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Performance Analysis of a Domestic Refrigerator using Al_2O_3 Nanoparticles

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Abstract: *Nanofluid, a new concept in nanotechnology has already got the attention of the research communities due to its unique property such as thermal conductivity. Therefore, the reliability and performance of a domestic refrigerator using nanorefrigerant is experimentally investigated in the present study. Experiments are performed using PAG (Polyalkylne Glycol) oil with Al_2O_3 nanoparticles to analyse the performance characteristics of a domestic refrigerator using refrigerant HFC134a (tetrafluoroethane). With different mass fraction of Al_2O_3 nanoparticles , the energy consumption test and freezing capacity test are investigated. From the experimental observations it is found that the refrigerator works normally and safely using HFC134a and PAG oil with Al_2O_3 nanoparticles. The coefficient of performance of the domestic refrigerator is improved by 12.14%, 27.8% and 39.46% with 0.47%, 0.952% and 1.42% mass fractions of Al_2O_3 nanoparticles respectively. Also the power consumption is reduced by 10%, 20%, 26.6% and the freezing capacity is also increased for above mass fraction of Al_2O_3 nanoparticles. This study helps to reduce energy consumption of the society.*

Keywords *- Al_2O_3 nanoparticles , COP , mass fraction , nanofluid , polyalkyline Glycol oil*

I. Introduction

In today's world everyone is thinking of reducing energy consumption and saving it for more longer period. A big amount of energy is consumed in our household devices like televisions, air conditioners and refrigerator. First two devices consumption can be reduced by controlling its use like whenever you need you use them or you switch them off. But refrigerator cannot be controlled by limiting its use, because it has to run all the time. So the solution to this is to build an energy efficient model. Conventional thermo fluids are responsible for poor thermal conductivity. So improving its thermal conductivity will enhance the heat transfer characteristics of the conventional fluid. As we know that metal particles have larger thermal conductivity than the base fluid, so suspension of the metal particles in the base fluid is expected to enhance the thermal conductivity. Lot of work has been done in suspending metal particles in the size of millimeters or micrometers but it has got very few practical applications as there always remain the problem of pressure drop due to sedimentation. So researchers have developed a new standard of fluid called the nanofluid which has got high surface area which prevents the particles being clogged. So we have replaced the conventional fluid with the nanofluid which is made by the use of nanotechnology, engineered to possess unique thermal properties which can improve the heat transfer and is energy efficient is thermal systems. The nanofliud are the mixtures of the base fluid and the nanoparticles. The base fluid can be water,refrigerant, engine oil etc and nanoparticles can be Al, Cu, Al_2O_3 , CNT etc. combined together to form a colloid called nanofluid. Lot of work has been done by using nano particles. Specifically in refrigerator, on replacing the base fluid with nano fluid which has enhanced the performance of the same. R Krishna Sabareesh et al[1]conducted experiment taking TiO_2 nanoparticles with mineral oil with R12 as refrigerant and found that the COP of the system increased after using the nanofluid. Sheng-shan Bi et al[2]mixed the mineral oil with 0.1% mass fraction of TiO_2 nano particles in place of POE oil in the HFC134a refrigerant and got 26.1% less energy consumption which in result increased the COP of the system. Sheng-shan Bi et al[3]did another experiment by mixing nano particles (0.5g/L TiO_2) with the refrigerant R600a and got the result of 9.6% less energy consumption in the domestic refrigerator. M Mahbubul et al[4] took 0.5 to 2% volume concentration of Al_2O_3 nano particle with refrigerant R141b which resulted in increased thermal conductivity and viscosity. Meibo Xing et al[5] proposed C_{60} nano oil as a promising lubricant. It is a mixture of C_{60} nano particles and mineral oil. This work of his improved the COP of two refrigerating system by 5.6% and 5.3% . F S Javadi et al[6] took a combination of R-134a refrigerant with TiO_2 and Al_2O_3 nanoparticles in 0.1% mass fraction and found that there is more energy reduction when compared with domestic refrigerator. My work consists of a model of domestic refrigerator working on vapour compression cycle. Our work is based on comparison of COP, Compressor work and Refrigerating Effect of the domestic refrigerator by replacing conventional base fluid (PAG oil as lubricant oil) with nanofluids (PAG oil + different mass fractions of Al_2O_3 nano particles) with R-134a as refrigerant.

II . Preparation Of Nanofluid

The preparation of nanofluid require mixing of nano particles with the PAG oil with even distribution of these particles with the lubricating oil for stable and durable suspension. There should not be any agglomeration of particles and no chemical change of the mixture. It is prepared in two steps:

2.1 First Step:

The nanoparticles are obtained from a company named SIGMA- ALDRICH. It has got the following properties :

Size – less than 50 nm, Colour - White, Density – 0.26 g/cc ,Melting Point – 2040 ^{o}C and Molecular Weight – 101.96

2.2 Second Step:

In this step, the desired amount of nanoparticles are added to the lubricant oil and for even distribution of nanoparticles in the lubricant oil, the mixture (PAG oil and nanoparticles) has to place in an ultrasonic vibrator for 6-7 hours.

We have prepared three nanofluid with three different mass fractions of 0.47%, 0.952% and 1.42% respectively.

Fig 2.1 : synthesis of nanofluid in Ultrasonic vibrator

2.2 : Nanofluid

TABLE I : Properties of PAG oil

LUBRICANT OIL	**SP10**
Lubricant Type	PAG
Specific Gravity	1.046
Colour (ASTM)	L 0.5
Kinematic Viscosity (cst)	47.73
Flash Point (°C)	242
Pour Point (°C)	< -50
Falex Load Test (lbs/in2)	1300
Critical Solubility Point Upper Lower (°C)	76 (3%) < -40

III . Experimental Setup

The refrigeration system consists of a compressor, air cooled condenser , capillary tube and an evaporator. The temperature and pressure at different points of the system are measured with the help of thermometers and pressure gauges. The temperature was measured with copper-constantan T type thermocouples which are fitted at the inlet and outlet of the compressor, condenser and evaporator to show the temperature directly. The ranges of pressure gauges for evaporator inlet/outlet and compressor inlet are 0 to 250 psi and for condenser inlet/outlet and compressor outlet is 0 to 500 psi.

Fig 3.1 : Vapour compression refrigeration system

IV. Procedure Of Charging Nanoparticle Into The Experimental Setup

Before charging the system, we need to evacuate it to get rid of detrimental effect of moisture. After the evacuation, various leakage tests like nitrogen and bubble tests and water submersion methods are done to confirm no leakage in the system. Then the charging of the system is done. First the nanofluid is inserted to the compressor through the service port and allowed to stabilize for 15-20 mins. After that R-134a is charged into the system. The charging process need to be stopped when the pressure gauge shows 60-65 kg/cm^2.

Fig 4.1: nanofluid is inserted into the compressor

Fig 4.2 : charging of refrigerant R134a into the system

V Result And Discussion

5.1 Energy Consumption

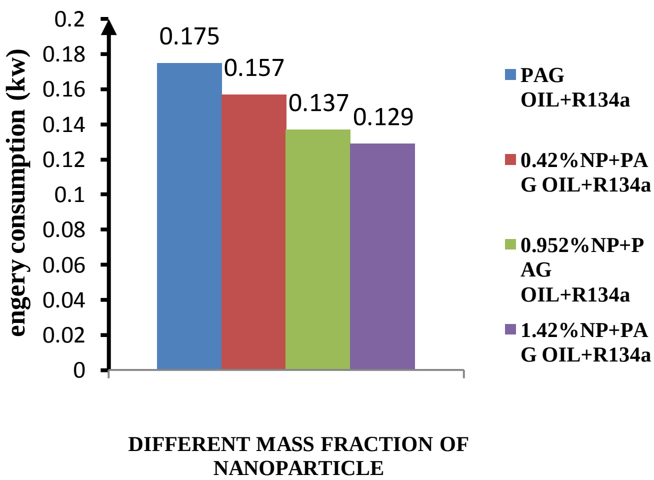

Fig 5.1: comparison of energy consumption for different mass fractions of nanoparticles

5.2 Refrigerating Effect

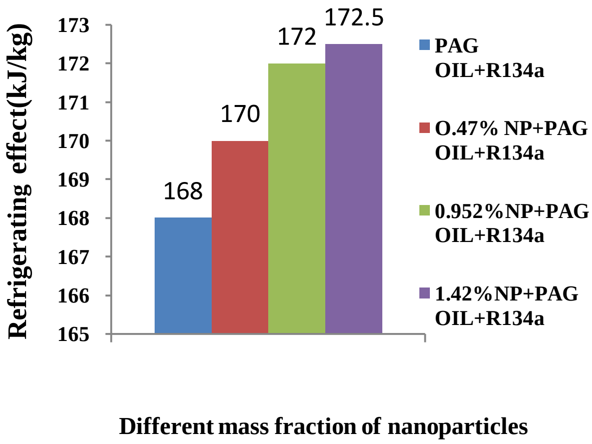

Fig 5.2: comparison of refrigerating effect for different mass fractions of nanoparticles

Figure 5.1 shows that the energy consumption reduces as the mass fractions of the nanoparticle increases in the lubricant oil(PAG oil). The presence of nanoparticles reduces friction and increases the viscosity of the lubricant oil.

Figure 5.2 shows that the refrigerating effect increases as the mass fractions of nanoparticle increases. The increase in the percentage of mass fractions of the nanoparticles increases the thermal conductivities of the nanofluid which gives an enhanced heat transfer effect.

5.3 Compressor Work

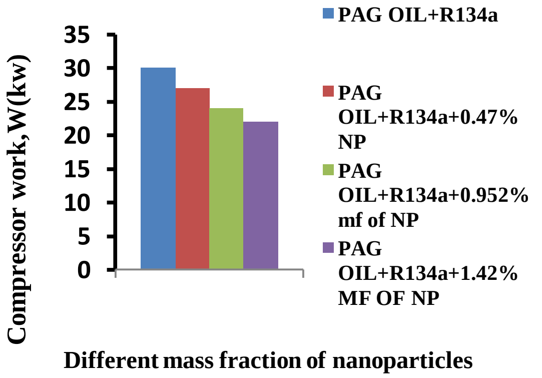

Figure 5.3: comparison of compressor work for different mass mass fractions of nanoparticles

5.4 Coefficient of Performance

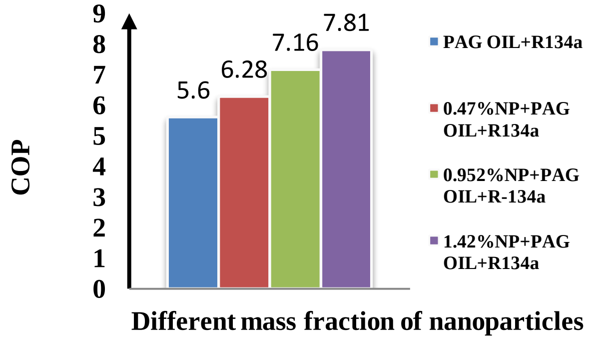

Fig 5.4: comparison of COP for different fraction of nanoparticles

Figure 5.3 shows that the compressor work reduces with increased percentage of mass fractions of nanoparticles.

Figure 5.4 shows that the COP of the system is enhanced by the presence of nanoparticle in the lubricating oil. Also as we increase the mass fractions of the nanoparticles, the COP is gradually increased.

5.5 Discharge and Suction pressure of compressor for different mass fraction of the nano particles

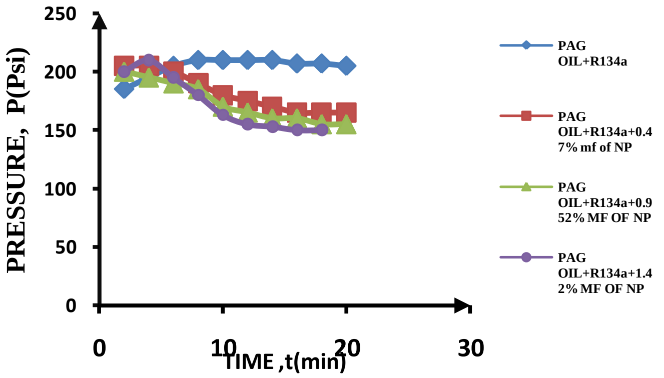

Fig 5.5: comparison of compressor discharge pressure for different mass fraction of the nanoparticle

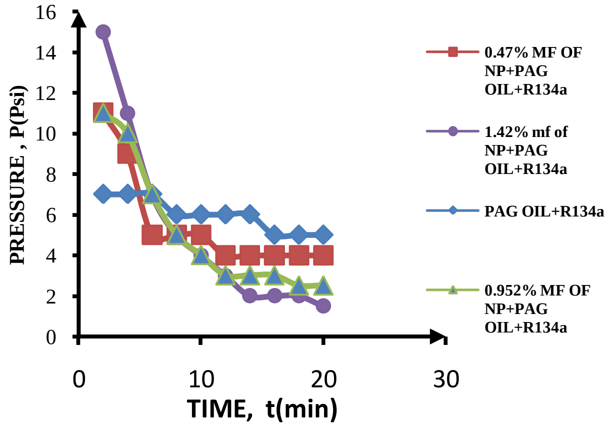

Fig 5.6: comparison of compressor suction pressure for different mass fractions of the nanoparticles

Figure 5.5 and 5.6 shows that discharge and suction pressure of the compressor decreases with increase in mass fractions of nanoparticles.

5.6 Temperature of Refrigerating Space

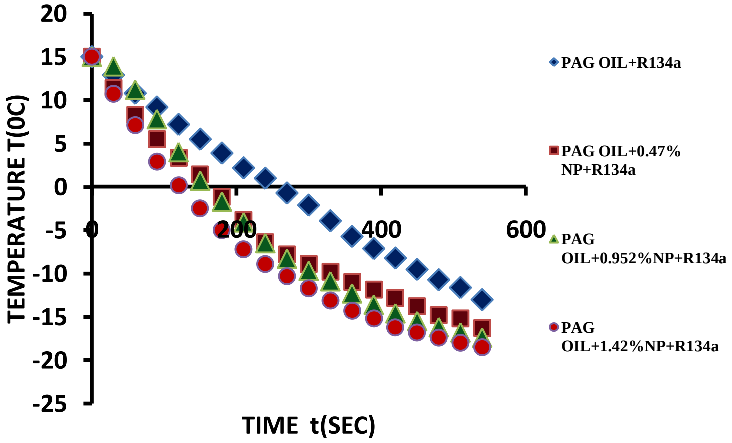

Fig 5.7: variation of temperature of the refrigerating space Using different mass fractions of nanoparticles.

The temperature is reduced from15^{0}c to -13^{0}c , -16.3^{0}c , -17.4^{0}c , -18.5^{0}c for the mixture of PAG oil and R134a , PAG oil and 0.47% mass fraction of nanoparticles and R134a , PAG oil and 0.952% mass fraction of nanoparticle and R134a , PAG oil and 1.42% mass fraction of nanoparticle an R134a respectively within 9 minutes (540Secs).

VI. Conclusion

The power consumption of the compressor was reduced by 10%, 20% and 26.6% for mass fractions of o.47%, 0.952% and 1.42% of Al_2O_3 nanoparticles respectively. The refrigerating effect is also enhanced by the use of the nanoparticles. The coefficient of performance of the refrigerating system was improved by 12.14% , 27.8% and 39.46% for the mass fractions of 0.47%, 0.952% and 1.42 % of Al_2O_3 nanoparticles respectively. There was also reduction of compressor's suction and discharge pressures with addition of nanoparticles. So from the above observations we can conclude that the present study can be helpful to the society in the reduction of energy consumption by using a simple vapour compression refrigerating system in which Al_2O_3 nanoparticles of different mass fractions are added in the lubricating oil.

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