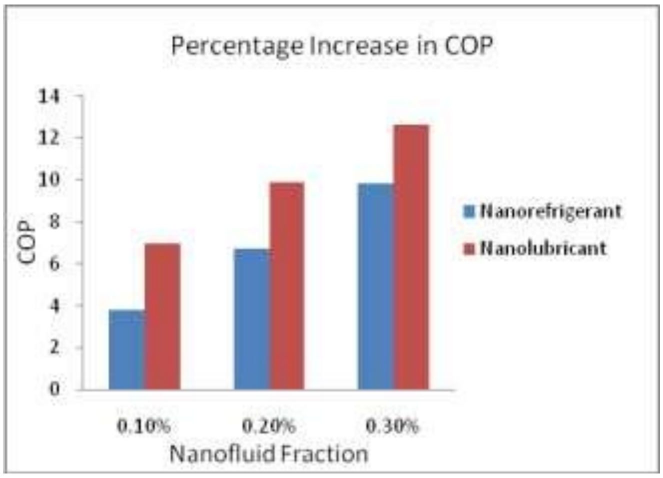

Fig 4.4 Percentage Increase in the COP of Refrigeration System

V. CONCLUSION

In this experimental study the nanoparticles of SiO2 (15-20 nm) are to be used as additive in refrigerant and lubricating oil. Nanoparticles of SiO2 are to be added in the refrigerant and in lubricant (R134 and lubricating oil) to prepare the nanorefrigerant and mineral oil with volume fraction 0.1, 0.2 and 0.3% by mass. Experimentation results shows that COP of experimental system for 0.1 %, 0.2% and 0.3% of refrigerant are increased by 3.77%, 6.70% and 9.86% respectively. Results shows that COP of experimental system for 0.1 %, 0.2% and 0.3% of lubricant are increased by 6.97%, 9.90% and 12.68% respectively.

VI. REFERENCES

[1] Bi et al. Experimental investigation of a refrigerator with a nano-refrigerant. J. Tsinghua Univ. 47 (2007), 1999-2002.

[2] Bi, S., Shi, L., Zhang, Li, 2008. Application of nanoparticles in domestic refrigerators. Appl. Therm. Eng. 28, 1834-1843.

[3] Jwo et al. Effects of nanolubricant on performance of hydrocarbon refrigerant system. J. Vac. Sci. Technol. B 27 (3), (2009) 1473 -1477

[4] Padmanabhan, V.M.V., Palanisamy, S., The use of TiO2 nanoparticles to reduce refrigerator ir-reversibility. Energ. Convers. Manage. 59 (2012)122e132.

[5] Kristen Henderson et al. Flow-boiling heat transfer of R-134a-based nanofluids in a horizontal tube. International Journal of Heat and Mass Transfer 53 (2010) 944–951.

[6] Shengshan Bi et al. Performance of a domestic refrigerator using TiO2-R600a nano-refrigerant as working fluid. Energy Conversion and Management 52 (2011) pp-733–737.

[7] D. Sendil Kumar & Dr. R. Elansezhian. Experimental Study on Al2O3-R134a Nano Refrigerant in Refrigeration System. Vol. 2, Issue. 5, Sep.-Oct. 2012 pp-3927-3929.

[8] Sabareesh et al. Application of TiO2 nanoparticles as a lubricant-additive for vapor compression refrigeration systems- an experimental investigation. Int. J. Refrigeration 35 (2012) 1989-1996.

[9] R. Reji Kumar et al. Heat transfer enhancement in domestic refrigerator using R600a/mineral oil/nano-Al2O3 as working fluid. International Journal of Computational Engineering Research, Vol. 03, Issue 4.
[10] T. Coumaressin and K. Palaniradja. Performance Analysis of a Refrigeration System Using Nano Fluid. International Journal of Advanced Mechanical Engineering, ISSN 2250-3234 Volume 4, Number 4 (2014), pp. 459-470.
[11] Meibo Xing et al. Application of fullereneC60nano-oil for performance enhancement of domestic refrigerator compressors. International journal of refrigeration 40 (2014) pp-398-403.

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