World Applied Sciences Journal 32 (9): 2005-2010, 2014
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2014.32.09.1269

Effect of Lubricating Oil on the Performance of Vapour Compression Refregiration System

[1]G. Kiranmai, [2]K. John Samuel, [2]G. Edison and [2]V. Jagan

[1]Govt. Polytechnic, Rayadurg andhra Pradesh, India, 515865
[2]VIT University, Vellore, Tamilnadu, India, 632014

Abstract: In any compressor, refrigeration oil absorbs heat generated during its operation. Conventional refrigerators have hermetically sealed compressors that require lubricating oil having excellentthermal properties and provide good serviceability.The present experimental work focuses on compressor performance for three different oils like mineral oil ISO 32, PolyolesterISO 22 and poly alkylene glycol ISO 46. The amount of oil used is also varied to find the optimum value of oil used for better lubrication. The experiments are conductedona refrigeration system with capacity 165 liters to evaluate compressor work and performance parameters. The results show that the PAG oil ISO 46 and POE oil ISO 22 are the best choices when compare to Mineral oil ISO. The refrigeration system C.O.P is maximum for PAG oil ISO 46 and its optimum quantity is 200ml for 65 grams of R134a.

Key words: Lubricating Oil · COP · Mineral oil · PAG Oil · PAE Oil

INTRODUCTION

In order to lubricate the moving parts of the compressor, oil is added to the refrigerant during installation or commissioning. The type of oil may be mineral or synthetic to suit the compressor type. Also, it is chosen so as not to react with the refrigerant type and other components in the system. In small refrigeration systems, the oil is allowed to circulate throughout the whole circuit, but care must be taken to design the pipe work and components such that oil can flow back under gravity to the compressor. In larger distributed systems, especially in retail refrigeration, the oil is typically captured at an oil separator immediately after the compressor and is in turn re-delivered, by oil level management system, back to the compressor. Oil separators are not 100% efficient so system pipe work must still be designed so that oil can drain back by gravity to the oil separator or compressor.

Compressor Lubrication: Oil-Refrigerant Mixture: In the middle of the last century Bambach [1] and Spauschus [2] demonstrated that the performance of the refrigeration system depends upon the quantity and the type of compressor oil, circulating in the system with the refrigerant. Mainly in the 80s and 90s, several studies related to oil–refrigerant mixture started being developed. Some of these works were directed towards the determination of the thermo physical properties of the mixtures [3-10]. Other researchers concentrated their studies on the behavior of refrigerant flows contaminated with lubricating oil (refrigerant-rich mixtures) with the objective of analyzing the influence of the oil in the mixture flow and heat transfer dynamics in compressors, evaporators, condensers and capillary tubes [11-15].

The important properties considered while selecting lubricating oil in refrigerant compressors are:

- Chemical Stability
- Pour/floc points
- Dielectric strength and
- Viscosity

In addition to the above, the nature of the refrigerant used, type and design of the compressor, evaporator and compressor discharge temperatures must be considered while selecting suitable lubricating oils. The oil should not undergo any chemical changes for many years of operation. This aspect is especially critical in hermetic compressor where, oil change is for ten years or more.

Corresponding Author: K. John Samuel, School of Mechanical and BuildingSciences (SMBS), VIT University, Vellore-632014, India. Tel: +91-9043456902.

The chemical stability of the oil is inversely proportional to the number of unsaturated hydrocarbons present in the oil. For refrigerant compressors, oils with a low percentage of unsaturated hydrocarbons are desirable.

The floc point of the oil is the temperature at which wax will start to precipitate from a mixture of 90% R12 and 10% oil by volume. In the case of refrigerants such as R12, viscosity of oil is reduced, as a refrigerant is soluble in oil. The floc point of the oil is a measure of the tendency of the oil to separate wax when mixed with an oil-soluble refrigerant. Hence, it is an important parameter to consider while selecting lubricating oils for these refrigerants. The concentration of oil in the refrigerant should be kept below 10percent with these refrigerants. Floc point is not necessary in case of refrigerants that are not soluble in oil (e.g. ammonia).

Dielectric strength of the oil is a measure of its resistance to the flow of electric current. It normally expresses the voltage required to cause an electric arc across a gap of 0.1 inch between poles immersed in oil. Since impurities such as moisture, dissolved solids (metallic) reduce the dielectric strength of oil, a high dielectric strength is an indication of the purity of the oil. This parameter is very important in case of hermetic compressors as oil with low dielectric strength may lead to shorting of the motor windings.

The viscosity of the oil is an important parameter in any lubricating system. The viscosity of the oil is maintained within a specified range for the lubrication system to operate efficiently. If the viscosity is too low then, the wear between the rubbing surfaces will be excessive; in addition to this it may not act as a good sealing agent to prevent refrigerant leakage. However, if the viscosity is too high then fluid friction will be very high and the oil may not fill the Small gaps between the rubbing surfaces, again leading to excessive wear. The problem is complicated in refrigerant compressors as the viscosity of the oil varies considerably with temperature and refrigerant concentration. The oil viscosity increases as temperature and concentration of refrigerant decrease and vice versa.

Compressor Lubricants: The choice of a compressor lubricant depends on the type and construction of the compressor, the gas being compressed, the degree of compression and the final outlet temperature. Piston compressors provide the highest gas pressures and are among the most difficult from the standpoint of cylinder lubrication. Rotary compressors with final pressures belowonemega Pascal (Mpa), approximately 145 psi, are less difficult to lubricate.Rotary vane compressors require the use of antiwear oil because R&O oil is often insufficient for the crankcase splash lubrication of a reciprocating compressor. The selection of the proper compressor and application-dependent lubricant with the appropriate physical-chemical properties is vital to a successful process.

Fig. 1: Experimental set-up

Experimental Set-Up & Procedure: This work focuses the effect of compressor oil on the performance of compressor and evaporator and to what extent it influences the performance of therefrigerationsystem. In order to know the performance characteristics of the vapor compression refrigerating system, the temperature and pressure gauges are installed at each entry and exit of the component. Experiments are conducted by changing quantity of compressor oil for three different types with thesameamount of refrigerant.

Fig. 1 Shows the experimental setup used for experimentation.

Table 1 and 2 shows the Specifications of compressor and properties of Oils used in this study.

The following procedure is adopted for theexperimental setup of the vapor compression refrigeration system:

- The domestic refrigerator is selected, working on vapor compression refrigeration system.
- Pressure and temperature gauges are installed at each entry and exit of the components.
- Pressurized nitrogen gas does flushing of the system.
- R 134a refrigerant is chargedinto the vapor compression refrigeration system.

Table 1: Specifications of Reciprocating Compressor used in this study

Compressors Model	THK 1340 YCF
Number of Cylinders	1
Displacement per rev (cc)	4
Cooling capacity (Btu/Hr)	365
Rated conditions Current (amps)	0.8
Power (watts)	94
Weight (kg)	7.7

Table 2: Properties of lubrication oils

S.No	Type	Viscosity at 40 °C (cSt)	Density (kg/m^3)
1	Mineral oil ISO 32	32	857
2	POE oil ISO 22	23.5	991
3	PAG oil ISO 46	46	861

Table 3: Experimental values for Mineral oil

S.No	R-134a & refrigerant oil	Quantity	Compressor inlet pressure kg/cm^2	Compressor outlet pressure kg/cm^2	Compressor inlet temperature °C	Compressor outlet temperature °C	Condenser outlet temperature °C
1	Mineral oil ISO 32	180	0.5	13.2	27.9	72.5	36.5
2.		200	0.46	12.7	29.2	71.6	35.4
3.		220	0.38	11.9	30.125	71.1	34.2

Table 4: Experimental values for POE oil

S.No	R-134a & refrigerant oil	Quantity	Compressor inlet pressure kg/cm^2	Compressor outlet pressure kg/cm^2	Compressor inlet temperature °C	Compressor outlet temperature °C	Condenser outlet temperature °C
1.	POE oil ISO 22	180	0.3	11.35	31.825	71.3	34.2
2.		200	0.28	10.05	32.625	69.4	33.1
3.		220	0.23	10.025	32.05	68.1	32.6

Table 5: Experimental values for PAG oil

S.No	R-134a & refrigerant oil	Quantity	Compressor inlet pressure kg/cm^2	Compressor outlet pressure kg/cm^2	Compressor inlet temperature °C	Compressor outlet temperature °C	Condenser outlet temperature °C
1.	PAG oil ISO 46	180	0.28	11.73	33.73	72.2	35.66
2.		200	0.22	11.26	31.73	71.6	35.66
3.		220	0.2	11.2	31.36	70.4	36.03

- Leakage tests are done by using soap solution, In order to further test the condenser and evaporator pressure, purging for 12 hours showed that there are no leakages present.
- The refrigerator is switched on and after 2 hours of observation,pressure and temperature readings at each sectionare noted.
- In the first step, the performance of the system is evaluated with R134 with 65 grams and mineral oil ISO 32 for compressor lubrication with three quantities (like 180 ml,200 ml,220 ml) and Temperature and pressure gauge readings are noted and the performance is evaluated.
- The refrigerant charge(quantity) is fixed in the system and for each lubricating oil at different oil quantities 4 readings are taken at constant time intervals and the average value is taken.
- In the second stage, the performance of the system is evaluated with R134 with 65 grams and Polyol esters (POE ISO 22) as compressor lubricant for three quantities (like 180 ml, 200 ml, 220 ml) and Temperature and pressure gauge readings are noted and the performance is investigated.
- In the third stage, the performance of the system is evaluated with R134 with 65 grams and poly alkylene glycols (PAG ISO 46) as compressor lubricant for three quantities (like 180 ml, 200 ml, 220 ml) and Temperature and pressure gauge readings are noted and the performance is investigated.

From the above experimental data set the values are tabulated for mineral oil, PAE and PAG oil.

Table 3, 4 and 5 shows the experimental values obtained for different oils used in different quantities.

RESULTS AND DISCUSSIONS

In the present experimental investigation, the performanceofRefrigeration systemhasbeenevaluated with change in oil and oil quantities. The performance varies considerably with a change of oil quantity with constant refrigerant quantity and its effect on evaporator temperature and compressor shell temperature has been plotted.

Effect of Mineral Oil on Performance: Figure 2 shows the variations in Evaporator temperatureand quantity of oil used for mineral oil. The values of evaporator temperature are used to find the cooling effect. The graph pattern for all the three different quantities of mineral oil kept rising withnumber of readings taken.It is evident from the graph that the cooling effect is more for 220ml quantity of compressor oil and it is less for 200ml quantity while the cooling effect for 180 ml of mineral oil is in between the two.

Figure 3 shows less compressor shell temperature for 220 ml quantity of compressor mineral oil. From the graph, it is evident that for mineral oil at different quantities the compressor shell temperature remained same. The value for 200ml quantitylies in middle &compressor shelltemperature is more for 180 ml quantity when compared with other two.

Effect of POE Oil on Performance: Figure 4 shows the plot for Evaporator temperatureand oil quantityfor POE oil. From the graph, it is evident that the cooling effect is more for 200ml quantity of POE oil and the cooling effect is less 180 ml and in between these two values for 220 ml of POE.

Figure 5 shows the variations in Compressor shell temperature with different proportions of POE oil quantity. From the plot, we can say that less compressor shell temperature for 220 ml quantity of compressor oil is more, less for 180 ml and intermediate for 200 ml.

Effect of PAG Oil on Performance: The variations between the Evaporator temperature and PAG oil quantity is plotted in Figure 6. The figure shows that cooling effect is more for 200ml quantity of compressor oil and it is less for 220ml and 180ml quantities.

Figure 7 shows the plot between compressor shell temperature and quantity of PAG oil. It is observed that for 200 ml quantity of compressor oil and it is equal to 220ml quantity& temperature is more for 180 ml quantity.

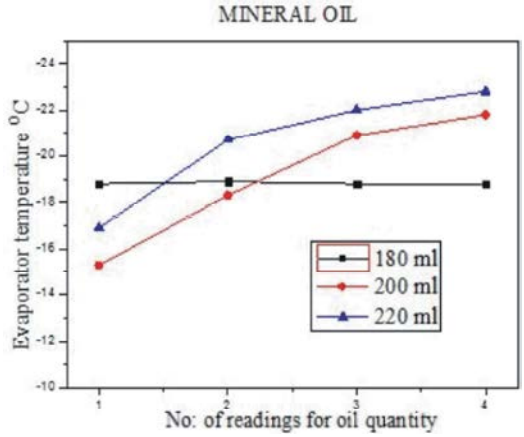

Fig. 2: No: of readings for Oil Quantity (ml) vs Evaporator temperature (°C)

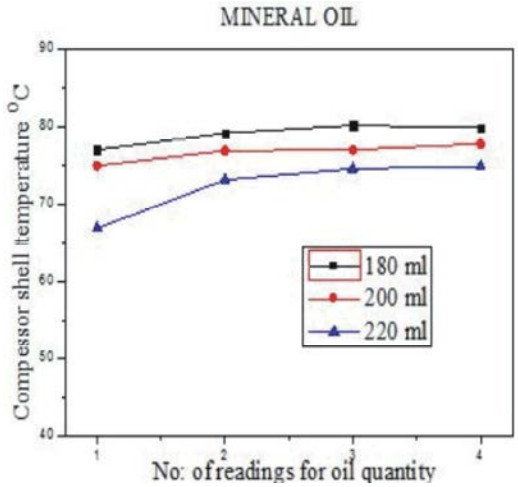

Fig. 3: No: of readings for Oil Quantity (ml) vs Compressor Shelltemperature (°C)

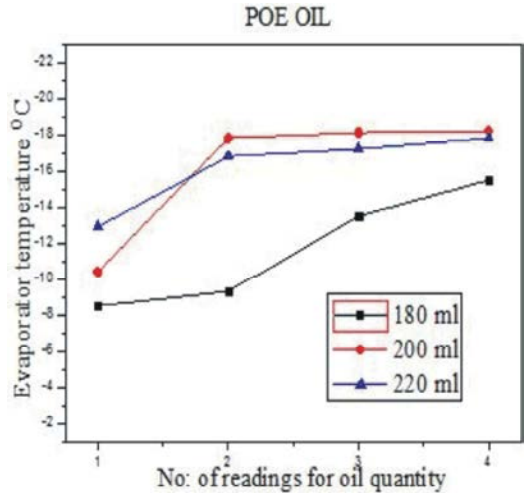

Fig. 4: No: of readings for Oil Quantity (ml) vs Evaporator temperature (°C)

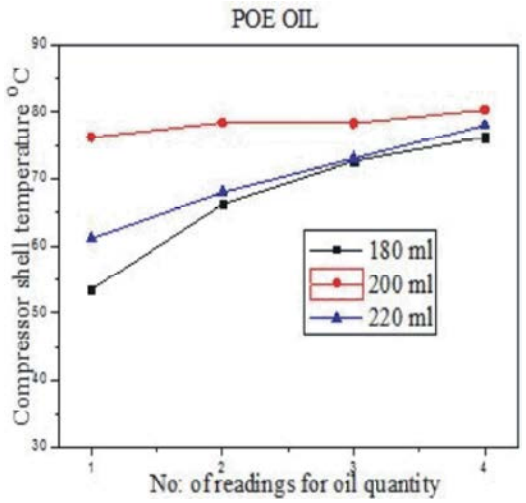

Fig. 5: No: of readings for Oil Quantity (ml) vs Compressor Shelltemperature (°C)

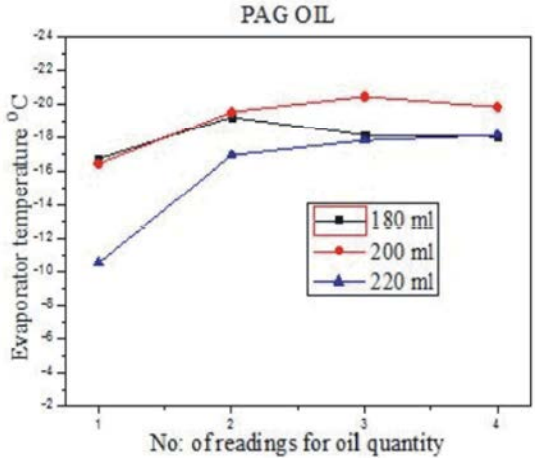

Fig. 6: No: of readings for Oil Quantity (ml) vs Evaporator temperature (°C)

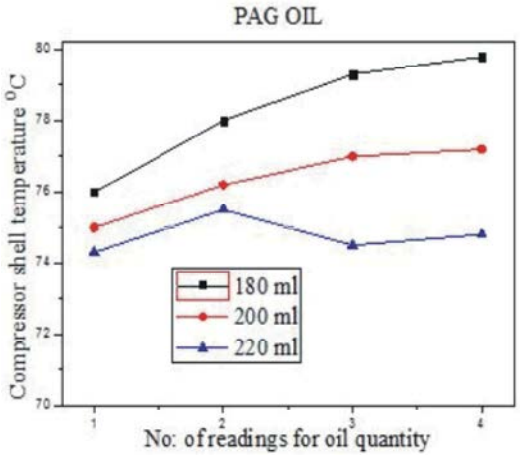

Fig. 7: No: of readings for Oil Quantity (ml) vs Compressor Shelltemperature (°C)

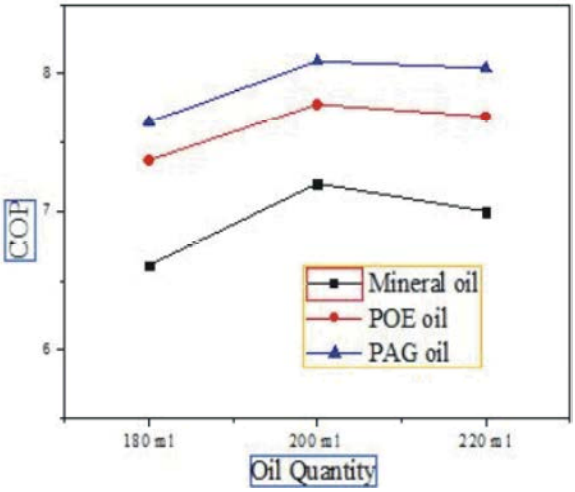

Fig. 8: Comparison of COP

From the above discussions, we can observe that 200ml quantity is the optimum quantity for all oils and in these PAG oil has more cooling effect and less compressor shell temperature with 200ml quantity.

CONCLUSIONS

In the present work experimental investigations were carried out to investigate the performance of vapor compression refrigeration system of a domestic refrigerator of 165 liters capacity, with R-134a as refrigerant and three types of compressor oils. From Figure 8, it can be said thatPAG oil has high COP when compared with remaining two oils and it is seen that for 200 ml has high COP. Therefore from this experimental work the optimum quantity of compressor oil is 200 ml for 65 grams of R134a. If quantityof oil is increased the COP decreases because there is achance of compressor oilentering into evaporator and capillary tube, it may block the valves and filters.From this experiment it is observed that there is an effect of compressor oil on the performance of refrigerator system and also the COP is maximum for PAG oil and optimum quantity is 200ml for 65 grams of R134a when comparedwith othertwo oils. Considering all aspects like evaporator temperature andcompressorshell temperature PAG oil and POE oil are the best choice over Mineral oil.

REFERENCES

1. Bambach, G., 1955. “Das Verhalten von Mineral oil - F12,” Kaltemachinen Abhandlung, 9: 17-21.

2. Spauschus, H.O., 1963. "Thermodynamic properties of refrigerant–oil solutions," ASHRAE J., 5: 47-52.
3. Martz, W.L., C.M. Burton and A.M. Jacobi, 1996, "Local composition modeling of the thermodynamic properties of refrigerant and oil mixtures," International Journal of Refrigeration, 19(1): 25-33.
4. Grebner, J.J. and R.R. Crawford, 1993. "Measurement of pressure temperature-concentration relations for mixtures of R12/mineral oil and R134a synthetic oil," ASHRAE Transactions, 99: 387-396.
5. Thomas, R.H.P. and H.T. Pham, 1992. "Solubility and miscibility of environmentally safer refrigerant / lubricant mixtures" ASHRAE Transactions, 98: 783-788.
6. Baustian, J.J., M.B. Pate and A.E. Bergles, 1986. "Properties of oil–refrigerant mixtures liquid with applications to oil concentration measurements," Thermo-physical and transport properties ASRHAE Transactions., 92: 55-73.
7. Thome, J.R., 1995. "Comprehensive thermodynamic approach to modeling refrigerant–lubricant oil mixtures," HVAC & R. Research, 1(2): 110-126.
8. Van Gaalen, N.A., M.B. Pate and S.C. Zoz, 1990. "The measurement of solubility and viscosity of oil/refrigerant mixtures at high pressures and temperatures: test facility and initial results for R22/naphthenic oil mixtures," ASHRAE Transactions, 96(2): 183-190.
9. Van Gaalen, N.A., M.B. Pate and S.C. Zoz, 1991a. "The solubility and viscosity of solutions of R502 in a naphthenic oil and an alkyl benzene at high pressures and temperatures," ASHRAE Transactions, 97(2): 5100-108.
10. Van Gaalen, N.A. and S.C. Zoz, 1991b. "The solubility and viscosity of solutions of HCFC-22 in a naphthenic oil and an alkyl benzene at high pressures and temperatures," ASHRAE Transactions, 97(1): 285-292.
11. Schlager, L.M., M.B. Pate and A.E. Bergles, 1987, "A survey of refrigerant heat transfer and pressure drop emphasizing oil effects and in-tube augmentation," ASHRAE Transactions, 93: 392-415.
12. Jensen, M.K. and D.L. Jackman, 1984. "Prediction of nucleate pool boiling heat transfer coefficients of refrigerant-oil mixtures," Journal of Heat Transfer, 106: 184-190.
13. Wallner, R. and H.G. Dick, 1975. Heat transfer to boiling refrigerant-oil mixtures. In: Proc. International Congress of Refrigeration, 2: 351-359.
14. Hambraeus, K., 1995. "Heat transfer of oil-contaminated HFC134a in a horizontal evaporator," International Journal of Refrigeration, 18: 87-99.
15. Motta, S.F.Y., J.A.R. Parise and S.L. Braga, 2002. "A visual study of R404a/oil flow through adiabatic capillary tubes" International Journal of Refrigeration, 25: 586-596.