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Performance Study of Ducted Air-Conditioning System with Different Mass Fraction of Al_2O_3 Nanofluids

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***Abstract* - The coefficient of performance (COP) of VCR system is depends on the refrigeration effect and work required. It is increased by increasing the rate of heat transfer or by reducing the compressor work. Recently it is found that the use of nanotechnology in the refrigeration system can increase the performance of system. This research is on the concept, application, properties of the nanofluids & experimentation on ducted air conditioning system by using various mass fractions (0.25%, 0.50%, 0.75%, and 1.00 %.) of Al_2O_3 nanoparticles. In this experiment the nanoparticles are added into the base fluid which is lubricating oil (POE oil) of Compressor. It has been found that Nano lubricant has much higher temperature dependent thermal conductivity than conventional lubrication oil and it improves the thermo-physical properties. This can be considered as one of the key parameter of enhanced performance for refrigeration & air conditioning system. This research is performed in order to check and clarify the effect of Nano lubricant on the air conditioning system.**

***Keywords:* Al_2O_3 Nanoparticle, POE Oil Refrigeration and Air Conditioning, COP and Compressor Work**

I. INTRODUCTION

The use of additives in the Compressor Oil to improve the performance of the air conditioner represents a new type of energy saving technology. the environmental problems like Ozone Layer Depleting (ODP) and Global Warming Potential (GWP) & Another problem of power consumption or freezing speed and heat transfer rate is solved by using of new modern type of fluid called nanofluids. The use of nanofluid will increases the rate of heat transfer and also it reduces the power consumption. Hence these increases in heat transfer and lower consumption of power results in increase of performance of system. Recently, the nanofluids or hybrid nanofluids have gained interest in many engineering fields due to its excellent thermo physical properties, which can be easily used in refrigeration and air conditioning systems by many roles for performance improvement. Bhattad, *et al.,* [1]This review summarizes the researches on preparation and characterization of nanofluids, various thermo physical and electrical properties (density, heat capacity, viscosity, thermal conductivity, surface tension, electrical conductivity, freezing characteristics, etc.) of nanofluids [2]. The relative movement between the nanoparticle and base fluid is the main reason behind this improvement, leading to direct contribution caused by the circulation of the nanoparticles, carrying the heat along and indirect contribution resulting from the micro convection formed by the movement of the fluid around the nanoparticles. M. SalemAhmed [3] investigated experimentally the performance of chilled-water air conditioning unit with and without alumina nanofluids. The experimental results have been shown a less time is achieved to obtain the desired child fluid temperature for all the different concentrations of nanofluids (Al_2O_3-water) compared with pure water. Nanoparticles (1 to 100 nm in diameter) are added to oil to make nano lubricants, and these can then be can use in applications such as the compressors of refrigeration systems. Shareef [4] investigate the performance of a refrigeration system based on the coefficient of performance (COP) and energy consumption of an air conditioning device. Results showed that the COP was increased and energy consumption decreased when nano lubricant was used, and that the optimum concentration was 0.05% Al_2O_3 by mass, where the enhancement in COP was 25% compared to plain MO 4E; the energy consumption in the compressor was also lower. In our Experiment we have taken readings of various mass fractions of Al_2O_3 Nanoparticles in 0.25%, 0.50%, 0.75% and 1.00%. The proportion of Al_2O_3 nanoparticle to be added in the lubricating oil is determined for various mass fractions and is then mixed into the POE Oil. For uniform mixing of nanoparticles into base fluid we have used ultrasonic agitator. The results show that there is increase in COP of the Air Conditioning System by increasing the % mass concentration of Al_2O_3 nanoparticle into the POE Oil.

II. LITERATURE REVIEW

Many researchers have investigated and studied on VCR system with nanorefrigerant and also on nanolubricant on performance of VCR system. Some of those literatures are as discussed below:

A.S.N. Husainy, Ankush R. Gurav *et al.,* (2018) [5] Published a paper “Preparation, Properties, Stability and Applications of Different Nanofluids: A Review". In this paper the attention is given on Preparation, characteristics, and applications of nanofluids in detail. It was found that the use of Nanofluids appears promising, but the development of the field faces several challenges like long term stability, pressure drop, erosion, power consumption, etc. In this paper, thermal physical properties of nanoparticles suspended in refrigerant and lubricating oil of refrigerating systems were reviewed.

A.S.N. Husainy, Pradnya M. Chougule *et al.,* (2018) [6] Published a paper “A Glance on Preparation, Stability, Properties and Applications of Nanofluids”. In this review, an attempt has been made to explain the method of preparation, stability, properties, and applications of nanofluids. It is clear that Nano-refrigerants have higher thermal conductivity than traditional refrigerants. Increasing of Nanoparticles concentration on volume basis thermal conductivity also increases. Increasing of nanoparticles results of increase viscosity and decreases with increasing of temperature.

Zhelezny *et al.,* (2017) [7] attempted an experiment to explore the effect of alumina nanoparticles on the surface tension with modified differential method of capillary rise. According to them; the essence of this method was measurement of difference in the height of liquid’s meniscus in few capillary pair and followed by the calculation of weighted average value of capillary constant. The refrigerant nano-oil solutions (RONS) were prepared by two step method. Conclusion were derived out from their investigation is, Presence of nanoparticles consequences decrease in surface tension of pure refrigerant, however, it boosts the solubility.

R. Kumar *et al.,* (2016) [8] ZnO nano particles with particle size 20nm were used as the lubricant additive along with blended hydrocarbon refrigerant (R290/ R600a).No surfactants were avoided, since it may adversely affect on the thermo physical properties of the colloid. Major finding were decrease in suction and discharge pressure by 17% and 21 % respectively, drop in condenser temperature by 21%. From the performance view point, it has been reported that the compressor energy expenditure was reduced by 7.48% and the COP was increased by 45 %.

Nilesh S. Desai and P.R.Patil (2015) [9] The stability of SiO2 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.

A. K. Singh *et al.,* (2014) [10] presented a paper on “Thermal Conductivity of Nanofluids”. This study provides a review of nanotechnology with focus on thermal conductivity studies of nanofluids. They concluded that nanofluids have great potential for thermal management and control involved in a variety of applications such as electronic cooling, micro electro mechanical systems (MEMS) and spacecraft thermal management.

Tiwari *et al.,* (2013) [11] did some research on “Heat transfer enhancement in domestic refrigerator using R600a/mineral oil/nano-Al_2O_3 as working fluid”. In the experiment, heat transfer enhancement was investigated numerically on the surface of a refrigerator by using Al2O3 nano-refrigerants, where Nanofluids could be a significant factor in maintaining the surface temperature within a required range. The experiment showed that freezing capacity is higher and power consumption reduces by 11.5 % when POE oil is replaced by a mixture of mineral oil and Aluminium oxide nanoparticles.

Abbas *et al.,* (2013) [12] conducted a performance test in a refrigeration system with CNT based nanolubricant with R134a refrigerant. Polyolester oil with particle volume fractions of 0.01%, 0.05% and 0.1wt% were used for the preparation of nanolubricant. Experimental results show that CNT nanoparticles into POE lubricant produced enhancement in COP of the system. Significant reduction in power consumption has also been noted. COP of the system increased with increase in CNT wt% and a maximum COP was obtained at a concentration of 0.1wt%.

III. EXPERIMENTAL PROCEDURE

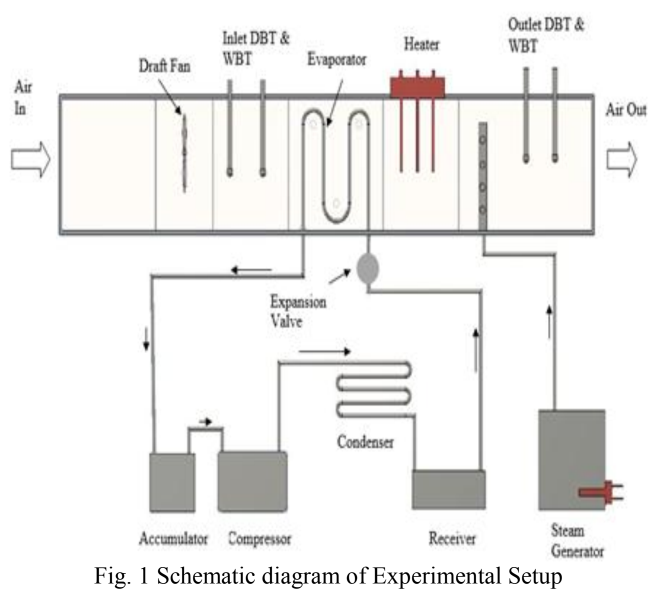

Fig. 1 Schematic diagram of Experimental Setup

In our experiment we have taken readings of various mass fractions of Al2O3 Nanoparticles in 0.25%, 0.50%, 0.75% and 1.00%. We have followed the procedure as given below.

1. The weight of Al2O3 nanoparticle to be added in the lubricating oil is 1gm, 2gm, 3gm, 4gm for mass fractions of 0.25%, 0.50%, 0.75% and 1.00% respectively.

2. After calculation we have taken weight of nanoparticles for 0.25% i.e. 1gm of nanoparticles. Then we have gone to mix this Al2O3 nanoparticle of proper weight into the base fluid (polyester oil).
3. For uniform mixing of nanoparticles into base fluid we have used ultrasonic agitation technology. The setup of ultrasonic agitation is at SGU, Atigre.
4. First of all we have taken 500ml of oil in beaker and added 1gm of nanoparticles into it. Then this beaker is placed into sump of agitator with full of water and start the vibrator. We have weight for 2 hrs and with controlling the temperature of water by changing it with cold water.
5. After2 hrs we get the proper mixture of particles and oil. Then nanofluid is formed and ready for taking readings.
6. For first reading we have learnt the process of discharging, vacuuming, charging and leak testing of vapour compression system from technicians. Then we have performed all the process for further reading of 0.25%, 0.50%, 0.75%, 1.00%.
7. For actual performance we started the ducted air conditioning system and remain as it is for 15 minutes. After 15 min we have taken readings of following parameters:
   i) Evaporator pressure, Condenser Pressure, Compressor energy meter reading for 10 blinks, Condenser inlet & outlet temperature, Evaporator inlet & outlet temperature, Inlet and outlet DBT and WBT.
8. After taking readings we have done calculations for COPs and SHF, LHF.

IV. ULTRASONIC AGITATOR

Ultrasonic Agitator is used to mix the Al2O3 Nanoparticles & POE Oil (Lubricant oil) homogeneously which uses ultrasound usually from 20–400 kHz. Ultra-Sonication can be used to speed dissolution, by breaking intermolecular interactions. Ultrasonic dispersion of nanoparticles is an excellent way to break up the aggregates, but care must be taken to avoid contaminating the samples when dispersing nanomaterial.Ultra-Sonication can also be used for the production of nanoparticles, such as nano-emulsions, nanocrystals, leptosomes and wax emulsions, as well as for waste water purification, production of biofuels.

Fig. 2 Ultrasonic Agitator

V. OBSERVATION TABLE

TABLE I FOR NANOPARTICLES OF 1.00% MASS FRACTIONS (WITH ADDITION OF 4GM NANOPARTICLES)

S. No.	Parameters	Observation	
1	Evaporator pressure	40Psi	2.76 bar
2	Condenser Pressure	150Psi	10.3448 bar
3	Compressor energy meter reading for 10 blinks	13 sec	

TABLE II PSYCHOMETRIC TEMPERATURES FOR SENSIBLE COOLING CONDITION

S. No.		DBT(°C)	WBT(°C)
1	Inlet	32.5	21
2	Outlet	16	14

S. No.	Description	Reading
1	Condenser inlet temperature	62
2	Condenser outlet temperature	38
3	Evaporator inlet temperature	5
4	Evaporator outlet temperature	8

V. RESULTS AND CONCLUSION

Mass Fraction	Actual COP	Theoretical COP	Carnot COP	Compressor Work (KW)	SHF
0.25%	0.969	3.127	6.40	1.250	0.846
0.50%	1.00	3.707	6.89	1.25	0.851
0.75%	1.00	3.38	7.079	1.305	0.777
1.00%	1.157	4.00	6.82	1.156	0.545

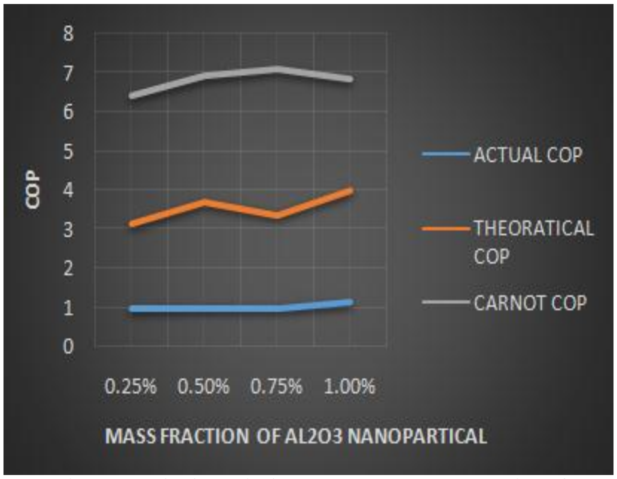

Fig. 3 Actual, Theoretical, CarnotCOP Vs Mass Fraction of Al_2O_3Nanoparticle

From the above Fig. 3 of Actual, Theoretical & Carnot COP Vs Mass Fraction of Al_2O_3Nanofluid we conclude that, As the mass fraction of Al_2O_3 increases the Carnot COP, Actual COP of refrigeration system increases also increase in the theoretical COP of refrigeration system.

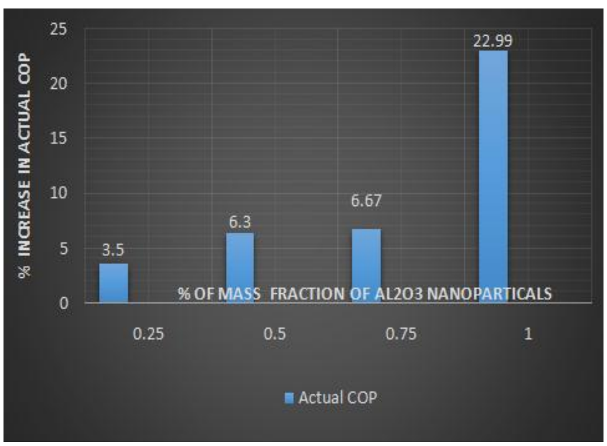

Fig. 4 % Increase in Actual COP Vs Mass Fraction of Al2O3 Nanoparticle

From the experimentation of this project we have the conclusions that

As the mass fraction of Al2O3 increases the actual COP of refrigeration system increases.
For 0.25% mass fraction it is increased by 3.5%
For 0.50% mass fraction it is increased by 6.3%
For 0.75% mass fraction it is increased by 6.67%
For 1% mass fraction it is increased by 22.99%

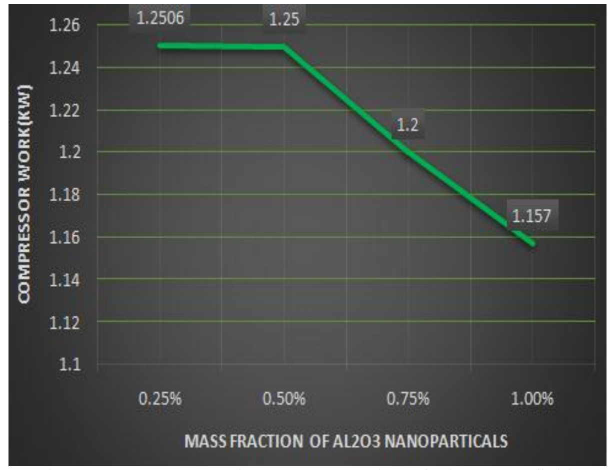

Fig. 5 Compressor Work Vs Mass Fraction of Al_2O_3 Nanofluids

The above Fig. 5 of Compressor Work Vs Mass Fraction of Al_2O_3Nanofluid, indicates that as the mass fraction of $Al2O_3$ increases the compressor work of refrigeration system decreases as follows.

For 0.25% mass fraction compressor work is 1.25 and it is decreased by 15.28%
For 0.50% mass fraction compressor work is 1.25 and it is decreased by 15.28%
For 0.75% mass fraction compressor work is 1.2 and it is decreased by 18.67%
For 1% mass fraction compressor work is 1.156 and it is decreased by 21.65%

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