EXPERIMENTAL ANALYSIS OF DOMESTIC REFRIGERATION SYSTEM USING NANOREFRIGERANT [CeO_2+ZnO+R134a]

by

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At the present scenario, the action of ensuing the philosophy of reducing energy consumption and saving it for longer period without drop off in performance is increased. On the other hand, global warming and ozone layer depletion become foremost challenges. These concerns are takes place in thermal systems like refrigerator and air conditioning. To resolve the challenges, the nanorefrigerants are used in refrigeration, which has previously got the attention due to its distinctive properties such as thermal conductivity. They also have the potential to improve the heat transfer performance of refrigeration. This project interrogated on the performance of domestic refrigeration system using normal condenser and micro-channel condenser with and without nanoparticles. The CeO_2 *and ZnO nanoparticles in the size of about 20-30 nm and 30-50 nm, respectively, with R134a domestic refrigerant were used. The experimentation carried out using 2 g of* CeO_2 *and ZnO nanoparticles in three different ratios [0.5:1.5, 1:1, and 1.5:0.5] with R134a refrigerant. Hereby, the result conquered that 33.3% increase in the actual COP of domestic refrigeration system using normal condenser with 1:1 ratio of nanoparticles when compared with the refrigeration system using micro-channel condenser with and without nanoparticles.*

Keywords*: domestic refrigeration system, R134a refrigerant, performance* CeO_2 *nanoparticles, ZnO nanoparticles, thermal conductivity, nanorefrigerant*

Introduction

A domestic cooler is a typical home device that comprises of a thermally protected compartment and which when works, transfers heat from within the compartment to its outside climate so that within the thermally protected compartment is cooled to a temperature

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beneath the surrounding temperature of the room. In domestic refrigeration systems the R134a refrigerant is working as a heat transfer substance [1-3]. The heat transfer is mainly depends on the thermal conductivity of the refrigerant. Investigation shows that the addition of nanoparticles with conventional fluids leads to better enhancement in heat transfer process [4]. Since contrasted with microsized particles, nanoparticles gangs high surface region to volume proportion because of the inhabitance of enormous number of molecules on the limits, which make them profoundly stable in suspensions [5]. Nanoliquids have the accompanying attributes contrasted with the typical liquids: higher warmth move between the particles and liquids because of the great surface space of the particles, better scattering dependability, essens molecule obstructing, and decreased siphoning power when contrasted with base liquid to get comparable warmth move [6-11].

The different nanoparticles like CuO, Al_2O_3, SiO_2, precious stone, CNT and TiO_2 were utilized with base refrigerants like R11, R113, R123, R134a, and 141b were utilized in refrigeration framework [12]. There is another nanoparticle, for example, CeO_2, ZnO, and SiO_2 are accessible with better thermophysical and warmth move capacities. In this experimentation the CeO_2 and ZnO nanoparticles in the size of around 20-30 nm and 30-50 nm separately added with the homegrown R134a refrigerant [8, 13]. This is around a 6.9% rise. In contrast to the R134a refrigerant, the power consumption was also reduced to 50% [14]. The addition of Nano Al_2O_3 to the refrigerant suggests an increase in the cooling system's COP. Nanorefrigerant use decreases the duration and cost-effectiveness of the capillary channel. Over time, the pressure of the discharge increases and reaches a maximum value and then decreases. For a load mass of 150 g, the maximum discharge pressure is obtained. Initially, the suction pressure decreases and then increases over time.

The impact of various nanoparticles concentration in the refrigerant/lubricants of vapor compression refrigeration and observed better exergy destruction results at 0.5% concentration without compromising the performance. The impact of copper (II) oxide (CuO) and copper/silver (Cu/Ag) alloy nanoparticles with HFC-R134a refrigerant in domestic refrigerators. The tribological effects on compressor parts were analysed after including the nano additives into the system and COP was analysed as performance parameter. Nanoadditives stability was studied using thermo gravimetric analysis. Adding 0.5 vol.% of CuO and Cu/Ag nanoparticles in POE resulted in great impact over the tribological and performance of VCR. The values of COP during the examination revealed about 20.88% increase due to the incorporation of nanorefrigerants. Also, the coefficient of friction for the developed nanolubricant was observed to be 5.5% lesser than that of CuO lubricant and 9.9% lower than traditional pure lubricants available.

In this experimentation a 2 g of CeO_2 and ZnO nanoparticles were added at different ratios such as 0.5:1.5, 1:1, and 1.5:0.5. The domestic refrigeration system using normal condenser and micro-channel condenser were used for this experimentation. The result indicates that the performance of the refrigeration system increases by adding nanoparticles with normal refrigerant. This experiment also shows the comparison of performance between refrigeration system using micro-channel condenser with and without nanoparticles. The following are the key points of research gap:

- The use of nanorefrigerants in commercial domestic refrigerator was not fully explored.
- Concentration of nanoparticles to be added in the refrigerants was yet to be determined for optimum results.
- Composite nanorefrigerants were very difficult to handle due to their varying thermal, physical, chemical, and fluid properties. Hence not widely used.

- Energy destruction due to randomness (exergy) was not clearly studied for most of the nano particles used in refrigeration system.
- Tribological properties of the nanoadditives were not clearly described.

Based on the past research works, the following problems were identified and listed.

- It was very difficult to identify and materialize the synthesis of composite nanorefrigerant owing to their variation in thermophysical properties.
- So many works were carried out on independent nanorefrigerant preparation and their utilization in refrigeration systems. However, limited works have been studied on composite nano refrigerants.
- Only limited studies were conducted on optimizing the results of nanorefrigerant in VCR systems. Among them, the availability of studies on composite nano refrigerants was very limited.
- The setback of individual nano additive was explained in literatures. But the procedure to overcome these setbacks by making them a composite was not proposed.

Hence in this research work, VCR system was studied by adding composite nanorefrigerants with various proportions of each nanoadditives. Based on the study carried out on the process, materials, and testing equipment the following methodology is proposed for the actual works carried out in this study.

Experimental set-up

The experimental set-up contains a number of parts that are compressor; air cooled condenser, expansion valve, evaporator, thermocouples, and pressure gauge. Capillary tube is used as an expansion device, which is used to control the flow rate. The coil type evaporator is used which is loaded with water. Capillary tube with filter is fitted with the evaporator coil. The thermo couples are fixed in different areas like bay and outlet of the blower, outlet of the condenser and channel of the evaporator. The pressing factor measures are fixed at channel and outlet of the blower. The trial arrangement was situated on a stage in a consistent room temperature. The ambient temperature was 27 ±1.5 °C.

The following procedures were followed in this experimentation: Initially the refrigerant R134a was filled in the refrigeration system when flow is available to both the condenser. After filing, flow of refrigerant to the condenser was closed. Now, the water was filled inside the evaporator cabin and note down its weight and temperature. The compressor was compressed the refrigerant R134a and it was started to flow through the refrigeration system. The temperature of the water, which available inside the evaporator cabin, was started to decrease. When its temperature reaches to 20 °C and 15 °C the temperature and pressure at compressor inlet and outlet temperature, capillary tube inlet and outlet and final energy meter reading were noted.

Methodology

Related journals and literatures from various articles was collected and studied thoroughly. From this, the present problems were found in the existing systems. The refrigerant properties of R134a was compared with the refrigerants used in now-a-days such that R11 and R22. From these properties, it shows that R134a can be used as a refrigerant for best. The components for the domestic refrigeration system with normal condenser were selected such as compressor, aluminium fined condenser, micro-channel condenser, pressure gauge, capillary tube, and evaporator. Proposed and existing refrigeration systems are fabricated with the required devices. The experiments were conducted in the existing system by using R134a with CeO_2 and ZnO nanoparticles as refrigerant and a round tube condenser. Also experiments were conducted on proposed refrigeration system with R134a as refrigerant and using a micro-channel condenser. By using these experimental values, COP and input power of both the refrigeration systems were calculated and compared. Comparisons on results of both the systems were plotted on graph. Results were discussed, and concluded finally.

Result and discussion

Figure 1 show that the actual COP of refrigeration system with pure R134a refrigerant and with the R134a with CeO2 and ZnO refrigerant in the ratio of 0.5:1.5, 1:1, and 1.5:0.5 is represented by using bar chart. The actual COP of refrigeration with pure R134a refrigerant at 20 °C is greater than at temperature 15 °C. When the actual COP of pure refrigerant is compared with the R134a with CeO_2 and ZnO in 0.5:1.5 and 1.5:0.5 ratios, pure R134a refrigeration has the greater actual COP than the R134a with CeO_2 and ZnO at 20 °C and 15 °C. The actual COP of refrigeration with R134a with CeO_2 and ZnO in 0.5:1.5 ratio is less than the actual COP of refrigeration with R134a with CeO_2 and ZnO in 1:1 ratio at 20 °C and 15 °C. Also the actual COP of refrigeration with R134a with CeO_2 and ZnO in the ratio of 1.5:0.5 is equal to the actual COP of refrigeration with R134a with CeO_2 and ZnO in 0.5:1.5 ratio at 20 °C and it has greater COP at 15 °C. The refrigeration with R134a with CeO_2 and ZnO in 1:1 ratio has greater actual COP than the actual COP of refrigeration with R134a with CeO_2 and ZnO in 1.5:0.5 ratio.

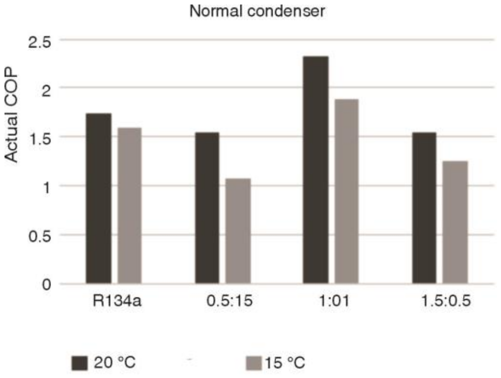

Figure 1. Actual COP of normal condenser with various ratios

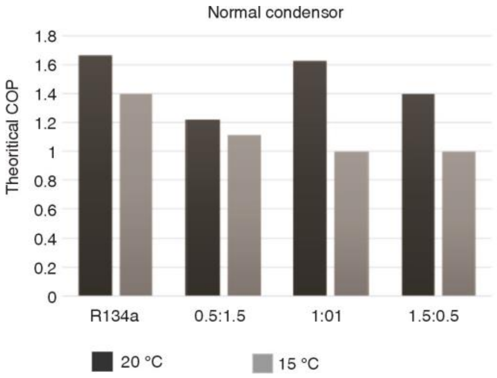

Figure 2. Theoretical COP of normal condenser with different ratios

Figure 2 shows that the theoretical COP of refrigeration system with pure R134a refrigerant and with the R134a with CeO_2 and ZnO refrigerants in the ratio of 0.5:1.5, 1:1, and 1.5:0.5 is represented by using bar chart. The theoretical COP of refrigeration with pure R134a refrigerant at 20 °C is greater than at temperature 15 °C. The theoretical cop of refrigeration with R134a with CeO_2 and ZnO in 0.5:1.5 ratio is less than the theoretical COP of refrigeration with R134a with CeO_2 and ZnO in 1:1 and 1.5:0.5 ratios at 20 °C and 15 °C. Also the theoretical COP of refrigeration with R134a with CeO_2 and ZnO in the ratio of 1.5:0.5 is equal to the theoretical COP of refrigeration with R134a with CeO_2 and ZnO in 1:1 ratio at 15 °C and. The refrigeration with R134a with CeO_2 and ZnO in 1:1 ratio has greater theoretical COP than the theoretical COP of refrigeration with R134a with CeO_2 and ZnO in 1.5:0.5 ratio at 20 °C. By comparing the theoretical COP of refrigeration with each type of refrigerants, the theoretical COP for the temperature of 20 °C is always greater than the theoretical COP of refrigeration at 15 °C. The theoretical COP of refrigeration with the pure R134a refrigerant is higher than others. The theoretical COP of refrigeration with the R134a with CeO_2 and ZnO in 0.5:1.5 ratio at 20 °C is lesser than others. The theoretical COP of refrigeration with the R134a with CeO_2 and ZnO in 1:1 and 1.5:0.5 ratio at 15 °C is lesser than others.

Figure 3 shows that by using micro-channel condenser, the actual COP of refrigeration system with pure R134a refrigerant and with the R134a with CeO_2 and ZnO refrigerant in the ratio of 0.5:1.5, 1:1, and 1.5:0.5 is represented by using bar chart. The actual COP of refrigeration with pure R134a refrigerant at 20 °C is greater than at temperature of 15 °C. When the actual COP of pure refrigerant is compared with the R134a with CeO_2 and ZnO in 0.5:1.5, 1:1, and 1.5:0.5 ratios, pure R134a refrigeration has lesser actual COP than the R134a with CeO_2 and ZnO at 20 °C and 15 °C. The actual COP of refrigeration with R134a+ CeO+ZnO in 0.5:1.5, 1:1, and 1.5:0.5 ratios are equal at 20 °C and 15 °C. By comparing the actual COP of refrigeration with each type of refrigerants, the actual COP for the temperature of 20 °C is always greater than the actual COP of refrigeration at 15 °C. The actual COP of refrigeration with the R134a with CeO_2 and ZnO refrigerant in all the three ratios are equal and higher than others.

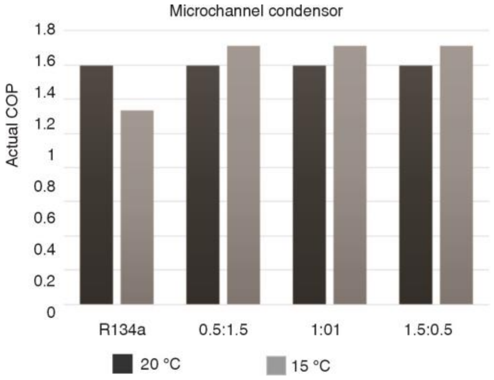

Figure 3. Actual COP of micro-channel condenser with various ratios

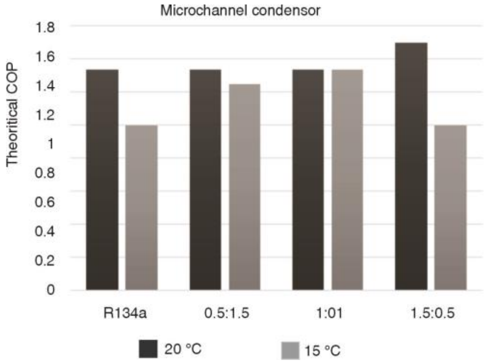

Figure 4. Theoretical COP of micro-channel condenser with different ratios

Figure 4 shows that in micro-channel condenser, the theoretical COP of refrigeration system with pure R134a refrigerant and with the R134a with CeO_2 and ZnO refrigerant in the ratio of 0.5:1.5, 1:1, and 1.5:0.5 is represented by using bar chart. The theoretical COP of refrigeration with pure R134a refrigerant at 20 °C is greater than at temperature 15 °C. When the theoretical COP of pure refrigerant is compared with the R134a with CeO_2 and ZnO in 1:1 and 0.5:1.5 ratios, pure R134a refrigeration has the lesser theoretical COP than the R134a with CeO_2 and ZnO at 20 °C and equal at temperature of 15 °C. The theoretical cop of refrigeration with R134a with CeO_2 and ZnO in 0.5:1.5 ratio is less than the theoretical COP of refrigeration with R134a with CeO_2 and ZnO in 1:1 ratio at 15 °C and equal at 20 °C. Also the theoretical COP of refrigeration with R134a with CeO_2 and ZnO in the ratio of 1.5:0.5 is equal to the theoretical COP of refrigeration with pure R134a at 15 °C and it has greater COP at 20 °C. The refrigeration with R134a with CeO_2 and ZnO in 1:1 ratio has higher theoretical COP than others at 15 °C. By comparing the theoretical COP of refrigeration with each type of refrigerants, the theoretical COP of refrigeration with theR134a with CeO_2 and ZnO in 1.5:0.5 ratio is higher than others at the temperature 20 °C. When compared, the actual COP of both experimental set-up with and without nanoparticles, the actul COP of refrigeration system with nanoparticles increases with decrease in energy consumption.

Conclusions

The performance of refrigeration system using normal and micro-channel condenser with and without nanoparticles was found through this experimentation. From this experimentation the following results were found.

- The actual COP of refrigeration system using normal condenser with CeO_2 and ZnO nanoparticles increased about 33.3% than the actual COP of refrigeration system with pure R134a domestic refrigerant.
- The actual COP of refrigeration system using micro-channel condenser with CeO_2 and ZnO nanoparticles increased about 8.32% than the actual COP of refrigeration system with pure R134a domestic refrigerant.
- When comparing the actual COP of refrigeration system using normal condenser and using micro-channel condenser, the refrigeration system using normal condenser had 53.9% greater COP than the refrigeration system using michro-channel condenser.

References

[1] Chokar, M., *et al*., Effect of Particle Size on Thermal Conductivity of Nanofluid, *Metallurgical and Materials Transactions A,* 39 (2008), Feb., pp. 1535- 1542
[2] Sendil Kumar, D., Elans Ezhian, R., Experimental Study on Al_2O_3-R134a Nano Refrigerant in Refrigeration System, *International Journal of Modern Engineering Research*, *2* (2012), 5 , pp. 3927-3929
[3] Dhilip Kumar, K., Ayyappa, T., An Experimental Investigation on Application of Al_2O_3 Nanoparticle as a Lubricant Additive in VCRS, *Int. J. of Engineering Research and Application*, *6* (2016), 10, pp. 32-38
[4] Ding, G.-L., Recent Developments in Simulation Techniques for Vapour-Compression Refrigeration Systems, *International Journal of Refrigeration*, *30* (2007), 7, pp. 1119-1133
[5] Mahbubul, I. M., *et al*., Thermal Performance Analysis of Al_2O_3/R-134a Nano Refrigerant, *International Journal of Heat and Mass Transfer*, *85* (2015), June, pp. 1034-1040
[6] Mahbubul, I. M., *et al*., Thermalphysical Properties and Heat Transfer Performance of Al_2O_3/R-134a Nano Refrigerant, *International Journal of Heat and Mass Transfer*, *57* (2013), 1, pp. 100-108
[7] Kedzierski, M. A., Effect of Concentration on R134a/Al_2O_3 Nanolubricant Mixture Boiling on a Reentrant Cavity Surface, *International Journal of Refrigeration*, *49* (2015), Nov., pp. 36-48
[8] Kumar, R. R., *et al*., Heat Transfer Enhancement in Domestic Refrigerator using R600a/mineral oil/nano-Al_2O_3 as Working Fluid, *Int. J. of Computational Engineering*, *3* (2013), Jan., pp. 42-50
[9] Haque, M. E., *et al*., Performance of a Domestic Refrigerator using Nanoparticles-Based Polyolester Oil Lubricant, *Journal of Mechanical Engineering and Sciences*, *10* (2016), 1, pp 1778-1791
[10] Subramani, N., Prakash, M. J., Experimental Studies on a Vapour Compression System using Nanorefrigerants, *International Journal of Engineering, Science and Technology*, *3* (2011), 9, pp. 95-102
[11] Sakthivel, P., et al., Experimental Study About Thermal Resistance of Windows with Air Gap Between Two Glasses Used in Single Houses, *Thermal Sciences, 20* (2020), 1B, pp. 515-518
[12] Dhandayuthabani, M., *et al*., Investigation of Latent Heat Storage System using Graphite Micro-Particle Enhancement, *Journal of Thermal Analysis and Calorimetry*, *139* (2020), 3, pp. 2181-2186
[13] Sudhagar, S, *et al*., Performance Analysis of Fin Tube Evaporator Using Various Refrigerants, *Thermal Sciences*, *20* (2020), 1B, pp. 609-612
[14] Karthick, M., *et al*., Performance Investigation and Exergy Analysis of Vapor Compression Refrigeration System Operated using r600a Refrigerant and Nanoadditive Compressor Oil, *Thermal Science, 24* (2020), 5A, pp. 2977-2989

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