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Performance Enhancement of Vapor Compression System using Nano Fluid Refrigerant

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Abstract: This paper contains the experimental studies performed on the nanofluid. The conventional refrigerants have major role in global warming and depletion of the ozone layer. Therefore, the need to improve the performance of vapour compression refrigeration system with the help of using suitable refrigerant opened the window of study of nano refrigerants. To execute this examination, a test setup was planned and manufactured in the workshop. The refrigeration system execution with the Nano oil was explored by utilizing refrigeration performance test. The outcomes demonstrate that R-134a and POE with TiO_2 powder works typically and securely in the refrigeration system. The refrigeration system execution was better than the customary R-134a and POE oil system. Therefore, the above Nano liquids can be used as a vital piece of refrigeration system to amazingly lower energy usage and for better Coefficient of performance (COP).

I. INTRODUCTION

During the past decade, the industrial revolution increased the utilization of the new technological products in our daily life. This caused more consumption of the energy and made it an inseparable part of the life. Also in the developing countries, the power generation is lagging behind the power demand.

The increase of power generation in the conventional methods leads to huge expenses in addition to negative environmental impacts which threatens the entire human society. Some of the impacts are Acid rain, melting of glaciers, Sea level raising, Health impacts, Atmospheric pollution, Ozone depletion, etc.

To avert those threats, one of the ways is to produce the electrical energy from the renewable sources and the other way is increasing the energy efficiency by better heat transfer methods. Now a days, Refrigerators and Air-conditioners came in the list of important equipment at various places like households, industries, transportations, offices etc. Improving the heat transfer technology in this area by new methods will save lot of thermal energy, in-turn the electrical energy. These problems persuaded the researchers for the use of nano technology in the field of heating ventilation and air conditioning, nanotechnology with its rapid development has grabbed the attention of many scientists, scholars, and engineers.

Nanofluids are one of the surprising outcomes of this technology that could increase the efficiency of thermal systems remarkably.

II. NANO PARTICLES

The basic idea of particle-dispersed fluid can be traced back to Maxwell's study in 1873. Afterward, in 1904, he indicated that the molecule that has nano-scaled diameter could be considered as starting the striking technology of nano. From that time up to now, the rapid development of nanotechnology has been seen in all aspects. Accordingly, nanofluid introduced as a new term, indeed, defined for the first time as liquids having nanometer-sized particles.

Nanofluids are solid–liquid mixtures in which the solid particles have usually a size more than 1 nm and less than 100 nm. The particles could be metal particles such as Al, Cu, and Ni; oxides such as Al_2O_3, TiO_2, CuO, SiO_2, Fe_2O_3 and Fe_3O_4; and some other compound materials such as AlN, SiC, and grapheme.

Nanofluids are new generation of heat transfer fluids with an anomalous behaviour, which are taken from stably suspending colloidal nanoparticles in the original fluids (conventional heat transfer liquids).

III. LITERATURE REVIEW

The Experimental analysis of Vapour Compression Refrigeration System using the refrigerant with Nano particles are classified into four sections. The first section concerns researches related to different nanoparticles and the following sections belong to Al2O3 nanoparticles, CuO nanoparticles and then TiO2 nanoparticles.

A. Research related to AL_2O_3

Prof (Dr.) R S Mishra [1] described the thermal modelling of Vapour Compression Refrigeration System using R134a in primary circuit and Al2O3-Water based Nano fluids in secondary circuit. The model uses information of the secondary fluids input conditions, geometric characteristics of the system, size of nanoparticles and the compressor speed to predict the secondary fluids output temperatures, the operating pressures, the compressor power consumption and the system overall energy performance. Such an analysis can be conveniently useful to compare the thermal performance of different nanoparticles (i.e. Al2O3, TiO2, etc.) based Nano fluid as a secondary fluid in a Vapour Compression Refrigeration System. He analyzed the exergy destruction and the first & second law efficiencies of thermodynamics. Still a very vast area is available for exploration using combination/ modification/ hybrid system and these systems could be tested with alternative/ newer refrigerants which have low global warming potential values.N. Subramani et al. [2] has made a test rig for the refrigeration system with hermetic sealed reciprocating compressor. He has given importance to the preparation stableness of nano fluid by ultrasonic sonication method and tested it for 72 hours for any sedimentation. He studied about the R134a, which is the most commonly used refrigerant in domestic refrigeration and air conditioning equipment. His experimental studies indicates the normal working of refrigeration system with nano refrigerant and he found that the freezing capacity is higher and the power consumption reduces by 25 % when POE oil is replaced by a mixture of mineral oil and alumina nanoparticles.

D. Sendil Kumar et al. [3] designed and manufactured an experimental setup in his laboratory for the vapour compression refrigeration system. In his work, he investigated the refrigeration system with the nano refrigerant of aluminium oxide and PAG oil combination. He found that addition of Nano Al2O3 to the refrigerant shows improvement in the COP of the refrigeration system and the usage of Nano refrigerant reduces the length of capillary tube and is cost effective.

B. Research related to CuO

Eed Abdel-Hafez Abdel-Hadi et al. [4] experimentally investigated the effect of using nano CuO-R134a refrigerant in the vapour compression system on the evaporating heat transfer coefficient. He designed an experimental test rig and constructed it for the testing purpose. The test section is a horizontal 'tube in tube' heat exchanger made from copper. The refrigerant is evaporated inside an inner copper tube and the heat load is provided from hot water that passing in an annulus surrounding the inner tube. He concluded that the evaporating heat transfer coefficient increases with the increase of heat flux upto 40 KW/m2 with CuO nanoparticles.

T. Coumaressin et al. [5] mentioned the drawback of R134a and its high global warming potential and informed that addition of nano-particles to the refrigerant will increase the performance characteristics of the system that will directly lead us to safe environment as well. He had done CFD analysis of the vapour compression system on FLUENT software using CuO-R134a nano-refrigerant. He found that the nano-refrigerant works efficiently and normally in the system. At last result indicates that the evaporating heat transfer is improved.

C. Research related to TIO_2

R. Saidur et al. [6] reviewed the heat transfer performance of different nano refrigerants with varying concentrations and presented the pressure drop and pumping power of refrigeration system with nano refrigerants. He reported the pool boiling heat transfer performance of CNT refrigerants and found that the R134a and mineral oil with TiO2 nanoparticles works normally and safely in the refrigerator with better performance. He identified the fundamental properties such as density, specific heat capacity and surface tension of nano refrigerants were not experimentally determined yet in the researches.

Omer A. Alawi et al.[7] reviewed the thermal–physical properties of nanoparticles suspended in refrigerant and lubricating oils of refrigerating systems and presented the effects of nano lubricants on boiling and two phase flow phenomena. He found that the nano refrigerants have a much higher and strongly temperature-dependent thermal conductivity at very low particle concentrations than conventional refrigerant. He also found that R134a and mineral oil with TiO_2 nanoparticles work normally and safely in the refrigerator with better performance.

IV. EXPERIMENTAL SETUP AND WORK DONE

A. Experimental Set up

The experimental refrigeration setup was fabricated with following components. A hermetically sealed reciprocating compressor for R-134a refrigerant, a forced type cool condenser, an expansion valve and an evaporator containing water. Five thermocouples, two pressure gauges and pinup energy meter are provided at respective locations to measure the temperatures at required locations, the inlet and outlet pressure of compressor and the power consumption.

B. Preparation of Nano refrigerants

The initial step is to prepare nano fluid by mixing POE oil and nano particles at ratio of 2.5 gm/ 350 ml. Then the second and final step is inserting the nano fluid into the compressor of the refrigeration system as a lubricant.

The TiO_2 nano particles were procured from Aligarh Muslim University.

No. of Tests	P_1 (psi)	P_2 (psi)	T_1 (^oC)	T_2 (^oC)	T_3 (^oC)	T_4 (^oC)	T_5 (^oC)	h_1 (kj/kg)	h_2 (kj/kg)	$h_{f3}=h_4$ (kj/kg)
1 reading	15	204	7.6	55.6	27.2	-1.3	-1.2	402.705	425.68	237.34
2 reading	15	204	8.1	57.8	26.1	-1.4	-1..5	403.27	426.29	235.90
3 reading	15	204	8.3	57.2	25.8	-1.5	-1.5	403.3	426.99	235
4 reading	15	204	8.4	57.3	26.2	-1.5	-1.6	403.3	426.29	237.3

C. Mixing of TiO_2 nano particles in POE oil

The nano particles were measured utilizing an electronic measuring balance for 2.5 gm and were blended in 350 ml of POE oil and the mixture was mixed well for 30 minutes following which the mixture was sonificated and kept for homogenous mixing of nano particles. The soundness of mixing is vital to guarantee the suspension of the nano particles in POE/Mineral oil amid drag out utilization of nano lubricant in the refrigeration system. The higher level of nanoparticles in the mineral oil will settle down effectively.

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D. Experimental Procedure

The prepared nano liquid was surged into the compressor and the refrigerant R-134a was parallely charged into the system. The performance test was led with R-134a refrigerant and POE oil at first, all the pressure and temperature readings are noted. The system was kept running for an hour. After the fruition of the test with POE oil the oil was totally emptied out of the compressor and the system was totally vacuumed out. Once again, the compressor was charged with the prepared nano liquid and R-134a refrigerant and the total performance test was completed.

V. RESULTS AND DISCUSSION

A. Readings for R134a with POE oil

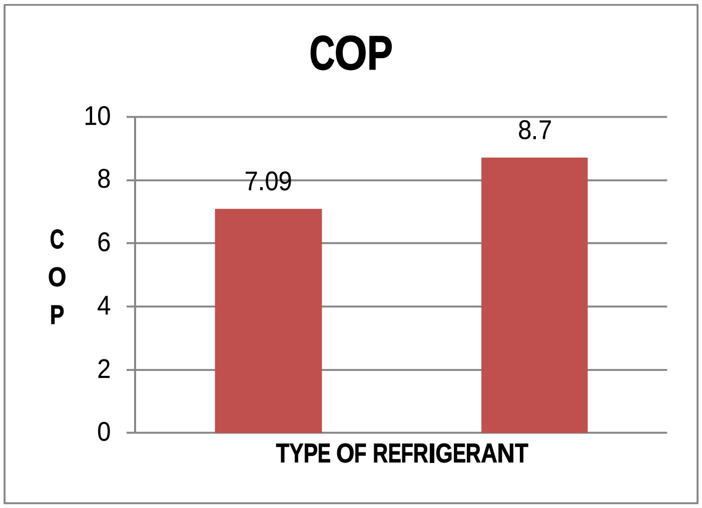
Here,
P_1 – Refrigerant Pressure at inlet of Compressor
P_2 – Refrigerant Pressure at outlet of Compressor
T_1 – Refrigerant Temperature at inlet of Compressor
T_2 – Refrigerant Temperature at outlet of Compressor
T_3 – Refrigerant Temperature at outlet of Condenser
T_4 – Refrigerant Temperature at inlet of Evaporator
T_5 – Aqua Temperature inside Evaporator Tank
h_1 – Enthalpy at entry of compressor
h_2 – Enthalpy at outlet of compressor
$h_{f3}=h_4$ – Enthalpy at exit of condenser.
Sample calculations without nanoparticles:
From test-1, h_1 = 402.705, h_2 = 425.68, h_{f3}= h_4=237.34 kJ/kg
We have, COP = (h_1 - h_{f3})/(h_2- h_1)
Where, h_1-hf3 = refrigeration effect = 402.705 – 237.34 = 165.3 kJ/kg
h_2 – h_1 = work input to compressor = 425.68 – 402.705 = 22.97 kJ/kg
Therefore,
COP = 402.705 – 237.34 / 425.68 – 402.705 = 7.19.
Similarly,
From above readings, Average COP = 7.09 (without nanoparticles).

B. Readings for R134a and POE oil with TiO_2

Readings taken	P_1 (psi)	P_2 (psi)	T_1 (^oC)	T_2 (^oC)	T_3 (^oC)	T_4 (^oC)	T_5 (^oC)	h_1 (kj/kg)	h_2 (kj/kg)	$h_{f3}=h_4$ (kj/kg)
1 reading	10	195	11.7	51	28	1.2	-2.0	405.51	424	238.77
2 reading	10	195	10.9	53	27.8	2.1	-1.5	404.955	424.69	238.3
3 reading	10	195	9.5	53.6	27.9	1.2	-1.9	403.84	424.7	238.7
4 reading	10	195	11.1	52.1	28	1.1	-2.1	405.23	424.35	238.77

Sample calculations with Titanium oxide nanoparticles:
From test- 1, h_1 = 405.23, h_2 = 424.35, h_{f3}=h_4=238.77 kJ/kg
We have, COP = (h1-hf3)/(h2-h1)
Where, h_1 - h_{f3}= refrigeration effect = 405.23 –238.77= 166.5 kJ/kg
h_2 – h_1 = work input to compressor = 424.35– 405.23 = 19.12 kJ/kg

Therefore,
COP = 405.23 – 238.77 / 424.35 – 405.23= 8.7.
Similarly, From above readings,
The Average COP = 8.6 (with nanoparticles TiO_2).
A graph is plotted taking COP on Y co-ordinate and type of lubricant on X co-ordinate, the red brick shows the COP of R134a and the green brick shows the COP of R134a+TiO_2.
Here it is clearly shows that the usage of nano fluid refrigerant increases the COP of the system.



At first the test was done with R134a and POE oil, and afterward POE oil is supplanted by POE oil nano fluids containing TiO2 nano powder in the proportion of 2.5gram/350ml. It is found that the Nano lubricant containing TiO_2 powder with R134a was working normally. Hence compatibility was observed in both the cases of R134a with POE oil containing TiO_2 nano powder. It is found that POE oil with 2.5gram/350ml of TiO_2 nano Powder obtained the higher COP than the normal POE oil.
The COP with nanoparticles TiO2 is 8.6 which is higher than 7.02 which is the COP Without nano particles.
From the above results it is clear that the use of nano fluid in vapour compression system enhances the performance of the system and likewise, the cooling effect on compressor, condenser and evaporator demonstrates that the introduction of cooling is speedier when R134a+TiO2 nano liquid is utilized contrasted with that of R134a, Also by the use of nano fluid the work done on compressor and condenser is reduced, indirectly saving the energy.

VI. CONCLUSION

The experimental investigation TiO_2 was carried out and the following conclusions:-

A. The R134a refrigerant and nano fluid of TiO_2 worked smoothly and efficiently in the vapour compression system.
B. The co-efficient of performance of the refrigeration system is improved in case of nano fluids compare to that of R134a with plain POE oil
C. The COP was found to be 22.5% higher when 2.5 grams/350 ml of TiO_2 and POE oil is used.

Hence the POE oil suspended with the TiO_2 nano particles improves the COP of the system.

VII. FUTURE SCOPE OF WORK

The test work observed nanofluids to be exceptionally and extremely effective contrasting option to customary liquids, giving the likelihood to improve transport properties, for the most part heat exchange, of working liquids and tribological properties of greases. Nanofluids can be effectively connected to HVAC&R frameworks, enhancing plants fiery execution and life cycle of compressors. Be that as it may, a wide test and hypothetical work is important to choose and enhance nanofluids relying upon applications prerequisites, the utilization of nanofluids appears to be alluring yet its application is upset by numerous elements like poor long haul steadiness, high pressure drop, high pumping power, low specific heat, particle settling, fouling and high production cost.

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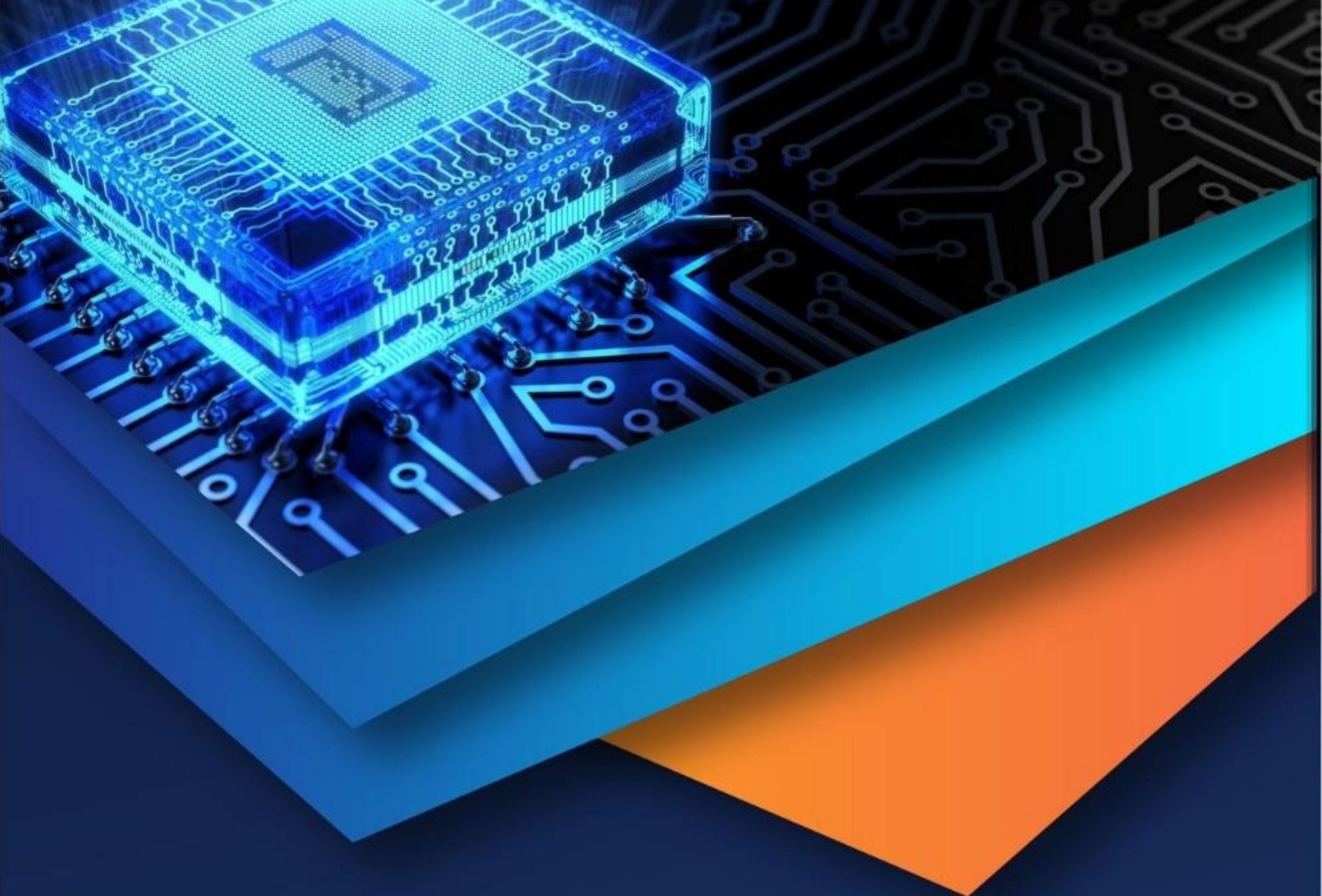

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