EPERIMENTAL INVESTIGATION ON THE PERFORMANCE OF VAPOUR COMPRESSION REFRIGERATION SYSTEM WITH ZNO NANOLUBRICANT

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Abstract: The main aim of this work is to explore the effect of ZnO nanoparticles on the thermo physical properties of base POE oil and performance of the air conditioner working on vapour compression cycle. In this work nanolubricant of 0.2%, 0.6% and 0.8% concentrations were prepared by mixing ZnO nanoparticles of 30 to 60 nm size in the POE oil. The experimental data reveals that the thermal conductivity and viscosity of nanolubricant is high at 0.8% by weight concentration and hence 0.8% by weight concentration is selected for experimental performance evaluation. Therefore, nanolubricant in vapour compression system is the passive approach to get better performance of the system. An investigational result concludes that the system works normally and safely with the addition of nanolubricant. COP of the air conditioner along with nanolubricant has been enhanced by 38% at 0.4Kw heat load due to reduction in the compressor power and increase in the refrigeration effect. Experimental results show that the compressor power has been reduced by 33% and refrigeration effect has increased by 7.8% with the supplement of ZnO nanoparticles to the base POE oil for 0.4Kw heat load. Results indicate that the time taken to reach 20°C from 38°C in the conditioned space is reduced by 33% for ZnO nanolubricant. Thus, the ZnO nanolubricant can be used in the refrigeration and air conditioning system to improve the performance.

***IndexTerms* - vapour compression refrigeration system, COP, Nanoparticles, Nanolubricant.**

I. INTRODUCTION

In refrigeration & Air conditioning nanolubricant is the mixture of compressor oil and nanoparticles. Nanoparticles have a ability to increase the heat transfer properties of the base fluid. Various researchers have conducted experiments to find the performance of vapour compression refrigeration system by adding nanoparticles to compressor lubricating oil and found that it is the modern technique to enrich the performance of the refrigeration and air conditioning system. The following are the major characteristics reported for nanofluids. They are

[3] found that adding TiO2 nanoparticles to the mineral oil enhances the solubility and also found that the system performing better by recurring more lubricant oil back to the compressor. Addition of nanoparticles to the base oil can improve thermal conductivity of the base fluid [1, 3, 4, 8, 11-13, 22, 24, 25]. Thermal conductivity of the base fluid can be improved either by mixing nanoparticles to the base fluid in large proportions or by using nanoparticles of having higher thermal conductivity. The second approach has been approved by the various researchers. [18] Conducted experiment to find the impact of nanoparticle size on thermal conductivity and concludes that nanofluid having smaller size nanoparticles can improve the thermal conductivity of the base fluid. The experimental results revealed that the thermal conductivity increases by 6.6%, 12.5% and 22.2% corresponding to 0.1%, 0.2% and 0.3% volume concentration of nanoparticles. This enhancement is observed due to the Brownian motion of the particles [21]. By mixing of ZnO nanoparticles to the base POE oil the thermal conductivity of the nanolubricant has been increased up to 12% for spherical shape nanoparticles and 18% for rectangular shape nanoparticles at 5.0 vol. % concentration [10].

Viscosity of nanolubricant is more than that of the pure oil. Also, the viscosity variation with the temperature agrees with the trend of the pure oil. The results from wear tests show that addition of CuO nanoparticles even up to 0.10% by mass of POE oil reduces the friction coefficient of the test specimen, note worthily [17]. Experiment values concludes that the viscosity and density of the mineral oil nanolubricant is lesser by 25.78% and 8.65% compare to the POE oil nanolubricant respectively and hence the mineral oil nanolubricant can give better performance [17]. The viscosity of Al2O3 nanolubricant of concentration 10 % by wt. of POE oil was 30 to 40 percent higher than that of pure POE oil [15]. The ZnO nanolubricant exhibits the enhanced viscosity by 7.7% for rectangular shape nanoparticles compare to spherical shape nanoparticles suspended in the POE oil up to 69% volume concentration [10].

The convective heat transfer coefficient increases appreciably with the mixing of MWCNT to the base POE oil [18]. The maximum increase in heat transfer co-efficient of 23.8% is observed by decreasing the nanoparticles size from 80nm to 20nm [8]. [2] conducted an experimental investigation on flow boiling of R-134a/POE mixtures and R-134a/POE/CuO nanofluid in a horizontal tube and found that for a nanolubricant mass fraction of 0.5%, no effect on the heat transfer coefficient and for nanolubricant mass fractions of 1% and 2%, the heat transfer coefficient was increased by 82% and 101% in comparison to R-134a/POE mixtures..

Application of nanolubricant in the refrigeration and air conditioning can improve the performance due to the above significant properties. Reduces power consumption by 13.89% at 0.5% vol concentration and C.O.P. is increased by 12.16% by using R134a/ POE oil /nano-SiO2 as working fluid [18]. [23] investigated the influence of ZnO - R152a in the performance enhancement of Air-conditioning system and found that the pressure drop occurs due to the presence of nano particles in the lubricant and this increases the COP. Experimental results reveal that the coefficient of performance (COP) of the refrigeration system is improved by 16.67% when 0.2 gm/lt of Mineral oil-Carbon nano powder is used [19]. [9] Found that the energy consumption of the domestic refrigerator decreased by 15.22% at a mass fraction of 0.1% with the addition of graphite nanolubricant. Application of SiO2 nanoparticles as lubricant additive in VCRS can enhances the energy saving from a minimum value of 7.03% to a maximum value of 12.30% [20]. With 0.2 gms/lit of TiO2 nanolubricant along with R134a refrigerant enhanced the refrigeration effect by 10.3% and reduces the power consumption by 9.65% and hence the overall COP has been improved by 20.2% [17]. [7] Investigated the working of window type air-conditioner by the addition of TiO2 nanoparticles to lubricant and found enhancement in the COP by 7.93% to 11.99 % and the average compressor input power for R22 with nanoparticles was (2.1 to 13.3) % lower than that of R22 without nanoparticles. [20] It is found that the addition of Al2O3 nanoparticles to the POE oil reduces the power consumption of the compressor by 11.5 % and the freezing capacity is higher. The results show that replacing R-134a refrigerant with hydrocarbon refrigerant and adding Al2O3 nanoparticles to the lubricant effectively reduces the power consumption by 2.4%, and the coefficient of performance was increased by 4.4% [16].

Thus the use of nanoparticles in an air conditioning system as a nanolubricant is the new innovative way to improve the performance. This paper studies the influence of nanoparticles in split air conditioner by calculating the performance.

II. Experimental Study

2.1 Nanoparticles characterization:

In this work ZnO nanoparticles is considered for the performance evaluation of a home air conditioner working on VCR system. SEM and XRD test were conducted to find the size and shape of the nanoparticles. From the SEM image of ZnO nanoparticles as shown in the fig 1 the shape of the nanoparticles are spherical or analogously spherical. Maximum intensity peaks in the XRD image is in between 30 – 60 nm and hence it is clear that the size of the nanoparticles is in between 30 – 60 nm as shown in fig 2

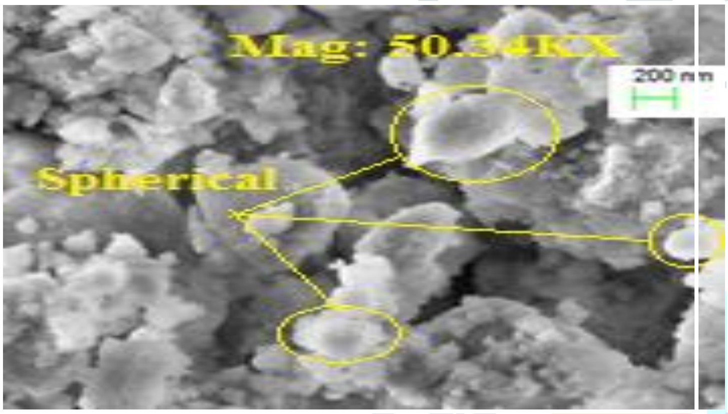


Fig: 1 SEM image of ZnO nanoparticle

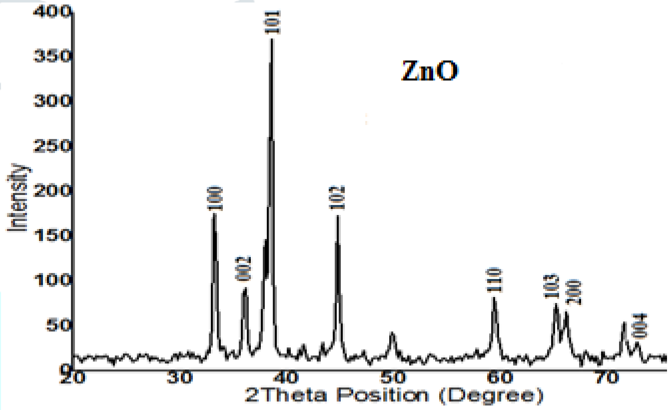


Fig: 2 XRD image of AlN nanoparticle

2.2 Preparation of nanolubricant

In this paper, three samples of 0.2 wt%, o.6 wt% and 0.4 wt% were prepared to evaluate the thermo-physical properties of the nanolubricant. The following is the procedure employed for the preparation of the nanolubricant.

1) Measure the weight of 25ml of POE oil.
2) Calculate the mass of nanoparticles required for 0.2 wt% concentration by using the following relation.

$$Wt\% = \frac{W_{np}}{W_{np} + W_{POE}} \times 100 - -(1)$$

3) Mix the obtained mass of nanoparticles to POE oil and stir in magnetic stirrer for 1 hour.
4) Nanoparticles are completely dispersed in the fluid by 3 hrs of sonication.
5) Again stir the mixture using magnetic stirrer.
6) Repeat the same procedure for 0.6 wt% and 0.8 wt% concentrations.

2.3 Thermo-physical properties of the nanolubricant:

2.3.1 Thermal Conductivity:

To measure the thermal conductivity of the nanolubricant a KD 2 pro thermal analyzer is used. The setup has a probe which is immersed in the nanolubricant sample. The values obtained are repeated twice for the accuracy. This test is performed at NIT, Thirchy.

2.3.2 Viscosity measurement:

Viscosity of the POE oil influence indirectly to the load carrying capacity and power consumption rate of the compressor used in air conditioning system. The objective of this work is to study the influence of ZnO nanoparticles on the performance of the air conditioning system. Viscosity of the oil is measured by using redwood viscometer for three samples of 0.2%, 0.6% and 0.8% weight concentration of nanoparticles.

III. EXPERIMENTAL SYSTEM:

The experimental setup was fabricated according to the standards. The indoor unit of the split type air conditioner is placed in a cabin made of wooden planks of 8' × 4' × 8' (lxbxh). The heat load in the conditioned space is calculated from load calculation by assuming 2 persons working with laptop and one light in the conditioned space. The heat thus obtained from the load calculation is given by four bulbs of each 100 watts is placed in the conditioned space to provide sensible heat.

The outdoor unit includes the condenser, expansion valve and a rotometer. Four thermocouples and two pressure gauges were placed at the required locations to collect the data for calculating the performance. The power consumed by the entire unit is measured from digital watt meter. The block diagram of the experimental set up was shown in the fig [4].

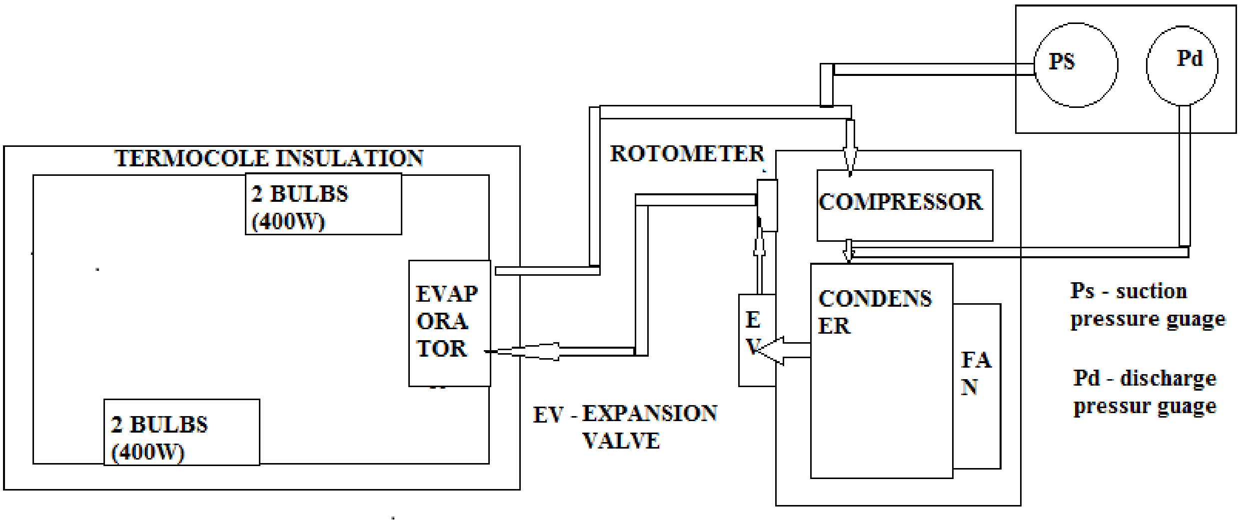


Fig: 3 Block diagram of experimental setup

1) Heat gain by the occupants:

$$Q_o = K \times q_g \times CLF$$

= 140 W. (CLF = 1.0)

2) Heat gain by the infiltration:

$$Q_{\inf} = m_0 \times C_{pm} \times (T_0 - T_i)$$

= 142W

3) Heat gain by the walls:

$$Q_w = U \times A \times (T_0 - T_i)$$

= 2.208 w

For four sides there is same material so

Q_w = 4*2.208

= 8.8w

4) Heat gain by the electric appliance:

$$Q_l = W_i \times UF \times BF \times CLF$$

= 100 w.

5) Heat gain from laptop (Q_{lt}) = 30w.

$$Q_{total} = Q_o + Q_{\inf} + Q_w + Q_l + Q_{lt}$$

= 390.4w

3.1 Experimental Procedure:

The performance of air conditioner was initially measured by using refrigerant R410a and POE oil in the compressor as the lubricant for the base data. Then, R410a and POE oil with 0.8% concentration of ZnO nanoparticles was used as working fluid for the same test. Experimental readings were taken when the conditioned space reaches the desired temperature of 20ºC.The performance of the unit is measured from the standard equations.

Results and discussions

In this work performance evaluation has been done with POE oil alone and POE + ZnO nanolubricant of 0.8% mass fraction.

4.1 Viscosity:

Fig 4 shows the comparison of the viscosity of nanolubricant at room temperature for different percentage concentration of nanoparticles in the base oil. It is evident from the results that the viscosity of nanolubricant has been increased by the increase of wt% concentration. The results indicate that the viscosity of nanolubricant has been increased by 10%, 32% and 37% corresponding to 0.2%, 0.6% and 0.8% weight concentration which is advantageous in terms of load capacity but not in terms of friction. The enhanced viscosity will increase the friction power. The enhanced viscosity of the nanolubricant can improve the fluid layer resistance which retains the more oil back to the compressor. However it is absolutely essential to optimise the percentage weight concentration of nanoparticle in the POE oil so as to complete the desired merit without affecting the other properties.

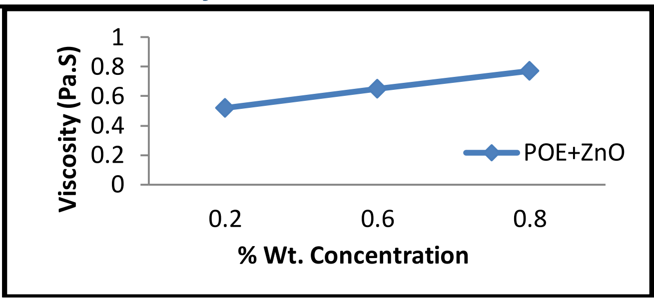


Fig 4: Viscosity Vs Wt. % Concentration

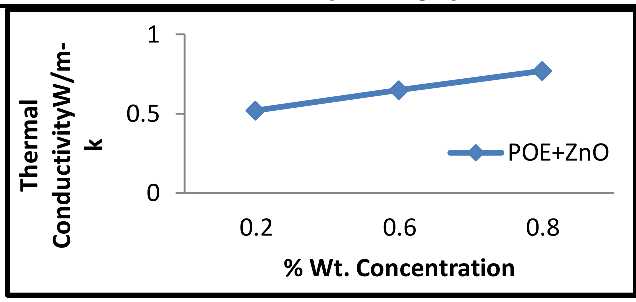


Fig 5: Thermal Conductivity Vs Wt.% Concentration

4.2. Thermal Conductivity:

Fig 5 shows the linear increase in thermal conductivity of nanolubricant with mass concentration at room temperature. It is shown that the thermal conductivity of nanolubricant has been increased up to 5 times more than the pure POE oil at 0.8% concentration. As the thermal conductivity of ZnO nanoparticles is higher than the base oil therefore the thermal conductivity of nanolubricant is higher than pure POE oil. As we know that the heat transfer coefficient is directly proportional to thermal conductivity, with higher thermal conductivity nanolubricants can improve the rate of heat transfer in condenser and evaporator. During working of the air conditioner, small quantity of the nanolubricant escapes along with the refrigerant from the compressor. The presence of the nanoparticles in the refrigerant and lubricant mixture can improve the heat transfer in the condenser and evaporator. This enhanced heat transfer property of the mixture fluid in the evaporator can improve the cooling effect in the conditioned space and reduces the time required for reaching the desired temperature.

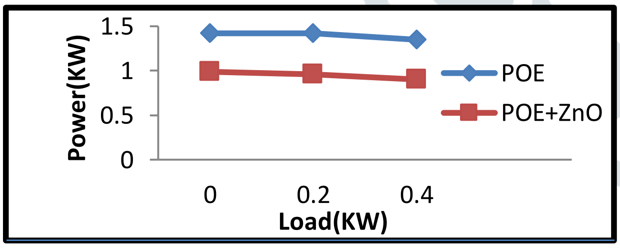
4.3. Coefficient of Performance:

The coefficient of performance of the air conditioner working on VCR cycle was compared with POE oil as lubricant and with ZnO nanolubricant of 0.8% concentration. Fig 6(d) shows the enhancement in the COP was observed with the addition ZnO nanolubricant to the air conditioner. The COP of the system is calculated using the refrigeration effect and power required to the compressor. The increase in COP is 60% at 0.4Kw heat load when POE oil is replaced with POE oil + ZnO nanoparticle. This increase in COP is due to increase in refrigeration effect by 7.8% as shown in the fig 6(b) and decrease in the power consumption of the compressor by 33% as shown in the figure 6(a). The enhancement in the refrigeration effect is due to the presence of nanoparticles in the refrigerant and nanolubricant mixture which improves the rate of heat transfer in the evaporator and condenser. The reduction in the power consumption is due to the following reasons.

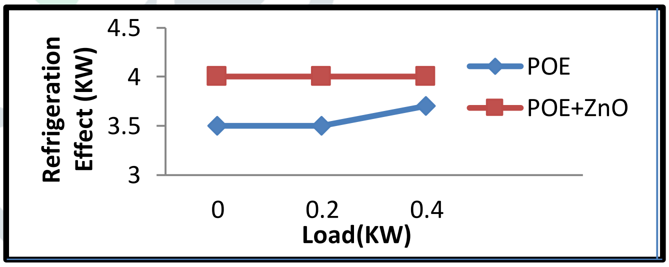
a) Addition of nanoparticles in the compressor oil reduces the pressure ratio as seen in the fig 6(g).

b) Presence of nanoparticles in the POE oil will increases the heat transfer from the compressor which is the reason for the drop of discharge temperature as show in the fig 6(f). The low discharge temperature and low pressure ratio can improve the life of the compressor and reduces the power required for the compression.

As the density and thermal conductivity of the nanolubricant is more than the POE oil and therefore the presence of nanoparticles in the refrigerant and POE oil mixture can improve the heat transfer in the evaporator and therefore the time taken to reach the desired temperature in the conditioned space has been reduced by 25% at 0.4kw heat load as shown in the fig 6(h).



(a)



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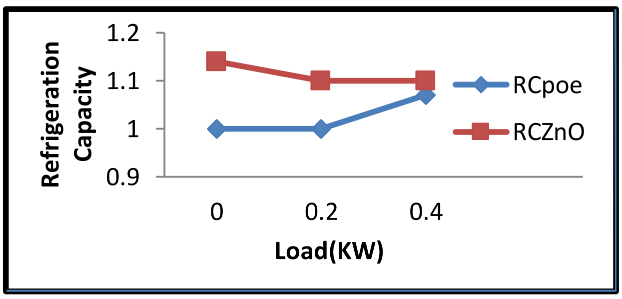
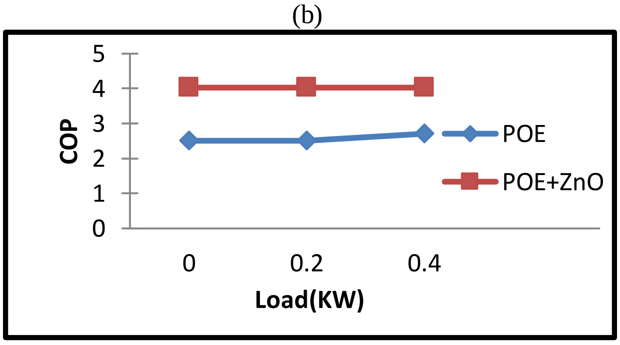
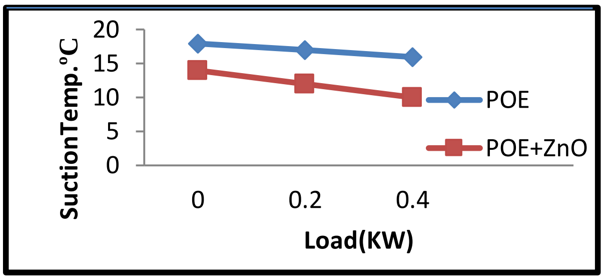


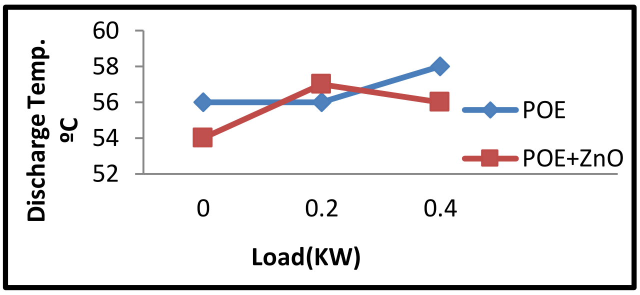
(c)



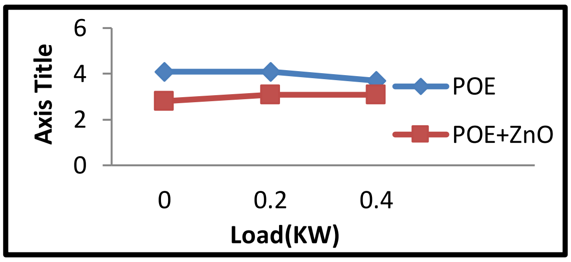
(d)



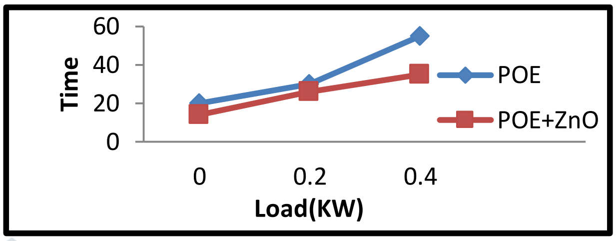
(e)



(f)



(g)



(h)

Fig: 4(a)Load Vs Power (b) Load Vs RE (c) Load Vs RC (d) Load Vs COP (e)Load Vs Suction Temperature (f)Load Vs Discharge Temperature (g) Load Vs PR (h)Load Vs Time

CONCLUSION:

Experiment was conducted to determine the thermo-physical properties of ZnO-POE oil nanolubricant and performance of the air conditioner working on the vapour compression refrigeration system was investigated by adding ZnO nanolubricant to the compressor. Several conclusions were drawn from the experimental studies. Accordingly, adding ZnO nanoparticles to the base POE can improve the thermal conductivity, viscosity and the system functioning safely and normally. The enhanced COP of the system was observed when nanolubricant was used by 38% at 0.4Kw heat load. Moreover, the power consumption of the reciprocating compressor was reduced by 33% with the application of nanolubricant instead of pure lubricant. The existence of nanoparticles in the oil + refrigerant mixture enhanced the heat transfer rate in the condenser and evaporator which improves the cooling capacity by 10.7% and refrigeration effect by 10.2% at 0.4 kw heat load of the air conditioner. Experimental results suggest that the nanoparticles, when used as additives to compressor oil, are effective when designing energy efficient refrigeration systems.

Nomenclature

T_o	Outside Temperature	A	Surface area
T_i	Inside Temperature	m_r	Mass of refrigerant
C_{pm}	Humid specific heat	T_3	Temperature inlet to condenser
P_d	Discharge Pressure	T_4	Temperature outlet to condenser
M_o	mass of air infiltered	P_s	Suction Pressure
U	overall heat transfer coefficient	W_i	Installed wattage

Subscripts

f	base fluid	np	nanoparticles
nf	nanofluid		

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