Improving the performance of VCR system by addition of Al_2O_3 Nano particles in lubricant

Thota ayyappa[1], MIdde Surendra goud[2] T.gouri shankar[3]

[1]*Associate professor, Dept of Thermal Engg, Mother Theresa Institute of Science and Technology*

[2]*Associate professor, Dept of Thermal Engg, Mother Theresa Institute of Science and Technology*

[3]*Associate professor, AMS, Mother Theresa Institute of Science and Technology*

***Abstract*-In this study, the Al_2O_3 nano-oil is proposed as a lubricant to improve the performance of vapour compression refrigerator compressor. The stability of Al_2O_3 nanoparticles in the oil is investigated experimentally. It was confirmed that the nanoparticles steadily suspended in the mineral oil at a stationary condition for long period of time. The application of the nano-oil with specific concentrations of 1.5%, 1.7% and 1.9 %(by mass fraction) were added in the compressor oil. The VCRS performance with the nanoparticles was then investigated using energy consumption tests. The result shows the COP of system were improved by 19.14%, 21.6% & 11.22%, respectively, when the nano-oil was used instead of pure oil. Keywords: VCRS, COP, PAG Oil**

I. INTRODUCTION

The Nanofluids are a relatively new class of fluids which consist of a base fluid with nano-sized particles (1–100 nm) suspended within them. These particles, generally a metal or metal oxide, increase conduction and convection coefficients, allowing for more heat transfer out of the coolant. Serrano et al. [1] provided excellent examples of nanometer in comparison with millimeter and micrometer to understand clearly. In the past few decades, rapid advances in nanotechnology have lead to emerging of new generation of heat transfer fluids called ‘‘nanofluids’’. Nanofluids are defined as suspension of nanoparticles in a base fluid. Some typical nanofluids are ethylene glycol based copper nanofluids; water based copper oxide nanofluids, etc. Nanofluids are dilute suspensions of functionalized nanoparticles composite materials developed about a decade ago with the specific aim of increasing the thermal conductivity of heat transfer fluids, which have now evolved into a promising nano technological area. Such thermal nanofluids for heat transfer applications represent a class of its own difference from conventional colloids for other applications. Compared to conventional solid–liquid suspensions for heat transfer intensifications, nanofluids possess the following adwantages .

- High specific surface area and therefore more
- heat transfer surface between particles and fluids. High dispersion stability with predominant
- Brownian motion of particles. Reduced pumping power as compared to pure
- liquid to achieve equivalent heat transfer intensification educed particle clogging as compared to conventional slurries, thus promoting system miniaturization.
- Adjustable properties, including thermal conductivity and surface wettability, by varying particle concentrations to suit different applications.

Recently scientists used nanoparticles in refrigeration systems because of its remarkable improvement in thermo-physical, and heat transfer capabilities to enhance the efficiency and reliability of refrigeration and air conditioning system. Elcock [2] found that TiO_2 nanoparticles can be used as additives to enhance the solubility of the mineral oil with the hydrofluorocarbon (HFC) refrigerant. Authors also reported that refrigeration systems using a mixture of HFC134a and mineral oil with TiO_2 nanoparticles appear to give better performance by returning more lubricant oil to the compressor with similar performance to systems using HFC134a and POE oil. Hindawi [3] carried out an experimental study on the boiling heat transfer characteristics of R22 refrigerant with Al_2O_3 nanoparticles and found that the nanoparticles enhanced the refrigerant heat transfer characteristics with reduced bubble sizes. Thermal conductivity of nanoparticles used in refrigerants Different concentrations of nanoparticles of CuO, Al_2O_3, SiO_2 , diamond, CNT, TiO_2 were used in base refrigerants such as R11, R113, R123, R134a, and 141b as found in the available literatures.

Table 1:Properties of aluminium Oxide nano particles.

Nano particles	Aluminium Oxide
Synonyms	Alumina, Aluminium Oxide, Corundum, Aluminium(III) Oxide
Formula	Al_2O_3, gamma
Atomic Number	Al 13
Molecular Weight	101.96
CAS Number	1344-28-1
EINECS Number	215-691-6
Colour	milky white
Form	Nano powder
Goods Nomenclature Code	2818200000 (aluminium oxide, other than artificial corundum)

II EXPERIMENTAL SET UP

1 Components

The vapour compression refrigeration system test rig consist of a compressor unit, condenser, evaporator, cooling chamber, controlling devices and measuring instruments those are fitted on a stand and a control panel. Electric power input to the compressor is given through thermostatic switch.

Fig .1vapour compression test rig.

Table 2: Refrigeration systemspecifications

Capacity	500 watt at rated at test condition
Refrigerant	R-134a
Compressor	Hermitically sealed
Condenser	Forced convective air cooled
Condenser fan motor	Inductive type
Dryer/filter	Dry all make
Expansion device	Capillary tube

2 Instrumentation

The temperatures at different parts of the experimental setup are measured using resistance thermocouples. Six resistance thermocouples were used for the experimentation. The suction pressure and discharge pressure at compressor are measured with the help of pressure gauges. The power consumption of the system was measures by a energy meter. A digital energy meter is also connected with the experimental setup.

III. EXPERIMENTAL PROCEDURE

1 Preparation of nano- Refrigerant

Nanoparticles of Al2O3 2are added to the refrigeration system by adding them to the lubricant in the compressor of the system. Thepreparation and stability of this lubricant and nanoparticle mixture is very important. The lubricant oil, a type commonly used in refrigeration and air-conditioning systems was poly alkylene glycol (PAG). This oil is selected owing to its common usage and superior quality. The nanoparticles of Al2O3 in the range 40-50 nm were mixed with PAG to synthesize nanolubricant in a recommended method for nanofluid. PAG oil was used as supplied by supplied without further purification. The nano particles of Al2O3 and PAG mixture was prepared with the aid of magnetic stirrer for 2 hrs. The mixture is then further kept vibrated with an ultrasonic homogenizer for half an hour to fully separate the nanoparticles and to prevent any clustering of particles in the mixture to obtain proper homogenization. No surfactant is added in this work as there may be any influence in reduction of thermal conductivity and performance.

Fig 2: magnetic asscillator for mixing of nano particles with lubricant

Fig 3: After Mixing of Nano particles in lubricant oil(PAG oil)

2 Nano- Refrigerant Concentration

Nano Refrigerant with different concentration of Al_2O_3 in the refrigerant R134a is prepared and tested in the setup.

3 Charging of set up

N_2 gas at a pressure of 5 bar to 7 bar and this pressure is maintained for 45 minutes. Thus the system was ensured for no leakages. A vacuum pump was connected to the port provided in the compressor and the system was completely evacuated for the removal of any impurities. This process was carried out for all the trials. Through the service ports refrigerant was carefully added to the system. Precision electronic balance with accuracy ±1% was used to charge a mass of 150gm. into the system. Every time the system was allowed to stabilize for 15 min.

IV. PERFORMANCE TEST

The system was charged with refrigerant (R 134) and a POE oil with different concentration using a charging line attached to the system. The temperature data were noted continuously, and the readings were taken an interval of 15 min. It was ensured that a constant temperature and humidity prevails in the surrounding space, when the experimental readings were taken. The experiment involved the measurement of the temperature T1- T6 of compressor, condenser, expansion valve, evaporator and inlet –outlet of water temperature. The power consumption rate of the compressor was determined by noting the time taken by the digital energy meter for 10 pulses. Using these data, the heat transfer rate at the evaporator cabin and the power consumption rate in the compressor were calculated using the standard expressions as follows.

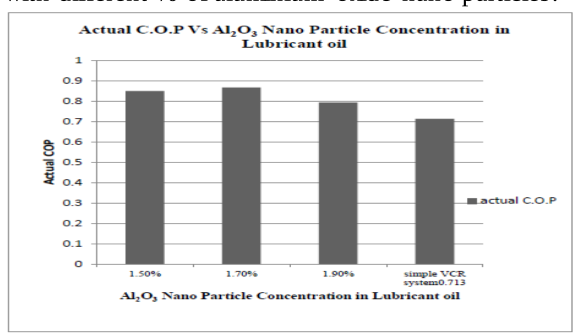
Factors affecting Refrigeration System

The important factors affect the performance of refrigeration system are Refrigeration effect, Coefficient of Performance (COP) and Energy factor(EF).

- Refrigeration effect q= Heat removal / mass flow rate or refrigerant (1)
- Coefficient of Performance COP = Heat Removal / Work Input (2)
- Energy Factor EF = Cooling capacity / Power consumption (3)
- work done by compressor(wc) wc = (3600*10) / (EMC*T). (4)
- Actual co efficient of performance (C.O.P) ACT (C.O.P) ACT = (refrigerant effect) / (work done by compressor) (5)

V. RESULT &DISCUSSION

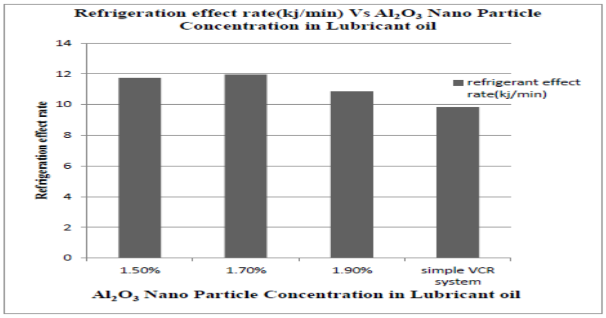
1 Comparison of actual C.O.P for nano refrigerant with different % of aluminium oxide nano particles.



Graph 1:Comparison of actual C.O.P for nano refrigerant with different % of aluminium oxide nano particles

In the above graph 6.6 shows that PAG oil with 1.7% of Al_2O_3 nano particles gives the better performance 0.8672 with compare 1.5%, 1.7% mass fractions of nano lubricant. because of the more surface area ,high thermal conductivity, higher heat transfer between the oil and fluids. These nano particles are weighed by the electronic weighing machine, mixed by the magnetic stirrer for 6 hours. The values for the different mass fractions of nano particles in the lubricant oils like 1.5%,1.7%,1.9% actual C.O.P are 0.8495,0.8672,0.793

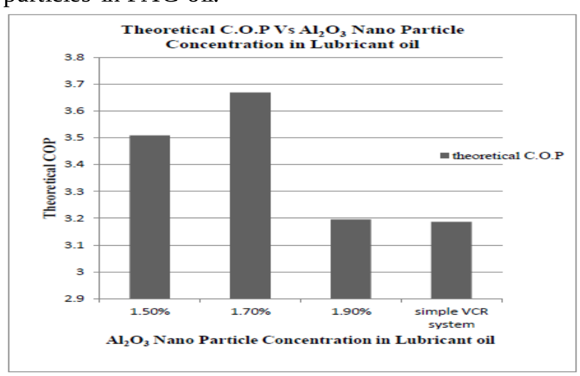
2 Comparison of refrigerant effect rate for different % mass fraction of aluminium oxide nano lubricant.



Graph 2:Comparison of refrigeration effect rate for different % mass fraction of aluminium oxide nano lubricant.

In the above graph 6.7 tells us that 1.7% mass fraction of Al2O3 nano lubricant gives the better cooling rate than other mass fractions. Because of the more surface area ,high thermal conductivity, higher heat transfer between the oil and fluids. These nano particles are weighed by the electronic weighing machine, mixed by the magnetic stirrer for 6 hours. Thevalues of refrigeration effect rate for the different mass fractions of nano particles in the lubricant oils like 1.5%,1.7%,1.9% of refrigeration effect rate are 11.74 kj/min,11.96 kj/min,
10.86 kj/min.

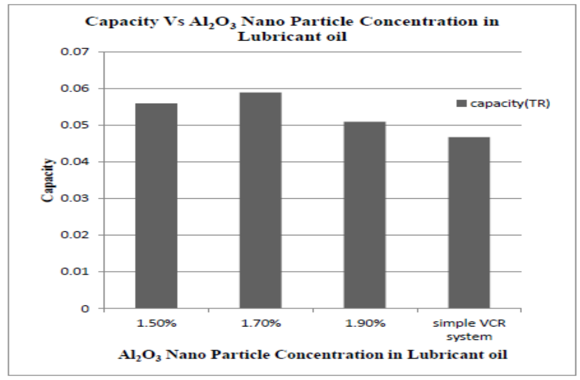
3 Comparison of theoretical C.O.P for nano refrigerant with different % of aluminium oxide nano particles in PAG oil.



GRAPH 3:Comparison of theoretical C.O.P for nano refrigerant with different % of aluminium oxide nano particles in PAG oil.

In the above graph 6.8 tells us that 1.7% mass fraction of Al2O3 nano lubricant gives the better theoretical C.O.P other mass fractions. Because of the more surface area ,high thermal conductivity, higher heat transfer between the oil and fluids. These nano particles are weighed by the electronic weighing machine, mixed by the magnetic stirrer for 6 hours. The values of refrigeration effect rate for the different mass fractions of nano particles in the lubricant oils like 1.5%,1.7%,1.9% of theoretical C.O.P are 3.51, 3.67, 3.196.

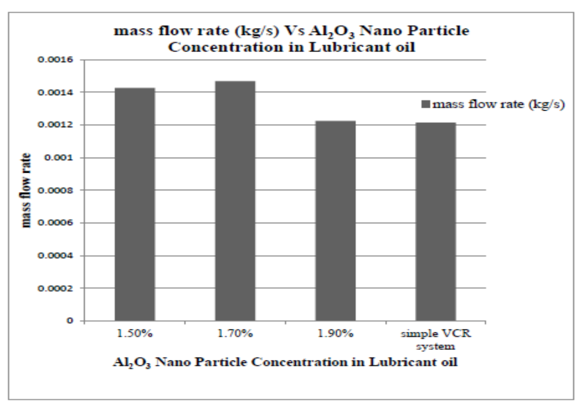
4 Comparison of capacity for nano refrigerant with different % aluminium oxide nano particles



Graph 5 Comparison of capacity for nano refrigerant with different % aluminium oxide nano particles.

In the above graph 6.9capacity is more for 1.7% of Al2O3 nano particles mass fraction mix is better than other mass fraction of nano particles for optimum capacity. Because of the more surface area, high thermal conductivity, higher heat transfer between the oil and fluids. These nano particles are weighed by the electronic weighing machine, mixed by the magnetic stirrer for 6 hours. The values of capacity for the different mass fractions of nano particles in the lubricant oils like 1.5%, 1.7%, 1.9% of capacity are 0.056 TR, 0.059, 0.0468 TR.

5 Comparison of mass flow rate for different mass fractions of nano lubricant



GRAPH 4:Comparison of mass flow rate for different mass fractions of nano lubricant.

In the above graph 6.10 mass flow rate is more for 1.7% of Al2O3 nano particles mass fraction mix is better than other mass fraction of nano particles for optimum mass flow rate. Because of the more surface area, high thermal conductivity, higher heat transfer between the oil and fluids. These nano particles are weighed by the electronic weighing machine, mixed by the magnetic stirrer for 6 hours. The values of mass flow rate for the different mass fractions of nano particles in the lubricant oils like 1.5%,1.7%,1.9% of mass flo rates are 0.001426 kg/s, 0.001467 kg/s, 0.001224 kg/s. This fig explains about mass flow rate of refrigerant in VCR system.1.7% of mass fraction of nano lubricant is higher than others. Eventually performance is more.

VI. CONCLUSION

The improvement of Vapour compression cycle Performance with the use of Nano-Particles in the lubricant oil is investigated. Apart from other literature studies the vapour compression cycle with constant energy input is fabricated and various mass concentrations of lubricant oil and Nano-particles are fed into the compressor and various performance parameters are recorded and concluded from the above graphs

- The thermal conductivities of nano refrigerants are higher than traditional refrigerants. It was also observed that increased thermal conductivity of nano refrigerants is comparable with the increased thermal conductivities of other nanofluids.
- From the experimental investigations Actual COP is increased upto 21.6% at 1.7%.mass concentration. After that it decreases so optimum percentage is 1.7% of Al2O3 for given 0.06 TR system.
- Refrigerant effect in evaporator is increased up to 21.6% due to more heat transfer surface area provided by Nano particles after the mixing with magnetic stirrer.
- Theoretical COP and mass flow rate of refrigerant increased by 15% and 20% respectively due to decrease in Viscosity of refrigerant.
- The Discharge pressure increases with time and attains a maximum value and then decreases.
- The Maximum discharge pressure is obtained for charge mass of 150gm.
- The suction pressure decreases initially and then increases with time.
- Suction pressure is found to be less for a charge mass of 150gm.
- Nanofluids stability and its production cost are major factors that hinder the commercialization of nanofluids. By solving these challenges, it is expected that nanofluids can make substantial impact as coolant in heat exchanging devices.

REFERENCES

[1] Serrano E, Rus G, Martı´nez JG. Nanotechnology for sustainable energy. Renewable Sustainable Energy Reviews 2009;13(9):2373–84.

[2] Elcock D. Potential impacts of nanotechnology on energy transmission applications refrigerant effect rate for different % of aluminium oxide nano particles

[3] Hindawi, Special issue on heat transfer in nanofluids; 2009.

[4] S heng-shan Bi et al. Application of nanoparticles in domestic refrigerators. Applied refrigerant effect rate for different % of aluminium oxide nano particles

[5] Eed Abdel-Hafez Abdel-Hadi et al .Heat Transfer Analysis of Vapor Compression System Using Nano Cuo-R134a. International Conference on Advanced Materials Engineering,

[6] K.henderson. Flow-boiling heat transfer of R-134a-based nanofluids in a horizontal tube.

[7] 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.

[8] Pawel K. P., Jeffrey A.E. and David G.C., (2005) Nanofluids for thermal transport. Materials Today, pp. 36-44

[9] D. Sendil Kumar, Dr. R. Elansezhian, (Sep.-Oct. 2012) Experimental Study on Al2O3- R134a Nano Refrigerant in Refrigeration System, International Journal of Modern Engineering Research (IJMER) Vol. 2, Issue. 5, pp-3927-3929

[10] R. Krishna Sabareesh Application of TiO2 nanoparticles as a lubricant-additive for vapour compression refrigeration systems -An experimental investigation.

[11] Reji kumar.R and Sridhar.K, (Apr 2013) Heat transfer enhancement in domestic refrigerator using nanorefrigerant as working fluid, Int. J. Comp.Eng. Res., 3(4).

[12] 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.
[13] X. Wang, X. Xu, and S. U. S. Choi. Thermal conductivity of nanoparticle fluid mixture. J.Thermophys. Heat Transf.,13(4):474–480, 1999.
[14] P. Keblinski Mechanisms of heat flow in suspensions of nanosized particles (nanofluids). Int. J. Heat Mass Transf., 45(4):855– 863, 2002.
[15] D. Kumar, H. Patel, V. Kumar, T. Sundararajan, T. Pradeep, and S. K. Das. Model for Heat Conduction in Nanofluids. Phys. Rev. Lett., 93(14): 4316, 2004.
[16] Y. Xuan and Q. Li. Investigation on convective heat transfer and flow features of Heat Conduction in Nanofluids. Phys. Rev. Lett., 93(14): 4316, 2004.
[17] H. Zhu, C. Zhang, S. Liu, Y. Tang, and Y. Yin. Effects of nanoparticle clustering and alignment on thermal conductivities of Fe3O4 aqueous nanofluids. Appl. Phys. Lett., 89(2):23123, 2006
[18] R. Saidur-A review on the performance of nanoparticles suspended with refrigerants