

Experimental Analysis on Vapour Compression Refrigeration System Using R134a Refrigerant Blended with Al₂O₃ Nanoparticles

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ABSTRACT: In this paper, an experimental work was investigated on nanorefrigerant. Nano Al₂O₃-mineral oil was used as nano-refrigerant in R134a vapour compression refrigeration system. An experimental setup was designed and fabricated in the lab. The system performance was investigated using thermal conductivity test and co-efficient of performance test. The results indicate that Al₂O₃ nano refrigerant works normally and safely in the refrigeration system. The results indicate that heat transfer coefficient increases with the usage of nano Al₂O₃. Thus using Al₂O₃ nanorefrigerant in refrigeration system is found to be feasible.

I. INTRODUCTION

HFC134a is the most widely used alternative refrigerant in refrigeration equipment such as domestic refrigerators, chillers and automobile air conditioners. HFC134a has been accepted as long term alternative refrigerant in many countries. Due to strong chemical polarity, the normally used mineral oil is replaced by Polyol-ester (POE) oil. Nano-particles suspended in lubricant of the compressor is found to be increasing the system efficiency and also the system works without any choking. Nano Al₂O₃ gives better performance by returning more lubricant oil back to the compressor. Eed et al. investigated the evaporating heat transfer co-efficient and heat flux in a domestic refrigerator. The presence of nano CuO in the refrigerant R1234a improved the evaporating heat transfer co-efficient with the particle size from 15 to 70 nm. Sheng et al. studied the reliability and performance of a domestic refrigerator with TiO₂ and mineral oil lubricant with R134a. The results showed reduction in 26.1% energy consumption. Ching-Song Jwo et al. studied the usage of alumina in R134a refrigeration system. The thermal conductivity was found to increase from 1.5 to 4.6%, when the sample temperatures were 20°C to 40°C at 1.5 wt.%. Park investigated the effect of CNTs on the nucleate boiling heat transfer of R123 refrigerant.

II. EXPERIMENTAL SETUP

A. COMPONENTS

The experimental consists of compressor, fan cooled condenser, expansion device and an evaporator section. Capillary tube is used as an expansion device. The Evaporator is of coil type which is loaded with water. Service ports are provided at the inlet of expansion device and compressor for charging the refrigerant. The mass flow rate is measured with the help of flow meter fitted in the line between expansion device and drier unit. The experimental setup was placed on a platform in a constant room temperature. The ambient temperature was $\pm 1.5^\circ\text{C}$. The air flow velocity was found to be less than 0.35m/s.

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Table 1. shows the specification of compressor.

Compressor specification are: Model Number	THK9414YGS
Displacement (CC)	6.90
Power (Watts)	230
Current (Amp)	1.60
LRA (Amp)	15.0
Circuit	CSIR

Table 1. Specification of compressor.

B. INSTRUMENTATION

The temperatures at different parts of the experimental setup are measured using resistance thermocouples. 5 resistance thermocouples were used for the experimentation. The pressure at compressor suction, discharge, condenser outlet and at evaporator outlet is measured with the help of pressure gauges. The power consumption of the system was measures by a digital Watt-hr meter. A digital wattmeter is also connected with the experimental setup.

III. PROPOSED REFRIGERATION SYSTEM

Considering an existing vapour compression refrigeration system explained above has consisting and working under round tube condenser. In this section, experimental setup we used was explained this experimental kit is a proposed kit and it is shown in figure.1

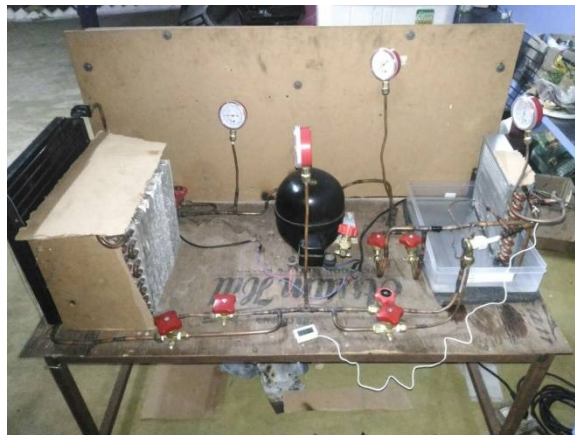


Fig 1.Photo copy of refrigeration system with micro channel condenser, but this proposed vapour compressor refrigeration system working under the round tube and also micro channel condenser in swapping with capillary and Thermostatic expansion devices.

IV. EXPERIMENTAL PROCEDURE

A. Preparation of nano- refrigerant

Nanoparticles of Al₂O₃ 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

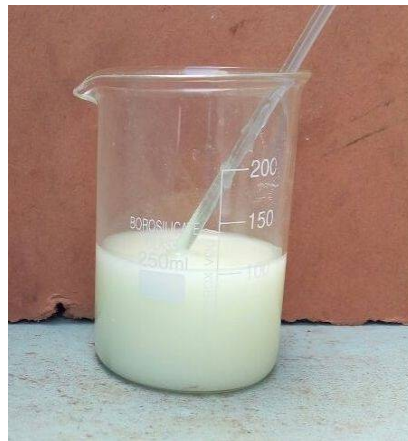
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oil is selected owing to its common usage and superior quality. The nanoparticles of Al_2O_3 in the range 40-50 nm were mixed with PAG to synthesize nanolubricant in a recommended method for nanofluid. PAG oil was used as supplied by supplied without further purification. The nano particles of Al_2O_3 and PAG mixture were 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. Fig.2 shows the preparation of nanolubricants.



. Fig.2 preparation of nanolubricants.

B. Nano- refrigerant concentration

Nano-Refrigerant with 3 gm of Al_2O_3 in the 100 ml mineral oil in the refrigerant R134a is prepared and tested in the setup.

C. Charging of the set up

The fabricated experimental setup was filled with N_2 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. The system was evacuated by removing N_2 gas. 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 nano refrigerant was carefully added to the system. Precision electronic balance with accuracy $\pm 1\%$ was used to charge a mass of 150 gm. into the system. Every time the system was allowed to stabilize for 15 min.

D. Experiment procedure

First of all, the refrigerant R134a was filled in the refrigeration system when flow is available to both the condenser. After filling, flow of refrigerant to the micro channel was closed. Now fill the water inside the evaporator cabin and note down its weight and temperature. Switch on the compressor, it compresses the refrigerant R134a and it starts to flow through the refrigeration system. Now the temperature of the water, which is available inside the evaporator cabin, is starts to decrease. When its temperature reaches to $25^\circ C$, the following readings were note down. Temperature at compressor inlet outlet temperature, Expansion valve inlet and outlet. Final Energy meter reading

Again the same procedure was repeated and note down the required valves when evaporator water temperature is $20^\circ C$, $15^\circ C$.

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V. RESULTS AND DISCUSSION

The results that were obtained after the addition of nano particles to the refrigerant R134a is tabulated below. Coefficient of performance and power consumption were changed during the process. It was found that addition of aluminium oxide nanoparticles to the refrigerant results in improvement in the thermo physical properties and heat transfer characteristics of the refrigeration system.

Table no 2 Experimental values on working with Normal condenser and capillary tube of refrigeration system

A. Experimental Calculation:

Here, abbreviations for the symbols were listed.

E_i =Initial energy meter readings

E_0 =Final energy meter readings

W =Work done of compressor

T_R =Room temperature

T_F =Final temperature

h_1 =Enthalpy of refrigerant at compressor inlet which is taken from p-h chat of R134a for its corresponding pressure and temperature.

h_2 = Enthalpy of refrigerant at compressor outlet which is taken from p-h chat of R134a for its corresponding pressure and temperature.

h_4 = Enthalpy of refrigerant at Evaporator inlet which is taken from p-h chat of R134a for its corresponding pressure and temperature.

h_3 = Enthalpy of refrigerant at Evaporator outlet / compressor inlet which is taken from p-h chat of R134a for its corresponding pressure and temperature.

i. Actual COP

Input power = $(E_0 - E_i) * 860.4$

= $(0.05 * 860.4)$

= 43.02kcal

Output power = $W (T_R - T_F)$

= $10(28 - 20)$

= 80kcal

Actual COP = output power / input power

= $80/43.02$

=1.859

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S l. N o	3gm of Al ₂ O ₃ +mi neral oil mixt ure (ml)	L oa d at ° C	Temperature at different inlet and outlet of Refrigerant in (°C)				Pressure at different inlet and outlet of refrigerant in (bar)				Energy meter reading in kWhr	
			T ₁	T ₂	T ₃	T ₄	P ₁	P ₂	P ₃	P ₄	Init ial	Fi na l
1	5	20	31.9	53.7	41.6	-2.7	0.83	10.68	10.41	0.34	1.95	2.0
2		15	29.7	57.1	42.5	-3.7	0.89	11.3	11.03	0.35	1.95	2.05
3	10	20	30.8	51.5	39.2	2	0.82	10.34	9.99	0.34	2.19	2.25
4		15	29.1	21.4	39.1	0.8	0.75	10.13	9.98	0.21	2.19	2.26
5	15	20	27.8	55.8	41.6	1.6	1.38	11.03	10.68	0.20	2.36	2.40
6		15	27.4	58.6	40.6	5.8	0.68	11.03	9.99	0.34	2.36	2.42

ii. Theoretical COP

$$\begin{aligned}
 \text{Theoretical COP} &= (h_4 - h_1) / (h_3 - h_2) \\
 &= (249 - 198) / (290 - 249) \\
 &= 51 / 41 \\
 &= 1.244
 \end{aligned}$$

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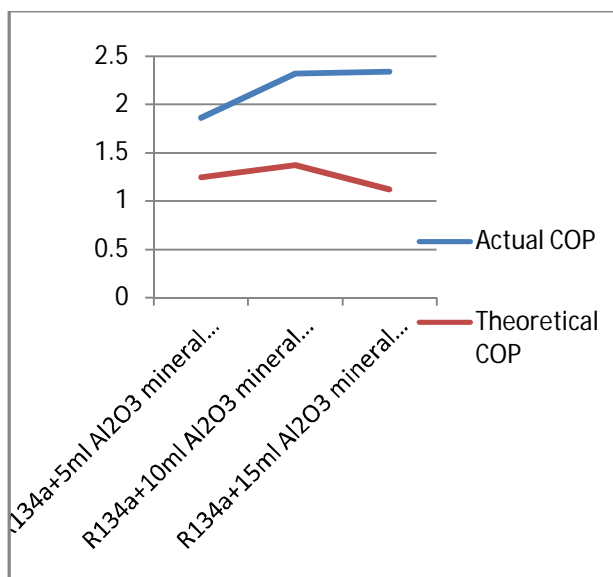
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Quantity of nano particles(g m)	Quantity of nanolubric ant (ml)	Final water temperature (°c)	Actual coefficient of performance	Theoretical coefficient of performance
3	5	20	1.859	1.244
		15	1.511	0.956
	10	20	2.324	1.371
		15	2.518	1.1
	15	20	2.342	1.12
		15	2.581	1.02

Table 2. Actual COP and Theoretical COP



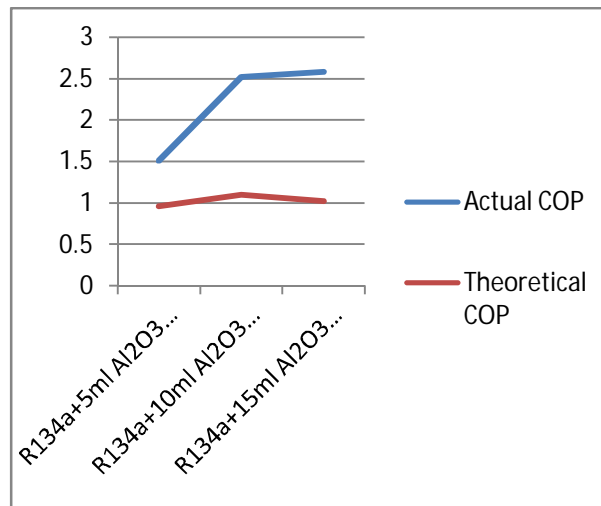
At 20°C of Water temperature
Graph 1. COP vs. R134a+Al₂O₃ mineral oil mixture

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At 15°C of Water temperature

Graph 2. COP vs. R134a+Al₂O₃ mineral oil mixture

VI. CONCLUSION

Addition of Nano Al₂O₃ in to the refrigerant shows improvement in the COP of the refrigeration system. Usage for Nano refrigerant reduces the length of capillary tube and cost effective. The following are the important results of the experimental investigation.

1. The COP of the system increases with increase in capillary tube length
2. Maximum COP of 2.581 is achieved for a capillary length of 0.5 m
3. The Discharge pressure increases with time and attains a maximum value and then decreases.

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