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Performance Test on Vapour Compression Refrigeration System with Graphene Nano Lubricants and R290 Refrigerant

K.Anjineyulu[1*] | Dr.K.Kalyani Radha[2]

[1]PG Research scholar, Refrigeration and Air Conditioning, JNTU College of Engineering, Ananatapuramu, India.
[2]Assistant Professor, Mechanical Engineering, JNTU College of Engineering, Ananatapuramu, India.
[*]Corresponding Author Email Id: aanji566@gmail.com

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ABSTRACT

Hydrochlorofluorocarbons, chlorofluorocarbons, and hydrofluorocarbons are all environmentally hazardous refrigerants. Due to the refrigerant R290's thermal properties being comparable to those of R134a, a performance test on a vapour compression refrigeration system employing R290 as a refrigerant alternative to R134a was done. It also has a lower potential for global warming and has no ozone depletion. Nanotechnology is used in a variety of technical applications, such as refrigeration and air conditioning. Graphene nanoparticles and POE oil are used to create three different types of nano-lubricant concentrations in this study. The nano-lubricant concentrations were 0.1 g/L, 0.2 g/L, and 0.3 g/L wt. percent, with a mass charge of 70 gms of R290 and pure POE oil and graphene nano-POE lubricant concentrations. The system's net refrigeration effect, work-done, performance co-efficient, and pull-down time are all evaluated.

KEYWORDS:COP, R290, POE oil, R134a and Graphene

1. INTRODUCTION

In a home, a refrigerator is a significant energy consumer. A vapour compression cycle is used in most residential refrigerators, and it consists of a compressor, condenser, capillary tube, and evaporator, all of which use a working fluid known as "refrigerant." HCFCs were the most common refrigerant for residential refrigerators in Europe and Iraq in the late 1980s. Chlorine-containing refrigerants have been discovered to permeate into the stratosphere, where they contribute significantly to the ozone layer's breakdown, which protects life on Earth from harmful UV light. As a result, the Montreal Protocol requires that HCFCs and CFCs be phased out. As a result, numerous refrigerants have been discovered as potential substitutes for HCFCs, which are now the most often used refrigerant in Iraqi refrigeration applications. One of them is R-134a, which is designed to nearly match R-12 performance with minimal design changes and for new equipment. Recently. After 2011, the European Union proposes banning the use of refrigerants with a global warming potential (GWP) greater than 150, effectively banning R134a from new mobile air conditioners and refrigerators. As a result, the US Congress proposed phasing out HFC production solely based on its GWP value, with a 90% cap in 2012 and a 15% cap in 2033[1]. As a result, the refrigerator should be charged with the proper amount of alternative refrigerant to ensure that it runs at peak efficiency for the duration of its life, reducing energy consumption and CO2 emissions. Due to their I close thermodynamic properties (ii) similarity with existing refrigeration systems aided with or without modification (iii) no or low ozone depletion characteristics, hydrocarbon refrigerants have been reported as an excellent replacement for conventional working fluids in several works of literature (iv) Hydrocarbon refrigerants have been cited as an excellent replacement for traditional working fluids in several types of literature, however their use is restricted due to flammability concerns. The fear of flammability [2] with the use of hydrocarbon-based refrigerators for domestic use with charges below 150g is disregarded because I the operating temperatures and pressures are high (ii) used in vapour compression refrigeration system with the minimum number of connections and properly sealed (iv) accessibility to open flame or source of ignition can be controlled. Fatah et al. [3], Mohammad [4], and Mehdi et al. [5] observed the following experimentally and theoretically when hydrocarbon refrigerants are used in domestic refrigeration: I high discharge temperatures and pressures (ii) low coefficient of performance (iii) switch from POE to mineral oil as compressor lubricant (iv) hydrocarbon replacement A compressor is utilised in place of the HFC compressor. R-600a (isobutene) is an environmentally friendly refrigerant when compared to other natural refrigerants like R-134a, and it was chosen for the research of [6], [7], [8], [9], [10]. Nanoparticles, which come in a variety of sizes, have been used to improve the performance of engineering systems in a variety of applications. The research focused on the VCRS performance test using pure POE and graphene Nano-POE lubricant concentrations, as well as the usage of R290 as an R134a replacement refrigerant.

2. PREPARATION OF NANO-LUBRICANT:

The (Graphene) Nanoparticles and polyester oil (POE) mixture is made by combining them together directly and agitating them with a magnetic stirrer. To prevent Nanoparticles in the blend from bunching together, the mixture is vibrated in an ultrasonic homogenizer to fully isolate the Nanoparticles in the lubricating oil. An ultrasonic vibrator is used to achieve uniform stability and dispersion of nanoparticles in the nano lubricant that is produced.

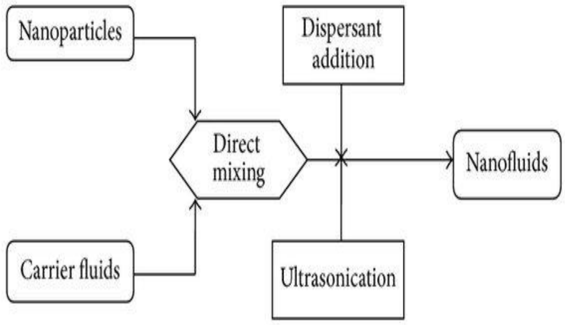

Fig.1. Preparation of Nano-Lubricants.

3. VAPOUR COMPRESSION REFRIGERATION SYSTEM:

The evaporator's low-pressure, low-temperature vapour refrigerant is sucked into the compressor via the suction valve, where it is compressed to a high-pressure, high-temperature vapour refrigerant and discharged to the condenser via the discharge valve, following the isentropic process. The superheated vapour is cooled to the saturation temperature of the refrigerant at its pressure. The discharge line and the first few coils of the condenser are desuperheated. By transferring its latent heat to the saturated liquid refrigerant, the saturated vapour refrigerant now condenses. Condensation is the term for this process. This condensation process is followed by a heat rejection process at constant pressure. As a result, the compressor's high-pressure, high-temperature vapour refrigerant passes through the condenser and is entirely condensed at constant pressure and temperature, converting the vapour refrigerant to liquid refrigerant. The liquid refrigerant is expanded to low pressure through the expansion valve by a throttle process at high pressure (P2=P3) and temperature. The technique is also known as vaporisation. At constant pressure (P4=P1), the liquid-vapor (mixture) refrigerant is evaporated and transformed to vapour refrigerant. The following are the P – h, table, and schematic diagram of a vapour compression refrigeration system.

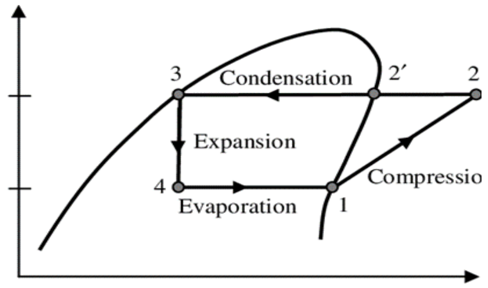

Fig.2.vapour compression refrigeration system

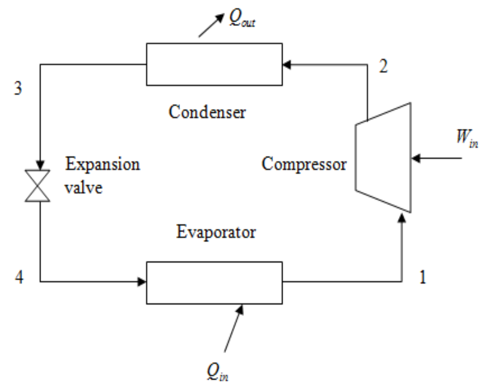

Fig.3. P-h diagram of VCRS system

4.EXPERIMENTAL PROCEDURE:

In a household refrigerator with a 175-liter capacity, inject 70g of R-290 refrigerant. Take note of the temperature readings on the evaporator from room temperature to -5 °C. Replacing the R-134a refrigerant with R-290, repeat the procedure toverify the temperature and pressure readings. After emptying the refrigerator's compressor and introducing a mass charge of 70g of R-290 refrigerant, replace the refrigerant oil with 0.1 g/L, 0.2 g/L, and 0.3 g/L of nano lubricant. Run the system and record the temperature readings from room temperature to -5°C in the evaporator. The scope of the experiment, experimental equipment features, graphene nanoparticle qualities, and lubricating oil characteristics are all detailed in the tables below.

Fig.4. Experimental Setup

Table.1. Characteristics of R290 refrigerant

Chemical formula	C3H8 or CH2CH3CH2
Chemical name	Propane
Boiling point(⁰C)	-29.3
Freezing point(⁰C)	-188
Critical Temperature(⁰C)	97
Critical pressure(Mpa)	4.25
Latent heat(kJ)	423.3
Global Warming Potential(GWP)	3
Ozone Depletion Potential(ODP)	0
Power consumption	Low
Average system charge by weight	< 300 grams
Average system charge by volume	~ 0.75 liters
Toxicity	Low

5. RESULTS AND DISCUSSIONS:

When R-134a, R-290, and 0.1 g/L, 0.2 g/L, and 0.3 g/L wt. % graphene Nano lubricants are employed in an experimental domestic refrigerator, the following findings are obtained:

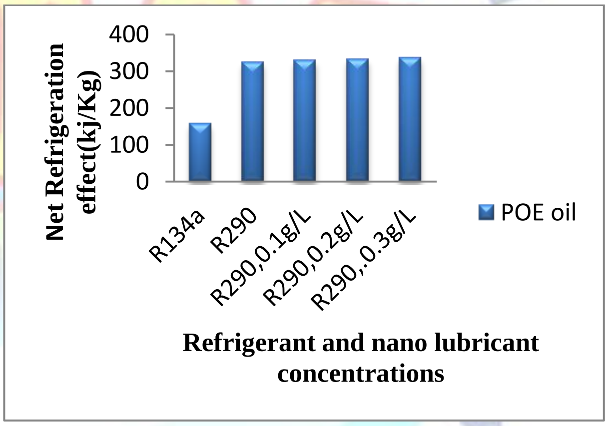

Fig.5.1. Comparison of Net refrigeration effect

The net refrigeration impact of the system with R134a refrigerant and pure POE oil and R290 refrigerant with 0.1g/L, 0.2g/L, and 0.3g/L wt. % Graphene POE Nano lubricant is shown in Fig.5.1. With pure POE oil and 0.1g/L, 0.2g/L, and 0.3g/L wt. -% of Graphene POE Nano lubricant, the R290 refrigerant has a larger net refrigeration effect than R134a. In R290 refrigerant with 0.3g/L wt. percent graphene Nano-lubricant, the system's maximum net refrigeration effect is absorbed. The net refrigeration impact of the system is improved due to the inclusion of nano-additives to the POE lubricant, which increases heat absorption and heat rejection.

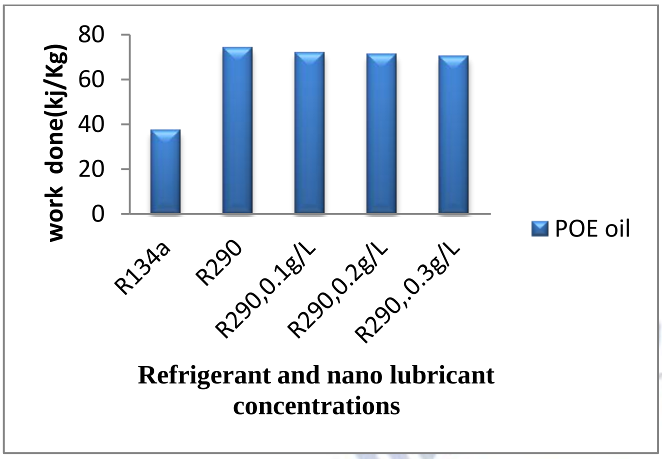

Fig.5.2. Comparison of work done of the system

Fig.5.2 shows the comparison of work done of the system with R134a and R290 with pure POE oil and 0.1g/L, 0.2g/L, and 0.3g/L wt.% of Graphene POE Nano lubricant. R134a refrigerant performs less work in the system when using pure POE oil than R290 when using 0.1g/L, 0.2g/L, and 0.3g/L wt.% Graphene POE Nano lubricant. The minimum net refrigeration effect of the system is absorbed in R134a with pure POE oil. Due to the refrigerant R290's having higher suction and discharge pressures than R134a refrigerant, when compared with R290 with pure POE and graphene Nano-lubricants, the minimal work-done of the system is at 0.3g/L wt.% graphene nano-lubricant than pure POE oil and other Nano-lubricant concentrations.

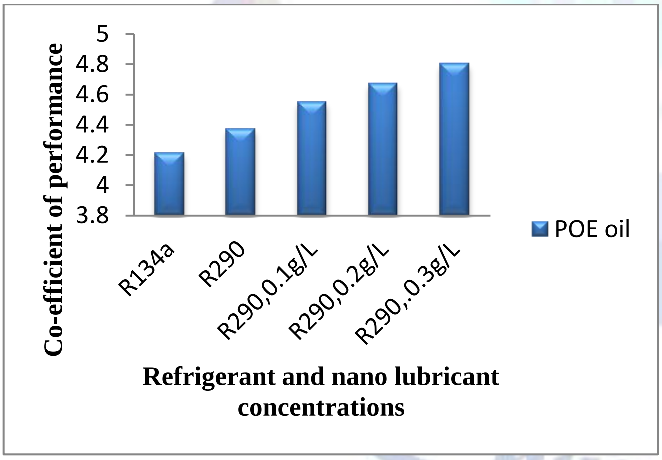

Fig.5.3.Comparison of Co-efficient of performance of the system

The performance co-efficient of the system for R134a with pure POE lubricant and R290 with pure POE and 0.1g/L, 0.2g/L, and 0.3g/L wt. percent Graphene POE Nano lubricant is shown in Fig.5.3. With pure POE oil with 0.1 g/L, 0.2 g/L, and 0.3 g/L wt. -% graphene POE Nano lubricant, the R290 refrigerant has a greater COP. At 0.3g/L wt. percent graphene Nano-POE lubricant, the system's maximum COP is obtained. related to a decrease in the system's work-done and an increase in the system's net refrigerant impact

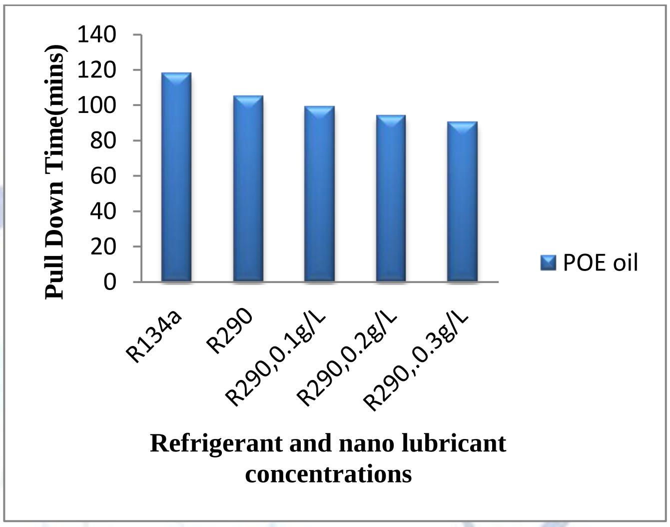

Fig.5.4. Comparison of pull downtime of the system

The pull-down time of the system for R134a refrigerant with pure POE oil and R290 refrigerant with pure POE oil and 0.1g/L, 0.2g/L, and 0.3g/L wt. percent Graphene POE Nano lubricant is shown in Fig.5.4. When compared to R134a with pure POE oil, the refrigerant R290 with pure POE oil and 0.1g/L, 0.2g/L, and 0.3g/L wt. percent Graphene POE Nano lubricant had a shorter pull-down time (to achieve -5^{0}C in the refrigerator cabin from ambient temperature). At 0.3g/L wt. percent graphene Nano-POE lubricant, the system's minimum pull-down time is obtained. The heat absorption in the evaporator rises as nano-additives are added to the base lubricant, lowering the system's pull-down time.

6. CONCLUSIONS:

From the above results, the following was concluded.

1)The net refrigeration impact of the system is higher when using R290 refrigerant with 0.3g/L wt. % graphene Nano-POE lubricant than when using other concentrations. Adding Nano additives to base lubricants boosts heat absorption and heat rejection of the system. As a result, the system's net refrigeration improves.

2)When compared to other Nano-lubricant concentrations with R290 refrigerant, the work done on the system is reduced with R290 refrigerant and 0.3g/L wt. percent graphene Nano-POE lubricant. The Brownian motion, thermal characteristics, and viscosity of the lubricant increase because of the addition of nano-additives in base lubricants, resulting in a reduction in compressor pumping power and a drop in system work-done.

3)R290 refrigerant at 0.3g/L wt. percent graphene Nano-POE lubricant has a greater Co-Efficient of Performance than other nano-lubricant concentrations and R134a refrigerant with pure POE oil. The COP of the system increases as the net refrigeration effect increases and the compressor effort decreases.

4)R290 refrigerant with 0.3g/L wt. % graphene Nano-POE lubricant has a faster pull-down time than other nano-lubricant concentrations and R134a refrigerant with pure POE oil. Due to less compressor work, the system's pull-down time is shortened.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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