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Performance Evaluation of Household Refrigerator using CuO Nanoparticle Lubricant Mixture and various Compressor Oils with Different Condenser Modes

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ABSTRACT :- *The objective of this paper was to study the performance of household refrigerator with 0.06% mass fraction CuO nanoparticle-lubricant mixture and different types of compressor oil having both air-cooled and water-cooled condenser. The experiment was done using HFC134a as the refrigerant, CuO nanoparticles, Polyol-ester oil (POE) oil which is used as the conventional lubricant in the household refrigerator and SUNISO 3GS mineral oil as the lubricant alternatively. The result indicates that the refrigerator performance had improved while using CuO nanoparticle-lubricant mixture. The performance was also improved when HFC134a/SUNISO 3GS mineral oil system was used instead of HFC134a/POE oil system and there was also an enhancement when water-cooled condenser was used instead of the conventional air-cooled condenser on all load conditions. The HFC134a/CuO/SUNISO 3GS mineral oil system works normally and safely in the refrigerator. HFC134a/CuO/SUNISO 3GS mineral oil system reduced the energy consumption between 12% and 19% when compared with the HFC134a/POE oil system and between 9% and 14% while working with water-cooled condenser on various load conditions. There was also an enhancement in coefficient of performance (COP) when CuO nanoparticle-lubricant mixture was used instead of POE oil as the lubricant. The water cooled heat exchanger was designed and the system was modified by retrofitting it, along with the conventional air-cooled condenser by making a bypass line and thus the system can be utilized as a waste heat recovery unit. Experimental result shows that about 200 litres of hot water at a temperature of about 58ºC over a day can be generated.*

KEYWORDS: - *CuO nanoparticles, Household refrigerator, HFC134a, POE oil, SUNISO 3GS mineral oil, Water-cooled condenser*

I. INTRODUCTION

A household refrigerator is a common household appliance that consists of a thermally insulated compartment and which when works, transfers heat from the inside of the compartment to its external environment so that the inside of the thermally insulated compartment is cooled to a temperature below the ambient temperature of the room. Heat rejection may occur directly to the air in the case of a conventional household refrigerator having air-cooled condenser or to water in the case of a water-cooled condenser. The survey of the literature regarding the CuO nanoparticle-lubricant mixture, waste heat recovery and using of various compressor oils in the household refrigerator and air-conditioners are listed. Sheng-shan Bi et al. [1] experimentally investigated the performance of a domestic refrigerator with SUNISO 3GS mineral oil and TiO2 nanoparticles in the working fluid. The results indicated that the energy consumption of the HFC134a refrigerant using SUNISO 3GS mineral oil and 0.06% mass fraction of TiO2 nanoparticle mixture as lubricant reduced the energy consumption by 21.2% when compared to that of HFC134a and POE oil system. Romdhane ben slama [2] developed a system that can recover heat from the condenser of the refrigerator. In this work the air-cooled conventional condenser is replaced by another heat exchanger to heat the water. The results show that water at a temperature of 60ºC was produced by the system. This paper also analysed the economic importance of the waste heat recovery system from the energy saving point of view. She ngshan Bi et al. [3] experimentally investigated the performance of a domestic refrigerator using TiO2-R600a nano-refrigerant. The test results shows that refrigerator performance was better than the pure R600a system, with 9.6% less energy used with 0.5 g/L TiO2-R600a nano-refrigerant. This study aims to compare the performance of a household refrigerator with air/water-cooled condenser and using HFC134a/POE oil, HFC134a/SUNISO 3GS mineral oil and HFC134a/CuO/SUNISO 3GS mineral oil.

II. EXPERIMENTAL SETUP

II.1. Experimental System

The refrigerator was of 190L capacity, single door, manufactured by Kelvinator. The system was retrofitted with a water-cooled condenser along with the conventional air-cooled condenser by making a bypass line. Water-cooled condenser is a tube in tube heat exchanger having an inlet for the cooling water and an exit for collecting the hot water. The modified household refrigerator was properly instrumented with temperature indicators, pressure gauges and digital energymeter. The temperature at various points was noted using calibrated K-type thermocouples.

Figure 1 shows the experimental test rig. The retrofitted water-cooled condenser can also been seen.

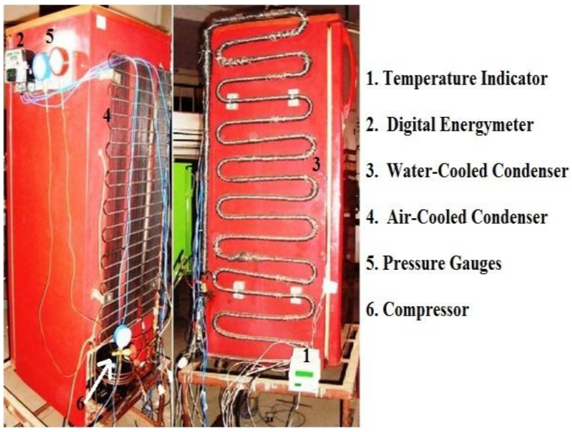

Figure 1: Experimental Test Rig

II.2. Experimental Procedure

Schematic diagram of the experimental apparatus is shown in Figure 2. The valve V 3 and V 4 was closed to make the system work only with air-cooled condenser and similarly valve V 1 and V 2 was closed to make the system work only with water-cooled condenser. The system was operated at five load conditions namely, No load, 40W, 100W, 160W and 200W. At each load conditions temperature and pressure at salient points were noted down at every five minutes interval. The temperature of the water at inlet and exit was also measured.

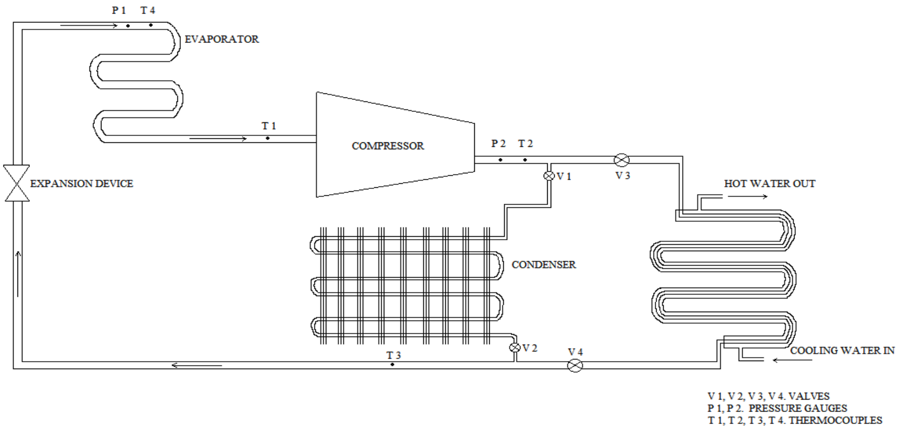

Figure 2: Schematic Diagram of the Experimental Apparatus

The experiment was done until steady state condition was attained in the evaporator. The energy consumption of the system is measured using a digital energymeter. The performance of the refrigerator was first measured using HFC134a/POE oil as the working fluid then by using HFC134a/SUNISO 3GS mineral oil and finally by HFC134a/CuO/SUNISO 3GS mineral oil in both air/water-cooled condenser mode. The test results of HFC134a/POE oil system, HFC134a/ SUNISO 3GS mineral oil system and HFC134a/CuO/SUNISO 3GS mineral oil system were compared in both air/water-cooled condenser modes.

III. RESULTS AND DISCUSSIONS

Figure 3 gives the comparison of the work done by the compressor with HFC134a/POE oil, HFC134a/SUNISO 3GS mineral oil and HFC134a/CuO/SUNISO 3GS mineral oil. The work done by the compressor was greater for the HFC134a/POE oil system than the HFC134a/SUNISO 3GS mineral oil system. The work done was further reduced on using HFC134a/CuO/SUNISO 3GS mineral oil system in both air/water-cooled condenser mode and similarly the work done by the compressor for the air-cooled system was higher than that of the water-cooled on all load conditions. This was because the condenser-evaporator pressure difference was high for the system when operating with HFC134a/POE oil than the HFC134a/SUNISO 3GS mineral oil system and HFC134a/CuO/SUNISO 3GS mineral oil system. The pressure difference was also high when operating with air-cooled condenser instead of water-cooled condenser. As the work done by the compressor increases the power consumption also increases.

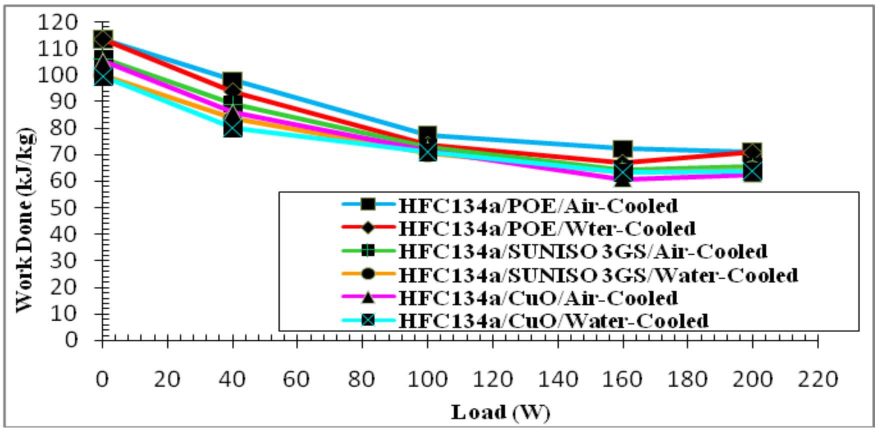

Figure 3: Variation of Work Done with Load

Figure 4 shows the COP variation of HFC134a/POE oil, HFC134a/SUNISO 3GS mineral oil and HFC134a/CuO/SUNISO 3GS mineral oil. The COP was greater for the HFC134a/CuO/SUNISO 3GS mineral oil system on various load conditions. The COP of air-cooled condenser was also lower when compared to the water-cooled condenser on all load conditions in both lubricants. This may be due to the inverse proportionality of COP to work done on all load conditions.

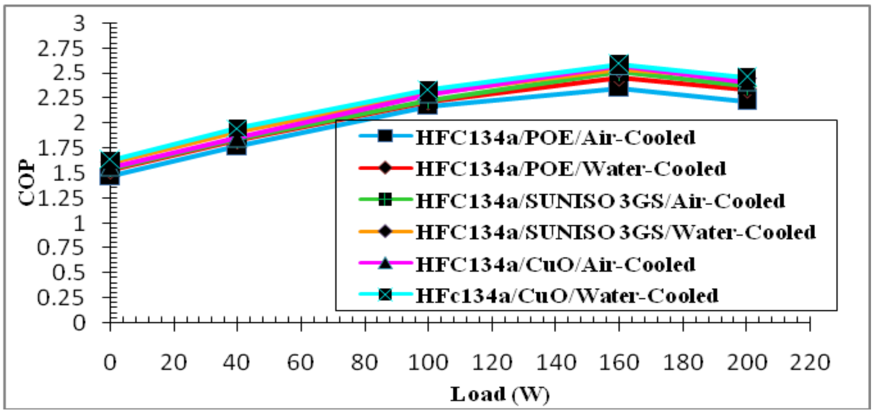

Figure 4: Variation of COP with Load

The experimental result also shows that about 200 litres of hot water at a temperature of about 58ºC over a day from the outlet of water-cooled condenser and thus analysed the economic importance of this waste heat recovery system from the energy saving point of view. Table I provides the energy consumption of the HFC134a/POE oil, HFC134a/SUNISO 3GS mineral oil and HFC134a/CuO/SUNISO 3GS mineral oil air-cooled system at steady state for a time period of five minutes. Table II shows the energy consumption of the HFC134a/POE oil, HFC134a/SUNISO 3GS mineral oil and HFC134a/CuO/SUNISO 3GS mineral oil water-cooled system at steady state for a time period of five minutes.

These results confirmed that the performance of household refrigerator with HFC134a/CuO/SUNISO 3GS mineral oil system was better than that of the HFC134a/POE oil system and there was an improvement in the operation when the refrigerator works with water-cooled condenser.

Table I

Energy consumption of HFC134a/POE oil, HFC134a/SUNISO 3GS mineral oil and HFC134a/CuO/SUNISO 3GS mineral oil for air-cooled condenser

Load (W)	HFC134a/ POE oil Energy consumption (kWh)	HFC134a/ SUNISO 3GS oil Energy consumption (kWh)	HFC134a/ CuO/SUNISO 3GS oil Energy consumption	Energy saving (%)
No load	0.00969	0.00844	0.00843	**13.00**
40	0.01250	0.01094	0.01094	**12.48**
100	0.01438	0.01250	0.01219	**15.23**
160	0.01563	0.01344	0.01281	**18.04**
200	0.01625	0.01438	0.01406	**13.48**

Table II

Energy consumption of HFC134a/POE oil, HFC134a/SUNISO 3GS mineral oil and HFC134a/CuO/SUNISO 3GS mineral oil for water-cooled condenser

Load (W)	HFC134a/ POE oil Energy consumption (kWh)	HFC134a/ SUNISO 3GS oil Energy consumption (kWh)	HFC134a/ CuO/SUNISO 3GS oil Energy consumption	Energy saving (%)
No load	0.00906	0.00813	0.00813	**10.26**
40	0.01125	0.01031	0.01000	**11.11**
100	0.01313	0.01188	0.01188	**9.52**
160	0.01406	0.01281	0.01219	**13.30**
200	0.01500	0.01344	0.01344	**10.40**

IV. CONCLUSIONS

The advantages of using CuO nanoparticle-lubricant mixture and SUNISO 3GS mineral oil as the lubricant instead of POE oil in a household refrigerator with air/water-cooled condenser was investigated experimentally. The main conclusions are listed as follow:

1) The HFC134a/CuO/SUNISO 3GS mineral oil and HFC134a/SUNISO 3GS mineral oil system worked normally and efficiently in the household refrigerator

2) The results confirmed that the performance of refrigerator with the HFC134a/CuO/SUNISO 3GS mineral oil system was better than that of the HFC134a/POE oil system and there was an improvement in the operation when the refrigerator works with water-cooled condenser.

3) POE oil is known to be hydroscopic and hydrolytic, so there are many problems in refrigeration systems using POE oil such as wadding deposition, bulging equipment that chokes the flow and severe friction in the compressor. The SUNISO 3GS mineral oil completely eliminates these problems, not only this SUNISO 3GS mineral oil is having excellent chemical stability. They do not precipitate wax deposit in an extremely low temperature section of the system such as valve or evaporator. SUNISO 3GS mineral oil is having better fluidity at low temperature condition resulting good oil returning in the refrigeration systems. These outstanding features may be the reasons for the better performance of the household refrigerator with the HFC134a/SUNISO 3GS mineral oil system than that of the HFC134a/POE oil system.

4) The better performance of CuO nanoparticle-lubricant mixture may be due to the enhancement of the solubility of the HFC134a and mineral oil as indicated by the high oil return ratio.

5) About 200 litres of hot water at a temperature of about 58ºC over a day from the outlet of water cooled condenser and this modification made the household refrigerator to be work as both refrigerator and water heater. The hot water which was obtained from the water-cooled condenser can be utilised for household applications like cleaning, dish washing, laundry, bathing etc.

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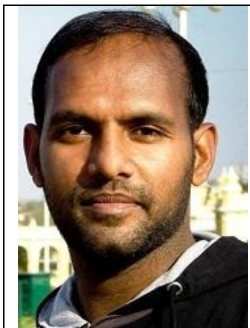	Mr. **Christy V. Vazhappilly** is working as Assistant Professor in Dept of Mechanical Engineering Jyothi Engineering College, Cheruthuruthy, Thrissur-679531, Kerala. He received B.E. degree (2007) in Mechanical Engineering from Anna University, Chennai, Tamil Nadu, India. He obtained M.E. degree (2009) in CAD/CAM from Anna University, Chennai, Tamil Nadu, India. He has been teaching for the past five years. He had attended many International Seminars and Conferences. He had published six papers in International Journals and presented five papers in International and National conferences. His research interests are in the areas of CAD, CAM, Engineering Design and also interested in Thermal Engineering etc.
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