Performance Improvement of Ducted Air-Conditioning System with Different Mass Fraction of CuO Nanoparticles Mixed in POE Oil

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Abstract – *In this work, the CuO nanolubricants of size 50nm is used for performance investigation of ducted air conditioning system. The application of nano-lubricant with specific concentration of 0.25%,0.50%,0.75% and 1% (by Mass fraction) were added in POE oil (polyolester oil) that is compressor oil and the results shows the improvement in COP of system and decrease in compressor work of system. By addition of nanoparticles to the refrigerant/lubricant, results in improvements in the thermophysical properties and heat transfer characteristics, thereby improving the performance of the air conditioning system.*

Keywords: CuO Nanoparticles, COP, Air Conditioning Performance, Compressor work.

1. INTRODUCTION

In today's world everyone is thinking of reducing energy consumption and saving it for longer period. A big amount of energy is consumed in our household devices among which refrigerators and air conditioners are used for large time of day. So the solution is to make an energy efficient model. Conventional thermo fluids are accountable for low thermal conductivity. Thus improving its thermal conductivity will enhance the heat transfer characteristics of the conventional fluid. Nanofluids are the new classes of fluids engineered by dispersing nanometer-sized particles. They are nearly-spherical particles with the size of its diameter in nm. Nanoparticles are between 1 and 100 nanometers (1×10^{-9} to 1×10^{-7} m) size [1].

Nanofluids are prepared by mixing nano-sized particles in conventional fluids in proper mass fraction. We mixed the CuO nanoparticles in POE oil (compressor oil), and then this fluid is stabilized with ultrasonic agitator. When the refrigerant is circulated through the compressor, it carries traces of lubricant plus nanoparticle mixture called nano lubricant so that all parts of the system have nanolubricants and refrigerant mixture [2]. Nanoparticles stay suspended much longer than micro-particles and the surface area per unit volume of nanoparticles is much larger (million times) than that of micro particles. [3] This leads to: 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) Reduced particle clogging 4) Reduced pumping power [4]. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. [5].Nanofluids are colloidal suspensions of ultra-fine metallic or non-metallic particles (organic/inorganic) in given fluid [2]. They are the two-phase system with the solid phase in the liquid phase. Based on the applications, nanoparticles are made using different materials. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes [5]. Nanoparticles could be of metal like copper (Cu), nickel (Ni), aluminum (Al), gold (Au), silver (Ag) etc. oxides like aluminum oxide (Al_2O_3), titanium oxide (TiO_2), copper oxide (CuO), silicon oxide (SiO_2); Carbides such as Silicon Carbide (SiC), Titanium Carbide (TiC), ceramics such as titanium, zinc, aluminum and various allotropes of carbon such as grafite, CNT (Carbon Nano Tubes)[2].

The common working fluids of heat transfer applications; such as water, propylene glycol, ethylene glycol, engine oil, POE oil, refrigerants and conventional fluid mixtures are used as base fluids for preparation of nanofluids.
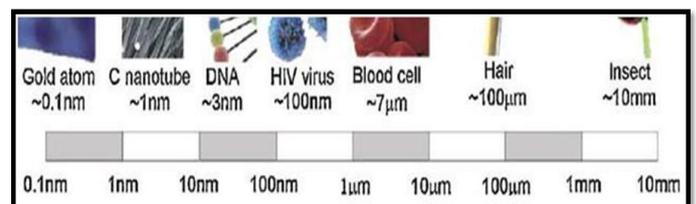

Fig.1 different type of Nanoparticles with length scale and related examples [6]

It is proved that chemical, physical and mechanical behaviours of material considerably change at the nanoscale, which encourages use of such enhanced behaviour of nano materials for new generation technology [7].

2. LITERATURE REVIEW:

Lots of researchers have investigated on VCR system including nano-refrigerant and also nano-lubricant on performance of VCR system. Some of those literatures are as discussed below:

1.   A.S.N. Husainy, Pradnya Chougule et al [2018] [8]

In this review paper many researchers tried to improve the Performance Enhancement of Simple Vapor compression

system by using nanofluids either in the form Nano-refrigerant or Nano-lubricant. It is clear that Nano-refrigerants have higher thermal conductivity than traditional refrigerants. Increasing of Nanoparticle concentration on volume basis thermal conductivity also increases. Temperature, particle size, constancy and dispersion are the important factors to determining thermal conductivity of Nanofluids. Increasing of nanoparticles results of increase viscosity and decreases with increasing of temperature.

2. Joshi Apurav, and Deepak Bondre et al. (2018) [9]

This work focuses on the experimental study of the performance on base refrigerant (R134a) with Nano-material. The effect of usage of Nano-materials on the thermal conductivity and coefficient of performance (COP) of the refrigeration systems has been studied. The effect on the rate of heat transferred through system and working parameters of set up is observed.

3. Nilesh S. Desai and P.R.Patil (2015) [10]

In this work, the SiO_2 nano-oil is proposed as a promising lubricant to enhance the performance of vapour compression refrigerator compressor. The stability of SiO_2 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%, 2% and 2.5 %(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 7.61%, 14.05% & 11.90%, respectively, when the nano-oil was used instead of pure oil.

4. Coumaressin & Palaniradja et al. (2014) [11]

They conducted performance analysis of a refrigeration system using nanofluid by CFD (Computational Fluid Dynamics) heat transfer analysis using the FLUENT software. The nanoparticles used for this was CuO (copper Oxide) with mass fraction of 0.05% to 1% and size range from 10nm to 70nm. The result shows that CuO nanoparticles used with R134a refrigerant would improve the heat transfer characteristics in refrigeration system. A model is designed and the basic theoretical heat transfer analysis of refrigeration system has been done. CFD heat transfer for design test section has been successfully performed FLUENT software. The result shows that, the heat transfer coefficient of evaporator increase with the use of CuO nanoparticles.

5. Fadhilah, Marhamad, & Izzat et al. (2014) [12]

In this work they studied the effect of suspended CuO nanoparticles in to R134a is investigated by mathematical modelling. The investigation includes heat transfer rate, thermal conductivity and also dynamic viscosity of nano-refrigerant in a tube of evaporator. The result shows that

thermo physical properties were increased. The nanoparticles concentration was ranged from 1% to 5%.

6. Kumar, Sridhar, & Narasimha et al.(2013) [13]

They conducted experimental study on performance of VCR system with Al_2O_3 nanoparticles, mineral oil as lubricant and R600a as refrigerant in the domestic refrigerator. The experimental setup for this purpose was build based on the national standards of India. The nanoparticles are added into refrigerant which results in increasing of thermal conductivity and heat transfer property of the refrigerant. The mass fraction of nanoparticles in lubricant is 0.06%. The heat transfer characteristics were estimated numerically. This study indicates that when mineral oil and Al_2O_3 nanoparticles were used then the power consumption of compressor is decreases by 11.5% and the freezing capacity is also higher. The coefficient of performance of the system also increases by 19.6% when POE oil changed with mixture of nanoparticles mineral oil.

7. Kotu & Kumar et al. (2013) [14]

They investigated the performance of the domestic refrigerant with mineral oil and R134a system was compared with mineral oil, nano-refrigerant and R134a, mineral oil and double pipe heat exchanger (DPHE) experimentally. The aluminum oxide with average size up to 50nm and mass fraction in lubricant was 0.06%. These nanoparticles were added in to compressor oil or lubricant. The result shows that the use of mineral oil, nano-refrigerant and R134a, mineral oil and DPHE works normally and safely. The power consumption of R134a, Mineral oil and DPHE system was decreased by 30% and also power consumption was reduced 26% when R134a, mineral oil and Al_2O_3 nanoparticles were used. The performance of R134a, Mineral oil and DPHE system increased by 10% and increased by 6% when R134a, mineral oil and Al_2O_3 nanoparticles were used.

8. Kumar &Elansezhian et al. (2012) [15]

In this experimental work of nano-refrigerant, an experimental test rig of VCR system was designed and fabricated in which R134a as refrigerant and PAG oil as lubricant was used Al_2O_3 nanoparticles were used. The nanoparticles were mixed with PAG (Poly Alkylene Glycol) lubricating oil. The concentration of nanoparticles in lubricant was 0.2% of volume. The result shows that system with R134a and PAG oil with Al_2O_3 nanoparticles as works normally and safely. The performance of system with nano-refrigerant was better than pure lubricant with R134a as working fluid with 10.32% less energy consumption and improvement in coefficient in performance up to 3.5. The uses of nano-refrigerant also reduce the length capillary tube.

9. Subramani & Prakash et al. (2011) [16]

In this experimentation they stated that, the nanoparticles added in to the refrigerant result in enhanced thermo-physical properties and heat transfer rate of

refrigerant. This results in improved performance VCR system. The refrigerant used for this purpose was R134a. Stable nano-lubricant was prepared for the experimental study. For experimental study there was three cases considered. The compressor filled with (1) pure POE oil, (2) mineral oil (3) mineral oil with Al_2O_3 nanoparticles and the mass fraction of nanoparticles in lubricant was 0.06%. It is found if mineral oil with Al_2O_3 nanoparticles used in system then system works normally and gives best result. The power consumption reduced by 25% and the freezing capacity is also higher with mineral oil and alumina nanoparticles. The improvement in COP of system was 33% when nano-refrigerant was used.

3. EXPERIMENTAL METHODOLOGY

Fig.2- Experimental set-up

In ducted air-conditioning system POE compressor oil is used as working fluid along with the nanoparticles. The temperature of the refrigerant at inlet/outlet of condenser and evaporator is recorded. Temperature measurement is necessary across each component of system in order to study the performance. Similarly pressure measurement also taken across evaporator and condenser of the air-conditioning system. Firstly, performance of the system is investigated with pure POE oil and then different mass fraction of CuO nanoparticles are suspended in the POE oil. The system is charged by using R134a refrigerant.

4. EXPERIMENTAL PROCEDURE:
4.1. Preparation of Nanofluid:

Nanoparticles of CuO are added to the compressor oil (POE oil) of the system. The preparation and stability of the nanolubricants is very important. The nanoparticles of CuO of size 50nm were mixed with POE oil to synthesize nanolubricant in a recommended method for nanofluid. The nanoparticles of CuO are mixed in POE oil. The mixture is then vibrated with an ultrasonic agitator for 3 hrs to prevent any clustering of particles and thus obtain proper homogeneous mixture.

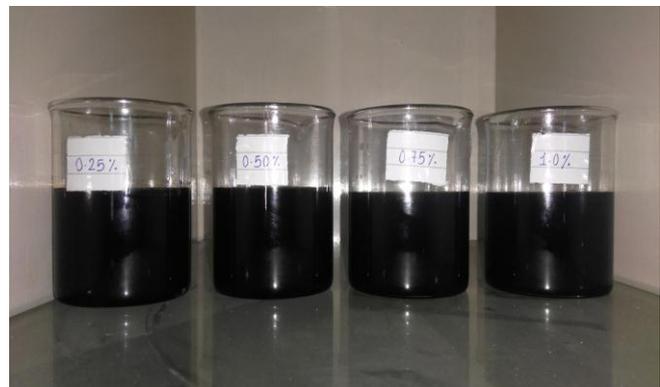**Fig.3-** Ultrasonic Agitator

Fig.4- Nano lubricants of different mass concentration of CuO nano particles

4.2. Nanofluid Concentration:

Nanoparticles with 0.25%, 0.50%, 0.75%, 1% mass fraction of CuO are added in 500 ml of POE oil separately to prepared and tested in the setup.

4.3. Performance Test:

The system was charged with refrigerant (R134a) and POE oil with different mass fraction of nanoparticles. The temperature data were noted and readings were taken. During experimentation, it was made certain to maintain a constant temperature and humidity of the surrounding. The reading of DBT and WBT of inlet and outlet are taken. The power consumption rate of the compressor i.e. compressor work was determined by noting the time taken for 10 blinks of energy meter. By using this data, the COP of system and the power consumption rate in the compressor were calculated using standard expression as follows:

1. Compressor work(Wc) = $\dfrac{Tc \times EMC}{10 \times 3600}$

2. (COP)Actual = $\dfrac{\text{Heat absorbed in evaporator from water}}{\text{Compressor work}}$

5. Result and Discussion:

Percentage of Nanoparticles	COP Carnot	COP Theoretical	COP Actual	Compressor Work (kW)
0 %	5.600	4.080	1.105	1.306
0.25 %	5.489	4.100	1.348	1.203
0.50 %	5.489	4.108	1.286	1.168
0.75 %	5.600	4.162	1.373	1.072
1.0 %	6.060	4.270	1.512	1.027

**Table no.1-** Results of different mass fraction of CuO nanoparticles

3.4. Effect on Carnot COP:
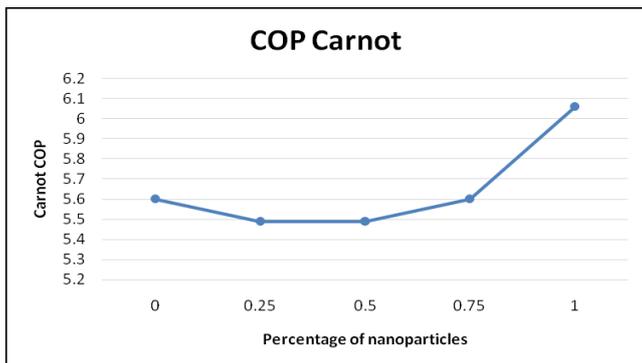
Graph -1: Carnot COP Vs Percentage of nanoparticles
After experimentation, COP with pure POE oil is found to be 5.6 and with nanoparticles of 0.25% and 0.5%, COP is 5.489 and 5.5 respectively. So with the nanoparticles of 0.75% and 1% Carnot COP was increases 5.600 and 6.060 respectively.
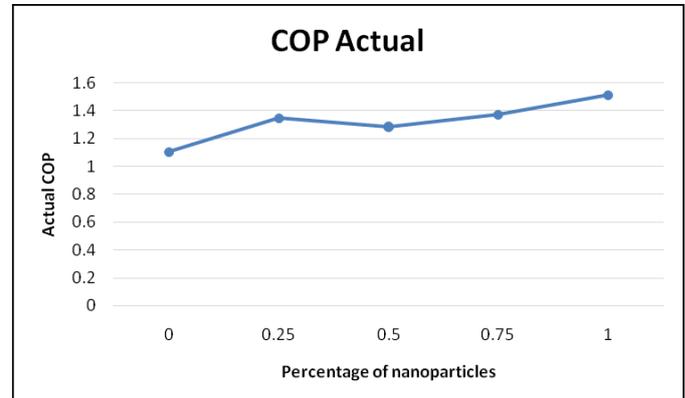
3.5. Effect on Theoretical COP:
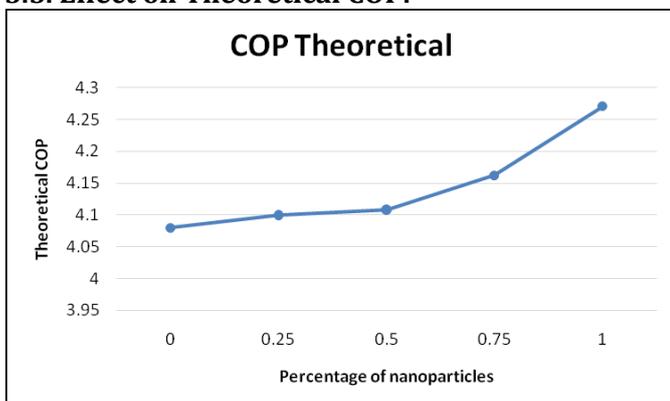
Graph -2: Theoretical COP Vs Percentage of nanoparticles

From the above Graph -2 theoretical COP of the system becomes maximum at 1%of mass concentration of CuO.
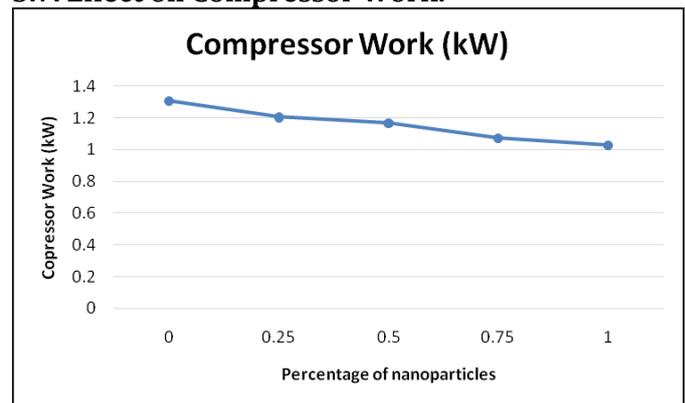
3.6. Effect on Actual COP:

Graph -3: **Actual COP Vs Percentage of nanoparticles**

From this Graph-3 we conclude that as concentration of the nanoparticles in POE oil increases the actual COP of system increases as compared to conventional system.

3.7. Effect on Compressor Work:

Graph -4: **Compressor Work Vs Percentage of nanoparticles**
From the above Graph-4 we can get the minimum capacity at 1% concentration.

CONCLUSIONS:

From the above experimentation it is concluded that, addition of 1% of CuO Nanoparticles in the compressor oil (POE oil) leads to improvement in the overall performance of the Ducted Air-Conditioning System as compared to pure compressor oil. From calculation it is concluded that the compressor work is reduced by 21.37% and actual COP, theoretical COP and carnot COP is increased by 26.92%, 4.45% and 7.6% respectively as compared to conventional system.

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