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RESEARCH ARTICLE OPEN ACCESS

An Experimental Investigation on Application of Al_2O_3 Nanoparticles as Lubricant Additive in VCRS

Dr. K.Dilip Kumar[1],T.Ayyappa[2]
[1]*Associate Professor: Department of Mechanical Engineering, LBRCE ,Mylavaram,*
[2]*M.Tech Student : Department of Mechanical Engineering, LBRCE,Mylavaram,*

ABSTRACT

In this work, the Al_2O_3 nano-oil is proposed as a promising lubricant to enhance 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

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 advantages

- 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.
- Reduced 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 Summary of research on nano particles and its % mixture in base fluid.

	particle	Base fluid	Average particle size	Volume fraction	Thermal conductivity enhancement	references
Metallic nano fluid	Cu	Ethylene glycol	10nm	0.3%	40%	24
	Cu	water	100 nm	7.5%	78%	21
	Fe	Ethylene glycol	10 nm	0.55%	18%	22
	Au	water	10-20 nm	0.026%	21%	22
	Ag	water	60-80 nm	0.001%	17%	23
Non metallic nano fluid	Al_2O_3	water	13 nm	4.3%	30%	25
	Al_2O_3	water	33 nm	4.3%	15%	26
	Al_2O_3	water	68 nm	5%	21%	27
	CuO	water	36 nm	3.4%	12%	29
	CuO	water	50 nm	0.4%	17%	28
	SiC	water	26 nm	4.2%	16%	27
	TiO_2	water	15 nm	5%	30%	29
	MWCNT	Synthetic oil	25 nm in dia 50 µm in length	1%	150%	39
	MWCNT	Decene/ Ethylene glycol/water	15nm in dia 30 µm in length	1%	20%/1%3/17%	30
	MWCNT	water	100nm in dia 70µm in length	0.6%	38%	36

Table : 2 Summary of research on nano particles and refrigerants

Year	Investigator	refrigerant	Nanoparticles	Size of nano particles	% volume concentrations	prformance
2007	19	R123,R134a	Carbon nano tubes	20nm*1µm	1	Heat transfer coefficient enhance up to 36.6%
2009	20	R141b	TiO_2	21 nm	0.01%,0.03%,0.05%	Nucleated heat transfer deteriorated with increasing particle concentration
2009	31	R113	CuO	40 nm	0.15-1.5%	Max enhancement of heat transfer is 26%
2009	34	R134a	CuO	30 nm	0.5%,0.1%,0.2%	
2009	35	R113	CuO	40 nm	0.01%,0.2%,0.5%	Frictional pressure drop increased by 28%
2009	36	R134a	CuO	30 nm	0.5%	Enhancement of heat transfer coefficient 50%-275%
2010	33	R113	diamond	10 nm	0-0.05%	Nucleate pool boiling heat transfer coefficient raises 63.4%
2006	37	R134a	TiO_2	-	-	reduction in energy consumption by 7.4.3%
2010	32	R134a	CuO	-	-	Heat transfer coefficient increased by 100%
	38	NH_3/H_20	Al_2O_3/CNT	-	0.06%/0.008%	Heat transfer rate was 20%higher than those without nano particles

II. EXPERIMENTAL SET UP

A. 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 .1 vapour compression test rig

Table 3 Refrigeration system specifications

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

B. 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

3.1 Preparation of nano- Refrigerant

Nanoparticles of Al_2O_3 $_2$are added to the refrigeration system by adding them to the lubricant in the compressor of the system. The preparation 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 Al_2O_3 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 Al_2O_3 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.

3.2 Nano- Refrigerant Concentration Nano-Refrigerant with 0.2% concentration of Al_2O_3 in the refrigerant R134a is prepared and tested in the setup.

Table 4 measurement equipment

Refrigerant flow measurement	Rotameter
Pressure indicators	Pressure gauges 2 no provaided
Energy meter	3200imp/kwh
Evaporator for refrigeration test rig	Immersed tube type,direct expansion coil
Temperature indication	Digital led
Insulation for water tank	Puf
Supply	230volts,50hzs,single phase

Fig 2: After Mixing of Nano particles in lubricant oil(PAG oil)

3.3. Charging of set up

N2 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 150 gm. 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.

4.1 Factors affecting Refrigeration System

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

a) Refrigeration effect q= Heat removal / mass flow rate or refrigerant------------**(1)**

b) Coefficient of Performance COP = Heat Removal / Work Input--------------- **(2)**

c) Energy Factor EF = Cooling capacity / Power consumption----------------------**(3)**

work done by compressor(w_c)

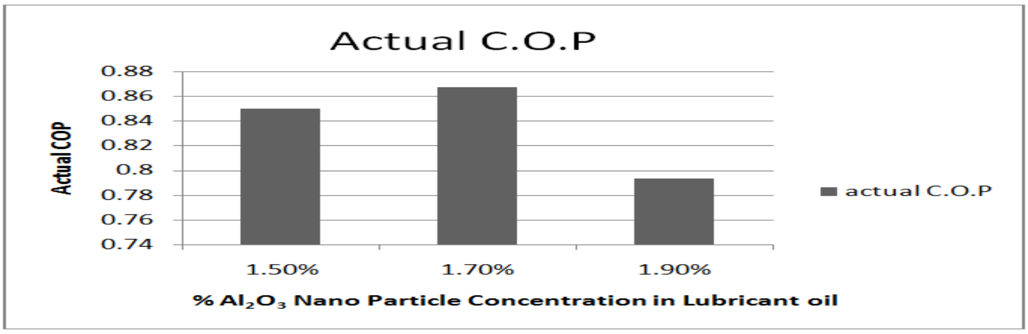
w_c = (3600*10) / (EMC*T).---------------------**(4)**

Actual co efficient of performance (C.O.P) ACT

(C.O.P) ACT = (refrigerant effect) / (work done by compressor)--------**(5)**

V. RESULT &DISCUSSION

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



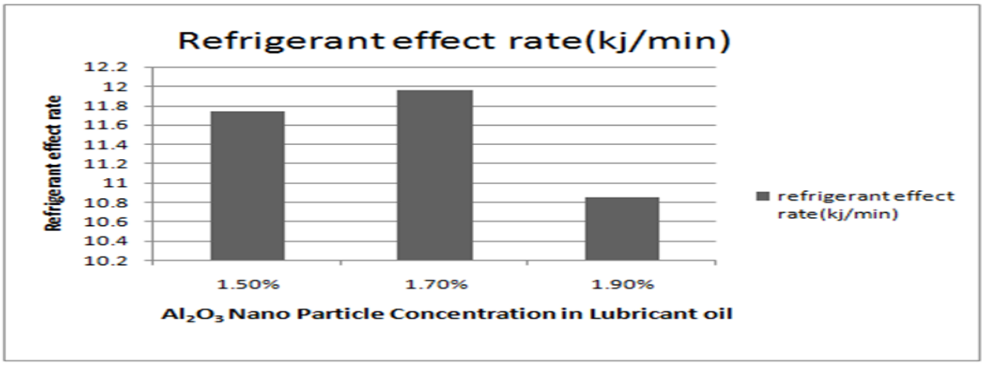
Graph 1: Actual COP Vs % Al_2O_3 nano particle concentration

From above Graph 1 we conclude that as the nanoparticles concentration in POE oil increases up to certain concentration, 1.7% of mass fraction of nano particles gives the optimum result. Table below shows the all values:

Table 5: Actual C.O.P Vs Al_2O_3 nano particle concentration

% Al_2O_3 nano particle concentration	Actual C.O.P
1.5	0.8495
1.7	0.8672
1.9	0.793

5.2. Graph of refrigerant effect rate for different % of aluminium oxide nano particles



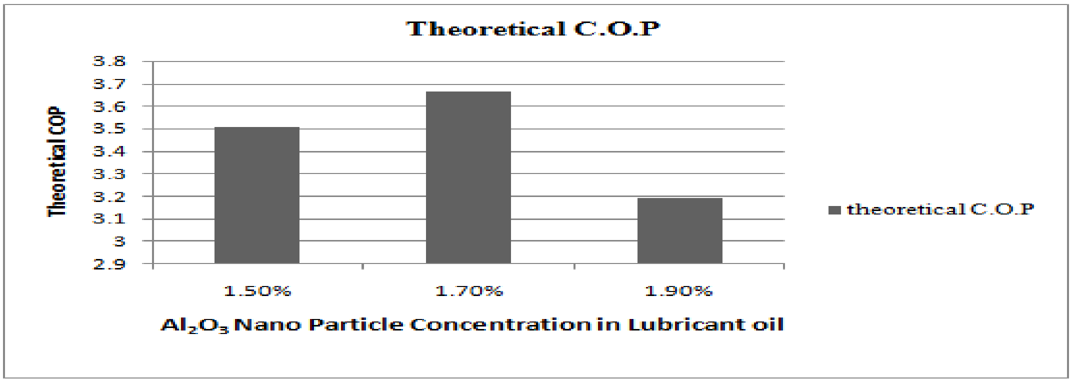
Graph 2: Refrigerating effect/min Vs % Al_2O_3 nano particle concentration

Above Graph 2 shows the 1.7% of aluminum nano particles increases refrigerant effect after that there is declination of refrigerating effect. Table IV below shows the all values

Table 6 Refrigerating effect/min Vs % Al_2O_3 nano particle concentration

Al_2O_3 nano particle concentration	Refrigerating effect/min
1.5	11.74
1.7	11.96
1.9	10.86

5.3.Graph of theoretical C.O.P for nano refrigerant with different % of aluminium oxide nano particles



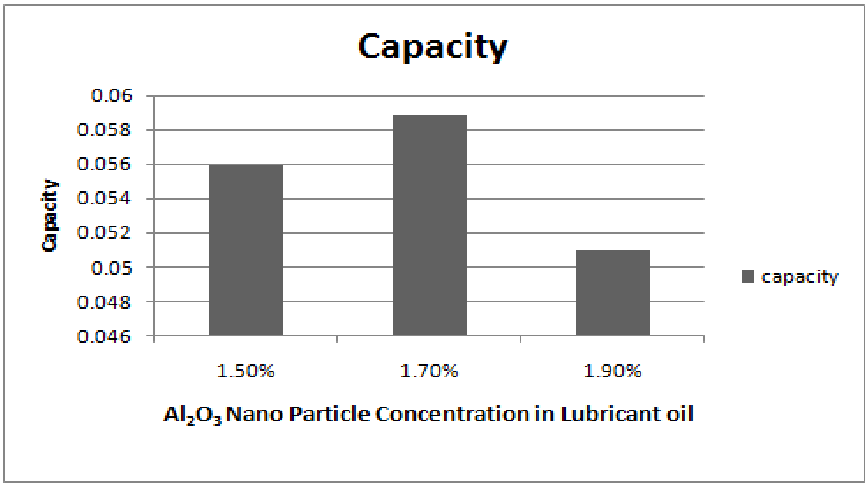
Graph 3: Theoretical C.O.P Vs % Al_2O_3 nano particle concentration

From the above Graph 3 theoretical C.O.P of the system becomes maximum at 1.7% of mass concentration due to increase in refrigerating effect

Table 7 Theoretical C.O.P Vs % Al_2O_3 nano particle concentration

% Al_2O_3 nano particle concentration	Theoretical C.O.P
1.5	3.51
1.7	3.67
1.9	3.196

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



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Graph 4: Capacity (TR) Vs % Al_2O_3 nano particle concentration

From the above Graph4 we can get the optimum capacity at 1.7% concentration.

Table 8 Capacity Vs % Al_2O_3 nano particle concentration

% Al_2O_3 nano particle concentration	Capacity(TR)
1.5	0.059
1.7	0.059
1.9	0.051

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 Nanoparticles are fed into the compressor and various performance parameters are recorded and concluded from the above graphs

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. 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.
3. 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.
4. Theoretical COP and mass flow rate of refrigerant increased by 15% and 20% respectively due to decrease in Viscosity of refrigerant.
5. The Discharge pressure increases with time and attains a maximum value and then decreases.
6. The Maximum discharge pressure is obtained for charge mass of 150gm.
7. The suction pressure decreases initially and then increases with time.
8. Suction pressure is found to be less for a charge mass of 150gm.
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.

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