Lubricant for refrigeration systems

In refrigeration systems, lubrication has crucial role on performance of the system and the selection of the right lubricant for the refrigeration system is very important. The choice of lubricant depends on the system, the refrigerant type and application. The lubricants which are commonly used in refrigeration systems include mineral oil (MO), polyol ester oil (POE), polyalkylene glycols oil (PAG), poly-alfa olefin oil (PAO), alkyl benzene oil (AB), poly222vinyl ether oil (PVE), etc. A lubricant in a refrigeration system plays different roles such as lubricating internal parts of the compressor, contributing in heat removal from compressor, and also sealing and cleaning the system, etc [1]. To investigate the acceptability of the lubricants to be used in the refrigeration systems, the parameters including the miscibility, viscosity, stability and compatibility must be taken into consideration. This factors have important influence on a sufficient lubrication of the refrigeration system. In fact, an improper selection of a lubricant may cause some problems in the refrigeration system. For example, when the viscosity of the lubricant-refrigerant blend is too low, friction and wear may increase due to incomplete or ineffective separation of the metal surfaces. On the other hand, when the viscosity is too high, it may cause a reduction in pumping efficiency due to the obstructed flow. Another example of the inefficient use of lubricant is the oil entrapment which may lead to a poor oil return and consequently oil starvation [2], and also a reduction in the heat exchange effectiveness in the heat exchangers), often, it is possible to add an oil separator after the compressor to decrease the lubricant flow into the heat exchangers. About the miscibility factor, for partly miscible oils and refrigerants, separation in the condenser may occur which could lead to the appearance of a refrigerant-rich phase and an oil-rich phase. In the oil-rich phase, the oil accumulation in the refrigerant reservoir can happen, while the refrigerant-rich phase is carried over to the expansion valve. This may cause a restriction of oil return to the compressor. Also, the problem of wax formation and consequently phase separation should be taken into account when the lubricant is subjected to low temperature in the evaporator. It is also observed that a low solubility of the refrigerant in oil may cause the problem of oil retention to the compressor.

Selecting basestocks

According to the refrigeration industry, mineral oils and synthetic alkylbenzenes were the lubricants of choice in the systems operating with CFCs, HCFCs and hydrocarbons due to their compatibility and miscibility with these lubricants. The regulations and legislative acts adopted by the European Union resulted in the phase-outs of CFC and HCFC refrigerants. Then, the refrigeration industry employed HFCs and later, their low-GWP alternatives, HFOs, in the refrigeration systems. But, for the highly polar HFC and HFO refrigerants, alkylbenzenes and mineral oils lubricants were insufficient due to the low polarity. To solve this problem, POEs and PAGs are proposed as appropriate lubricants for HFCs and HFOs.

In refrigeration systems operating with **HFCs**, the lubricants basestocks are primarily based on POEs and PAGs (POEs as the choice for most stationary systems while PAGs for automotive air conditioning systems). Considering the compatibility of **HFOs** such as R1234yf with lubricants, POEs are the lubricants of choice, while it is not recommended to use mineral oils in HFO refrigeration systems.

Hygroscopic characteristic (the ability of the oil to absorb moisture) of POE and PAG lubricants makes it essential to consider special care in manufacturing, storing and using these oils to avoid chemical reactions in the system such as hydrolysis in POE. For Example, hydrolysis in POE oil causes the decomposition of the oil into partial esters, organic acid and alcohol in the presence of water. Comparing to POE oils, PAGs are more hygroscopic, but this oil does not undergo hydrolysis in the presence of water.

In **ammonia** refrigeration systems, the lubricant must provide good fluidity at low temperatures and yet still maintain good film thickness at operating temperatures, so a high viscosity index is desirable. When using ammonia in refrigeration systems, most of the oils are not miscible with this refrigerant. In these systems, the use of oil separator is necessary as the miscibility of oil and refrigerant during the liquid phases is not possible. In ammonia refrigeration system, non-soluble/miscible oils are advantageous, so, PAOs and mineral oils are of choice lubricants to use with ammonia [3], and also alkylated benzene particularly when working at low temperature. PAOs also can be used in blends with mineral oils in ammonia refrigeration systems.

In the refrigeration systems operating with **carbon dioxide**, extreme mechanical stress on moving parts and bearings are expected due to the much higher service pressures than halogenated refrigerants. CO2 is extremely soluble in oils and consequently remarkable drops in viscosity and breaking down of the oil film are expected. The lubricants of choice for CO2 systems are POE and PAG oils [1], while the lubricant oils which are not suitable for the refrigeration systems working with CO2 include mineral oil, PAO and alkyl benzene. When using PAGs, the viscosity drop in the system is not as noticeable as the time POEs are used. Reduced viscosity in the case of using POEs may have negative influence on the lubrication in some parts of the compressor specially at start-up. Specially designed POEs for CO2 systems are developed to withstand the high solvency of the CO2 to minimize the improper sealing of clearances and loss of compression caused by inadequate lubrication. It also should be noted that, to avoid the acidification of the oil, the water content in the refrigeration systems operating with CO2 should be controlled to be less than 5 ppm. **Hydrocarbons** have very low GWP, good material compatibility and excellent thermodynamic properties, but, these refrigerants have high flammability (belonged to safety category A3). Mineral oils and POEs are of choice for the refrigeration systems operating with hydrocarbons as these refrigerants have high solubility with mineral and ester oils. At very low temperatures, the lubricants for HC refrigeration systems are required to have a very low pour point (indicating the lowest temperature at which a lubricant is designed to flow) and also a very low vapour pressure. For these applications the common choices are PAG and PAO. Table 1 shows how some lubricant chemistries perform with the refrigerants [3] and Table 3 represents the lubricants of choice for some low-GWP (≤750) refrigerants [4].

	Traditional oils				New lubricants			
	Mineral oil	Alkylbenzene	Mineral oil + alkylbenzene	poly-alpha olefin (PAO)	Polyolester (POE)	Polyvinyl-ethe (PVE)	Polyalkylene glycols (PAG)	Hydro cracke mineral oil
HCFC	Good suitability	Good suitability	Good suitability	Application with limitations	Application with limitations ⚠+VG	Not suitable	Not suitable	Not suitable
HFC + blends	Not suitable	Application with limitations	Not suitable	Not suitable	Good suitability	Good suitability	Application with limitations ⚠	Not suitable
HFC/HC blends	Suitability dependant on system design	Suitability dependant on system design	Suitability dependant on system design	Not suitable	Good suitability	Good suitability	Not suitable	Not suitable
HFO + HFO/HFC blends	Not suitable	Not suitable	Not suitable	Not suitable	Good suitability AD	Good suitability AD	Not suitable	Not suitable
HC	Good suitability VG	Application with limitations VG	Application with limitations VG	Good suitability VG	Good suitability VG	Not suitable	Application with limitations ⚠	Not suitable
NH3 . R723	Good suitability	Application with limitations	Application with limitations	Good suitability	Not suitable	Not suitable	Application with limitations ⚠	Good suitability
CO2	Not suitable	Not suitable	Not suitable	Suitability dependant on system design	Good suitability AD	Not suitable	Good suitability AD	Not suitable

Good suitability; Application with limitations; Suitability dependant on system design; Not suitable; ⚠ Especially critical with moisture; VG Possible higher basic viscosity; AD special formulation

Table 1: Lubricant Options for Refrigerant Chemistry (adopted from [3])

Regarding the use of PAG and PVE lubricants it should be noted that PAG oils exhibit relatively low dielectric strength and it makes them to be less suitable for semi-hermetic and hermetic compressors. PVE oils have high dielectric strength and good stability (thermally and chemically), despite the higher hygroscopic character than POEs. PVEs are being increasingly employed as lubricants in compressors for factory-made air conditioners and chillers, and PAG oils are more suitable for mobile air conditioning systems with open drive compressors [3]. In electric vehicle ACs, R1234yf is developed and introduced as electric vehicle industry standard (as low GWP drop-in alternative to R134a). The main concern in using R1234yf is that it is more chemically reactive than R134a, so, the lubricant of choice must have suitable stability properties to neutralize the reactivity behavior of the refrigerant. Other major factors in right selection of the lubricant including the suitable miscibility, compatibility, etc with respect to the refrigerant type should also be taken into account. In this case, PAG oils have the most preferential properties and are the lubricant of choice for electric vehicle ACs [5].

Table 2. Lubricants for some low-GWP refrigerants (adopted from [4])

ASHRAE #	GWP	Replaces	Lubricant
R1234yf	1	R134a	Alkylbenzene, Synthetic (POE, PAG)
R1234ze	1	R134a	Alkylbenzene, Synthetic (POE, PVE, PAG)
R455A	146	R404A-R507	Synthetic (POE)
R450A	547	R134a-R401A R401B-R409A	Synthetic (POE)
R1233zd	1	R123	Alkylbenzene Mineral oil Synthetic (POE, PVE)
R466A	733	R410A	Synthetic (POE)

It can be concluded that each lubricant has its own advantages and limitations in working with specific refrigerant types and a careful consideration is required to select the right lubricant basestocks.

Reference

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