Optimizing Domestic Refrigerator Performance with Varied Lubricants for R134a Refrigerant: Comparative Analysis

Optimización del rendimiento del refrigerador doméstico con lubricantes variados para el refrigerante R134a: un análisis comparativo

Otimização do desempenho de refrigeradores domésticos com diferentes lubrificantes para o refrigerante R134a: análise comparativa

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Summary. - The efficiency and performance of domestic refrigerators don't only depend on refrigerant but also on lubricating oil used in the refrigerator compressor. The lubricant of the compressor is responsible for the absorption of heat energy evolved during the compressor work. The primary objective of this study is to examine and compare the effects of two distinct lubricating oils utilized with the refrigerant R134a on various performance metrics of the domestic refrigerator compressor, including evaporator capacity, compressor power consumption, and the coefficient of performance (COP) of the refrigerator. These performance parameters were compared for two different cases, viz., domestic refrigerator having R134a as a refrigerant with Mineral oil (MO) and Polyol ester oil (POE), and for two different methods such as manually by using R134a ph chart and EES software. The tests were conducted on a 329-liter refrigerating capacity double-door refrigerator. The effect of changing oil from MO to POE resulted in the increment of evaporator capacity from 1.81 kW to 1.99 kW and COP from 4.9 to 5.7 while the compressor power consumption reduced from 370 watts to 340 watts which concluded that POE oil is the better lubricant in the domestic compressor as compared to MO.

Keywords: Lubricants, Polyol ester oil, Mineral oil, R-134a, EES, Domestic refrigerator.

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Resumen. - *La eficiencia y el rendimiento de los refrigeradores domésticos no solo dependen del refrigerante, sino también del aceite lubricante utilizado en el compresor. El lubricante del compresor es responsable de la absorción de la energía térmica desarrollada durante el trabajo del compresor. El objetivo principal de este estudio es investigar y comparar el efecto de dos aceites lubricantes diferentes utilizados con el refrigerante R134a en varios parámetros de rendimiento del compresor del refrigerador doméstico, como la capacidad del evaporador, el consumo de energía del compresor y, por último, pero no menos importante, el COP del sistema de refrigeración. Estos parámetros de rendimiento se compararon para dos casos diferentes: un refrigerador doméstico con R134a como refrigerante, aceite mineral (MO) y aceite de polioléster (POE), y para dos métodos diferentes, como el manual mediante el uso de una tabla de pH del R134a y el software EES. Las pruebas se realizaron en un refrigerador de doble puerta con capacidad de refrigeración de 329 litros. El efecto de cambiar el aceite de MO a POE resultó en el incremento de la capacidad del evaporador de 1,81 kW a 1,99 kW y el COP de 4,9 a 5,7 mientras que el consumo de energía del compresor se redujo de 370 vatios a 340 vatios, lo que concluyó que el aceite POE es el mejor lubricante en el compresor doméstico en comparación con MO.*

Palabras clave: *Lubricantes, Aceite de polioléster, Aceite mineral, R-134a, EES, Refrigerador doméstico.*

***Resumo*. -** *A eficiência e o desempenho de refrigeradores domésticos dependem não apenas do refrigerante, mas também do óleo lubrificante utilizado no compressor. O lubrificante do compressor é responsável pela absorção da energia térmica liberada durante o funcionamento do compressor. O principal objetivo deste estudo é examinar e comparar os efeitos de dois óleos lubrificantes distintos, utilizados com o refrigerante R134a, em diversas métricas de desempenho do compressor de um refrigerador doméstico, incluindo a capacidade do evaporador, o consumo de energia do compressor e o coeficiente de desempenho (COP) do refrigerador. Esses parâmetros de desempenho foram comparados em dois casos diferentes: um refrigerador doméstico com R134a como refrigerante, utilizando óleo mineral (MO) e óleo de éster de poliol (POE), e por dois métodos distintos: manualmente, utilizando a tabela de pH do R134a, e por meio do software EES. Os testes foram realizados em um refrigerador de duas portas com capacidade de refrigeração de 329 litros. A mudança do óleo de MO para POE resultou no aumento da capacidade do evaporador de 1,81 kW para 1,99 kW e do COP de 4,9 para 5,7, enquanto o consumo de energia do compressor reduziu de 370 watts para 340 watts, concluindo-se que o óleo POE é um lubrificante melhor para compressores domésticos em comparação com o MO.*

Palavras-chave: *Lubrificantes, óleo éster de poliol, óleo mineral, R-134a, EES, refrigerador doméstico.*

1. Introduction. - There are many challenges facing energy conservation and environmental protection today, and how energy is supplied and consumed, both practices require major changes (Allouhi et al., 2015). Energy conservation has recently emerged as an important social issue. It involves efforts to reduce energy consumption by utilizing less energy-intensive services and ensuring more efficient equipment management (Ollukkaran & Sreedharan, 2023). According to the Montreal and Kyoto treaties, home refrigerators are the main source of emissions of the fluorine and chlorine gases which are present in refrigerants. These emissions contribute significantly to the degradation of the ozone layer and the acceleration of global warming. The release of chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs) from these appliances leads to increased ultraviolet radiation reaching the Earth's surface. This not only harms ecosystems and human health but also exacerbates climate change by trapping heat in the atmosphere. . Nowadays, Ozone Depletion (OD) and Global Warming (GW) are increasing day by day (Khan, ul Haque, Khan, Obaidullah, & Khan, 2024), and refrigerant compounds such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs) are responsible (Damola S. Adelekan et al., 2017). Previously, refrigeration systems commonly used hydrochlorofluorocarbon (HCFC) refrigerants such as R12 (dichlorodifluoromethane) and R22 (chlorodifluoromethane). However, their use is now prohibited due to their ozone-depleting effects (Tada et al., 2016).

Researchers (D. S. Adelekan et al., 2021) examined the performance of an altered household refrigerator under varying mass charges of R600a refrigerant, TiO2 nanoparticle concentrations, and ambient temperature conditions. The refrigerator's energy consumption at 0.2 g/L and 0.4 g/L concentrations of TiO2 nanolubricant was lowered by 0.13 to 14.09% in comparison to the baseline concentration (0 g/L). Utilizing 0.2 g/L of nanolubricant in the refrigerator, the greatest coefficient of performance was reached with a 60g charge of R600a and at ambient temperature of 22°C.

A domestic refrigerator using R134a and LPG as the refrigerant was studied in 2018 with two different lubricants, including POE, MO. It also investigated nano-oils comprising of TiO2, SiO2, and Al2O3, nanoparticles in combination with MO. The results showed that compressor power consumption was 15.87% lower and the COP was 56.32% higher than calculated for R134a/POE lubricant (Gill, Singh, Ohunakin, & Adelekan, 2018). In 2019, an experiment was carried out to investigate the performance of a refrigeration system using an R134a/PAG oil mixture and R134a/PAG/Al2O3 (R134a/nano-oil) mixture which shows that COP was increased by 6.5% after the addition of the nanoparticles in the compressor (Nair, Parekh, & Tailor, 2020).

In 2019, an Energy analysis of a domestic refrigerator system with Artificial neural network (ANN) using different concentration combinations of LPG/TiO2 – lubricant as a replacement for R134a was used and the findings revealed that compressor power consumption and pressure ratio using LPG with nano-oil was 3.20–18.1 and 2.33–8.45% respectively lower and the cooling capacity and COP was around 18.74–32.72 and 10.15–61.49% respectively higher in comparison with R134a as a refrigerant (Gill, Singh, Ohunakin, & Adelekan, 2019). In 2019, hexagonal boron nitride (h-BN) was used as a solid nanoparticle in POE with R134a as a refrigerant and the findings showed that using 3 vol% of h-BN nanoparticle improved the energy saving by 60% in comparison with pure POE oil (Harichandran, Paulraj, Maha Pon Raja, & Kalyana Raman, 2019). In 2021, the performance of a domestic refrigerator was investigated via R134a with POE and R600a with nano-oil (MO with Al2O3) which resulted in an improvement of COP and compressor discharge pressure by 37.2% and 8.9% respectively, and a reduction in power consumption and evaporator pressure by 28.7% and 24.7% respectively by using 0.1 wt.% of R600a with nano-oil (MO with Al2O3) as compared to the conventional refrigeration system (Yogesh, Dinesh, & Sandeep, 2021). In 2022, authors investigated the performance of the refrigeration cycle of a domestic refrigerator by adding ZrO2 nanoparticle of concentration 0.2 g/L in R134a refrigerant and found out that by using nano-oil, the refrigeration capacity of the system was increased to 38.7% (Baskaran, Manikandan, Tesfaye, Nagaprasad, & Krishnaraj, 2022).

An experimental comparison of a residential refrigerator's performance analysis using MO oil versus POE oil is needed to determine which lubricant performs the best with R134a. The literature review indicates that there are no or very little studies that compare the thermodynamic performance of home refrigerators using the same refrigerant but two different lubricants, and a comparative analysis using EES. Chlorine in refrigerant compounds such as CFC and HCFC is responsible for OD and GW. However, in this experimental research work, R-134a, which is an HFC compound, is used. It is chlorine-free, making it environmentally feasible for the analysis. This study aims to perform the thermodynamic analysis experimentally of two different compressor lubricating oils to find the better lube oil which can be used in a domestic refrigerator with the Refrigerant R134a, and comparative analysis was performed with the EES Professional V10.4-3D software. The comparison was made based on performance parameters including COP, compressor power consumption & evaporator cooling capacity.

2. Materials and Methods. -

2.1 Experimental setup. - The experiment conducted by utilization of an experimental setup consists of a double-door domestic refrigerator with a gross capacity of 397 Litres. It includes a hermetic reciprocating type of compressor in which HFC – R134a is used as a refrigerant with a charged mass of 190 grams, a dryer, a capillary tube, an air-cooled condenser, and an evaporator. Table I represents the specification of the experimental setup.

S/N	Refrigerator description	Units
1	Climate Class	Tropical
2	Protection Class	I
3	Storage Volume	329L
4	Freezer Volume	68L
5	Power rating	180W
6	Voltage/frequency rating	200-240V/50 Hz
9	Condenser type	Air cooled
10	Refrigerant type	R134a
11	Mass charge	190 g
12	Freezing Capacity	4kg/24 hr
13	Lamp rating	10 Watt
14	Overall size	620 x 600 x 1700 (mm)
15	Compressor type	Hermetic (HFC)
16	Number of doors	Double

Table I. Specification of the refrigerator.

Figure I shows the pressure gauges installed at the suction & discharge lines of the compressor while Figure II shows temperature sensors at different locations within the refrigerator to record data in the data logger.

Figure I. Pressure gauge installed at compressor's suction & discharge lines.

(a)

(b)

Figure II. Temperature sensors installed inside & outside of the refrigerator.

The overall experiment was performed by using two different lubricants that are MO and POE oil with the refrigerant R134a for both oils. Table II represents the range of experimental setups while Table III & Table IV shows the properties of the POE oil & MO.

S/N	Parameter	Range of experiment	
1	Refrigerant name	R – 134a	R – 134a
2	Refrigerant charge	190 g	190 g
3	Compressor Lubricant	MO	POE
4	Lubricant charge	300 ml	300 ml
5	Evaporator type	Air-cooled	Air-cooled

Table II. Range of experimental conditions.

S/N	Lubricating oil characteristics	Units
1	Oil Type	POE
2	Density at 15°C kg/L	0.980
3	Kinematic viscosity @ 40°C	32.0 cSt
4	Kinematic viscosity @ 100°C	5.8 cSt
5	Viscosity index	125
6	Flash Point	235 °C
7	Pour Point	– 48 °C
8	Cu Corrosion @ 100°C x 3 hrs	1a
9	Water ppm	<100

Table III. Characteristics of POE Oil.

S/N	Lubricating oil characteristics	Units
1	Oil Type	MO
2	Density at 15°C kg/L	0.916
3	Kinematic viscosity @ 40°C	55 cSt
4	Kinematic viscosity @ 100°C	5.9 cSt
5	Viscosity index	41
6	Flash Point	179 °C
7	Pour Point	– 35 °C

Table IV. Characteristics of MO.

3. Performance analysis. -

3.1 Evaporator capacity. - The evaporative heat transfer rate through the refrigeration system was calculated separately for the compressor, charged with MO and POE lubricants, respectively. The formula used for the refrigeration effect is given by eq (1):

$$\dot{Q} = \dot{m}\ (h_5 - h_4) \qquad (1)$$

The refrigerant mass flow rate is calculated by eq (2):

$$\dot{m} = \frac{\dot{W}_{comp}}{(h_2 - h_1)} \qquad (2)$$

In eq (1), h_4 & h_5 represents the enthalpies at evaporator inlet and commencement of superheating of the refrigerant. In eq (2), h_1 & h_2 represents the enthalpies at compressor inlet and compressor outlet/condenser inlet while W ̇_comp indicates the compressor power consumption.

3.2 Compressor power consumption. - The data logger which was used to record experimental readings at different locations inside and outside the refrigerator can also measure voltage and current consumed by the compressor during the time interval when the refrigerator was in operation. The power consumed by the compressor can be calculated by the eq (3):

$$Power = voltage\ x\ current\ \ (W) \qquad (3)$$

3.3 COP. - The actual COP values for the VCRS were evaluated using EES software by first charging the compressor with MO, and the same procedure was repeated for POE lubricating oil. The COP values obtained were validated against the COP values calculated using ASHRAE Ph Chart for HFC R – 134a (Handbook, 2017).

To determine the COP for the refrigerator, the temperature sensors were attached at different positions to the refrigerator itself, and the temperature readings were recorded using a data logger. In contrast, the pressure at the suction and discharge of the compressor was noted by operating the two pressure gauges after every five minutes. The temperature and pressure readings were recorded for the entire day, but average values were used in the calculation. Figure III shows the schematic diagram of the refrigerator with a data logger for data measurement.

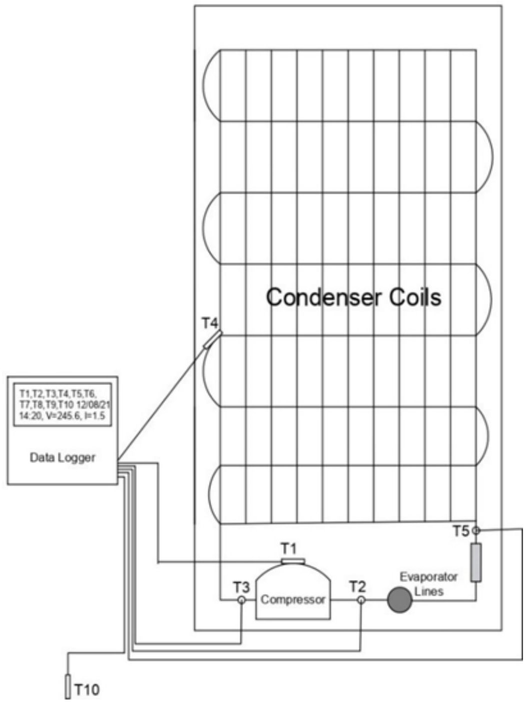

Figure III. Schematic diagram of a refrigerator showing temperature sensors and data logger.

The COP of the domestic refrigerator is given by eq (4):

$$COP = \frac{\dot{Q}}{\dot{W}_{comp}} \qquad (4)$$

3.4 Compressor & evaporator temperatures. - The compressor was charged with two different lubricants, MO, and a synthetic lubricant, each time with the same amount of refrigerant, i.e., HFC R – 134a. To compute the effect on refrigerator performance by using two different lubricating oils, the performance parameters such as compressor suction & discharge pressures & temperatures and compressor dome temperatures were recorded during the time interval when the refrigerator was in operation. In the first step, the compressor was charged with 190 grams of R134a and 300 ml of MO. The compressor was charged again with the same amount of refrigerant for the second run, using 300 ml of POE. Figure IV depicts the placement of the temperature sensors at the compressor dome.

The experimental setup consists of ten DS18B20 digital temperature sensors, each utilized to obtain internal freezer compartment temperatures using the data logger alongside time, voltage, and current. Figure V depicts the placement of temperature sensors. Temperature readings were taken twice for the bottom and right-side walls of the freezer compartment while changing the compressor lubricant from MO to POE oil.

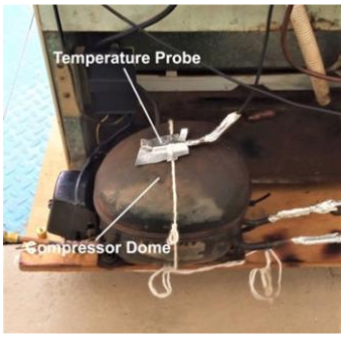

Figure IV. Placement of temperature sensors at compressor dome

(a) (b)

Figure V. Placement of temperature sensors in the freezer compartment

4. Results and Discussion. - The investigation involved a double-door domestic refrigerator which used two different lubricants, mineral oil (MO) and polyolester (POE) oil. HFC R-134a performance was evaluated using the ASHRAE pressure-enthalpy (P-h) chart and Engineering Equation Solver (EES) software.

4.1 Calculation of COP by using P-h chart. - The refrigeration cycle was hand-drawn on the R134a Ph chart by using the average values of temperature and pressure recorded during the experiments. The COP is then calculated and listed in Table V for both lubricating oils. Figure VI depicts the calculated COP values while Figure VII & Figure VIII represents the refrigeration cycle on the R134a Ph chart for MO & POE oil respectively.

S/N	Refrigerant	Lubricating oil	COP
1	HFC R134a	MO	4.958
2		POE	5.795

Table V. COP values for MO & POE lubricants using R134a ph chart.

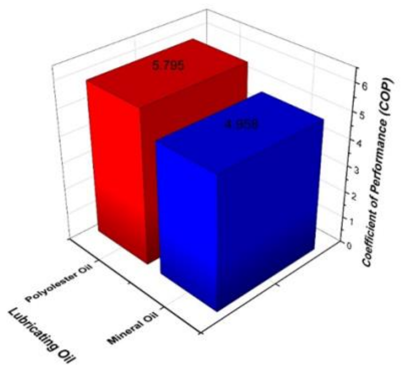

Figure VI. COP (MO vs POE oil).

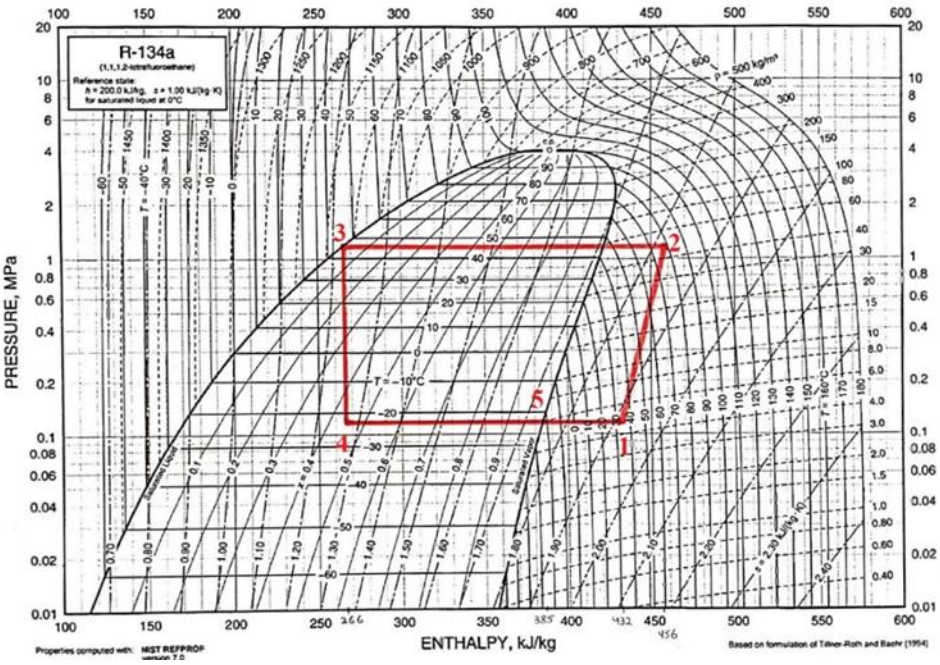

Figure VII. Refrigeration cycle on R134a Ph chart for MO

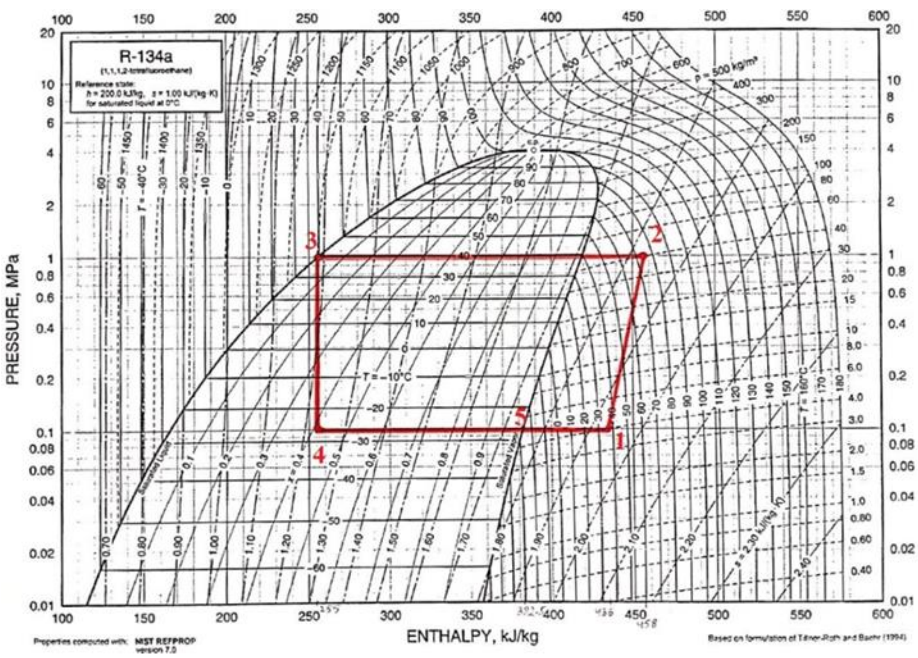

Figure VIII. Refrigeration cycle on R134a Ph chart for POE oil

R-134a and the majority of HFC refrigerants do not mix well with mineral oil. For this reason, the evaporator and pipes retain oil as a result of this poor miscibility. These retained mineral oil acts as an insulator and hinders in the heat transfer (Sundaresan, Judge, Chu, & Radermacher, 1996). On the other hand, POE oil and R-134a mix quite well. By circulating with the refrigerant, it improves heat transfer and lessens oil logging in the evaporator. As a result of this better miscibility of POE oil with R-134, more effective evaporation and condensation occur which improves the COP value.

As compared to mineral oil, POE oil has superior lubricity under high pressure and high temperature condition which is common in the R-134 compressor (Sundaresan, Pate, Doerr, & Ray, 1996).

4.2 Compressor power consumption. - The power consumed by the compressor when it is charged with POE oil came out to be less than it is consumed by the compressor using MO as a lubricant. The compressor voltage and current data were obtained using the data logger. Table VI represents the average current & power consumed by the compressor when using MO & POE oil. Figure IX depicts the compressor power consumption recorded by data logger; Figure X shows the graph representing the current drawn by the compressor while Figure XI depicts the bar chart showing the compressor average power consumption when both the oils were used.

S/N	Refrigerant	Lubricating oil	Average Current (Ampere)	Average Power (Watts)
1	HFC R134a	MO	1.535	370.91
2		POE	1.391	340.62

Table VI. Average Current & Power consumed using MO & POE oil.

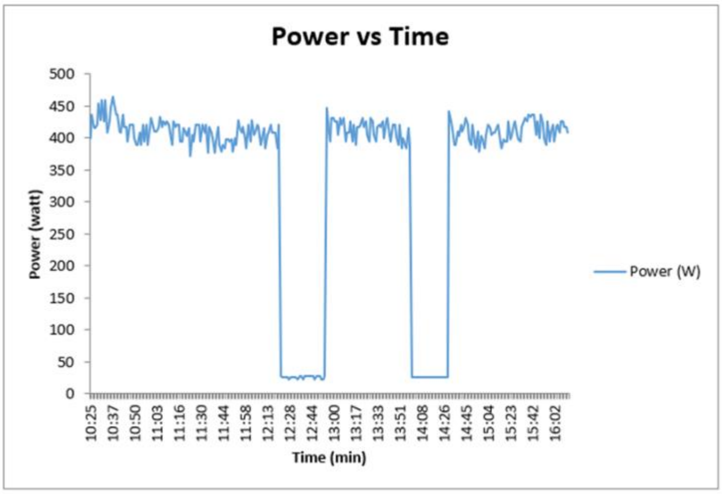

Figure IX. Compressor power consumption.

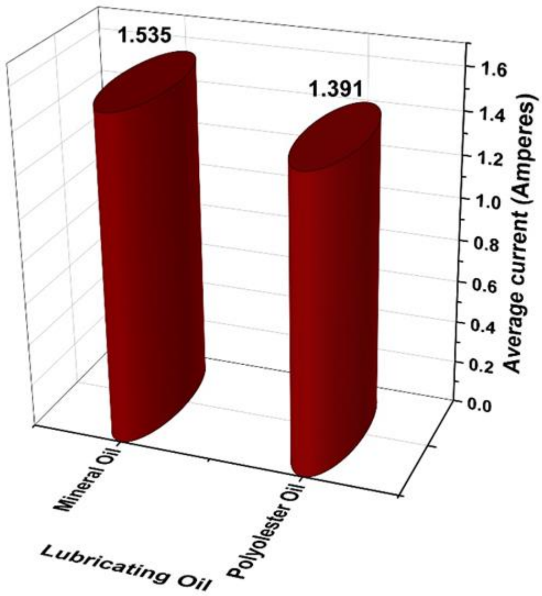

Figure X. Average current drawn (MO vs POE oil).

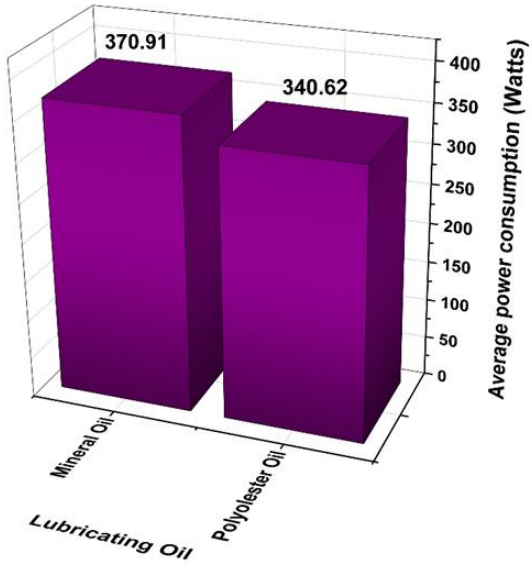

Figure XI. Average power consumption (MO vs POE oil).

POE oils are outstanding lubricants in high-temperature, high-pressure environments, which are typical in HFC systems. This characteristic results in reduced mechanical friction and weir losses in the compressor. A lower frictional loss reduces the power requirement of the compressor and hence higher COP values are achieved.

4.3 Evaporator capacity. - By using eq (1) & eq (2), the mass flow rate and refrigeration effect of the refrigerant can be calculated easily which is also shown in Table VII. Figure XII depicts the bar chart representing the evaporator capacities when both the oils i.e., POE and MO were used in the experiment.

S/N	Refrigerant	Lubricating oil	Mass flowrate (kg/s)	Evaporator capacity (Kilowatts)
1	HFC R134a	MO	0.0152	1.8171
2		POE	0.0156	1.9992

Table VII. Evaporator cooling capacity using MO & POE oil.

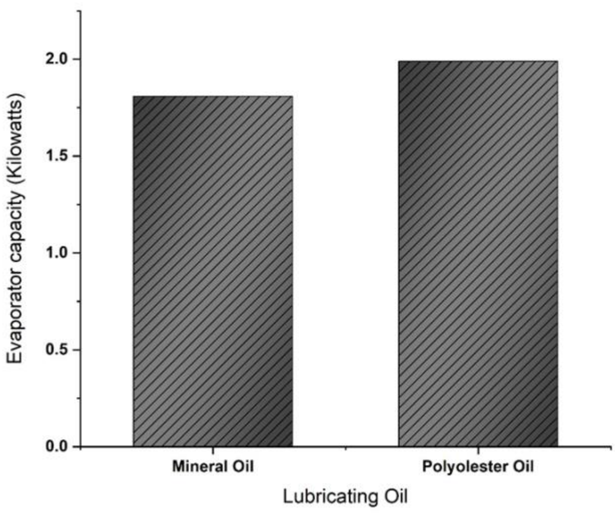

Figure XII. Evaporator cooling capacity (MO vs POE oil).

4.4 Compressor & evaporator temperatures. - Table VIII represents the thermophysical properties of MO and POE lubricants. The temperature and pressure were measured several times, and the average readings were used for calculations. The DS18B20 temperature sensors used in this setup have a measurement range of -55°C to 125°C with an accuracy of ±0.5 °C.

S/N	Lube oil	Viscosity at 40 ºC (cSt)	Viscosity at 100 ºC (cSt)	Flash point (ºC)	Density at 15ºC (kg/L)
1	MO	55	5.9	179	0.916
2	POE	32	5.8	235	0.980

Table VIII. Thermophysical properties for MO and POE lubricants.

Table IX shows average experimental data using MO and POE lubricants. It is evident that POE has a lower compressor temperature difference leading to lower compressor ratio which means compressor doesn't have to work as hard to compress the refrigerant. Less heat is generated during compression, leading to lower operating temperatures within the compressor. Cooler operating temperatures help prevent overheating and thermal degradation of compressor components, contributing to increased reliability and longevity.

S/N	Lube oil	Pressure (bar)		Temperature (ºC)		
		Compressor Suction	Compressor discharge	Compressor suction	Compressor discharge	Condenser outlet
1	MO	1.2	12	31.06	83.98	46
2	POE	1	10	36.23	82.98	39.72

Table IX. Experimental data using MO and POE lubricants.

Table X represents the average evaporator temperatures and compressor dome temperature using MO & POE lubricating oils. Figure XIII, Figure XIV and Figure XV represent the graphs of evaporator right and bottom side walls and compressor dome temperatures recorded by data logger when both the oils were used in the compressor for analysis.

S/N	Lube oil	Temperature (ºC)		
		Evaporator Right side wall	Evaporator Bottom side floor	Compressor dome
1	MO	**1.165**	**-3.560**	89.3
2	POE	**-6.794**	**-6.140**	98.9

Table X. Temperature data using MO & POE lubricating oils.

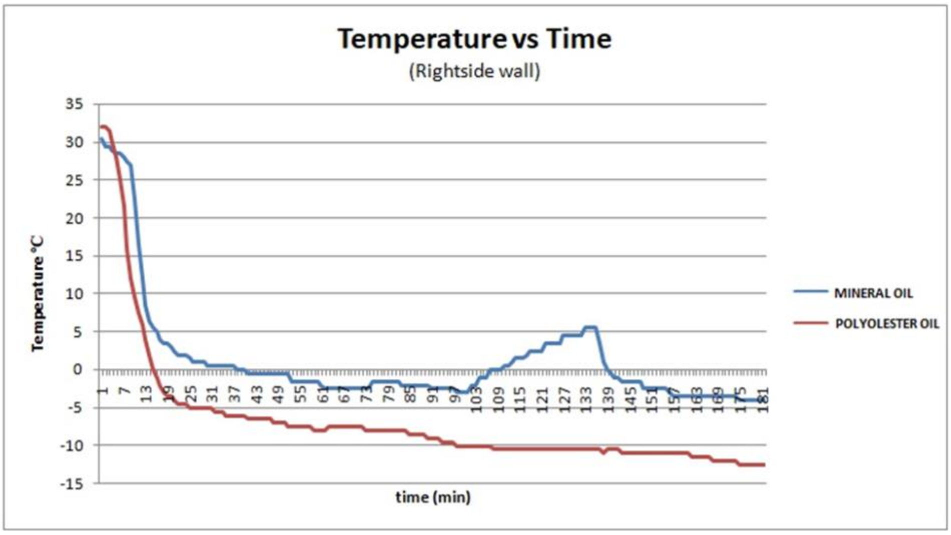

Figure XIII. Evaporator right side wall temperature.

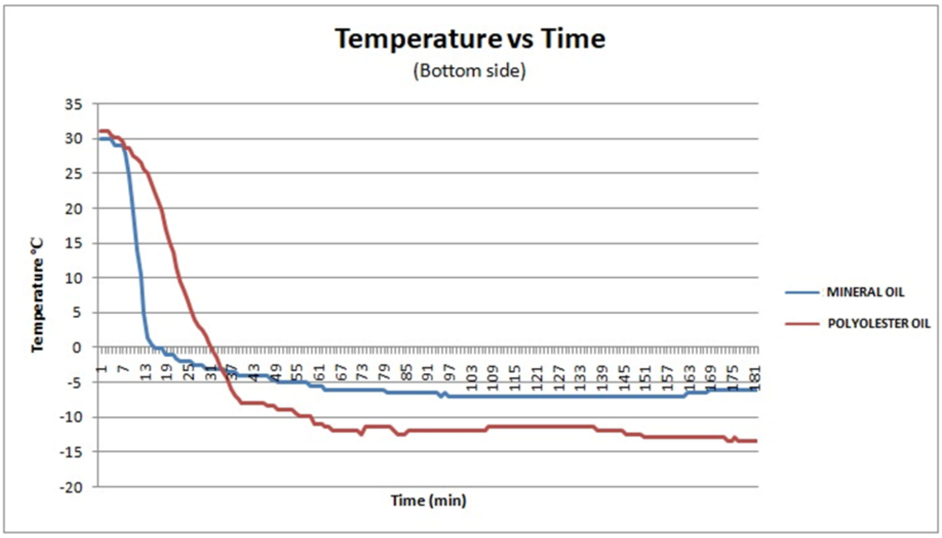

Figure XIV. Evaporator bottom side wall temperature.

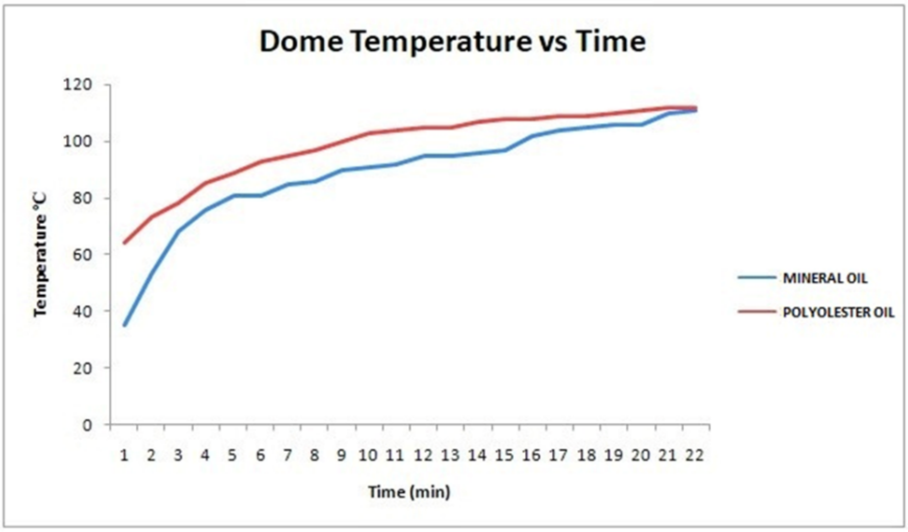

Figure XV. Compressor dome temperature.

The COP of the refrigerator is greater when POE oil is used, as opposed to when mineral oil is used. Because POE oil mixes better with R-134a, decreases heat exchanger oil film development, increases heat transfer, provides dependable oil return, and lowers compressor mechanical losses.

5. Validation by EES Software. -

5.1 Mineral Oil. - The performance analysis results are compared and validated by EES software. Three parameters of the present work, i.e., COP, refrigeration effect, and compressor power are validated with the EES software. Figure XVI shows the validation results i.e., COP, compressor power & evaporator capacity of the refrigeration system when using MO with R134a as a refrigerant. Figure XVII & Figure XVIII shows the ph & T-s plots for MO given by EES.

Unit Settings: SI C bar kJ mass deg

COP = 4.523 $\dot{m}$ = 0.0152 [kg/s] P = 0.4006 [kW] $\dot{Q}$ = 1.812 [kW]

Q_H = 189.5 [KJ/kg] Q_L = 119.2 [KJ/kg] W_c = 26.35 [KJ/kg]

Figure XVI. Validation of MO by EES software.

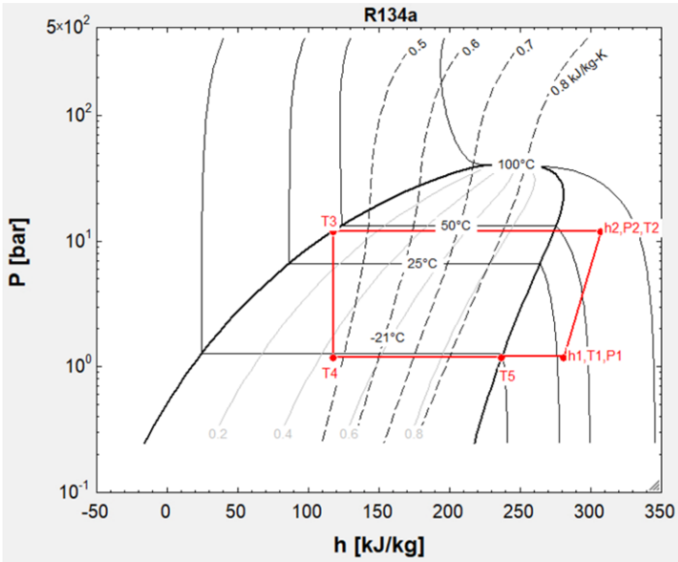

Figure XVII. ph plot for MO by EES software.

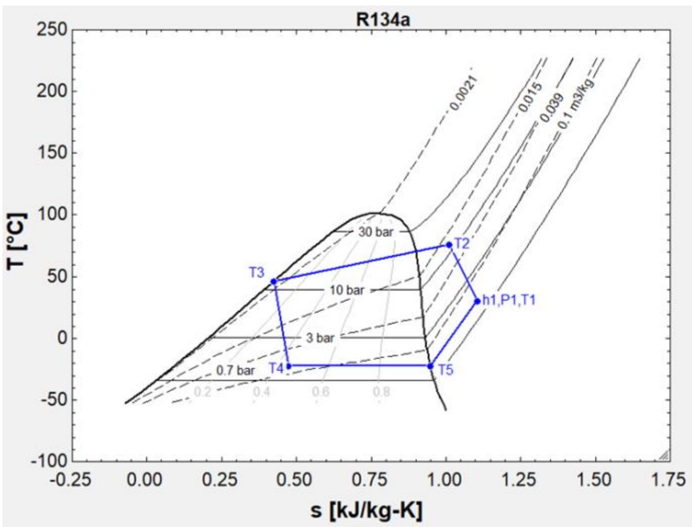

Figure XVIII. T-s plot for MO by EES software.

When compared with the values obtained from the ph chart in tables V, VI, and VII, it is evident that the EES software values validate the values obtained from the ph chart.

5.2 POE Oil. – Figure XIX depicts the validation results i.e., COP, compressor power & evaporator capacity of the refrigeration system when using POE oil with R134a as a refrigerant. Also, Figure XX & Figure XXI shows the ph & T-s plots for POE oil given by EES.

Unit Settings: SI C bar kJ mass deg

COP = 5.781 $\dot{m}$ = 0.0156 [kg/s] P = 0.343 [kW] $\dot{Q}$ = 1.983 [kW]

Q_H = 200.7 [KJ/kg] Q_L = 127.1 [KJ/kg] W_c = 21.99 [KJ/kg]

Figure XIX. Validation of Mineral Oil by EES software.

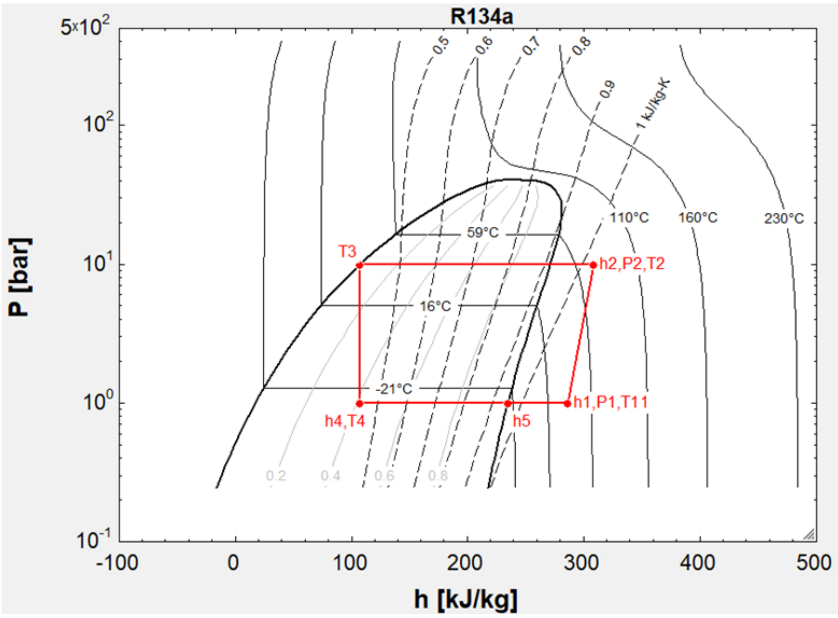

Figure XX. ph plot for POE oil by EES software.

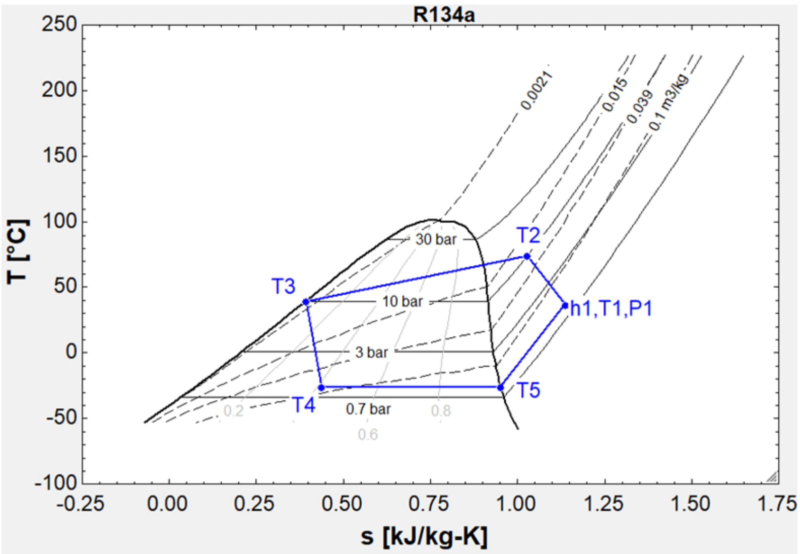

Figure XXI. T-s plot for POE oil by EES software.

5.3 Comparison of the results. - The COP, compressor power consumption & refrigeration effect of the refrigeration system with two different lubricating oils with the same refrigerant R134a using two different methods i.e., EES software and R134a Ph chart are listed in Table XI.

S/N	Compressor Lube oil	COP		Compressor power (kW)		Evaporator capacity (kW)	
		ph chart	EES	ph chart	EES	ph chart	EES
1	MO	4.958	4.523	0.370	0.400	1.8171	1.812
2	POE	5.795	5.781	0.340	0.343	1.9992	1.983

Table XI. Comparison of the performance parameters.

The percentage errors between the two methods i.e by using the R-134a ph chart and EES software for COP, compressor power and evaporator capacity are shown in Table XII.

S/N	Compressor Lube oil	Parameters	% Error
1	MO	COP	9.6
		Compressor Power	7.5
		Evaporator Capacity	0.28
2	POE	COP	0.24
		Compressor Power	0.87
		Evaporator Capacity	0.81

Table XII. Percentage error.

Figure XXII, Figure XXIII, and Figure XXIV represent the 3D graphs showing COP, compressor power consumption, and refrigeration effects when using both oils, i.e., POE and MO, and both methods, R-134a and EES software. This allows for an easy comparison of values at a glance.

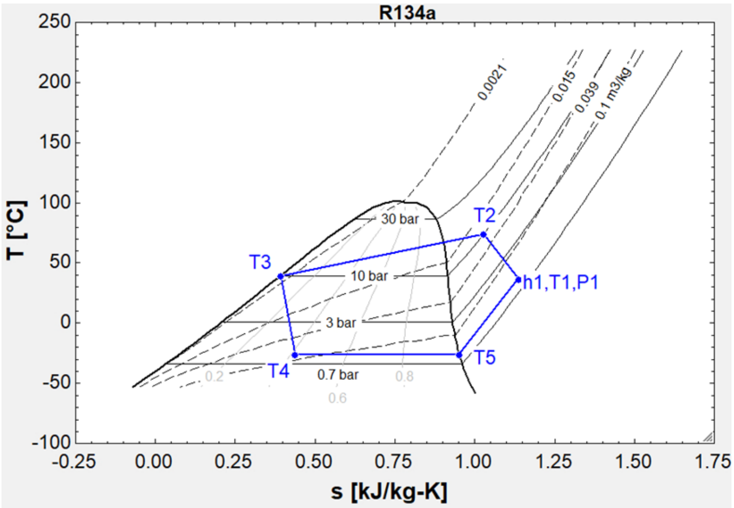

Figure XXII. COP (R134a ph chart vs EES).

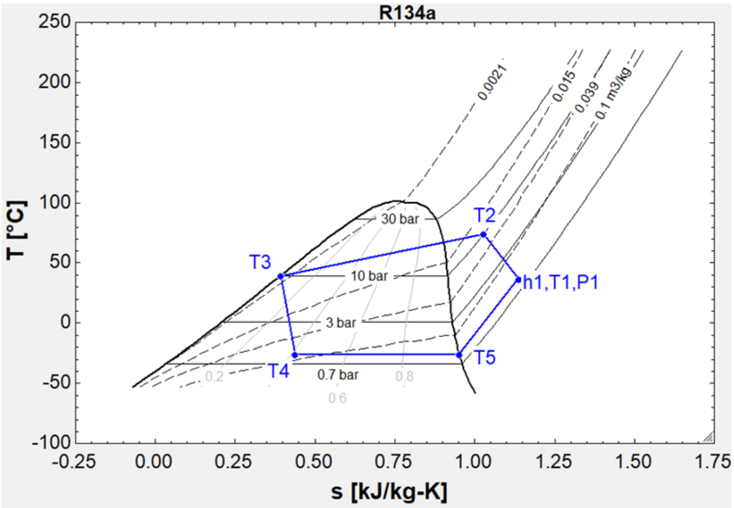

Figure XXIII. Compressor Power consumption (R134a ph chart vs EES).

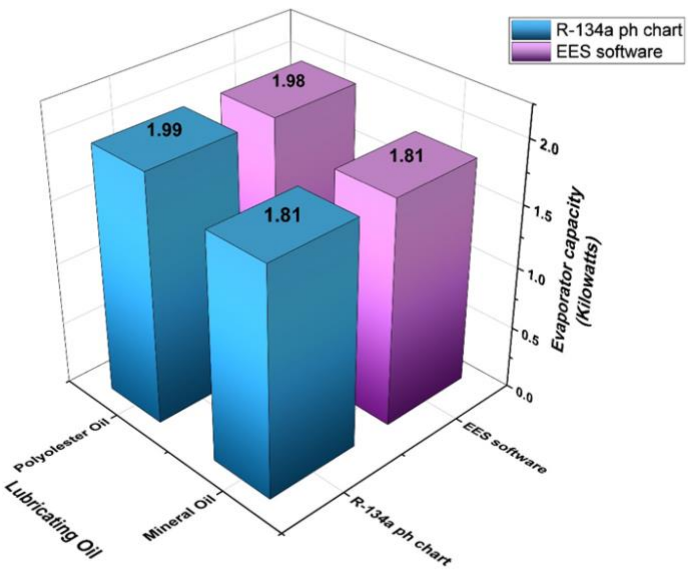

Figure XXIV. Refrigeration effect (R134a ph chart vs EES).

6. Conclusion. - Based on the experimental investigation and performance analysis of the domestic refrigerator using two different compressor lubricating oils i.e., Mineral Oil and POE oil, the following conclusions are noted keeping in mind the comparative analysis of the lubricating oil performance parameters with the same refrigerant R134a:

a. COP (Coefficient of Performance) is used to measure the efficiency of vapor compression refrigeration systems. The COP values were obtained manually using the ASHRAE Ph chart for R134a and validated by the EES program while using two different compressor lubricants, i.e., MO and POE. The error associated with these two methods is very less, as observed in Table XI. From Figure XXII, it is evident that the COP value obtained for MO is significantly less when compared to the COP value for POE; this is because of increased refrigeration effect as shown in Figure XXIV.

b. From Figure XI, it is evident that there is a considerable reduction in compressor power consumption while using POE lubricant. Around 30 watts less power is consumed when the compressor is shifted from MO to POE which is also depicted in Table XI. The difference in power consumed is due to enhanced lubricity. Changing the lubricant has significantly reduced the current consumed by the compressor, which is evident from Figure X.

c. Since refrigerant R134a is miscible with POE oil used, there is an increase in refrigeration from 1.817 KJ/s to 1.999 KJ/s. Moreover, the mass flow rate calculated is approximately the same using two different lubricants. Therefore, the increase in evaporator capacity indicated in Figure XII is due to an increase in the heat transfer rate from the air to the refrigerant in the evaporator.

d. The lubricant's thermophysical properties significantly impact refrigerator performance parameters. The properties of both lubricants are listed in the Table IX depict that MO will be carried along with the refrigerant into the system in more significant amounts, compared to POE, due to its decreased flash point and density. The oil inside the evaporator and condenser significantly decreases the heat transfer rate by creating an insulating effect. In contrast, POE oil has a high return rate to the compressor due to its miscibility with R134a. From Table IX, the increase in compressor suction temperature when POE is used suggests that heat transfer through the evaporator has enhanced. Hence, the refrigerant returned to the compressor has a high temperature. A similar effect can be observed for condenser outlet temperature.

e. The lowest shell temperature, i.e., 111 ºC, is obtained for the compressor charged with R134a and MO mixture indicated in Table X. In contrast, in Figure XV, the comparatively higher temperature curve shown in red is for the compressor charged with POE. The increase in compressor dome temperature is due to more excellent heat dissipation from the shell.

Experimental work and theoretical studies have been carried out in this research to investigate the performance of a VCRS using two different classes of compressor lubricants, namely MO and POE oil. Lubricant effects on system performance are easily measurable, as evidenced by the difference in performance parameters evaluated such as COP, evaporator capacity & compressor power consumption. The miscible POE oil outperformed an immiscible MO with R134a refrigerant. From Table XI, it could be concluded that the COP value obtained is higher for POE oil, implying that the factor of miscibility has positive effects on system performance. System reliability should not be the only priority when selecting a compressor lubricant but also enhanced system performance and efficiency.

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Author contribution:

1. Conception and design of the study
2. Data acquisition
3. Data analysis
4. Discussion of the results
5. Writing of the manuscript
6. Approval of the last version of the manuscript

MEuH has contributed to: 1, 2, 3 4, 5 and 6.

ASK has contributed to: 1, 2, 3 4, 5 and 6.

AAK has contributed to: 1, 2, 3 4, 5 and 6.

MAI has contributed to: 1, 2, 3 4, 5 and 6.

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