Performance Evaluation Using Graphene Oxide Nanomaterial as a Nano-Lubricant for R600a Refrigeration Systems

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In vapour compression refrigeration systems, power consumption is a significant problem. Nowadays, the cooling system consumes considerable amounts of energy in many domestic and commercial applications. An investigation was conducted into the use of graphene nano lubricant in a VCR to optimize the efficiency of environmentally friendly refrigerant R600a. The graphene nanomaterials were incorporated with the polyolester oil to produce into three different samples with proportion of 0.1, 0.2, & 0.3 g/L of graphene nano lubricant. Each of the three samples were examined with 40gram, 50 gram and 60 gram of R600a natural refrigerant. Investigations were carried out with an emphasis on variables including coefficient of performance, cooling effect, and power required to run the system. The base lubricant (Polyolester oil) was used to compare the performances. Results show that the best performance is achieved with a 50 grams of R600a refrigerant & 0.2 g/L GO nanoparticles with POE oil, by a maximum cooling capacity of 0.1539 Kw, the highest possible COP of 1.39, & a low energy requirement of 0.11 Kw for the system. To conclude, the system's cooling rate and energy-saving potential were significantly improved by the incorporation of GO nanoparticles.

Keywords: V Vapour compression refrigeration, Natural refrigerant, Nano material, Graphene oxide, Nano lubricant.

1. Introduction

Human activity has been contributing to a rise in global warming. The manufacture of vapour compression systems employing HFC and the energy needed to power them are two of the main reasons for global warming and energy consumption in the modern world. Based on the vapour compression method, the most common form of residential refrigerator is used in houses. For the purpose of preserving food, a household refrigerator is considered an indispensable device. The majority of household refrigerators on the market today use HFC. R134a has no ozone depleting potential, but because of its high chlorine concentration, its potential to cause global warming is very strong [1]. HFC gas will be phased out of residential freezers in the upcoming days, according to the Montreal and Kyoto Protocols [2], because of its high greenhouse gas potential caused by its chlorine concentration. Earth needs sunshine for plant growth, however because of the collapse of the stratosphere, the earth receives more sunlight than usual, causing a raise in Earth's temperature [3]. Thus, in order to lessen global warming, alternative natural refrigerants must be used in place of R134a in home refrigeration.

R600a is one of the natural refrigerants that have been used as a replacement because of its reduced global warming potential (GWP) and zero Due to their high GWP and ODP, CFC refrigerants are no longer permitted for use in residential refrigerators globally. HFC refrigerants are now used instead. Because R134a has zero ODP, it has been chosen to replace R12 in residential refrigerators with HFC[4]. Isobutene (R600a) is one of the hydrocarbon refrigerants that have been utilized. Many studies have attempted to substitute & enhance the execution of HC refrigerant in VCR systems. [5], [6], & [7] have everyone come to the conclusion that hydrocarbon refrigerants can be used in place of R12 & 134a in VCR systems.

It has been discovered that refrigeration system performance is actively enhanced by nanotechnology. Recent refrigeration system applications have seen a rise in the use of nanofluid produced as either nano-lubricants (mixed nanoparticles and lubricants) or nanorefrigerants (mixture nanoparticles and refrigerant) [8, 9]. Enhanced energy efficiency is one argument in favor of using nanofluids in refrigeration systems [10].

When disseminated in a suitable base fluid, stable suspensions of nanoparticles are known as nanofluids. These suspensions are guaranteed to be homogenous. With a range of 1–100 nm size, nanoparticles are solids that increase the efficiency of thermal systems due to their tiny size and huge specific surface area [11]. The combination of nanoparticles with solids results in better fluids known as nano lubricants or nano refrigerants because mixture improves thermal conductivity as compared with pure fluid. Nanorefrigerant is a combination of nanoparticles and refrigerant, whereas nano-lubricant is a combination of nano material particles and lubricant. Refrigerator longevity and efficiency are increased when compressor friction effects are created using nano lubricant [12].

Certain investigations claim that nano materials can be added to lubricating oil. In the Babarinde et al. research [4], graphene nanoparticles were mixed with the mineral oil base lubricant. The findings demonstrated that, in comparison to base lubricant (mineral oil), graphene nano lubricants exhibit the highest coefficient of performance, reduce cooling temperatures, and the least amount of energy consumption in the VCR system. Adelekan et al. [13] investigation with titanium dioxide nano material utilising R600a (isobutane) as the refrigerant.

The observation reveals that the mean discharge temperature was 3.23–4.03 and the COP range was 50–62° C.In addition, Adelekan et al. [14] introduced titanium dioxide (TiO_2) nanoparticles to the R600a (isobutene) system. The outcome shows that the R600a-TiO_2 nano refrigerant operates in the refrigerator more safely and effectively than a pure R600a system. Experimentative investigation was carried on a domestic refrigerator by Saravanan et al. [14] using different concentrations of Al_2O_3, TiO_2 nano-materials & nanocomposites particles deposited in the base oil POE. According to the results, R134a performs best when used with lubricant composed of nanocomposite materials (50% Al_2O_3/50% TiO_2/POE oil). It also achieves the highest actual COP 2.33, the minimum energy requirement of 61.24 kJ/kg, the minimum of energy requirement 92.2 W et al. Subhedar [15]. Using a nano materials with different volume proportion of Al_2O_3 in mineral oil (02 %, 0.1%, 0.075% & 0.05%), the research was meant to assess the effectiveness of an R-134a refrigerant in a VCR system. According to the results, the nano lubricant increases COP above base fluid by almost 85% [16]. A different variety of temperatures and concentrations with the R600a refrigerant were tested using mineral oil with compressor, Al_2O_3, & TiO_2 nano materials. Refrigerant/oil mixes have been demonstrated to exhibit a decrease in surface tension and an increase in viscosity upon the addition of nanoparticles, Narayanasarma [17].

Uses of nano material mixing with halogenated refrigerants, which are not environmentally favourable and may be outlawed globally, has been the subject of increased research recently. This study, however, takes into account the use of nanotechnology to improve the efficiency of residential refrigerators that use hydrocarbon refrigerants. For the current investigation, graphene nanoparticles have been chosen.

In this study, the researchers examined the effects of mass charge variation of R600a refrigerant and GO nano lubricants on a VCR system. Examining the impact of these variables on energy and parameters such as energy consumption, coefficient of performance, and evaporator air temperature is the goal of this study.

2. Methodology

2.1 Selection of natural refrigerants

Over the 160 years of refrigeration experience, roughly fifty distinct mixtures have been utilized pretty much generally as working media. For a considerable length of time, the vast majority of them have been dismissed as unsatisfactory, however a sensible measure of decision exists to adjust to various execution prerequisites [18]. An assortment of regular coolants, like water, smelling salts, hydrocarbons and carbon dioxide, are among them. Options in contrast to an assortment of CFC, HCFC and HFC refrigerants are given by regular refrigerants. Despite their limited capacity to consume ozone and their minimal or nonexistent ability to change global temperatures (Table 1) [19].

Table 1: Effects of refrigerants on Environment. Sources: [20,21,22,23].

Refrigerant	Composition	Ozone Depletion Potential	Global Warming Potential (100 Years Prospect)
R11	CFCs	1	3800
R12		1	8100
R115		06	9000
R22	HCFC	0.055	1500
R123		0.02	90
R23	HFCS	0	11700
R134a		0	1300
R143a		0	3800
R290	Natural Refrigerants	0	3
R600a		0	3
R717		0	0

2.2 Nano-lubricant preparation

The most important step in research investigation is to prepare lubricant with nanoparticles to produce nano lubricants. In the present work, graphene oxide was added to polyolester oil to make nano lubricants. The 0.8–2 nm-sized graphene oxide nanoparticles were purchased from Ad-Nano Technologies Pvt. Ltd. A SEM was utilized to investigate the graphene oxide nanopowder, shown in Fig. 1.

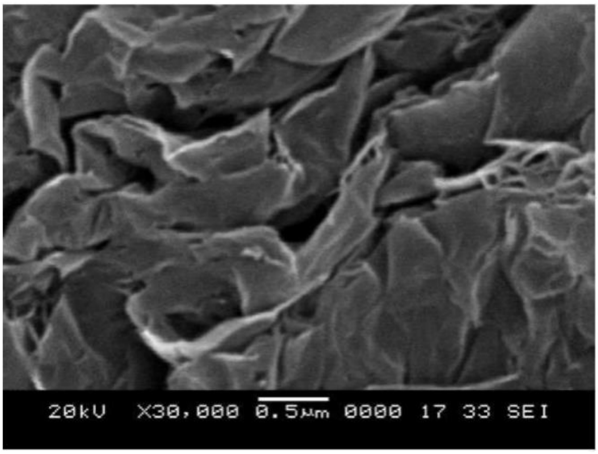

Fig 1. Scanning electron microscope of graphene nano material (24)

One litre of Polyolester oil was used to create three distinct samples in this experimental study, each having a nano ubricant content of 0.1 g/L, 0.2 g/L, and 0.3 g/L. With a measurement range of 0.001 to 110g, a digital weighing balance was used to weigh each nanoparticle as shown in fig.2.

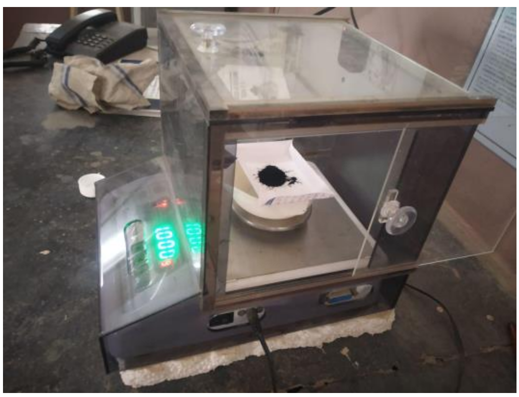

Fig 2. Measurement of Graphene powder using digital weighing

The Graphene oxide nanoparticles were combined with mineral oil at three proportions. Fig. 3 shows the Nano lubricant preparation process. The one step & two step methods can be selected for preparing nano-bubricant. In this research two step technique is selected for preparation of nano-lubricant.

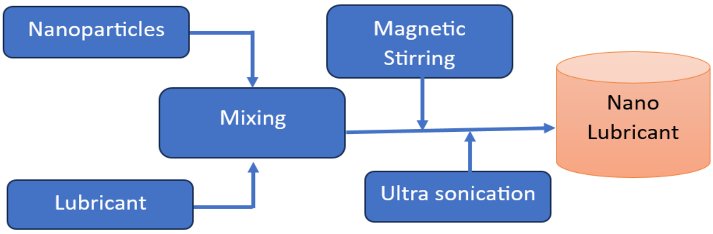

Fig. 3. Nano lubricant preparation process

To enhance the uniformity of nanoparticle dispersion within the lubricant, the GO nano-lubricants were then kept at atmospheric temperature for 50 minutes at a speed range of 1000 rpm on a magnetic stirrer, as shown in Figures 4.

Fig. 4 Ultra sonication using magnetic stirrer

According to Mahbubul et al., Ultra sonication time consider for nano lubricant solution has been three hours at temperatures between 15 and 20 °C using an ultrasonic homogenizer. [25]. samples of pure oil and nano lubricants are shown in fig 5 for different concentrations of graphene oxide mixed with lubricant oil as 0.1, 0.2, 0.3 g/L.

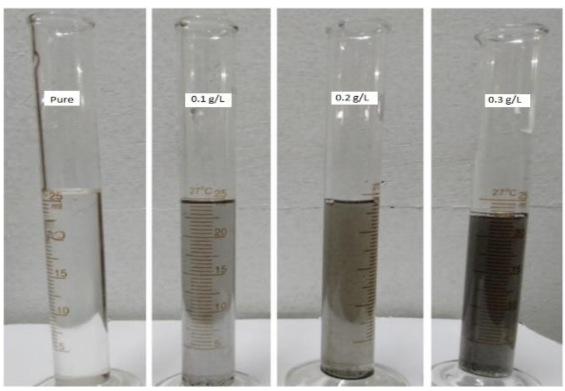

Fig. 5 Nano-lubricant sample at concentrations of 0.1, 0.2, and 0.3 g/L.

3. Experimentation

Every VCR system has major components: compressor, condenser, expansion device and evaporator. Its input and output temperatures are measured. The temperature at each refrigerator component's input and outflow was measured using K-type digital thermocouples. To measure the compressor suction and discharge pressure, two pressure gauges (Bourdon gauges) were connected. Also, the energy requirement to operate the compressor was measured using a digital Wattmeter.

Experiment Specification.

Sr. /No.	Parameters
1 Refrigerant	R600a
2 Mass charge (600a)	40 g, 50 g & 60 g
3 Nano Material	Graphene oxide
4. Lubricant	POE oil + GO nano particles
4 Nano-particles size	2 nm to 8 nm
5 GO in POE oil	0.1, 0.2 & 0.3 g/L
6. Compressor Type	Hermetically sealed
10 Lubricant	Polyolester oil

The system was completely flushed and cleaned out with a vacuum pump. Because of its exceptionally low GWP and zero ODP, R600a refrigerant is considered in this test configuration. The refrigerant amount of R600a varies from 40 g - 60 g because of its lower density in comparison to R134a. Because Polyolester oil (POE) is compatible with both R600a and the refrigerator parts, it was selected as the primary lubricant for this experiment. Nitrogen gas was pumped into the experimental test setup at a pressure of 60 to 70 bar, and it remained there for two hours. Consequently, no system leaks were found. Gases other than nitrogen were removed from the system. Using a suction apparatus attached to the compressor suction valve, the system was fully evacuated to remove any contaminants. This protocol was adhered to in every trial. Refrigerant 600a is charged through the suction line.

The VCR system performance was assessed through the Equations (a)–(c).

Cooling capacity $= \dot{m} * Cp_w * (T_i - T_f)$ KW …………………….. (a)

Compressor Work = $(E_f - E_i) * 3600/t$ KW ……………………… (b)

Coefficient of Performance is -

COP = Cooling Capacity/Compressor Work …………………………(c)

4. Result

This part shows the outcomes of varying the amount of nano lubricant in aVCR system using R600a refrigerant at particular room temperatures.

4.1 Cooling capacity

In Figure 6, the system's refrigeration impact is displayed. Graphene-oxide nano lubricant provides a higher cooling effect than pure lubricating oil on every mass filled of R600a in the VCR system. Enhancing the refrigerating effect of lubricant is possible by increasing its heat transfer by mixing graphene-oxide nano material. The 50g mass filled of R600a in 0.2 g/L GO nano lubricant provides the maximum possible refrigeration effect of 0.1539 KW. With pure POE oil as lubricant, the experimental results reveal the minimum refrigeration effects of 0.8545, 1.03780, and 0.79604 KW while utilizing 40 g, 50 g, & 60 g of R600a in the refrigeration device.

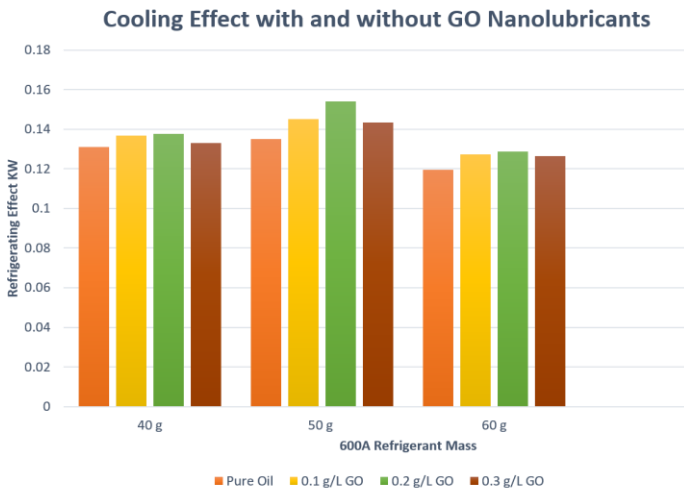

Fig. 6 cooling effect with and without GO Nano lubricants

Just a little amount of graphene-oxide nanomaterials in the lubricant oil (POE oil) is required for the system to have the cooling effect, as displayed in Figure 6. Based on the findings, the performance coefficient rises when graphene-oxide nano lubricants are dispersed because they enhance the refrigeration effect.

4.2 Energy Consumption

To evaluate the system's performance, varying concentrations of polyolester (POE) oil/R600a nano lubricant and variable R600a mass charges were used. Figure 7 shows the power requirement of the compressor at different concentrations of nano lubricant. By incorporation of 0.1 g/L, 0.2 g/L, and 0.3 g/L of GO nano lubricant, the power requirements for 40 g, 50 g, and 60 g of R600a were computed. Impressively, the lowest power requirement of 0.11 kW was recorded when 50 g of R600a were charged at an amount of 0.2 g/L for GO nano lubricant.

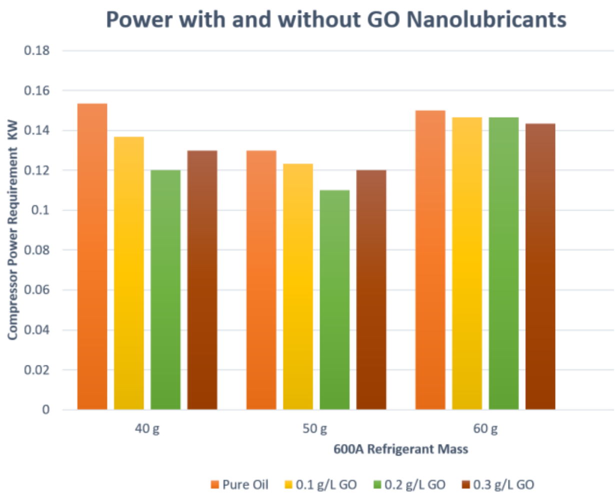

Fig. 7 Power with and without GO Nano lubricants

4.3 VCR System Performance

The coefficient of performance is a crucial factor to take into account when choosing a different refrigerant for a VCR system. Figure 8 has the system's COP values displayed. The GO nano lubricant executes better in terms of coefficient of performance when compared to pure lubricants.

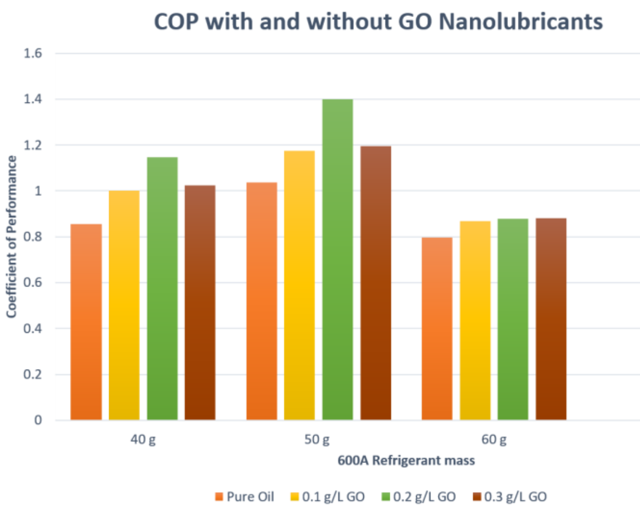

Fig. 8 COP with and without GO Nano lubricants

With coefficients of performance (COP) ranging from 1 - 1.02, 1.17 - 1.19 & 0.86 - 0.88 , respectively, with different amount R600a refrigerant incorporated is 30 g , 40 g, and 50 g and the graphene-oxide as nano lubricant. The highest possible increase in COP of 1.39 was achieved at a 0.2 g/L of GO nano lubricant.

5. Conclusion

This experimental investigation used the cooling effect, energy consumption, and COP to evaluate the performance of GO nano particles in POE oil. Graphene-oxide amounts in POE oil are 0.1 g/L, 0.2 g/L, & 0.3 g/L are evaluated on R600a by varying refrigerant amounts 40 g, 50 g, and 60 g. At GO nano lubricant proportions of 0.1, 0.2, and 0.3 g/L, minimum refrigerating temperatures and power usage were observed during the research. Following analysis were observed are:

- Incorporating the nano lubricant ensured the system operated securely.
- With a 0.2g/L amount of GO nano lubricant and 50 gram mass charge, the system's lowest power was recorded as 0.11kW.
- The ideal COP of 1.39 was attained at room temperature using 0.2 g/L of TiO2 nano lubricant and 50 gram mass charge.
- The highest achievable cooling effect of 0.1539 KW is achieved with a 50g mass charge of R600a in 0.2 g/L GO nano lubricant.

In the R600a VCR system test rig, graphene-oxide nano lubricant can be used with polyolester oil which optimizes the good power requirement, COP and cooling effect.

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