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Experimental Study of Vapour Compression Refrigeration System by Using Aluminum Oxide Nanoparticles as Lubricant Additive

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***Abstract*— The use of nanoparticles along with the normal lubricating oil in vapour compression cycle is a relatively a new idea. By using nano particles in lubricating oil we can improve the thermal and physical properties of the conventional lubricating oil, thus improve the overall performance of Vapour Compression Refrigeration System. In this study heat transfer enhancement was investigated experimentally by using alumina (Al_2O_3) nanoparticles of size 40-50 nm diameter with lubricant (PAG oil) and the refrigerant (R134a). Stable nanolubricant has been prepared with the help of magnetic stirrer followed by sonication. The experimental studies indicate that the refrigeration system with nanolubricant works normally. It is found that the freezing capacity is improved and increases by 86.26% for .3% of Al_2O_3 (% wt.) nanoparticles and the COP increases by 31% in comparison to normal lubricating oil. Thus using Aluminum oxide nanolubricant in refrigeration system is feasible.**

***Index Terms*— Alumina (Al_2O_3), Nanolubricant, Refrigeration effect, Coefficient of Performance (COP)**

1. INTRODUCTION

(A) Vapour Compression Refrigeration System

In very basic terms, refrigeration systems are used to remove heat from one part and transfer it to another part. Vapour Compression Refrigeration system uses mechanical energy by repeating compression and expansion of coolant fluid to achieve cooling by Joule–Thomson effect. Vapor compression refrigeration cycle is widely used in the air conditioners, heat pumps and HVAC system. The main purpose of refrigeration was to produce ice, which was used for cooling beverages, food preservation and refrigerated transport etc. Now-a-days refrigeration and air conditioning find so many applications that they have become very essential for mankind, and without refrigeration and air conditioning the basic fabric of the society will be adversely affected. Refrigeration and air conditioning are generally treated in a single subject due to the fact that one of the most important applications of refrigeration is in cooling and dehumidification as required for summer air conditioning. Of course, refrigeration is required for many applications other than air conditioning, and air conditioning also involves processes other than cooling and dehumidification .As mentioned before, air-conditioning is one of the major applications of refrigeration. Air-conditioning has made the living conditions more comfortable, hygienic and healthy in offices, work places and homes. Air conditioning involves control of temperature, humidity, cleanliness of air and its distribution to meet the comfort requirements of human beings and/or some industrial requirements. Air-conditioning involves cooling and dehumidification in summer months; this is essentially done by refrigeration. It also involves heating and humidification in cold climates, which is conventionally done by a boiler unless a heat pump is used.

For a closed cycle of refrigeration employing the condensable refrigerant vapour, the following processes are required:

(i) Compression of the vapour, thereby increasing pressure.

(ii) Condensing these vapours and rejecting heating to the cooling medium (usually water or atmospheric air)

(iii) Expanding the condensed liquid refrigerant thereby lowering the pressure and corresponding saturation temperature.

(iv) Evaporating the liquid refrigerant thereby absorbing heat from the body or space to be cooled or refrigerated. It is due to this requirement of compression that the system is called Vapour Compression System and the cycle of operation is called Vapour Compression Cycle of refrigeration.

(B) Nano lubricant

Nanolubricants are a relatively new class of lubricant which consist of a base lubricant 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. In the few decades, rapid advances in nanotechnology have lead to emerging of new generation of heat transfer fluids called the “nanolubricant”. Nano lubricant are defined as suspension of nanoparticles in a base lubricant. Some typical nanolubricant are ethylene glycol based copper nanolubricant; water based copper oxide nanolubricant etc. Nanolubricant are dilute suspensions of functionalized nano particles composite materials developed about a decade ago with the specific aim of increasing the thermal conductivity of heat transfer composite thermal heat transfer fluids, which have now the evolved into a promising nano technological area. Such thermal nano lubricant for heat transfer applications represent a class of its own difference conventional colloids for other application compared to conventional solid, liquid suspension for heat transfer intensifications.

Nano lubricant possesses the following advantages:

1. Higher heat transfer between the particles and fluids due to the high surface area of the particles
2. Better dispersion stability with predominant Brownian motion
3. Reduces particle clogging
4. Reduces pumping power as compared to base fluid to obtain equivalent heat transfer.
5. Adjustable properties, including thermal conductivity by varying particle concentrations to suit different applications.

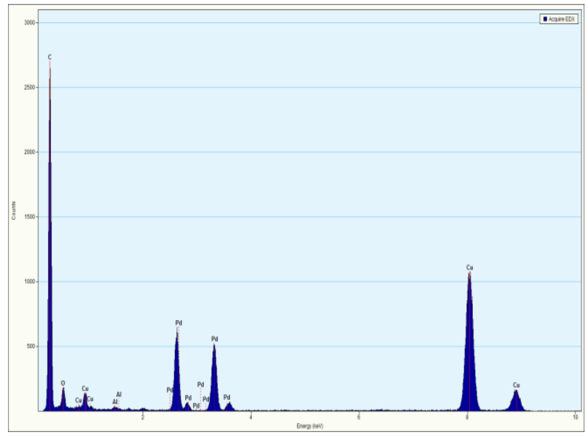
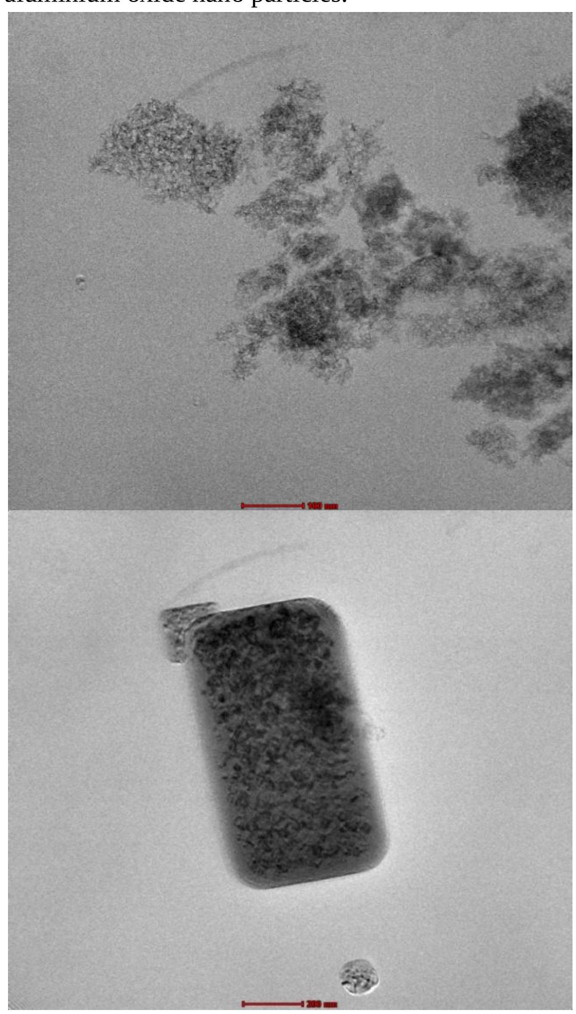


Image of nano particles by XRD spectroscopy

The morphology of nanopartocles were examined by Transmission Electron Microscopy (TEM) Images of aluminium oxide nano particles.



(A)TEM Images of Al_2O_3 nano particles

(B) TEM Images of Al_2O_3 nano particles

2. LITERATURE REVIEW

Continuous efforts have been made by numerous researchers on different ways to improve refrigeration system. Wonder to improve their performance and make them cost effective. Some researchers have made their Immense effort on enhance its efficiency.

Name of Researcher	Content and specification	Results
S.M.S.Murshed K.C.Leong C.Yang	Enhanced thermal conductivity of TiO_2-water based nanofluids	Performance increases nearly by 33%.
D.Sendil Kumar, Dr.R.Elansezhian	Worked on Al_2O_3-R134A nano refrigerant with PAG oil	COP increases by 11 %
Dr. K.Dilip Kumar,T.Ayyappa	Worked on R134A refrigerant with nano lubricant , Al_2O_3 nanoparticles and mineral oil	COP increases by 21.6 %
T. Coumaressin and K. Palaniradja	Worked on CuO-R134A nano refrigerant by CFD heat transfer analysis	COP increases by 15 %
R.dharmalingam , K.K sivagnanaprabhu, J. yogaraja, S. gunasekaran , R. mohan	Nanofluid consisting of water and 1% Al_2O_3 (volume concentration) nanoparticles used for heat transfer characteristics of for parallel flow counter flow and shell and tube heat exchanger.	Improvement in convective heat transfer of 42% for Al_2O_3 nanofluid when compared with water.
Juan Carlos Valdez Loaiza, Frank Chaviano Pruzaesky, Jose Alberto Reis Parise	A Numerical Study on Vapour Compression Refrigeration System by Using four different Nanofluid water-based nanofluids, Cu, Al2O3, CuO and TiO_2.	Greatest reductions in evaporator area were obtained with Cu+H2O nanofluid
Pravesh Kumar Kushwaha, Pavan Shrivastva, Ashish kumar shrivastva	Studied on nanorefrigerant (R134A+Al_2O_3) with POE oil based on vapour compression refrigeration system.	COP increases by 11.6 %

3. EXPERIMENTAL SETUP & METHODOLOGY

3.1 EXPERIMENTAL SETUP

This section provides a detailed description on the facilities developed for conducting the experimental work on vapour compression refrigeration system test rig. The technique used for charging nanoparticles and evacuation of the system is also discussed here. A detailed report on this facility development is as follows:

It 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.

Table 3 Refrigeration system specifications

Capacity	1/3 Ton 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
Magnetic stirrer	200-2000 RPM
Sonicator	20KHz
Charging kit	For charging refrigerant
Vacuum Pump	Rotary vane type

vapor compression refrigeration test rig

Charging kit Sonicator machine

4. EXPERIMENTAL PROCEDURE

In this part we have decribed about the steps and procedures taken to carry out our experiment. This experiment is performed on VCRS with different concenttration of nanoparticles by weight percentage of refrigerant. Nanopartices is blended with lubricant and used as nanolubricant. Preparation of nanolubricant and charging of setup is the main area of concern is this section.

4.1 Preparation of nano lubricant

Nanoparticles of Al_2O_3 are added to the refrigerant system by adding them to the lubricant in the compressor of the system. The preparation and stability of this lubricant and nanoparticles 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 Al_2O_3 in the range 40-50 nm were mixed with PAG oil to synthesize nanolubricant in a recommended method for nanofluid. The nano particles of Al_2O_3 and PAG mixture were prepared with the aid of magnetic stirrer for 2 hrs. The mixture is then further kept vibrated with an ultrasonic homogenizer i.e in sonicator for half an hour to fully separate the nanoparticles and to prevent any clustering of particles in the mixture to obtain proper homogenization. Thus the same procedures are then repeated to make lubricant with different concentration of Al_2O_3 with respect to refrigerant.

4.2 Charging of set up:

Charging of set up with Nitrogen gas (N_2) 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. With Precision electronic balance charging of mass of 350 gm of refrigerant were done.

4.3 Performance Test

The system was charged with refrigerant (R 134) and PAG oil with different concentration of nanoparticles using a charging line attached to the system. The temperature data were noted continuously, and the readings were taken at an interval of 5min.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-T5 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 5 pulses. Using these data, the heat transfer rate at the evaporator cabin and the power consumption rate in the compressor were calculated.

5. CALCULATION OF EXPERIMENTAL DATA

(1.) Refrigeration effect = Heat removal by the refrigerant- (1)

Calculated as RE = $m_*Cp_*(T_{5(initial)} - T_{5(final)})$ in KJ.

Where m = mass of the water

C_p = Specific heat of water in KJ/KgK

T_5 =Water temperature

(2.) Compressor work is measure by the energy meter ,

Electrical input power, Ip = (5/ Te)*(1/EMC)

Where, Energy Meter constant (EMC) = 1200 rev / kw / hr.

Te = Time of revolution for Indications to Complete 5 revolutions

Taking motor efficiency as 75% we have input shaft power

Work input (SP) = Elect. I.P x 0.75

(3.) Coefficient of Performance= Refrigerating effect / Work Input

6. RESULTS

In this present work experiments were carried out on VCRS system by using different concentration of nanoparticles by weight percentage of refrigerant. Nanoparticles were blended with lubricant to prepare nanolubricant. This section includes the results and its analysis of the experiment.

6.1 Refrigeration Effect

Refrigeration is the process by which heat (thermal energy) is transferred from a low temperature body to a high temperature body and the heat that is removed from the low temperature body accounts for the refrigeration effect. Here it is maximum for .3% of Al_2O_3 nanoparticles of the refrigerant

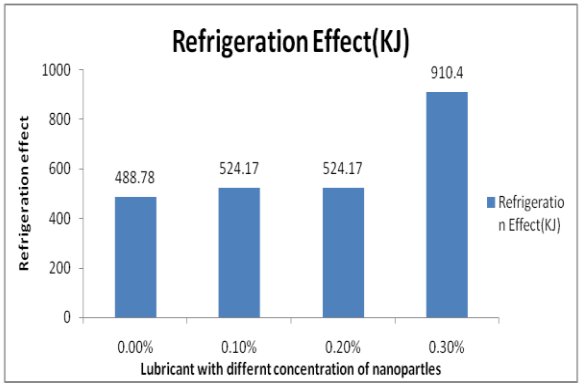
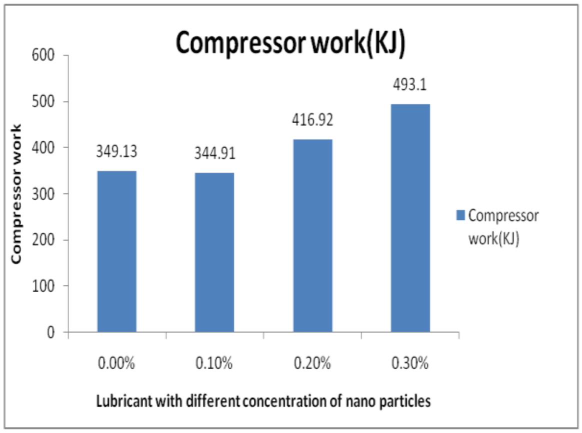


Fig.5.1: Refrigerating effect

6.2 Energy consumption by compressor

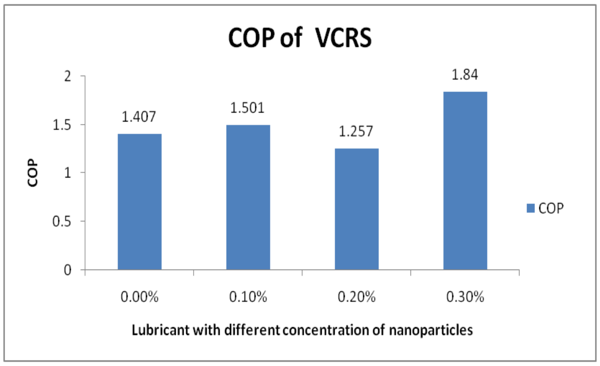
The compressor has to raise the pressure of the refrigerant to a level at which it can condense by rejecting heat to the cooling medium in the condenser. In doing so it has to take energy from system which is called as compressor work. Here it is maximum for .3% of Al_2O_3 nanoparticles of the refrigerant.



5.2 compressor work

6.3 COP (coefficient of performance) of VCRS system:

The coefficient of performance or COP of a refrigeration system is a ratio of useful cooling provided to work required. Here it is maximum for .3% of Al_2O_3 nanoparticles of the refrigerant.



COP (Coefficient of performance)

7. CONCLUSIONS

After blending different concentration of Al_2O_3 nanoparticles with PAG oil lubricant and using R134a as a refrigerant, we have reached to some important conclusions which are listed below:

1 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.

2 Actual COP was increased upto 31% by adding 1.05 gm of Al_2O_3 with lubricant. Initially on adding .35gm of Al_2O_3 nanoparticles COP increases by 6.68% then after that it decreases by 11% on adding .70gm of Al_2O_3 nanoparticles.

3 Refrigerant effect in evaporator is increased up to 86% by adding 1.05 gm of Al_2O_3 with lubricant. Initially on adding .35gm of Al_2O_3 nanoparticles refrigerating effect increases by 7.37% but on further increase of Al_2O_3 nanoparticles upto .70gm there is no change in refrigerating effect.

4 Energy required to run compressor is maximum for refrigerant having 1.05 gm of Al_2O_3 nanoparticles with lubricant and it is 41.23% more than base reading but with .35gm of nanoparticles compressor is minimum and even it decrease by 1.208% than its base reading.

5 The discharge pressure increases with time and attains a maximum value and then decreases.
6 The maximum suction & discharge pressure is obtained for charge 1.05 gm of Al_2O_3 nanoparticles with lubricant.
7 The suction pressure generally increases with time.
8 Suction pressure is found to be less for .35gm of Al_2O_3 nanoparticles.
9 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.
10 On further increasing the concentration of nano particles it may start to block the capillary tubes or in long term it may affect the performance of compressor.

8. FUTURE SCOPE OF THE PRESENT WORK

1 Research can be done by mixing of nanoparticles with refrigerant.
2 2 .Further researches will open new road for not only to increase the refrigeration effect but also to decrease the cost refrigeration system.
3 Here we can try with some other nanoparticles also like nanoparticles of copper, titanium, zinc etc except to see its refrigerant effects.
4 Uniform blending and homogenization method for preparation of nanolubricant and nanorefrigerant can be done.
5 Can work on reducing the size of refrigeration system by increasing the cop.
6 Preparation of nanoparticles with reduced size.

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