



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 8, August 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.118

 9940 572 462

 6381 907 438

 ijirset@gmail.com

 www.ijirset.com



A Review on Experimental Investigation on Refrigeration System Using Various Refrigerant

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ABSTRACT: The test mechanical assembly was worked by the public principles of India. The presentation of the refrigeration framework relies on the warmth move limit of the refrigerant. R600a utilized as a refrigerant. This refrigerant warmth move limit is slightly below average and increment power utilization. Because of these impediment nanofluids are improved with the ordinary grease and expands the warmth move limit and lessens the force utilization. Silicon dioxide nanoparticles were utilized for upgrading the warmth move limit of the refrigerant in the refrigeration System. In this analysis heat move improvement was examined mathematically on the outside of a cooler by utilizing SiO₂ nano-refrigerants, where nanoparticles could be a huge factor in keeping up the surface temperature inside a necessary range. The expansion of nanoparticles to the refrigerant outcomes in enhancements in the thermo physical properties and warmth move attributes of the refrigerant, in this manner improving the presentation of the refrigeration framework. Stable nanoparticles have been ready for the examination. The test considers demonstrate that the refrigeration framework with nano-refrigerant works typically. It is discovered that the freezing limit is higher and the force utilization diminishes by 3% when R600a refrigerant blended in with Silicon dioxide nanoparticles. Consequently, utilizing Silicon dioxide nanoparticles in refrigeration framework is achievable.

I. INTRODUCTION

In past time just refrigerants were utilized in refrigeration cycle and they were having a dangerous atmospheric deviation coefficient at elevated level. Presently, as time change the cutting-edge methods are appearing with the assistance of them the refrigeration cycle become more effective and more secure as contrast with past in climatic forthcoming. Nano fluid is a serious sort of liquid, which contain nanometre measured (10⁻⁹ m) strong particles known as nanoparticles. Nanoparticles upgrade the property of ordinary liquid. In recent years, nano-refrigerant has gotten more famous for huge number of exploratory fume pressure frameworks on account of lack in accessibility of vitality and ecological contemplations. Late headways in nanotechnology have started the new developing warmth move liquids called nano-liquids. Nano-liquids are set up by scattering and stable suspending nanometre estimated strong particles in customary warmth move liquids. Past explores have demonstrated that an extremely limited quantity of suspending nanoparticles can possibly improve the thermo physical, transport and radiative properties of the base liquid. Because of improved properties, better warmth move execution is gotten in numerous vitality and warmth move gadgets when contrasted with conventional liquids which open the entryway for another field of logical exploration and imaginative applications.

The expansion of nanoparticles to the refrigerant outcomes in upgrades in the thermo physical properties and warmth move attributes of the refrigerant, in this manner improving the presentation of the refrigeration framework. Nanoparticles coordinated the imaginative world into another heading by its capacity to impact working properties of liquid. Nanofluids are progressed class of liquids with particles of nano size (1-100 nm). The idea depends on the way that solids have high warmth limit when contrasted with liquid. So nano estimated particles or nanoparticles are scattered into a base liquid so as to upgrade physical properties of base liquid. The nanoparticle materials are generally of metal, non-metal and their oxides, which improve the warmth move execution of base liquids. Thus, there is

enormous extent of its application in heat move territory. As of late, a few examinations uncovered the utilization of nanoparticles in refrigeration frameworks and critical improvement in execution has been watched.

In refrigeration frameworks the nanoparticles can be either added to blower greasing up oil or to refrigerant. Scattering of nanoparticles into greasing up oil (Nano oil) improves the oil of blower or abatement erosion of moving parts. Also, the on the off chance that airtight fixed blower fragmentary measure of grease oil is diverted by refrigerant in blower arch. Along these lines this implies the warmth move attributes can be improved and henceforth execution of the refrigeration framework. On other hand when nanoparticles are scattered in refrigerant (named as nano-refrigerant), at that point it straightforwardly upgrades the refrigerant warm properties and along these lines execution of refrigeration framework is discovered to be improved. The regular refrigerants have significant part in a worldwide temperature alteration and consumption of the ozone layer. Subsequently, there is have to improve the exhibition of fume pressure refrigeration framework with the assistance of reasonable refrigerant.

II. LITERATURE SURVEY

Kaufui V. Wong et al. [1] has presented A review article in the year 2009 on Application of Nanofluids: Current and Future. In this paper, they concluded that nanofluids are significant and it can be used in many applications involving heat transfer and other applications. Researchers found that nanofluids can be used in industrial cooling systems, resulting in high cooling effects and high energy efficiency resulting in reducing emissions. It could benefit from engine oils, automotive transmission fluids, refrigerants, lubricants and other heat transfer devices. They also concluded that nanofluids can be used to boost brake fluid properties in automobiles. Nanofluids can also be used in electronic applications such as microchip cooling in computers and other heat-emitting electronic components. In biomedical applications and nanomedical applications for nanogels or gold-coated nanoparticles, nanofluids and nanoparticles can also be used of heat exchanger.

Diana C. Hernandez et al. [2] presented a research paper Analysis of working of Nanofluids for a Refrigeration system in 2015. They published a paper showing the applications of nano-refrigerant fluid to boost the refrigerants thermal conductivity and also improve the refrigeration system's thermal efficiency. They conducted stimulation with a mixture of refrigerant R113, R123 and R134a with Al₂O₃ nanoparticles at 1%vf and 5%vf (%vf- volumetric fraction density concentration) flowing through a steady wall temperature horizontal pipe. Through adding 1%vf and 5%vf of Al₂O₃, the result shows an increase in thermal characteristics. Finally, they picked 1%vf of 30nm medium diameter Al₂O₃ because it has higher thermal efficiency and its beneficial properties as a refrigerant. They also found that the size of nanoparticles does not affect nanofluids thermal properties.

Satnam Singh et al. [3] has presented a paper on The Behaviour of nano refrigerant in vapor compression cycle. They found that the thermal nanofluid properties did not affect the size of nanoparticles. Similar experiments were also carried out with the refrigerant mass the size of 150gm, 180gm and 200gm. The outcome was that the length of the capillary tube was 10.5m, the maximum COP of 3.5 was reached and then declines with the expansion of the capillary tube path. They found that the use of low concentration nano-refrigerant is not always accurate. Consequently, they suggested measuring the nano-refrigerant in different concentration. they also proposed that an investigation into the impact of different types of nanofluid with different base refrigerant under different compressor pressure ratio, evaporator and condenser parameters such as temperature and pressure decrease should be carried out.

K. T. Pawale et al. [4] has presented a paper named as *Performance analysis of VCRS with nano refrigerant*. In their experiment they used Al₂O₃ nanoparticles of 40- 50nm diameter which were dispersed in R134a refrigerant to enhance its heat transfer performance to have their improved thermal and physical properties over the conventional refrigerant. The concentration of nanoparticles was chosen as 0.5 to 1% by mass. They performed experiment on the project setup made by themselves. Theoretical COP evaluated was 4.17 for pure R134a and for 0.5% and 1% Al₂O₃ was found to be 3.75 and 3.54. 0.5% Al₂O₃ shows reduction in COP by 10.07% and 1% Al₂O₃ shows reduction by 15.1%. While actual COP of pure r134 was 2.69 after adding 0.5% and 1% Al₂O₃ cop was found to be 3.52 and 2.92. 0.5% Al₂O₃ shows increment by 30.85% and 1% of Al₂O₃ shows decrement by 8.55%. Discharge temperature of compressor of pure R134a was 84°C. at 0.5% discharge temperature was reduced by 2.8% and increased by 3.55% at 1% Al₂O₃. Suction temperature for pure R134a was 52°C and it was decreased by 23.07% and 28.84% in 0.5% and 1% of Al₂O₃. Suction pressure was reduced by 28.9% at 0.5% Al₂O₃ and for 1% Al₂O₃ reduced by 18.42%. Discharge pressure was increased by 0.005% and 8% for 0.5% and 1% Al₂O₃. Superheat was improved by 200% and 114% for 0.5% and 1% Al₂O₃. Sub cooling was improved by 118% and 181% for 0.5% and 1% Al₂O₃. Compression ratio for pure R134a was 4.68 and was increased by 37.82 and 31.83 % for 0.5 and 1 % Al₂O₃. They concluded that addition of 0.5% Al₂O₃ with R134a refrigerant gives best result which leads us to improvement in overall performance of VCRS than pure

refrigerant. they also concluded that increment in % of nanoparticles in refrigerant will result in decrement in performance of a system.

T. Coumaressin et al. [5] has done performance Analysis of Refrigeration system using Nanofluid. In this project, CuO nanoparticles with R134a refrigerant were used in the refrigeration system for Vapour compression. This research was first analysed using the FLUENT technology for CFD heat transfer analysis. After that they made a project setup and tested nanoparticles with refrigerant. The size of nanoparticles was from 10 to 70 nm. The consequences are that the heat transfer coefficient of the evaporator decreases with the use of nano CuO. Result from fluent shows that heat transfer coefficient of CuO from 0 to 0.55% but after that it decreases. At heat flux $q=10\text{kWatt}$, $h=3.04\text{Kwatt/m}^2\text{K}$. At $q=20\text{kWatt}$, $h=18.09\text{kWatt/m}^2\text{K}$. At $q=30\text{kWatt}$, $h=48.45\text{kWatt/m}^2\text{K}$. And at $q=40\text{kWatt}$, $h=93.02\text{kWatt/m}^2\text{K}$.

K. Dilip Kumar et al. [6] has presented a paper on An Experimental Investigation on Application of Al₂O₃ Nanoparticles as Lubricant Additive in VCERS in the year. In their project, they used Al₂O₃ nano oil which was proposed as a good lubricant in vapor compression refrigerator compressor. They experimentally studied the mobility of Al₂O₃ nanoparticles in oil. The size of nanoparticles was 40 to 50 nm and base fluid used to make nanofluid was PAG oil (poly alkylene glycol) and then this mixture was added with compressor oil. They performed experiment by adding nano oil with concentration 1.5%, 1.7% and 1.9% by mass fraction were mixed with compressor oil. And the outcome that has been obtained has been good. This raised the COP of the refrigeration system by 19.14%, 21.6% and 11.22% respectively.

D. Sendil Kumar et al. [7] presented a paper on Experimental Study on Al₂O₃ with R134a Nano Refrigerant in Refrigeration System. In this paper, they used nano Al₂O₃ with PAG oil with R134a refrigerant in a vapor compression refrigeration system in an experimental setup which was fabricated in lab by themselves. Using energy Sumpstion and freezing capability test, this device output was investigated. And the result so obtained indicated that Al₂O₃ nano refrigerant works safely and normally in the VCERS. The refrigeration system performance was enhanced by 10.32% than pure R134a refrigerant. They used 0.2% concentration of Al₂O₃ nanoparticles in R134a refrigerant of 150gm. The similar test was performed repeatedly for 3 to 4 times with mass of order of 150gm, 180gm and 200gm. COP of refrigeration system was enhanced 2.4 to 3.5 with length of capillary tube from 8m to 10.5m but after that it decreased. The discharge pressure shows increment with time and attains maximum value but then it decreases while suction pressure decreases at starting and then increases with time. For a load weight of 150gm, less suction force was observed.

R. Reji Kumar et al. [8] published a paper named as Heat transfer enhancement in Domestic Refrigerator System using R600a/ mineral oil/ nano Al₂O₃ as a working fluid. They used Al₂O₃ nanoparticles with R600a refrigerant in a domestic refrigerator in their experiment. They presented 3 cases, 1) the hermetic compressor filled with pure POE oil, 2) mineral oil and 3) mineral oil+ Al₂O₃ nanoparticles lubricant with concentration of 0.06%. Their experiment concluded that R600a refrigerant and mineral oil+ Al₂O₃ nanoparticles oil mixture has highest COP as compared to other cases. The cooling capacity of the refrigeration system with mineral oil+ Al₂O₃ oil mixture was higher compared to the POE oil system. They found at the time that the compressor's power consumption was decreased by 11.5% when that nano lubricant was used instead of standard POE oil and the system's COP was raised by 19.6%.

F. T. Ndoye et al. [9] has done Numerical study of Energy Performance of Nanofluids for Refrigeration system in the year. In this paper, they developed a mathematical model to predict the energy performance of the refrigeration system using nanofluid for use in cold chain cooling plants. This model was based on combining the efficiency number of the method of the transfer unit with the classical heat transfer unit. They had tested tubular heat exchangers in turbulent and laminar regimes. System has been tested using published data. The simulation shows that with increased concentration of nanoparticles for laminar and turbulent regimes, heat transfer coefficient has been significantly increased.

D. Sendil Kumar et al. [10] presented their project of ZnO nano refrigerant in R152a in refrigeration system for energy conversion and green environment. In this paper, they explored the reliability and performance of a vapor compression refrigeration system in a working fluid with ZnO nanoparticles. They used VCERS refrigerant R152a. The concentration of ZnO that they used 150gm of R152a in their experimental study varies of 0.1%, 0.3% and 0.5%vf. ZnO nanoparticles were 50nm in diameter. Their experimental results revealed that ZnO nano refrigerant operates in refrigeration system normally and safely. The efficiency of the system increased by 21% less energy consumption when refrigerant was 0.5%vf ZnO and R152a. during this process, the use of nano refrigerant decreased both suction and discharge pressure by 6%.

V. K. Dongre et al. [11] has represented a paper named as Enhancement of Vapor Compression Refrigeration System Using nanofluid. In their experiment they mixed some different types of refrigerant such as R134a, M149, R600a and R290 with nanoparticles like CuO and Al₂O₃. Firstly, they had taken results of pure R134a and the COP was found to

be 10.08 and with CuO nanoparticles on 300gm mixed with lubricating oil the COP was increased to 13.85. Then they used Al₂O₃ of 300mg with R134a and COP was found to be 12.96. they had also done testing of M049 with CuO and the COP was increased to 14.09 and with Al₂O₃, it was decreased to 10.78. Finally, they had done trial with R290 and R600a with CuO nanoparticles and COP was 13.4. Trial with R290 and R600a with Al₂O₃ had given the COP of 14.72. They concluded that the nanoparticles- free cooling system's COP is lower than the nanoparticles COP. By adding refrigerant nanoparticles to the refrigeration system, the COP of the system was improved by 4% to 5%. They found that the COP of Al₂O₃ nanoparticles with refrigerant was smaller than that of CuO nanoparticles with refrigerant.

Shengshan Bi et al. [12] (2010) presented a paper on Performance of A Domestic Refrigerator using TiO₂+ R600a Nano refrigerant as a working fluid. The size of TiO₂ nanoparticles was 50nm and their mass purity of 99.5%. They dispersed nanoparticles with refrigerant in concentration of 0.1 and 0.5g/L in their investigation. They concluded that TiO₂ with R600a works normally and efficiently as compared to pure R600a. The concentration of 0.1 and 0.5g/L of TiO₂ + R600a nano-refrigerant can save 5.94 and 9.6% of energy consumption and nano-refrigerant freezing rate was faster than pure R600a.

Kuljeet Singh et al. [13] (2014) has done An Investigation into the Performance of a Nano refrigerant (R134a+ Al₂O₃) based Refrigeration system. In this experimental study they used Al₂O₃ nanoparticles of 20nm diameter sized nanoparticles dispersed in R134a. they used 0.5 and 1% vf of nanoparticles with R134a Refrigerant in the refrigeration system. When they used 0.5%vf of Al₂O₃ the COP of the system was 8.5% and for 1%vf of Al₂O₃ the COP was decreased by 5.4% the effectiveness of condenser and evaporator increased in case of R134a+0.5% of Al₂O₃.

Doshi Sachindra J [14] (2017) presented A Review on Enhancement of COP of Refrigeration system by inclusion of Nanoparticles in refrigerant. In this review they concluded that the nanofluids reveal many compulsive properties and in this they discussed about the enhancement in COP of refrigeration system by mixing nanofluids with base refrigerant. Also, refrigerant thermal conductivity increases and compressor work has been reduced. They also concluded that energy was reduced by 26.1% and that the cooling system's performance was increased Using various types of nanoparticles in the cooling system by 4.4 percent.

I. M. Mahbubul et al. [15] (2013) has published a paper named as Thermal Conductivity, Viscosity and density of R141b refrigerant based nanofluids. In this paper, they analyzed the behavior of Al₂O₃ nanoparticles based with refrigerant. Based on refrigerant analysis, with the rise in concentration and temperature, the thermal conductivity increases. They concluded that viscosity increases as the fraction of particles increases and decreases with temperature rise. Similarly, nano-refrigerant density increases with % vf enhancement and decreases with temperature increase. He also concluded that in order to achieve efficient energy efficiency, optimum volume fraction should be calculated based on thermal conductivity, viscosity and density of nano refrigerant.

P. K. Kushwaha et al. [16] (2016) presented a paper on Experimental study of nano refrigerant (R134a + Al₂O₃) based on vapor compression refrigeration system. They used Al₂O₃ nanoparticles of size 60 to 70 nm each and the system was charged nano refrigerant R134a + Al₂O₃ with 0.25gm and 0.50gm mass. They observed that there was more temperature drop across the condenser for the nano refrigerant from 12.37% to 10.88 percent. They also noted a reduction in power consumption of 4.35% and 14.7%.

N. S. Desai et al. [17] (2015) has presented a paper on Application of SiO₂ nanoparticles as Lubricant additive in VCRS: An Experimental Investigation. They used SiO₂ nanoparticles with the concentration of 1%, 2% and 2.5% by mass in POE oil. They observed that at concentration of 0%, 1%, 2% and 2.5 % of SiO₂, the compressor work done in kW was 0.484, 0.45, 0.4245 and 0.4327. Likewise, for 1%, 2% and 2.5% respectively, COP was found to be 7.61, 14.05 and 11.90.

Veera Raghavulu K et al [18] (2018) presented A Review on Applications of Nanofluids used in Vapor compression Refrigeration system for COP enhancement. They found that nano refrigerants ' thermal conductivity was higher than the pure refrigerant. The refrigerant's thermal conductivity also increases by increasing the volume-based concentration of nanoparticles. They also concluded that the size and material of nanoparticles also effects on the performance of VCR system.

Melih Aktas et al. [19] (2014) published a paper on A theoretical comparative study on nano refrigerant performance in a single stage vapor compression refrigeration cycle. They had theoretically studied Al₂O₃ with R12, R134a, R436a and R600a. It was agreed that Al₂O₃ density was equivalent to 3096kg/m³. Their result shows that COP was increased by inserting pure nanoparticles with refrigerant and achieving the maximum value for the mixture R600a+ Al₂O₃.

M. A. Soliman et al. [20] (2015) presented a paper on Performance Enhancement of Vapor compression cycle using nano material. In this experiment they used Al₂O₃ nanoparticles with POE oil with R134a refrigerant. The size of



nanoparticles was less than 50nm and its density was 3600kg/m³ and the weight concentration of nano lubricant mixture was 0.1%. They filled the reciprocating compressor with POE oil + Al₂O₃ and the theoretical results show that the heat transfer coefficient increased by 50% and energy losses dropped by 28%. While the experimental result shows that the system's COP with nanomaterial was higher than the system's COP without using nanoparticles theoretically and experimentally by 9.11 percent and 10.53 percent, and energy consumption was reduced by 13.3 percent. at that same time heat transfer coefficient was increases by 70.83%.

A. Senthil Kumar et al. [21] (2015) presented a paper on Performance analysis of a domestic refrigerator using CuO-R600a nano refrigerant as a working fluid. In this experiment they used CuO nanoparticles with R600a refrigerant in concentration of 0.1 and

0.5 g/l in the refrigeration system. They firstly investigated the performance test for pure R600a. the discharge and suction pressure of compressor were reduced for CuO-R600a nano refrigerant than pure R600a refrigerant and the largest reduction was for 0.5 g/l. they came up with result for 0.1 and 0.5% g/l concentration, energy consumption was 0.8435 and 0.7856 kWatt/hr and energy saving was 11.83% and 17.88%. They also concluded that the freezing velocity for CuO- R600a was more quickly than pure R600a refrigerant.

EXPERIMENTAL SETUP

The experimental setups following devices were used:

1. Refrigeration system
2. Compressor (R600a suitable only)
3. R600a Refrigerant
4. Compound pressure gauge (Qty- 2)
5. Thermocouple (Qty- 5)
6. Heater and heater temperature controller
7. Switches
8. Energy meters (Qty- 2)

Name of component	Specification
Refrigeration system	Videocon refrigeration system of 180 lit cooling space
Compressor	Single stage compressor (R600a)
Condenser	Fined type natural convection
Filter	Copper mater filled with silicon gel ball
Capillary tube	1.5 m and of 1mm diameter
Copper tube	10 feet long of 1/4-inch diameter
Pressure gauge	Compound pressure gauge (NO. 2 PROVIDED)
Thermocouple	J type thermocouple (NO. 5 PROVIDED)
Heater	Cell tube type heater with heat controller

Experimental setup was made as per Indian standards. Two compound pressure gauges were used and were connected at the inlet and outlet pipe of the compressor. At the same time, 5 thermocouples were also connected which were named as T1, T2, T3, T4 and T5. Along with it two separate energy meters were connected and were named as E1 (for measuring total load) and E2 (for measuring only compressor load). And set looks like as shown in the figure.



Figure 1: Experimental Set-up



Figure 2: Setup for adding nanoparticles with refrigerant

III. METHODOLOGY

Firstly, simple test on the refrigeration system will be performed. Pure POE oil was added as a lubricant in the compressor of the refrigeration system. Then we have taken readings of pressure gauges (P1 and P2) at the same time we have taken readings of the thermocouples connected at different places. Refrigeration effect will be calculated, work required for compressor, and COP. After that, added 0.035 gm (0.1% by mass of refrigerant charged in the refrigeration system) of nanoparticles with the refrigerant and similar testing will be performed. Same tastings will be taken for 0.070, 0.105, 0.140 and 0.175 gm of nanoparticles with refrigerant.

Calculation

1. Theoretical Coefficient of performance (COP) = Refrigeration effect (R.E.) / Work done (WD)
2. Theoretical Refrigerant effect (R.E) = $h_1 - hf_3$ (or) $h_1 - h_4$
3. Theoretical Work done by compressor (WD) = $h_2 - h_1$



4. Actual Refrigeration Effect = $m \times C_p \times (T_5(@\text{initial}) - T_5(@\text{final}))$
Time (sec)
5. Actual Work done by compressor = 10×3600
Time $\times 3200$
6. Actual Coefficient of Performance = $\frac{\text{Actual Refrigeration Effect}}{\text{Actual Work done by compressor}}$
7. Tonnage Refrigeration Capacity = Actual Refrigeration Effect
251

IV. RESULTS AND DISCUSSION

COP is proportion of refrigerating impact and work input. In this work, COP will be determined with assistance of exploratory information. Refrigeration impact is assessed by methods for vitality meter associated with radiator. At last the warmer is providing warmth to evaporator by methods for warming water and same measure of warmth is taken out by refrigerant in the wake of accomplishing consistent state.

Summary

From the exploratory outcomes unmistakably, we can utilize SiO₂ nanoparticles in the refrigeration framework. Additionally, we can expand the coefficient of execution of the refrigeration framework can be expanded by including nanoparticles with refrigerant. Nanoparticles have the properties to be upgrading the thermo physical properties of the base liquid. Thus, they can utilize attainably for the improvement in the presentation of the warmth exchanger gadgets like refrigeration framework, cooling, radiator, and so forth.

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SJIF Scientific Journal Impact Factor
Impact Factor: 8.118



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