Experimental Investigation for TiO2 nanoparticles as a Lubricant-Additive for a Compressor of Window Type Air-Conditioner System

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ABSTRACT

The coefficient of performance of a window type Air-Conditioner system can be improved if a reduction in the work of compressor can be achieved by a suitable technique. The present study investigates the effect of dispersing a low concentration of TiO2 nanoparticles in the mineral oil based lubricant, as well as on the overall performance of a window type Air-Conditioner system using R22 as the working fluid. An enhancement in the COP of the refrigeration system has been observed and the existence of an optimum volume fraction noticed, with low concentrations of nanoparticles suspended in the mineral oil. Results showed that the average compressor work reduced by 13.3%, which ultimately resulted in an increase of 11.99% in the COP due to the addition of nanoparticles in the lubricating oil.

Key words: nanoparticle; nanofluid , lubricant , air-conditioner system, coefficient of performance

تحقيق تجريبي للدقائق النانوية لاوكسيد التيتانيوم المضاف لمزيّت ضاغط مكيّفِ هواء نوعِ شباكي

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الخلاصة

معامل أداءِ نظامَ مكيّفِ هواء شباكي يُمْكِنُ أَنْ يُحَسّنَ إذا قل استهلاك عملِ الضاغطِ والذي يُمْكِنُ أَنْ يُنجَزَ مِن قِبل تقنية مناسبة. تَتحرّى الدراسةُ الحاليةُ تأثيرُ تركيز منخفض للدقائق النانوية لاوكسيد التيتانيوم في الزيت المعدني ، بالإضافة إلى الأداءِ العامِّ بإستعمال نظامِ مكيّفِ هواء ذو مائع تبريد R22. لوحظَ تحسين في معامل اداء النظامِ التبريدَ و لوحظَ ان الكسر الحجمي المثالي

كان عند تراكيز واطئة من الدقائق النانوية في الزيت المعدني. . اظهرت نَتائِجَ الإختبارِ بأنّ معدل عملَ الضاغطِ خفّضَ الى 13.3 %، الذي أدّى إلى زيادةِ في النهاية 11.99 % في معامل اداء بسبب إضافةِ دقائق نانوية في الزّيت.

1. INTRODUCTION

One recent report , **Omer, AM 2007**, proposed by the USA Department of Energy showed that the global energy consumption in 2020 would be more than twice of the present level according to the current tendency. Such an increasing energy requirement will aggravate energy shortage and environment pollution. Forty percent of the annual global energy demand is consumed by buildings, while more than half of the building energy demand is consumed for air-conditioning, and this proportion is larger in hot-weather areas. Therefore, improvement in energy efficiency of air-conditioning system can significantly reduce the global energy consumptions. Nanofluids, which are suspensions of nanoparticles in base fluids, have been introduced as new enhanced media , especially during the last decade. An experimental investigation has been carried out on nanofluid effects on the coefficient of performance of a window type Air-Conditioner system. Many researches were accomplished in this field**. Ruixiang, W., 2010,** studied the application of nano-fluids in refrigerating systems is considered to be a potential way to improve the energy efficiency and reliability of HVAC&R facilities and to make economic the use of environmentfriendly refrigerants. The reliability and performance of RAC with nanoparticles in the working fluid have been investigated experimentally. A new mineral-based nano-refrigeration oil (MNRO), formed by blending some nanoparticles (NiFe2O4) into naphthene based oil B32, was employed in the RAC using R410a as refrigerant. The results indicate that the mixture of R410a/MNRO works normally in the RAC. The cooling/heating EER of the RAC increased about 6% by replacing the Polyol-Easter oil VG 32 lubricant with MNRO. **Venkataramana, M., 2012,** studied the ir-reversibility at the process of a vapour-compression refrigeration system (VCRS) with nanoparticles in the working fluid was investigated experimentally. Mineral oil (MO) with 0.1 gL^{-1}TiO2 nanoparticles mixture were used as the lubricant instead of Polyol-ester (POE) oil in the R134a, R436A (R290/R600a56/44wt.%) and R436B (R290/R600a-52/48-wt.%) VCRSs.The VCRS ir-reversibility at the process with the nanoparticles was investigated using second law of thermodynamics. The results indicate that R134a, R436A and R436B and MO with TiO2 nanoparticles work normally and safely in the VCRS. The VCRSs total ir-reversibility (529, 588 and 570 W) at different process was better than the R134a,R436A and R436B and POE oil system (777, 697 and 683 W). The same tests with Al2O3 nanoparticles showed that the different nanoparticles properties have little effect on the VCRS ir-reversibility. Thus, TiO2 nanoparticles can be used in VCRS with reciprocating compressor to considerably reduce irreversibility at the process. **R. Krishna Sabareesh, 2012,** studied the coefficient of performance of a refrigeration system can be improved if a reduction in the work of compression can be achieved by a suitable technique, for a specified heat removal rate. The present study investigates the effect of dispersing a low concentration of TiO2 nanoparticles in the mineral oil based lubricant, on its viscosity and lubrication characteristics, as well as on the overall performance of a Vapor Compression Refrigeration System using R12 (Dichlorodifluoromethane) as the working fluid. An enhancement in the COP of the refrigeration system has been observed and the existence of an optimum volume fraction noticed, with low concentrations of nanoparticles suspended in the mineral oil. The physics involved in the interaction of nanoparticles with the base fluid has been further elucidated by estimating the Optical Roughness Index using a Speckle Interferometer, by performing measurements on the pin surface following tests with a Pin-on-Disk tester. Is to compare the work of compressor when lubricated with nanolubricant (nanoparticles of Tio_2 dispersed in mineral oil) with its work when lubricated with mineral oil only, to evaluate the enhancement in the coefficient of performance of the air conditioner system.

2. THEORETICAL ANALYSIS

A window type Air-Conditioner system consists of a compressor, condenser, expansion valve and evaporator that are connected in a closed loop through piping that has heat Transfer with the surroundings, as shown in **Fig. 1**. Therefore, the rate of heat transfer to the cycle at the low temperature, in the evaporator, can be written as, **ASHRAE, 2009.**

$$Q_e = \dot{m}((h_3 - h_2) \qquad (1)$$

where: Q_e = Cooling duty gained in evaporator (kW).

Similarly, the rate of heat transfer between the refrigerant and the sink in the condenser is

$$Q_c = \dot{m}((h_4 - h_1) \qquad (2)$$

By applying the first law of thermodynamics,the work input to the compressor can also be expressed as

$$Wc = \dot{m}((h_4 - h_3) \qquad (3)$$

where h_4 is the enthalpy of refrigerant at the outlet of compressor (kJ/kg).

The Compressor input power (*Wc*, kJ/s) is given as

$$Wc = I\ V\ COS\ \Theta \qquad (4)$$

where COS Ɵ = power factor=0.7 ,**Ministry of Electricity in Iraq**, I is the current in Amper, and v is the voltage in Volt.

Defining the COP as the refrigeration effect over the compressor work, we get

$$COP = Qe/Wc \qquad (5)$$

3. EXPERIMENTAL APPARATUS

3.1. General Description

The used experimental rig is comprised of a window type air condition which was built for the objective of the present work. A Mitsubishi trade mark of 2-ton window type Air-Conditioner cooling unit (model WRC-1801K3SA) is selected to be as a test rig. The overall physical external dimensions of the evaporator are (42.8×42.4×8.2) cm, and condenser are (60×42.4×8.2) cm. **Fig.2** shows photographs of the unit, and manifests the instrumentation and measurement tools. The unit is powered by a reciprocating compressor (Mitsubishi co., model JAH5522E-RE68295A). As designed, the SAC is utilized R22 as a circulating refrigerant and a 3 GS Mineral lubricating oil. All components of the unit are connected by copper tubing with brazed connection.

3.2. Measuring Instruments

A Bourdon gauge type "AIMINDER" shown in **Fig.3** was used to measure the refrigerant side pressure at different locations, including pressure drop across the evaporator and condenser as shown in **Fig.2**. Two pressure gauges were installed on the high pressure side having a range of (0 to 500psi), the division (5 psi), and two pressure gauges installed on the low pressure side having range (-30 to 220psi), the division (2 psi).The temperature of the refrigerant is measured by three temperature gauges were installed on the refrigerant to measure the temperature of the refrigerant at different position. The technique used is by installing the thermometer immersed through the flow as shown in **Fig.2**. This method provides a direct contact between the bulb and the refrigerant to give more accurate measured values for temperature measurements. **Fig.4** shows temperature gauge were installed on the high pressure side and low pressure side. These where manufactured by HEIZUNGWILDMANN with a temperature range of (0 to 120 ºC) at a division of (2º). The current was measured by digital clamp meter, type (266 Digital clamp meters).Voltage is measured by using Multimeter type (PRO'SKIT 345) where the measuring is obtained continuously. All temperature and pressure gauges used for experiments were calibrated in the Central Institution for Standardization and Specify Control with error ± 0.4 % for temperature gauge and error ±0.3 % for pressure gauge .

4. PREPARATION OF NANOFLUID

In this study two-**step** has been used to prepare of nanofluid. This method require produce nanoparticle firstly and then mixing with the base fluid. The first step Titanium Oxide TiO_2 is used as nanoparticle with specification(20 nm mean diameter, 3900 kg/m^3 density, 8.9 w/m.℃ Thermal conductivity and 886.2 J/kg.℃ Specific heat. The second step The ultrasonic mixer is shown in **Fig.5** have its specifications are given (Model JP-120ST, Ultrasonic Frequency 40 kHz , Ultrasonic Power 720 Watt , Capacity 38 liter and Heating Power 800 Watt. Twelve transducers are used at the bottom of the bath, drain valve and basket; the transducers convert the electrical signal with low frequency (50 Hz) to high frequency (40 kHz) mechanical vibrations. The valve for emptying the tank and basket used to put the flask on it.

5. NANOPARTICLES VISCOSITY

The viscosity of the mineral oil relates indirectly to the load carrying capacity and power consumption rate of the compressor used in refrigeration system. The addition of foreign particles in the mineral oil alters the viscosity of the oil. **Lee et al., 2009**, found that addition of fullerene nanoparticles increased the viscosity of oil, and the enhancement was proportionate to the volume fraction. From the tribological characteristics of bearings, it is known that in a boundary lubrication system, an optimum level in the viscosity enhancement can result in a notable reduction in the power consumption**,** Bi, **Sheng Shan, 2008,[Jwo, Ching Song, 2009,and Sajith, V 2010 .**Considering these observations, the addition of nanoparticles must be low enough to make the process viable and effective; in reducing the power consumption. An optimal percentage of nanoparticles in the mineral oil is 0.01% volume fractions of TiO2 nanoparticles, **R. Krishna Sabareesh, 2012**. **Fig.6** shows optimal percentage of TiO2 nanoparticles in mineral oil 200 h after preparation .

6. RESULTS AND DISCUSSIONS

The results of performance comparison of the investigated refrigerants R22 without nanoparticles and with nanoparticles in the window type air-conditioning system are shown in **Figs. 7 to 10**. The result of the system compression ratio obtained at different ambient air temperatures for refrigerant R22 without nanoparticles and with nanoparticles is shown in **Fig. 7**. From the figure it was observed that the pressure ratios for the investigated refrigerants increased with the increase of ambient air temperature. Increase ambient air temperature will increase the temperature gradient between ambient air and conditioned room, which will increase the work of compressor and the compressor pressure ratio. **Fig. 8** shows the variation of the compressor power with ambient air temperature of R22 without nanoparticles and with nanoparticles. From the figure, it can be deduced that compressor power increases as the ambient air temperature increases. This is as a result of the dependence of compressor power on the outside temperature. Increase in the outside temperature increased the load on the system which increased the compressor power. The average compressor input power for R22 with nanoparticles was (2.1 to 13.3) % lower than that of R22 without nanoparticles. The variation of the compressor discharge temperature with ambient air temperature for R22 without nanoparticles and with nanoparticles is shown in **Fig. 9**. As depicted in the figure, the compressor discharge temperature increases as the ambient air temperature increases for R22 without nanoparticles and with nanoparticles. Increase in discharge temperature is as a result of increase in the work of compressor due to increase in the ambient air temperature. The average compressor discharge temperature for R22 with nanoparticles was (3.33 to 8.95) % lower than that of R22 without nanoparticles. **Fig. 10** shows the variation of COP with varying ambient air temperature for the investigated. This figure indicates that when ambient air temperature increases the COP reduces for both R22 without nanoparticles and with nanoparticles. COP is inversely proportional to the power input through the compressor, therefore, increase in compressor power due to increase in ambient air temperature reduces the COP of the system. The average COP for R22 with nanoparticles was (7.93 to 11.99) % higher than that of R22 without nanoparticles.

7. CONCLUSION

In this paper the performances of refrigerant R22 without nanoparticles and with nanoparticles in the window type air-conditioning system were investigated experimentally and compared. Based on the investigation results, the following conclusions are drawn:

- The COP of R22 with nanoparticles is 7.93 to 11.99 % higher than that of R22 without nanoparticles.
- The compressor discharge temperature of R22 with nanoparticles lower than that of R22 without nanoparticles.
- The average compressor input power for R22 with nanoparticles was (2.1 to 13.3) % lower than that of R22 without nanoparticles.

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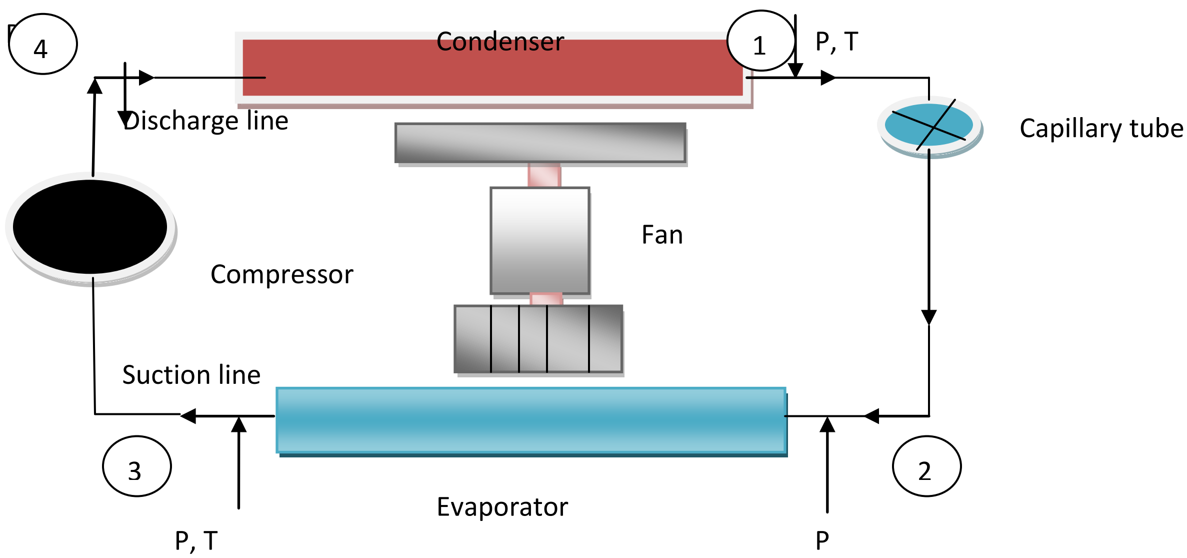

Figure 1. Schematic of a window type air-conditioner cycle.

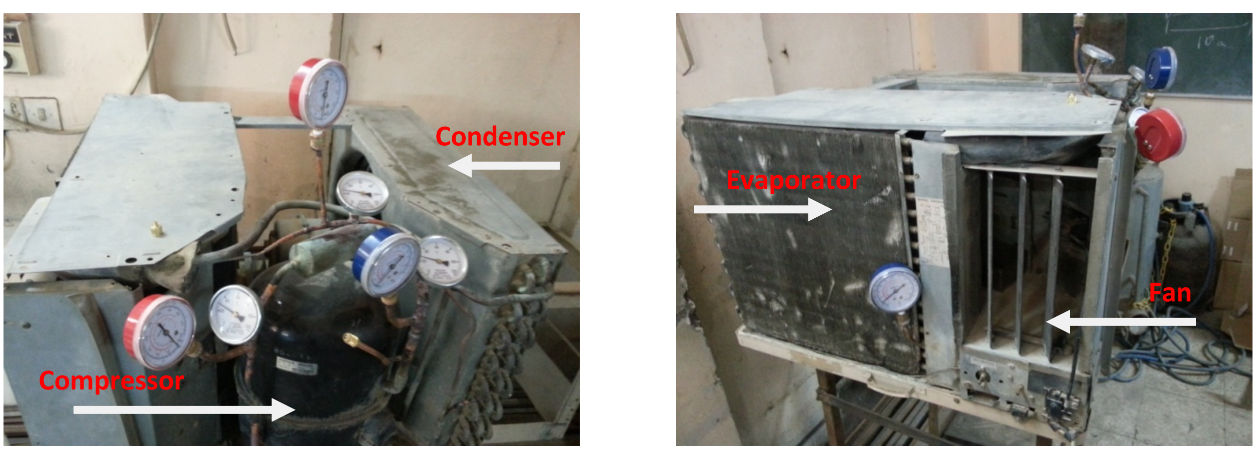

Figure 2. Photograph of test apparatus.

Figure 3. Pressure gauges.

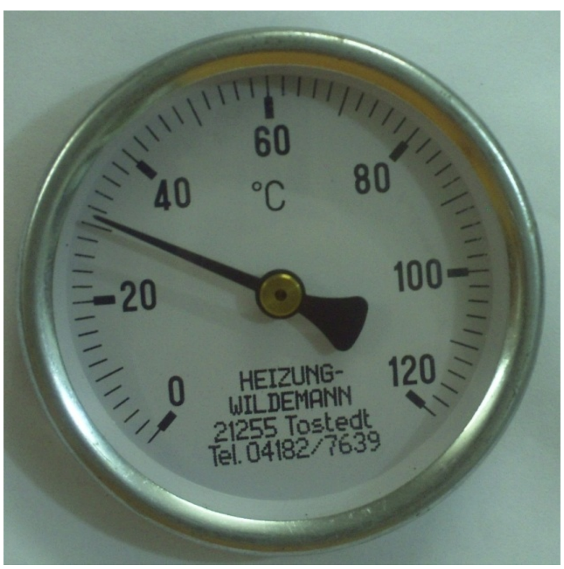

Figure 4. Temperature gauge.

Figure 5. Ultrasonic mixer with electric motor.

Figure 6. 0.01% Volume fractions of TiO_2 nanoparticles in mineral oil 200 h after preparation.

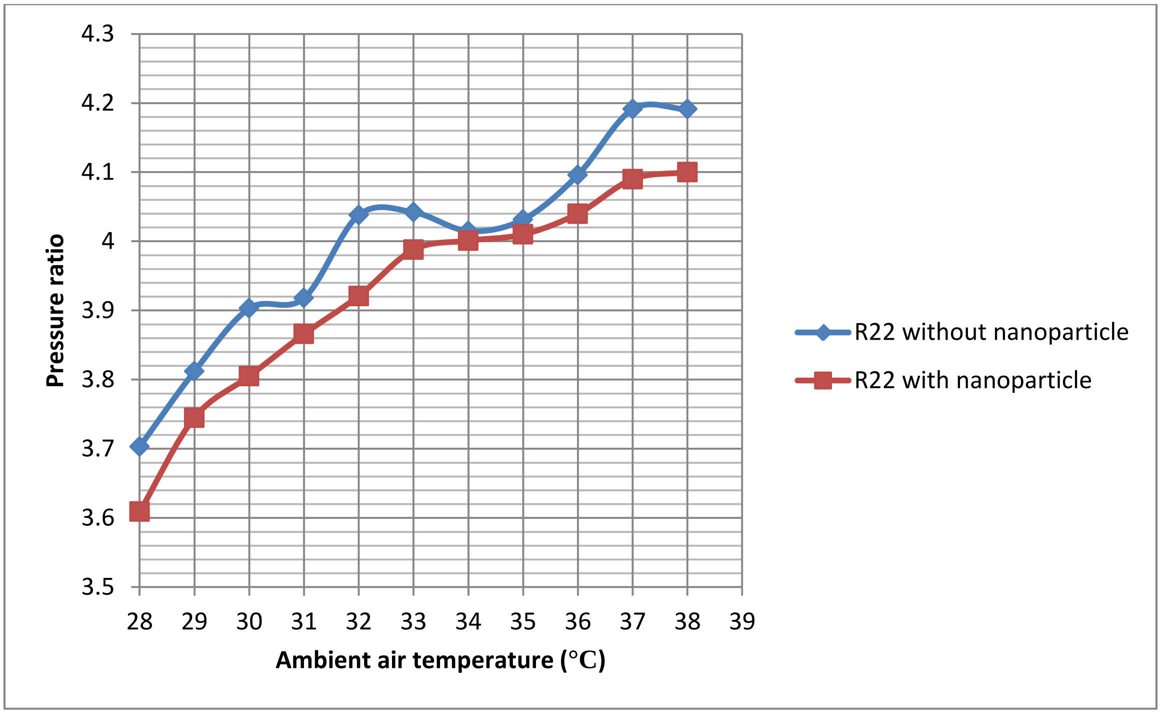

Figure 7. Variation of pressure ratio with ambient air temperature.

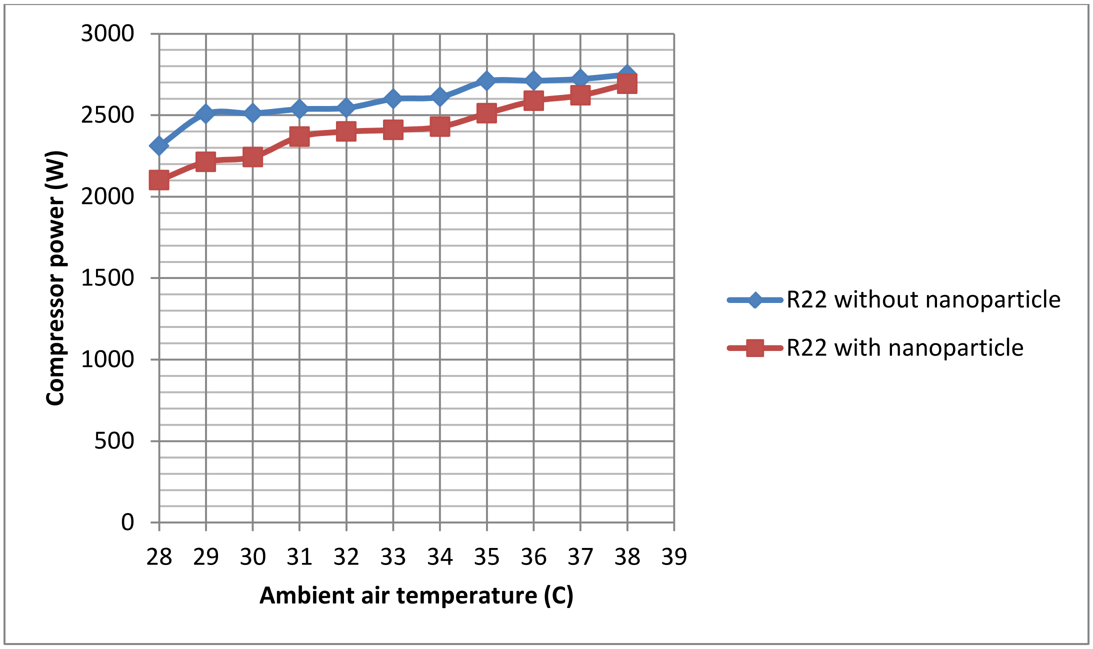

Figure 8. Variation of compressor power with ambient air temperature.

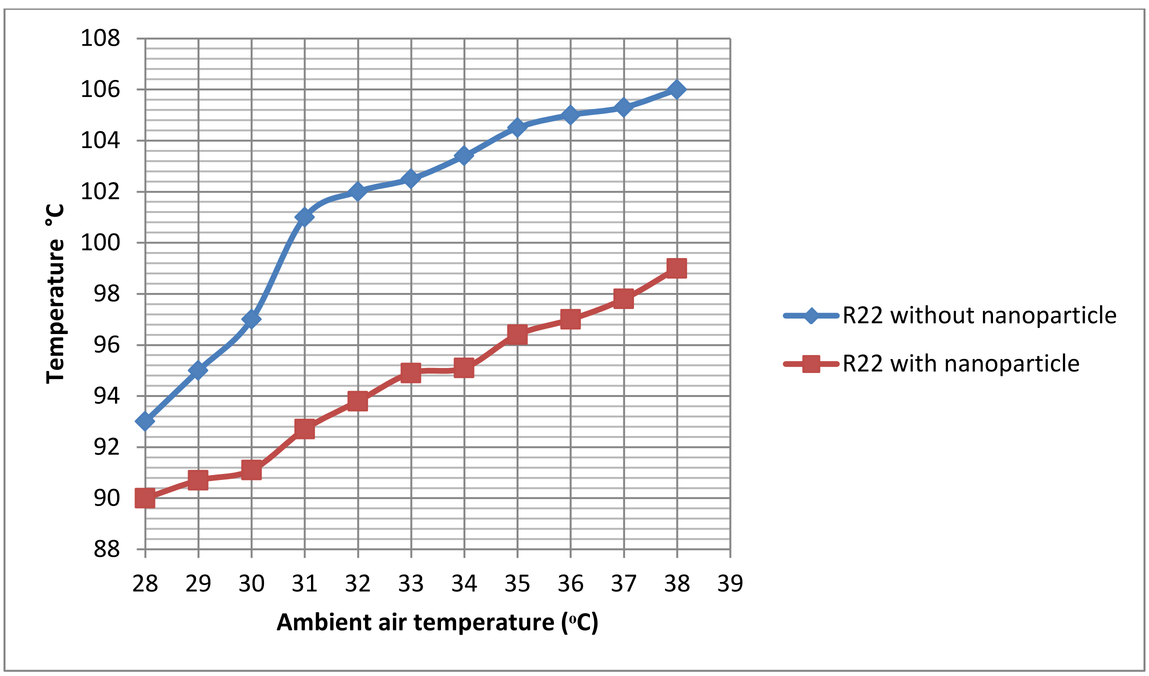

Figure 9. Variation of compressor outlet temperature with ambient air temperature.

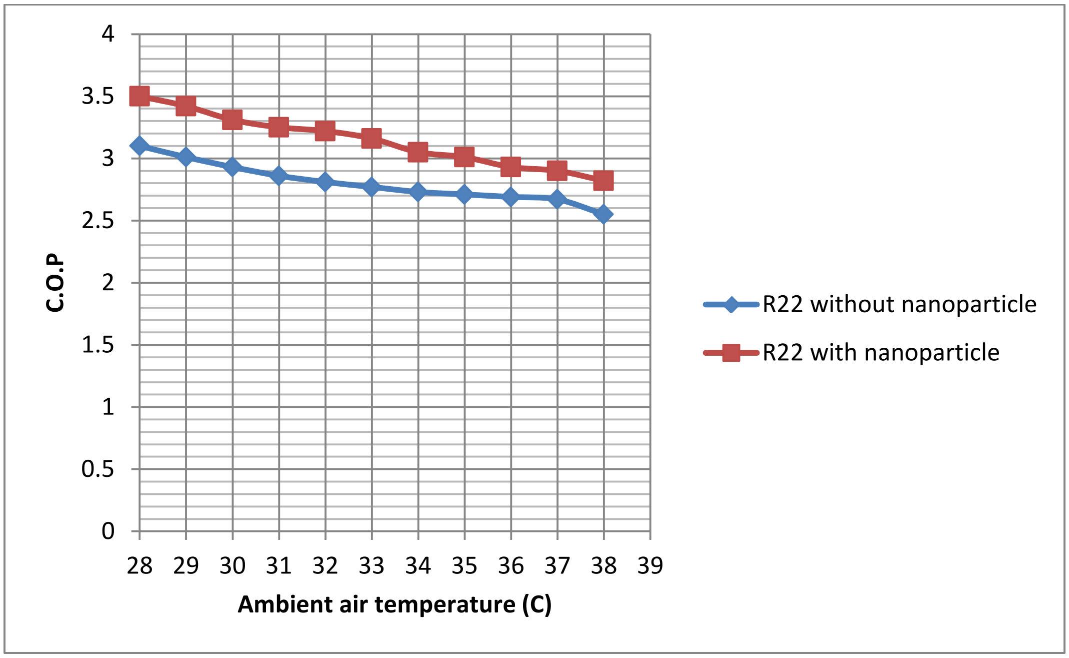

Figure 10. Variation of coefficient of performance (COP) with ambient air temperature.