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The effect of nano-particles concentration AL2O3 on the performance in compression refrigeration system

Abbas Alwi Sakhir[1] and Rawnak Khalid Mahmoud[2]

1Department of mechanical engineering college, University of Al- Qadisiyah, Al- Qadisiyah, Iraq
2Department of mechanical engineering college, University of Al- Qadisiyah, Al- Qadisiyah, Iraq

Abbas.abed@qu.edu.iq, mech.post03@qu.edu.iq.

Abstract:

An experimental study of the performance of compression refrigeration system. when adding nanoparticles of 20 nm size and mixed with PAG oil. After preparing the nano-lubricant, it is injected into the compressor and the Refrigerant R134a is charged. in the present work is used different volume fractions (0.2%, 0.4%, 0.6%) of AL2O3 nano-particles to study the performance of the refrigeration tester. Energy consumption check and freezing capacity test. Experimental results have shown that the system operates safely and normally, the maximum improvement of the coefficient of performance is 32.219% at a concentration of 0.6% at temperature 40°C. In addition, power consumption decreases from 4% to 22%, and the temperature decreases by (40 °C - 17 °C). The cooling effect of the system increases when the concentration of the nano-particles increases. It can be inferred that nano-refrigerant can be competitive and economically efficient for use in vapour compression systems.

Keywords – aluminum oxide nano-particles, coefficient of performance, Polyalkyline Glycol oil, Refrigerant.

1. Introduction:

Everyone in the world of today is thinking about reducing and saving energy consumption for longer periods. Our household appliances, such as television, air conditioners, and refrigerators, consume a lot of energy. The first device can be reduced by controlling their use as long as you need to use them or switch them off. However, the refrigerator cannot be controlled by limiting its use, because it's got to run all time. The solution is to build an energy-efficient model. Conventional thermal fluids are responsible for poor thermal conductivity Research has therefore developed a new fluid standard called nano-fluid, which has a high surface area that prevents the clogging of the particles. We have therefore replaced the conventional fluid with nano-fluid produced by the use of nanotechnology, designed to possess unique thermal properties that can improve the heat transfer and is energy efficient thermal systems [1]. **R. S. Mishra et al [2],** Investigated the physical thermal properties of different nano-particle adding to refrigerant and analyzed their effects on the performance of the system. The result experimentally shows an increase in thermal conductivity by 15%, dynamic viscosity increased by 94%, density and use different nano-particles cu, AL2O3, CuO, and TiO2 with three type refrigerants (R134a, R407and R404A) increased from 12to 34% compared to the pure refrigerant. Moreover, nano refrigerant AL2O3-R134a shows 35% higher cop, but R404Aand R407 show enhancement in cop by 3 to 14% and 3to 12% with different nano-particle. **Soliman et al. [3]** studied the theoretical and experimental effect of added nano-particles AL2O3 to the refrigerant. The experimental results increase in cop theoretical by 9.11% and actual by 10.53%.The theoretical analysis results showed the evaporator heat transfer coefficient increased by 50%, and results showed a decrease in energy loss by 28% when was use nano-particles, and water heat transfer coefficient increased by 70.83% as cooling load and reduced in energy consumption by 13.30%. **Kedzierski** [4] investigated the pool performance of nano-particles AL2O3 with an R134a /polyester. The mixed lubricant was used in three different volume fractions and R134a to the mixture adding in a different mass fraction. For different mixture, concentrations showed an increase of approximately 13%,10%and 9%, because agglomeration of nano-particles was showed heat transfer degradation of approximately 14% **Kuljeett Singh et al** [**5**].Conducted an investigation into the performance of a refrigeration system based on nano refrigerant (AL2O3+R134a). The improvement in the performance coefficient was found to be maximum (7.2to 8.5%) with 0.5% AL2O3. The mass fraction of nanoparticles in refrigerant cop was found to be lower than that of pure R134a when the mass fraction of nanoparticles in refrigerant cop was increased to 1%. **Omer A. Alawi et al [6].** Investigated the physical properties of nano- refrigerants such as surface tension, density, viscosity, and specific heat affect boiling of the nucleate pool, condensation, and convective flow boiling. the results showed an increase in heat transfer coefficient when increased nano-particle mass fraction, from the literature, it has been found that the power consumption was reduced by 2.4%, and the performance coefficient increased by 4.4%, when it used o.1%mass fraction of TiO2 and POE oil it was found enhance in performance by 26.1% comparison with pure refrigerant **Javari and Saidur [**7] investigated the potential use of nano-refrigerant in domestic refrigerators to reduce the co_2 emissions and power consumption in Malaysia. They studied the effects of adding two nano-particles (AL2O3, TiO2) with three mass fractions of (0.06%,0.1%) to the mineral of oil R134arefrigerant . their results shows the maximum energy savings of 25% When 0.1% TiO2 nanoparticles were added to mineral oil R134a, researchers discovered a reduction of more than seven million tons of CO2 by 2030. **Kumar R.R et al [8].** Study of the effect of nano-lubricants (Alumina-mineral oil) on the compression system. Experimental set up was build and use different refrigerant such as R12, R22, R600a, R600and R134a.The results showed improvement of thermal physical properties of refrigerant and increased cop of a system by 19.6%, and by 11.5%, power usage was decreased. compared to polyester **Mahbulul et al. [9]** investigated experimental using nano-particles of AL2O3 volume fraction from 0.5% to 2% with R141b refrigerant at a temperature of 5- 20 ^{o}C. The results show an increase in thermal conductivity of with nano-particles increase in concentration, highest value observed at volume concentration 2% to be 1.026 W/Mk. **D.Sendil Kumar et al [10]**. Investigated the compression refrigeration system when added AL2O3 nano-particle and lubricant (PAG) The nano-refrigerant R134a was made from oil.The results showed improvement in the system for the coefficient of performance, the length of the capillary tube reduces when used nano-refrigerant. The results showed reduced in energy consumption by 10.32% with a 0.2% volume fraction and improvement cop compared with pure refrigerant. **Subramanian and Prakakash [11]** investigated experimental added AL2O3 to R134a in vapour refrigeration system and study the performance of the system. They used three types of oil of R134a such as POE oil, SUSISO 3GS oil, and SUSISO 3GS oil nano-particles as a lubricant. The results show the highest cop appeared at the mixture R134a and SUSIOS 3GS oil with AL2O3 lubricants. Its results show an increase in cop by 33%, compressor consumption decreased to 25% compared to another type of oil, and the refrigeration capacity increased by using R134a/AL2O3 nano-refrigerant in the system.

The present study aims to investigate, experimentally, the performance of the vapour compression cycle with AL2O3 nano-particles, and the refrigerant is used R134a. A new vapour compression refrigeration rig system was built according to the requirements of this study with Three concentrations (0.2%, 0.4%, 0.6%) and size 20 nm from nano-particle AL2O3 and mixed with PAG oil used as lubricant and R134a used as a refrigerant. The experiment is conducted to show the ability of nano-particles mixed with PAG oil to improve the power consumption of the compressor and enhance the heat transferability of the system. The coefficient of performance of the system with nano-particles compared with the coefficient of performance of the pure refrigerant.

2. Experimental setup

The experiment testing was carried on the VCR system test rig and the experimental experiments were carried out to investigate the VCR system test rig. In two cases the refrigeration system output, initially a pure refrigerant R134a the baseline case was used nano-refrigerant were used in the second case (AL2O3). The refrigeration system consists of a compressor, an evaporator, a condenser cooled by air, and a capillary tube with the aid of thermometers and pressure gauge, the temperature and pressure at various points of the device are measured The temperature was calculated to use a sensor temperature at the compressor inlet and outlet. To explicitly demonstrate the temperature, the condenser and evaporator in the inlet measured low pressure from 0 to 150 psi and the outlet high pressure from 0 to 500 psi [1].

2.1. Work of experimental rig:

Vapor compression employs a circulating liquid refrigerant as a medium that absorbs and removes heat that rejects the space to be cooled and then rejects heat from elsewhere. Figure 1shows the typical single-stage steam compression system. All these systems have four components: compressor, condenser, capillary tube, and evaporator. Refrigeration flowing in the compressor in a thermodynamic state known as saturated vapor and compressed to a higher pressure, resulting in a higher temperature the hot steam was routed through a condenser where the condenser was cooled and cooled to a lower temperature the hot steam was routed through a condenser where the condenser was cooled and cooled to a lower temperature the hot steam was routed through a condenser where the condenser by allowing liquid to run through a coil or tube through a cold air flow coil Condensed liquid refrigerant, also known as a saturated liquid in thermodynamics, is then routed through a capillary tube where there is a sudden decrease in pressure, Pressure is used in the adiabatic flash evaporation of a liquid refrigerant component. This cold mixture is then passed through the evaporator's coil. [12].

Components of rig

1. Compressor

2. Condenser

3. Filter dryer

4. Capillary tube

5. Evaporator

6. Heater

7. Energy meter

8. Sensors temperature

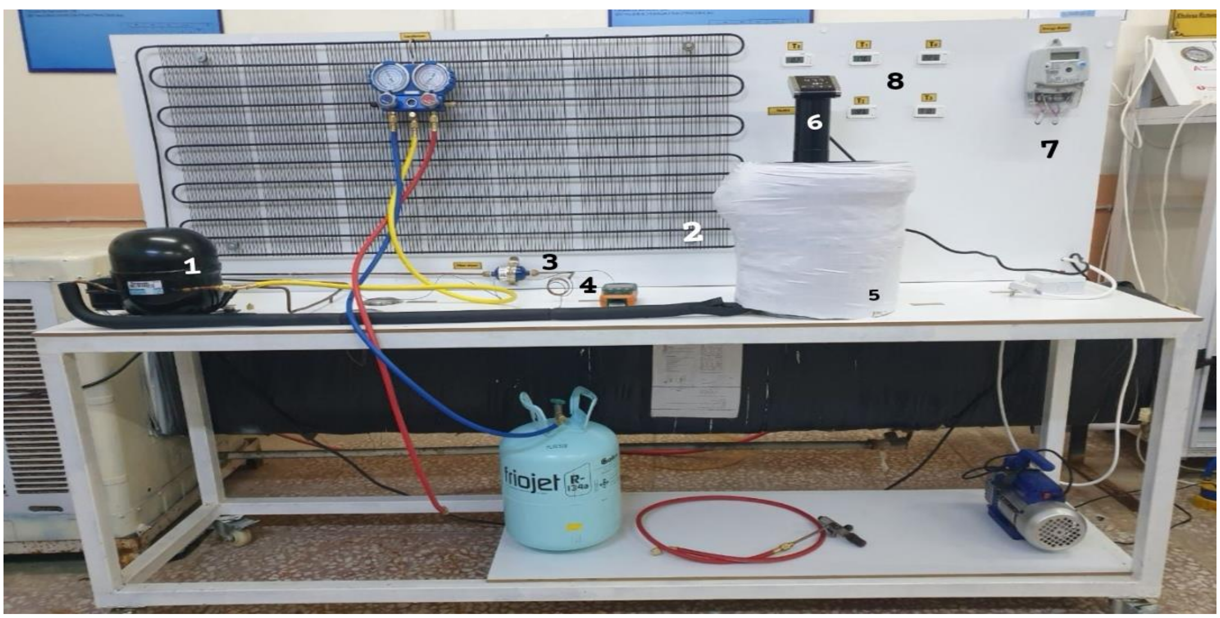

Figure 1. Refrigeration test rig

3. Experimental procedures:

3.1. nano-refrigerant preparation:

The lubricating fluid is prepared by nano-particles (AL2O3) were added to PAG oil base fluid. The volume concentration (0.2%, 0.4%, 0.6%) of AL2O3 can estimate the mass of nano-particles by using equation (1), The required mass of the corresponding nano-particles was precisely measured using a precision electronic balance. shown in table (1), the mass of nano-particles was added to 200 ml of PAG, and the mixture put on a magnetic stirrer was extended to one hour to obtain a homogenous mixture of nano-particles and the base fluid, finally, the mixture transfer to an ultrasonic cleaner of three hours used to actuate and disperse nano-particles into fine particles and it is become to be charged in a compressor of the system is shown in Figure 2.

$$\varphi\% = \frac{(m_p \backslash \rho_p)}{(m_p \backslash \rho_p)+(m_{bf} \backslash \rho_{bf})} \quad (1)$$

The concentration φ	Mass of AL_2O_3 m (g)	Thermal conductivity W/m.K	Density Kg/m^3	Specific heat KJ/kg.K
0.2%	1.9g	0.084802	1216.85	1.4494
0.4%	4.5g	0.092501	1243.36	1.4355
0.6%	6.7g	0.111064	1269.87	1.4118

Table1. Properties of nano-particles AL2O3

a b c

Figure2. Equipment used in the preparation of nano-fluid (a) electronic balance (b) stirring hotplate (c) ultrasonic cleaning.

3.2. Charging of set up:

We need to evacuate before charging the device to get rid of the adverse effect of moisture. Then the system is charging is completed. The Nano-fluid is first applied to the compressor, first, the nano-fluid is injected through the service port into the compressor and allowed to stabilize for 15-20 minutes R134a is then charged into the device after that. The charging phase needs to be stopped when the pressure gauge indicates.

4. Experimental calculations:

4.1. Coefficient of performance:

a. Volume of water tank

$$V = \pi/4\ D^2\ h \quad (2)$$

b. Mass of water

$$m = \rho\ .v \quad (3)$$

c. Power input to compressor

$$P = (E_O - E_i).\ 3600 \quad (4)$$

d. Refrigeration effect

$$RE = M_w cp_w\ dT \quad (5)$$

e. Coefficient of performance

$$COP = \frac{M_w cp_w\ dT}{(E_O - E_i)\ 3600} \quad (6)$$

5. Result and Discussion:

In the experimental analysis, four cases have been considered. Initially, the test was carried out with R134a and PAG oil, after use three-volume concentration of AL2O3 (0.2%, 0.4%, and 0.6%) Nano-Particles with R134a refrigerant.

5.1.The coefficient of performance at a temperature is 40 ^{o}C.

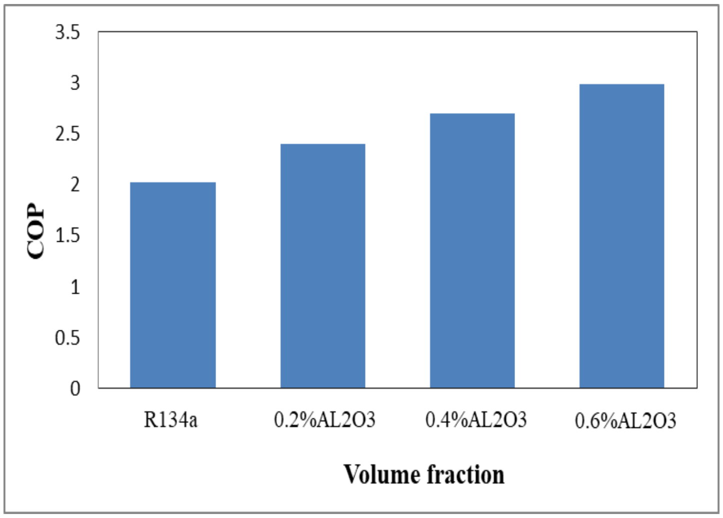

Figure3. Coefficient of performance and volume fraction of different concentrations of AL2O3 at temperature 40 ^{o}C.

Figure 3. Gives a comparison of the performance for refrigerant with and without nano-fluids at a temperature of water in the evaporator 40 ^{o}C, the performance is the ratio of cooling effect and the input of the power. In this study, it was calculated using experimental data, the heater supplies heat to the evaporator using heating water, and the same amount of heat was removed by the refrigerant. The coefficient of pure R134a refrigerants is 2.01757 whereas the performance of nano-refrigerant at concentration 0.2% of AL2O3 is found to be 2.39008 and the coefficient at concentration 0.4% of AL2O3 is 2.6909 and the performance at 0.6% concentration from AL2O3 is 2.9766. The improvement in the performance is 15.586% at concentration 0.2% at AL2O3, and the improvement of the coefficient at 0.4% AL2O3 by 25.022% and the enhance in the performance at a concentration at 0.6% of AL2O3 is 32.219%. It is observed at adding nano-fluids to refrigerant enhance refrigeration compared with pure refrigerant.

5.2.The coefficient of performance at a temperature of 50 °C.

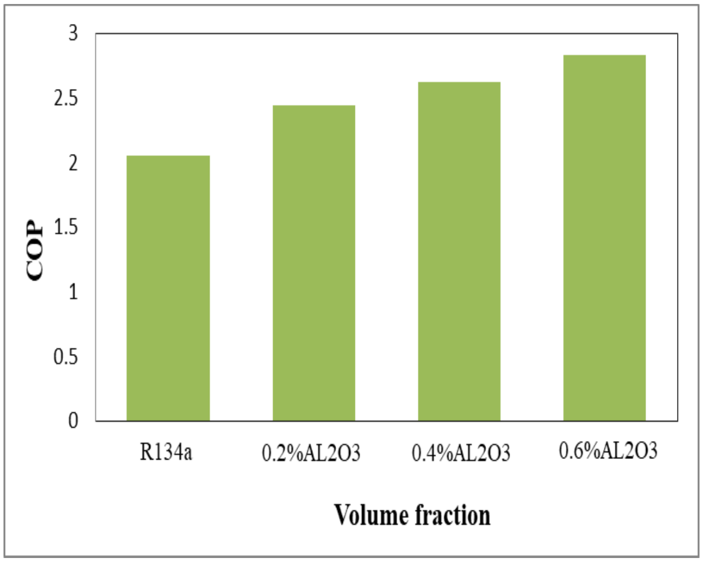

Figure4. Coefficient of performance and volume fraction of different concentrations of AL2O3 at temperature 50 °C
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Shows in figure4: a comparison of the performance for refrigerants with and without nano-fluids at temperature 50 °C, the coefficient of pure R134a refrigerants is 2.0558 whereas the performance of nano-refrigerant at concentration 0.2% of AL2O3 is found to be 2.44123, and the performance at concentration 0.4% of AL2O3 is found 2.6183 and the coefficient at concentration 0.6% of AL2O3 is 2.823. So there the improvement is 15.789% in cop at concentration 0.2% of AL2O3, there is an improvement at 0.4% of AL2O3 concentration is 21.485%, and the improvement of the performance at 0.6% concentration of AL2O3 is 27.416%.

5.3.The coefficient of performance at a temperature of 60 °C.

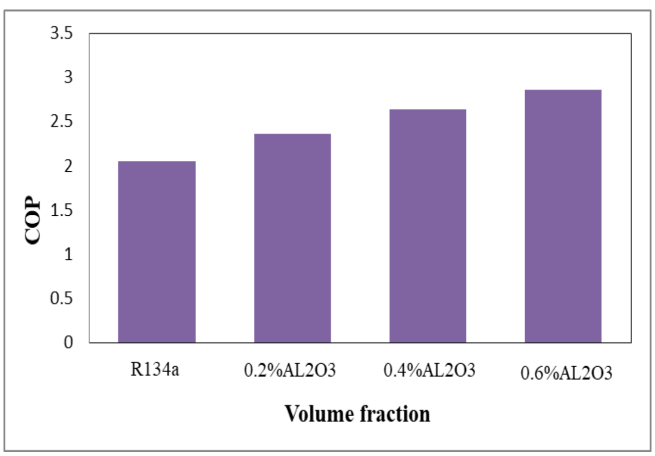

Figure5. Coefficient of performance and volume fraction of different concentrations of AL2O3 at the temperature 60 °C.

Figure 5. Shows a comparison of the coefficients of performance with and without nano-fluids at a temperature of 60 °C, it is used experimental data to calculate the coefficient of performance, the performance of pure R134a refrigerant is found to be 2.04967 whereas the performance of nano-refrigerant at 0.2% concentration of AL2O3 is found to be 2.365, the performance of the system at 0.4% concentration from AL2O3 is 2.637 and cop at 0.6% of AL2O3 is 2.859. So there is improvement in cop at 0.2% of AL2O3 is 13.332%, there is the improvement of a cop at 0.4% concentration of AL2O3 is 22.282% and there is enhancement at concentration 0.6% of AL2O3 is 28.308% in the performance at, It is observed at adding nano-fluids to refrigerant improvement the performance of the system when compared with pure refrigerant.

5.4.Comparison Refrigeration effect for nano-refrigerant and temperature of a heater from 40 °C to 60 °C.

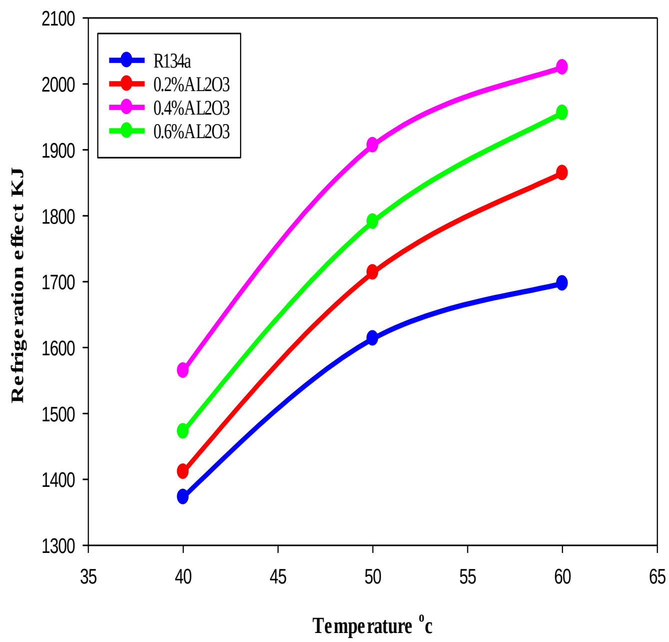

Figure6.Refrigeration effect and temperature of a heater.

Figure 6 shows that the refrigeration effect of R134a using AL2O3+PAG oil is greater than that of the refrigerant. The AL2O3+PAG oil improves the heat transfer rate across all components. The refrigeration effect for concentrations 0.2%, 0.4%, and 0.6% at evaporator water temperature 40 °C increase about 2.717%, 6.771%, and 12.2549% . while at the same concentrations but temperature 50 °C increase by 5.856%, 9.914%, and 15.384%. Finally, they are at the same concentration at temperature 60°C they increase by 8.979%, 13.229%, and 17.202% compared with pure refrigerant.

5.5.The power consumption of the compressor at temperature 40 ^{o}C.

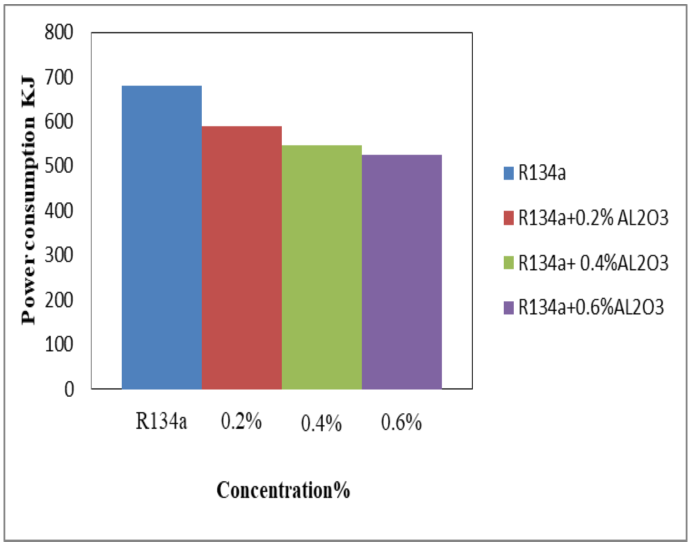

Figure 7 comparison power consumption at a different concentration of AL2O3

Figure 7 shows a comparison between power consumption for pure refrigerant and different concentrations of AL2O3 at temperature 40 ^{o}C. when compressor running with nano-lubricant containing 0.2% concentration is reduced 13.228%,and the reduction in power consumption at 0.4% of AL2O3 concentration is 19.577%, and at concentration 0.6% of AL2O3 is 22.751% .

5.6.The power consumption of the compressor at temperature 50 ^{o}C

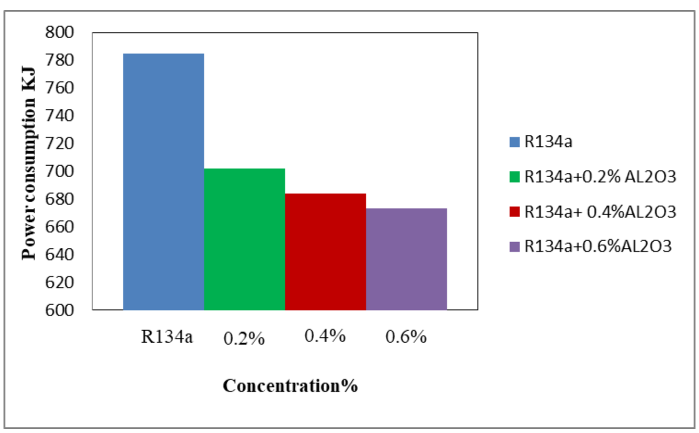

Fig 8 Comparison between power consumption and different concentrations of AL2O3

Figure 8 shows a comparison between power consumption for pure refrigerant and different concentrations of AL2O3 at temperature 50 ^{o}C. when compressor running with nano-lubricant containing 0.2% concentration is reduced 10.551%,and the reduction in power consumption at 0.4% of AL2O3 concentration is 12.844%, and at concentration 0.6% of AL2O3 is 14.222%.

5.7.The power consumption of the compressor at temperature 60 °C

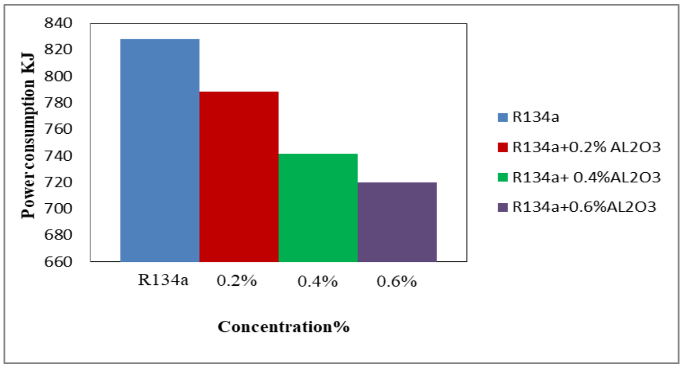

Figure 9 Comparison between power consumption and different concentrations of AL2O3

Figure 9 shows a comparison between power consumption for pure refrigerant and different concentrations of AL2O3 at temperature 60 °C. when compressor running with nano-lubricant containing 0.2% concentration is reduced 4.783%, and the reduction in power consumption at 0.4% of AL2O3 concentration is 10.434%, and at concentration 0.6% of AL2O3 is 13.043%**.**

5.8. Thermo-physical properties of nano- refrigerant:

5.8.1.Thermal conductivity:

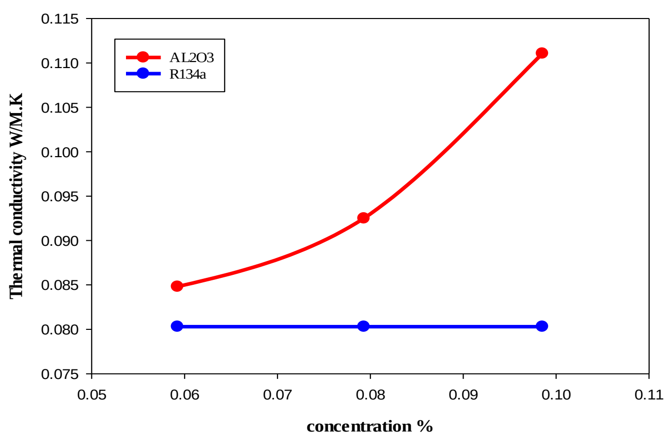

Figure 10 thermal conductivity and concentration of nano-refrigerant

Shows figure 10 comparison between the thermal conductivity of AL2O3 nano-refrigerant and pure refrigerant, it is observed improvement in thermal conductivity at 0.2% concentration of AL2O3 is 5.308%, and the improvement at concentration 0.4% is 13.19%, and at 0.6% concentration is improved 27.69% when compared with pure refrigerant.

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5.8.2.Density of nano-refrigerant:

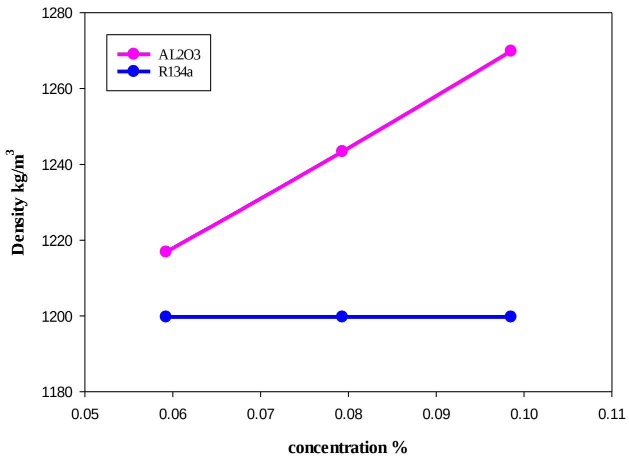

Figure 11 density and concentration

Shows in figure 11 comparison between the density of nano-refrigerant AL2O3 and pure refrigerant. It is found a density of refrigerant with nano-particle concentration at 0.2% is 1216.851, and at 0.4% concentration is 1243.363, and at 0.6% concentration is 1269.873. It is observed the density of refrigerant is increased with nano-lubricants when compared with pure refrigerant.

6. Conclusion:

The current work An experimental analysis is performed on Vapour Compression Refrigeration System is aimed at using AL2O3 nanoparticles in PAG oil with R134a refrigerant. The size of nanoparticles (AL2O3) has been used 20 nm and three concentrations (0.2%,0.4%,0.6%). In the present work are used three temperatures (40°c, 50°c,60°c) of water in the evaporator. The results are showed that the improvement in the coefficient of performance is the highest increase of the system was 32.219%. and the highest increase in refrigeration effect by 17.202% and get less in the energy consumed by the compressor is 22.751% there is available at concentration 0.6% of nano-particles. When compared pure refrigerant R134a with the above results we get an improvement for a coefficient of performance and thermophysical properties.

NOMENCLATURE

COP: Coefficient of performance

D: Diameter of the tank water

H: Height of the tank water

ρ: Density of pure water

Eo: Readings output of the energy meter

E_i: Readings input of the energy meter

M_w: Mass of water in the tank

CP_w : Specific heat of water

dT: Different temperature of the water

ABBREVIATIONS

AL2O3: Aluminum oxide

PAG: polyalkylne Glycol

VCR: vapour compression refrigeration

7. Reference

1. R.K Adyanshee Pattanayak, Nilamani Sahoo, Prashant Mishra. "Performance Analysis of a Domestic Refrigerator using Al2O3 Nanoparticles."IOSR Journal of Mechanical and Civil Engineering(IOSR-JMCE): ISSN: 2278-1684, P –ISSN: 2320-334X, Volume 12, ISSN:4 ver, pp 12-16.2015.

2. R.S.Mishra, Rahul Kumar Jaiswal, "Thermal Performance Improvements of Vapour Compression Refrigeration System Using Eco Friendly Based Nanorefrigerants in Primary Circuit." International Journal of Advance Research and Innovation, volume 3, Issue3, page no. 524-535,2015.

3. Soliman,AMA,TaherSH, Abdel Rahman AK,"Performance enhancement of vapor compression cycle using nano materials". International Conference on Renewable Energy Research and Applications,IEEE,P.8216.DOI:10.1109/ICRERA7418526.2015.

4. Kedzierski,M.A."Effect of concentration on R134a/Al2O3 nanolubricant mixture boiling on a reentrant cavity surface." International Journal of Refrigeration 49: 36-48.2015.

5. Kuljeeet Singh, et al. "An Investigation intothe performance of a Nanorefrigerant (R134a+AL2O3) Based Refrigeration System", IJRMET Vol. 4, ISSUE 2, October 2014.

6. Omer A. Alawi, Nor Azwadi Che Sidik, H. A. Mohammed, "A comprehensive review of fundamentals, preparation and applicationsnanorefrigerants."International Communications in Heat and Mass Transfer 54, page no 81-95,2014.

7. Javadi,F.S., Saidur,"Energetic, economic and environmental impacts of using nanorefrigerant in domestic refrigerators in Malaysia. Energy Conversion and Management. 73, 335 -339-2013.

8. Kumar, R. R., Sridhar, K, Narasimha,M., "Heat transfer enhancement in domestic refrigeratorusingR600a/mineraloil/nano-Al2O3 as working fluid." International Journal of Computational Engineering Vol. 03, pp.42 – 50. 2013.

9. M.Mahbulul,R.Saidur,et al.“Influence of particle concentration and temperature on thermal conductivity and viscosity of AL2O3-R141b, of nano-refrigerant “international commnication In heat and mass transfer 43, pp. 100-104,2013.

10. D.Sendil Kumar, Dr. R. Elansezhian. "Experimental study on Al2O3-R134a nano refrigerant in refrigeration system." International Journal of Modern Engineering Research (IJMER) Vol. 2, ISSue.5, page No 3927-3929, Oct 2012.

11. Subramani, Prakash, M.J, "Experimental studies on a vapour compression system using nanorefrigerants."International Journal of Engineering, Science and Technology” 3(9), 95-102.2011

12. T.Coumaressin and K.Palaniradja "Performance analysis of a refrigeration system using nano fluid." International Journal of Advanced Mechanical Engineering, Vol. 4 no 4, pp. 459-470.2014.