

## The effect of nano-lubricant TiO<sub>2</sub> in cooling system R134a on vapour compression cooling system

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### ABSTRACT

In this day and age, cooling frameworks assume a significant part in gathering human requires, and consistent exploration should be finished by numerous analysts are attempting to work on the presentation of these frameworks. Here, an endeavor was made to further develop framework execution. Our present review on the trial examinations of TiO<sub>2</sub> nanomotes scattered in polyalkylene glycol (PAG) oil with R134a cooling system, noticed that there is a lessening in the evaporator' glow, an improvement in the thermo-actual properties of the nano-cooling system, and an improvement in the exhibition coefficient by (13.948%, 22.645%, 28.249% ) at the hotness heap of the evaporator 40 oC, and it is observed that the presentation coefficient improved (14.913%, 19.266%, 23.755%) at the hotness heap of the evaporator 50 oC and the exhibition coefficient improved (11.821%, 20.113%, and 24.358%) at the hotness heap of the evaporator 60 oC. Contrasted and unadulterated cooling system R134a. The exploratory results show that the hotness move coefficient of cooling system-based nano-fluid is more imperative than that of pure cooling system, very much like the coefficient of execution and when are utilized nano-cooling systems, power use is diminished by 3 to 20%, and the glow is decreased by (40 oc – 17 oc).

**Keywords:** Cooling system, titanium oxide nano-mote, polyalkylene glycol oil.

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### 1. Introduction

Warm frameworks, for example, cooling and fridges devour a ton of energy electrical power, so techniques creating energy-effective cooling and cooling frameworks. Quick advances in nanotechnology have brought about the improvement of new age heat move fluids known as nano-fluids. Nano-fluids have warm conductivity more noteworthy than that of base fluids since they are made by dissolving nano-sized motes (1-100nm) in customary fluids. Nano-fluids have properties that vary from conventional strong fluid suspensions. a) more prominent hotness moves among fluids and motes because of the motes' high surface region b) improved dispersion stability C) decreases particulate clogging d) decreases pumping capacity Compared to the basic fluid to obtain an equivalent transfer of heat. Because of its significant increase in thermo-physical and thermal transferability, nano-motes can be utilized in the cooling system to boost the efficiency of cooling systems. Nano motes are small motes that have a high surface area. Nano motes can be mixed into the lubricant in a compression system the mixture called nano-lubricant [1]. concentrated on the impact of adding nanometers on refrigerator household performance and energy consumption was investigated TiO<sub>2</sub> (0.4 and 0.6 g/L ) nano-motes were used in the R600a cooling system instead of R134a. The results showed that the highest performance coefficient was shown at 0.4 g/L containing the lubricant oil and reduced energy consumption compared to R134a cooling system[2][3].Using Nano powder with conventional cooling systems A relatively new concept in the vapor compression process, as the obtained nano-cooling systems were found to be improved physical and thermal properties on conventional chillers. Nano-motes may be utilized in combination with cooling system for improving vapor-compression cooling efficiency installation 20 nano-

meters alumina nano-motes in this research the diameter of cooling system R-134a is distributed to increase its performance of heat transfer. After conducting the pilot study, it lost improved system performance is detected. Improvement in performance factor when using 0.5% amount of alumina (7.2- 8.5%). Additionally increased  $AL_2O_3$  Volume part one percent, decreased glow and, pressure after nano-cooling system expansion in the valve extension. Besides that, the basic heat of the coolant is going down. Thus, both of these factors will lead to a reduction in the cooling impact, so cop. Also besides, the device operates normally nano-cooling system.

The test discoveries show 9.11% ascent in hypothetical police and a 10.53% increment in genuine cop. When Nano motes have been utilized, the evaporator warming coefficient of move expanded by half, bringing about a 28% decrease in energy misfortune, and the bath warming coefficient of move expanded by 70.83% as cooling load, bringing about a 13.30% decrease in energy utilization[4][5]. Checked out the pool execution of  $AL_2O_3$  Nano motes in a R134a/polyester framework. Three different volume rates of the blended ointment were utilized, and R134a was added to the combination to add a shifted mass portion.

Assessment of the warm properties of suspended nan motes in cooling and grease oils for cooling frameworks[6]. The effects of nano-greases on bubbling and stream peculiarities in two stages were likewise introduced. The outcomes showed that the nano-motes  $TiO_2$  with cooler works securely and normally and builds heat move on the grounds that Nano motes have a lot higher and solid warm conductivity contrasted with the unadulterated cooling system[7]. Tentatively concentrating on the expansion of various Nano motes of ( $AL_2O_3$ ,  $TiO_2$ ,  $CuO$ ) in various cooling systems (R407c, R134a, R404A) and examining the thermo-physical properties of the nano cooling system and the exhibition coefficient of the framework. The outcome showed that the warm properties of the framework expanded by 15% to 94%, 20%, and 12 to 34%, individually, and the particular hotness was lower in nano-cooling systems contrasted with an unadulterated cooling system. R407) observed improvement in execution factor from 3-14% and 2 to 12%, separately[1]. Tentatively review the expansion of different sizes of ( $AL_2O_3$  and  $TiO_2$ ) Nano motes to a grease (POE) at two unique sums (0.05 - 0.1 v%) Then, at that point, were trial of the freezing limit just as the energy utilization of the cooler and the exhibition factor test. The outcomes exhibited an increment in the presentation element of the fridge by 19% and 22% at the referenced sums just as a diminishing in energy utilization at the sum (0.1%) of  $AL_2O_3$  and  $TiO_2$  (27.73% - 14.19%) less when contrasted and that of the unadulterated oil used with the coolant. From the consequences of the analysis, we inferred that the exhibition of the cooler is better with nano greasing up oil contrasted with the unadulterated oil used with cooling system.

Nano-fluid take it higher heat transfer power, higher thermal properties compared to traditional ones working fluid s that improve the coefficient cooling framework with R-134a as unadulterated cooling system and  $CuO$ -R134a mix as Nano Cooling system. Nano-fluids have high hotness move power[8], increment the warm properties of conventional working fluids that further develop the effectiveness coefficient cooling framework. In this review correlation between the energy utilization of R-134a unadulterated cooling system and cop and 1.6% of the nano-cooling system  $CuO$ -R-134a was tentatively inspected. Nano cooling systems arranged by scattering the cauldron oxide nano-motes in base cooling system R-134a and ready with processor ultra sonicator in this observational there is a 16.66% ascent in cop and a 13.79% decrease in energy fatigue contrast and unadulterated cooling system[9]. Cooling systems have become more common in people's everyday lives, using more electricity, and It is critical for improving energy-efficient cooling and cooling frameworks utilizing harmless to the ecosystem cooling systems. Nano-fluid s are new Thermo fluid s that, when combined with pure cooling system at a certain ratio, are said to expand the cooling system's heat transfer coefficient and thus the efficiency of the vapor compression cooling device. Hydrofluoroc-olefins, particularly HFO-1234yf, has no ozone consumption potential and an exceptionally low potential for an Earth-wide glow boost. Therefore, we expect HFO to be a cutting-edge cooling system. Furthermore, the impact of  $AL_2O_3/TiO_2/CuO$  and  $ZnO$  Nano motes on the heat transfer characteristics and efficiency the flow of cooling system-based nano-fluid s through the vapor compression cooling device will be theoretically investigated. The heat transfer coefficient and device efficiency were assessed using TK Solver at nano amounts ranging from 0% to 1%. According to the results of the experiments, The heat transfer coefficient of cooling system-based nano-fluid is higher than the heat transfer coefficient of pure cooling system, and the efficiency coefficient is greater than that of the current device[10]. The purpose, this research is to study the impact of using nano-materials on the VCRS system, where  $AL_2O_3$  was utilized with R-134a cooling system. Freezing capacity and system performance were tested. The results demonstrated that there is a superior performance when using  $AL_2O_3$  over traditional work, as well as an increase in the thermal conductivity of the refrigerator when using a lubricant on the oil utilized. The results also demonstrated a decrease in the viscosity of the

lubricant when performing the viscosity test, which leads to a decrease in power consumption. A PH test was performed and it was found that an optimized compressor for cooling purposes was required [11].

The attempt to improve the performance of the compressive cooling system for the characteristics of heat transfer by adding (  $AL_2O_3$ , R-134a, size 20 nanometers ) nano- cooling system was studied. Changing the Volume part of the cooling system  $AL_2O_3$  ( 0.5 – 1% weight )  $AL_2O_3$  cooling system and the flow rate, the amount of energy consumption, the glow drop at the trimmer, the evaporator, and the freezing capacity were examined. The study utilized three types of Nano motes, pure R-134a, (0.5% and 1% by weight) at a flow rate of R-134a and  $AL_2O_3$  (6.5 -11 L / h). Also, the use of nano-motes led to a decrease ( 3 – 23.77% ) in glow across the trimmer, and a significant increase in the cooling capacity of the cooling system. And an increase (4.69%– 39.30%) in the glow of the evaporator.

### 1.1 Gaps in study

Numerous analysts are dealing with the thermo-actual qualities of nano-fluid s and the variables that impact them, like thickness, warm conductivity, nano-fluid properties, molecule volume division, molecule material, base fluid, molecule size, and molecule shape. Scientists have been exploring different avenues regarding fluctuating Nano mote focuses in the base fluids to perceive how they work. Just a little measure of exploration has been done on nano-cooling systems and their effect on the presentation of the fume pressure cycle. In the fume pressure cycle, an assortment of normal cooling systems is utilized. As per the writing, adding nanomotes to a base fluid expands its properties and execution. Nano motes-based cooling systems, otherwise called nano-cooling systems, are thought to expand the exhibition of cooling frameworks.

The reason for this examination is to assess the exhibition of the fume pressure cycle utilizing nano-motes  $TiO_2$  and R134a as the cooling system. Contingent upon the expects of this examination, another fume - pressure cooling testing framework has been created utilizing Three sums (0.2%, 0.4%, and 0.6%) of  $TiO_2$  Nano motes with a width of 20 nm were joined with PAG oil as an ointment and R134a as a cooling system. The test has been performed to exhibit the capability of nano-motes joined with PAG oil to lessen blower power utilization and further develop warming adaptability. When contrasting the exhibition of a framework and Nano motes to that of an unadulterated cooling system, the presentation coefficient of the framework with Nano motes beats the competition.

## 2. Experiment analysis

Plan the cooling test rig for pressure. The test rig is contained the blower, a trimmer, a thin chamber, and the evaporator. The reacting blower is impenetrable fixed, the evaporator is a barrel molded one as a curving circle and is totally lowered in bath and made of cauldron. A trimmer is a finned twist in a hotness exchanger that is similarly made of cauldron. A scout was utilized to check glows at the channel and outlet of the central parts. A glow scanner was utilized. An energy meter was utilized at the blower to find how much energy depleted in it. Preceding blaming the contraption for gas and nanomaterial, the system was completely checked for spills. After the break test, with the help of a vacuum siphon, the device was gotten free from soggy to be blamed for the nano-fluid and cooling system for the present circumstance, use R134a cooling system. In light of its low ozone layer fatigue potential and close thermodynamic properties.

### 2.1. Nano-lubricants preparation

The nano-fluid was prepared by adding a Nano mote ( $TiO_2$ ) to the base fluid is PAG oil. The greatness of the Nano motes for each not really set in stone from Condition 1, and the vital weight was surveyed using a sensitive balance and the Nano mote aggregate was referred to in Table 1 and the Nano mote oil was prepared In a two-adventure way, by adding a Nano mote size mass (0.2%, 0.4%, 0.6%) to the PAG oil and setting the mix on an appealing stirrer for an hour, moving the mix to a ultrasonic all the more perfect. For three hours, the means ought to be noticeable in the figure1 After the nano-treatment has been organized, it is injected into the blower through the mixture device, and a short time later the blower is blamed for cooling system and the most well-known method of catch readings starts [3].

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

Table 1. Properties of nano-motes TiO<sub>2</sub>

The amount <sup>φ</sup>	Mass of TiO <sub>2</sub> m (g)	Thermal conductivity W/m.K	intensity Kg/m <sup>3</sup>	Specific heat KJ/kg.K
0.2%	1.6g	0.084563	1217.58	1.44907
0.4%	3.2g	0.091323	1244.83	1.434155
0.6%	4.8g	0.106156	1272.07	1.408801

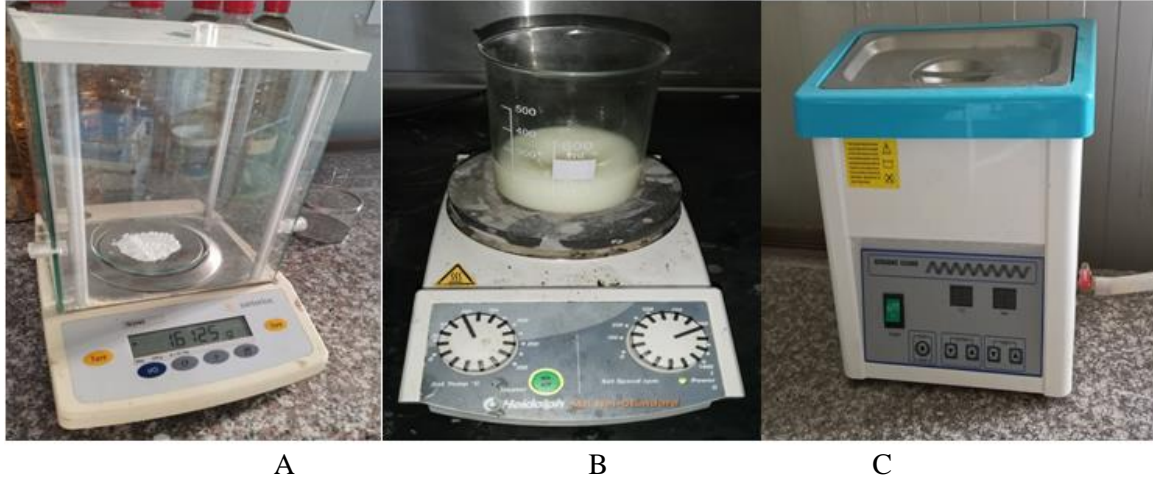


Figure 1. Equipment utilized in experimental rig (A) electronic balance (B) stirring hotplate (C) ultrasonic cleaning.

## 2.2. Charging of rig

We need to empty prior to charging the gadget to dispose of the destructive effects of dampness. This is done through the vacuum gadget. After the test gadget is dumped from dampness, we begin infusing the nano-ointment through the charging gadget to the blower, then, at that point, permit it to agree to 15-20 minutes, then, at that point, the blower is accused of cooling system. R134a The charging stage should be halted when the strain measure shows the necessary tension cutoff.

## 2.3. Work of experimental test rig

Fume pressure depends upon a streaming fluid cooling framework to ingest and discard hotness, reject the cooled region, and accordingly reject heat from somewhere else. Figure 2 portrays a standard single-stage fume pressure structure. A blower, a trimmer, a flimsy, and an evaporator are generally bits of these designs. The glow increments subsequently. Its warmed smoke is shipped off a trimmer, where it is cooled into a fluid by going through a circle or chamber with cold air. Thick Cooling framework is a sort of cooling framework that is full into an In thermodynamics, a soaked fluid is worked with through a tight chamber where there is an unanticipated tension drop, which diminishes strain in the dissipating of a static impact of the cooling framework part expecting the contamination mix is then arranged through the curve from the evaporator, where it adapts heat from the climate. The coolant disperses and gets back to the blower to be cooled, and the cycle is reshaped.

### Rig's Components

1. Compressor: The compressor is an integral and important part of any cooling system. It has been used as a reciprocating compressor, single-cylinder with 410 BTU/hr capacity.
2. Trimmer: The trimmer is used to condense the cooling system to change the phase from vapor to fluid and reject heat from the trimmer to the environment.
3. Filter's dryer: The filter dryer was used at the outlet of the trimmer to prevent any impurities present from blocking any part of the system, the size of the filter mesh varies from (5-5000) nanometres
4. Capillary tubes: a capillary tube was used to reduce the pressure and boiling point of the cooling system
5. Evaporator: The evaporator-type emersion coil was used in the rig
6. Heater: A heating element is a component that converts electricity into heat through the process of resistivity

7. Energy meter: An energy meter is a device that calculates the amount of electrical energy used by a system that runs on electricity.
8. Temp's scouts: glow scouts were used to measure glow at relative points.

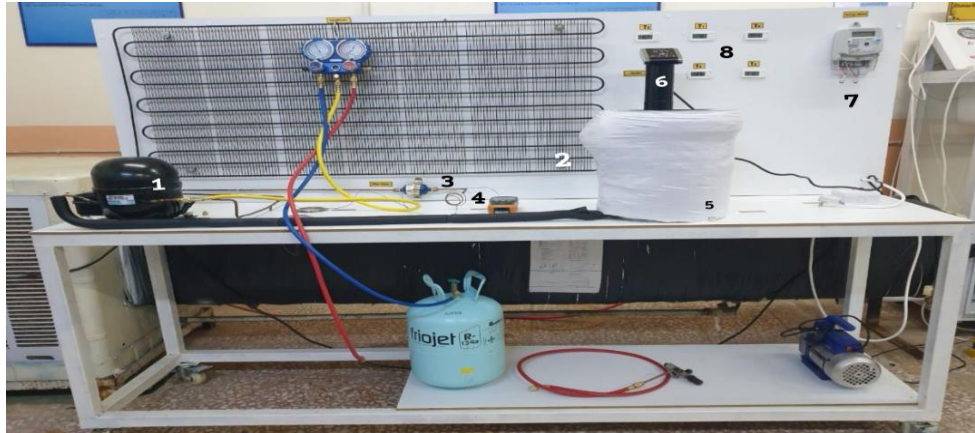


Figure 2. Experiment test rig

## 2.4. Experimental procedures

The first performance of the pilot tester was recorded with R134a, PAG oil is utilized as a cooling system in the cooling system circuit as well as a compressor lubricant. In the evaporator, data on glow, pressure, and energy usage were recorded. After that, readings are taken when the test device is charged with a nano-lubricant. Three volume fractions of TiO<sub>2</sub> nanomotes (0.2%, 0.4%, 0.6%) were utilized in the lubricant to the compressor. The refrigerator has been tested to verify the influence of the properties of nanomotes on its performance, allowing the refrigerator to settle for 30 minutes each time after the refrigerator and lubricants are charged.

## 3. Theoretical analysis

### 3.1. Calculation thermo-physical properties for nano-lubricant

The accompanying connection is used to ascertain the thermo-actual properties of nano-ointment [12].

Thickness of nano-oil

$$\rho_{n,o} = (1 - \psi_n) \rho_o + \psi_n \rho_n \quad (2)$$

Specific heat of nano-lubricant (pak and cho)

$$c_{p,n,o} = (1 - \psi_n) c_{p,o} + \psi_n c_{p,n} \quad (3)$$

Warm conductivity of nano-lubricant (Hamilton and Crosser)

$$K_{n,o} = K_o \left( \frac{K_n + 2K_o - 2\psi_n(K_o - K_n)}{K_n + 2K_o + \psi_n(K_o - K_n)} \right) \quad (4)$$

### 3.2. Calculation Thermo-physical properties for nano-cooling system [14]

Intensity of nano-cooling system

$$\rho_{n,r,o} = [(X_{n,o}/\rho_{n,o}) + ((1 - X_{n,o})/\rho_r)]^{-1} \quad (5)$$

Explicit hotness of nano-lubricant

$$c_{p,r,n,o} = (1 - X_{n,o}) c_{p,r,o} + X_{n,o} c_{p,n,o} \quad (6)$$

Thermal conductivity of nano-cooling systems

$$K_{n,r,o} = K_r (1 - X_{n,o}) + k_{n,o} X_{n,o} - (0.72 X_{n,o} (1 - X_{n,o}) (K_{n,o} - K_r)) \quad (7)$$

### 3.3. Calculation of the coefficient of performance (COP) [15]

- a. The volume of the bath tank

$$V = \pi/4 D^2 h \quad (8)$$

- b. Mass of bath

$$m = \rho.v \tag{9}$$

c. Power contribution to blower

$$P = (E_o - E_i).3600 \tag{10}$$

d. Cooling impact

$$RE = M_w cp_w dT \tag{11}$$

e. Coefficient of performance

$$COP = \frac{M_w cp_w dT}{(E_o - E_i) 3600} \tag{12}$$

#### 4. Result and discussion

In the exploratory assessment, four cases were considered. From the get go, R134a and PAG oil were utilized in the test, and a while later three proportions of TiO<sub>2</sub> (0.2%, 0.4%, and 0.6%) nano-motes were attempted with PAG oil and R134a cooling system. Experimentation was coordinated with a smoke pressure cooling structure to chip away at the show. The delayed consequences of the preliminary examinations are portrayed underneath[13].

##### 4.1. Coefficient of performance at a heat load 40 °C

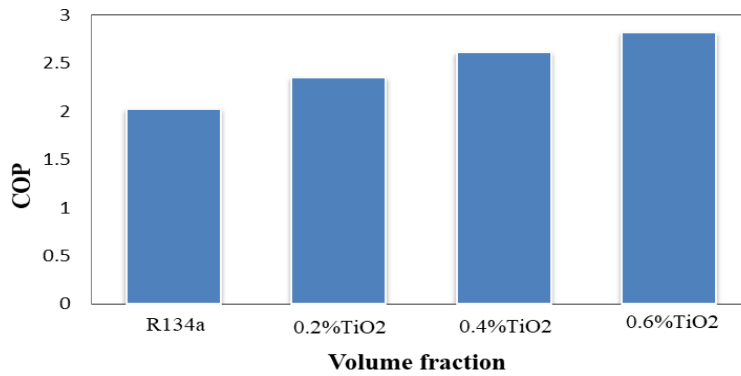


Figure 3. Coefficient of performance of volume fraction at heat flux 40 °C

Figure 3. Exhibits the examination between the presentation parameters of different amounts of nanomotes at a heat load of 40°C with a pure cooling system. It is found that the performance coefficient of a pure cooling system was 2.01757, while it is found when using a nano-cooling system with 0.2% of the amount of TiO<sub>2</sub> nano-motes that it is 2.3446, and the coefficient of The performance when using 0.4% TiO<sub>2</sub> nano-mote amount is found to be 2.608 and the performance coefficient at 2.608 for the 0.6% TiO<sub>2</sub> nano-mote amount is 2.8119 so there is a 13.948% improvement in the performance at 0.2% TiO<sub>2</sub>, and a 22.645% improvement for the coefficient for 0.4% TiO<sub>2</sub> and 28.249% improvement in the performance for 0.6% TiO<sub>2</sub>, the vapor compression cooling system is improved when compared to pure cooling system.

##### 4.2. The coefficient of performance at a heat load of 50 °C

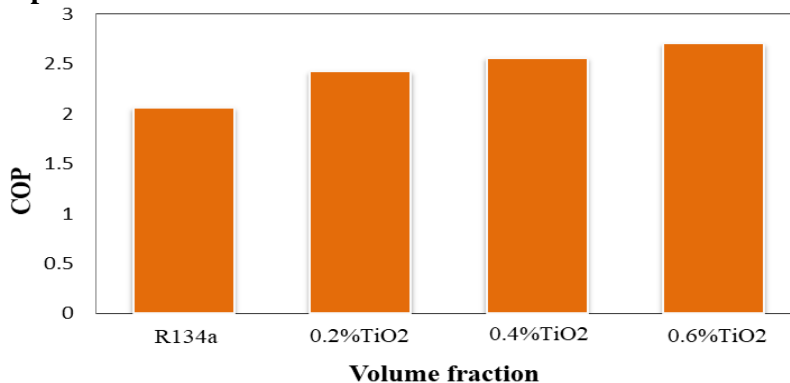


Figure 4. Coefficient of performance of volume fraction at heat flux 50 °C



Figure 4 demonstrates the comparison of performance parameters for different amounts of nanomotes at 50 °C heat load with pure cooling system. I noticed that the performance coefficient when a pure cooling system is 2.05579, while when using 0.2% TiO<sub>2</sub> nano-mote amount to be 2.4161, and I found the coefficient of performance when using 0.4% TiO<sub>2</sub> nanomote amount is 2.54638 and the performance coefficient at 0.6% TiO<sub>2</sub> nanomote amount is 2.6963. So, there is an improvement of 14.913% at a amount of 0.2% TiO<sub>2</sub> and 19.266% improvement for a amount of 0.4% TiO<sub>2</sub> and 23.755% improvement in a condition of 0.6% TiO<sub>2</sub> amount for performance, and from the results is noted an improvement in the performance factor of the device at different amounts[14].

### 4.3. Coefficient of performance at a heat load of 60 °C

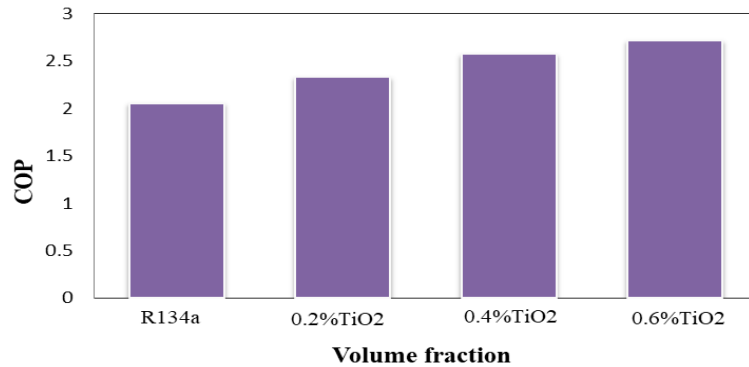


Figure 5. Coefficient of performance of volume fraction at heat flux 60 °C

Figure 5 shows the correlation between the presentation parameters of different amounts of nanomotes at a heat load of 60 °C with pure cooling system. It is found that the performance coefficient when a pure cooling system is 2.04967 while the coefficient when using 0.2% TiO<sub>2</sub> amount is 2.32445 and the performance coefficient at 0.4% TiO<sub>2</sub> amount is 2.5657, and the performance coefficient at 0.6% TiO<sub>2</sub> nanomotes amount is 2.7097. It is noticed from the results that there is an improvement in the performance by 11.821% at 0.2% TiO<sub>2</sub> amount, and the improvement is 20.113% at 0.4% TiO<sub>2</sub> amount, and the improvement percentage is 24.358% at 0.6 %TiO<sub>2</sub> amount. This improvement of vapor cooling system when compared to the pure cooling system. The addition of TiO<sub>2</sub> nanomotes to PAG oil lowers the coefficients of friction. The inclusion of nano-motes lowers the lubricating oil's the coefficient of friction, due to a reduction in the compressor's energy usage and, as a consequence, an increase in the compression cooling system's performance coefficient.

### 4.4. Cooling impact (RE)

Cooling impact for R134a cooling system and TiO<sub>2</sub> nano-lubricants at an evaporator bath glow from 40 °C - 60 °C

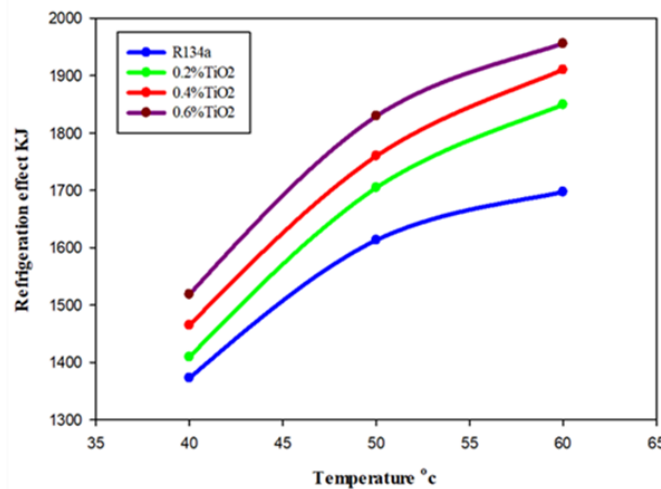


Figure 6. Comparison of cooling impact between the pure cooling system and different volume fractions of TiO<sub>2</sub> nano-motes

Shows the comparison of cooling impact for unadulterated cooling system and with nano-cooling system in figure 6. The cooling impact for fixations 0.2%, 0.4%, and 0.6% at evaporator bath glow 40 oC increment around 2.6115%, 6.283%, and 9.596%. while at similar fixations however at bath glow 50 oC increment by 5.362%, 8.334%, and 11.814%. At long last, the same concentrations at 60 °C glow of bath in evaporator increase by 8.231%, 11.155%, and 13.229%. When comparing all results with pure cooling system. In all three nano-cooling system is observed an increase in the proportion of volume fractions of nano-motes raises the thermal conductivities of the nano-fluid, resulting in improved heat transmission.

**4.5. Evaporator glow and time**

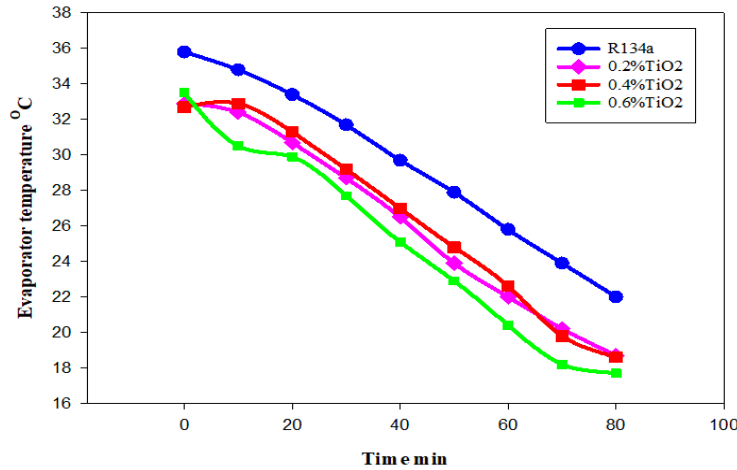


Figure 7. The relation between glow and time in the evaporator

Figure 7 demonstrates the cooling load glow - time and freezing capacity for different amounts of TiO<sub>2</sub> and comparing it with pure R134a cooling system. It is noticed that the amount of time necessary reach the required glow, which is the freezing point of the bath inside the evaporator from 35 °c -17 °C less with the use of nano-cooling system at a different amount of TiO<sub>2</sub> nanomotes compared with pure cooling system. For example, with nanomotes at an amount (0.2%), the time required for bath to reach the freezing point is 90 minutes. While the time required at a amount (0.4%) is 100 minutes, and the time required at a amount (0.6%) of the nanomote is 80 minutes, and found the time required for the pure cooling system is 120 minutes. The ability of to freeze the R134a-TiO<sub>2</sub> nanomote mixture is higher than that of the pure cooling system. It has been found that nanomotes increase the heat transfer rate at the cooling system side of the evaporator[2].

**4.6. Power consumption of compressor at different amount of nanomotes TiO<sub>2</sub>**

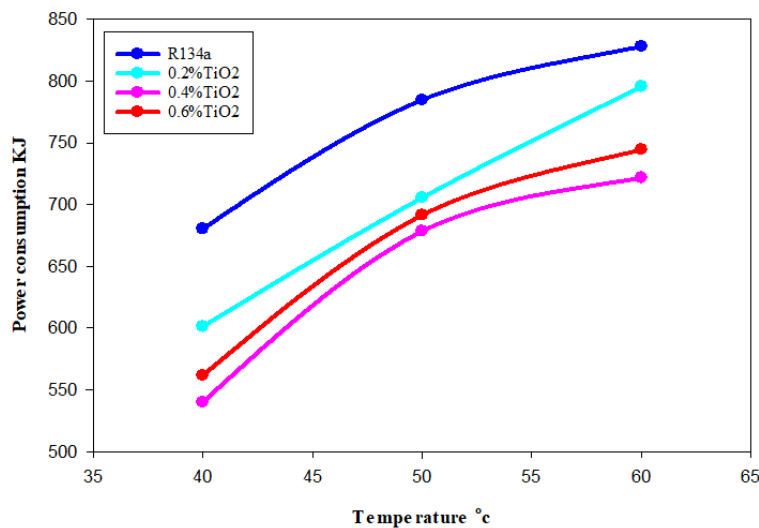


Figure 8. comparison power consumption at different amounts of nano-motes with pure cooling system. Figure 8 exhibits that the power utilization of the blower is less on account of R134a with TiO<sub>2</sub>+ PAG oil when contrasted and unadulterated cooling systems. The TiO<sub>2</sub>+PAG builds the hotness move rate in the



blower, subsequently, the particular volume of compacted cooling system abatements which prompts a decrease in power utilization of the blower. The power utilization when blower running with nano-grease containing (0.2%, 0.4%, 0.6%) TiO<sub>2</sub> nano-motes at bath glow in evaporator 40 oC around 11.640%, 17.4603%, and 20.635% decrease in power utilization. at similar three sums however 50 oC of bath in evaporator power utilizations are 10.0917%, 11.927%, and 13.539%. at last, at a three-volume portion and evaporator glow, 60 oC are 3.913%, 10.084%, and 12.826%, contrasted and unadulterated cooling system[15].

#### 4.7. Thermo-physical properties of nano-cooling system

##### 4.7.1 Thermal conductivity

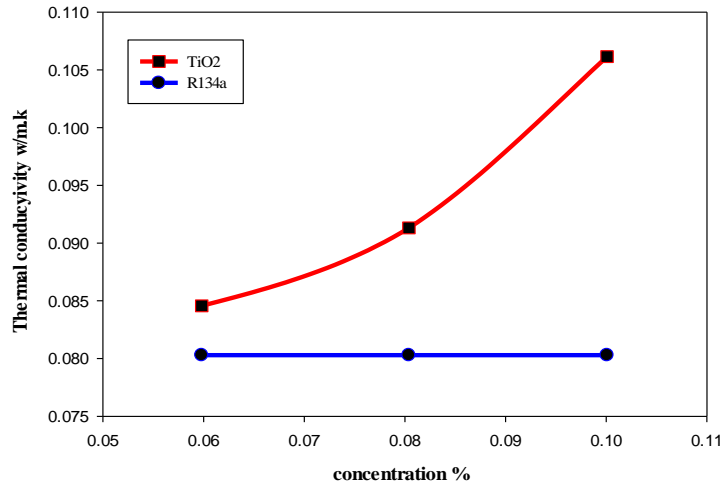


Figure 9. Thermal conductivity and different amounts of nano-motes

Figure 9 shows the correlation between the warm conductivity of unadulterated cooling system and nano-cooling system. It is tracked down the warm conductivity of nano-cooling system expanded with increment nano-molecule sums contrasted and the warm conductivity of unadulterated cooling system R134a.

##### 4.7.2 Intensity of nano-cooling system

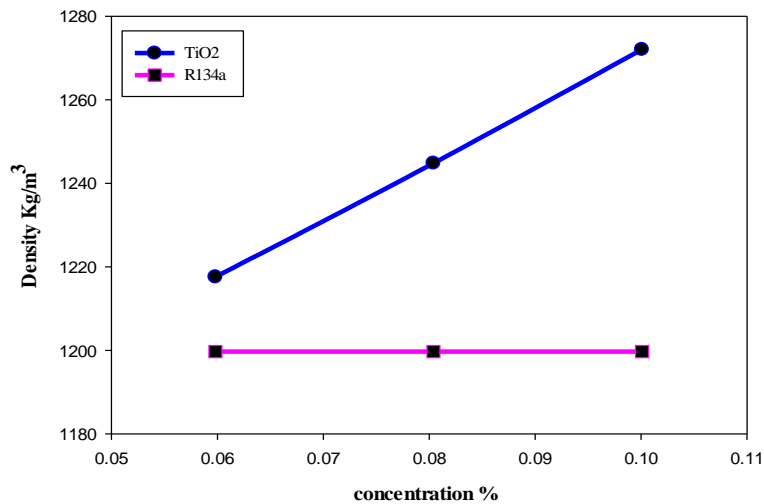


Figure 10. intensity and amounts

Figure 10 shows the correlation between the thickness of unadulterated cooling system with various measures of nano-motes. It is seen the thickness of nano-cooling system TiO<sub>2</sub> expanded with nano-motes sum increments contrasted and of unadulterated cooling system R134a.

## 5. Validation

Validation of current study with that of Experimental studied was used  $\text{TiO}_2$  nano-motes with PAG oil in R134a cooling system. In a vapour compression cooling system, at volume fraction of  $\text{TiO}_2$  nanomotes at 0.4% [16]. The result validation is showed in figure 11 and in Table 2

Table 2. Validation the current study with that of F. Selimefendigil et al by coefficient of performance

Volume fraction	Present work	Volume fraction	F. Selimefendigil et al
0.4%	2.608	0.4%	2.2

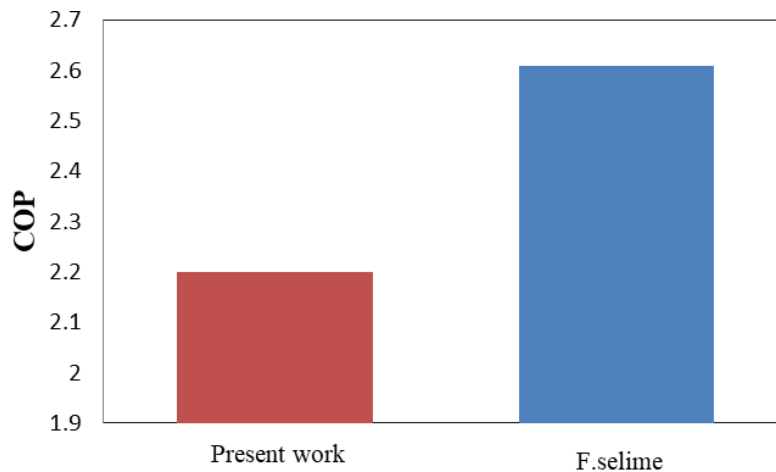


Figure 11. validation between present study and other scholars

## 6. Conclusion

The present research, titled "The effect of  $\text{TiO}_2$  nano-lubricant with R134a cooling system on vapor compression cooling system," focuses on the use of  $\text{TiO}_2$  nanomotes in PAG oil with R134a cooling system. The nanomote size ( $\text{TiO}_2$ ) was 20 nm, and three sums were used (0.2% ,0.4%,0.6%). In this study, three bath glows (40, 50, and 60 °C) were utilized in the evaporator. The conclusions of this experimental work are summarized as

1. In the cooling system, it is found that mixing of  $\text{TiO}_2$  nano-lubricant with pure cooling system R134a work normally.
2. Cooling capacity and COP of the system is found to be increasing with increase in concentration of nano-motes.
3. Thermal conductivity is improved with using R134a- $\text{TiO}_2$  nano-cooling system from 5.041% to 24.357%.
4. A reduction power consumption of the compressor from (3% to 20%) along with glow drop from (40 °C – 17 °C) is also achieved when nano-cooling systems used.
5. Cooling effect is increased from (2.6115% to 13.229%) along with glow drop from (40 °C – 17 °C).
6. It is observed maximum enhancement in coefficient of performance 28.249% at 0.6% concentration and at a glow 40 °C.

## Recommendations for future work

1. This system can be used different lubricants with different cooling systems
2. Investigate effect different length of capillary tube and volume size of nano-motes on COP and RE of vapour compression system.

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