LUBRICATION OF SCREW-TYPE PROCESS COMPRESSORS

Selection of the Correct Lubricant is Decisive Not Only for Reliable Machine Operation but also for the Profitability of the Processing Plant as a Whole

By Holger Körber

Klüber Lubrication München specializes in the formulation of lubricants for all types of compressors used in the process industry. Lubrication varies greatly for the different compressor types. In screw-type compressors, in particular, lubricating oil is in intense contact with the process gas. Long oil service life is a major requirement for this type of oil circulation system, as opposed to the total loss lubrication in reciprocating compressor cylinders.

Process gas compressors are used to compress a wide variety of different gases and gas mixtures, from inert gases, such as hydrogen, nitrogen or helium, via reactive gases, such as ammonia, methyl chloride or hydrogen sulphide through to hydrocarbon gases, such as methane, propane or heptane. Some gas mixtures may include moisture or acid components, such as hydrogen chloride or hydrogen sulphide.

These very specific and varying gas flows make lubricant selection a difficult task. While oxidation of the lubricating oil is a major problem in air compressors, reactions in gas compressors may be considerably more complex and far less predictable. Apart from chemical reactions between the gas and the lubricating oil, acidification of the oil, corrosion and sludge formation, the solubility of the process gases in the oil needs to be observed, as this may considerably affect oil viscosity during operation.

The possible problems resulting from these reactions include damaged bearings and rotors, corrosion, solid or sludge-type deposits, shortened oil- change intervals, high oil consumption, foam formation or even damage to downstream process catalysts, resulting in lengthy and costly compressor downtime and subsequent standstill of the entire process plant.

Component Wear and Viscosity Reduction

Certain gases may dissolve in lubricating oils under pressure and thus reduce the oil's viscosity. This can lead to undesirable wear of compressor bearings and rotors.

This effect is explained quite clearly in the following example: carbon dioxide gas is dissolved in beer under pressure and escapes from the beer upon decompression — i.e., when the bottle or can has been opened — through foaming. In the same way, when pressure is applied, process gases are dissolved into the lubricating oil in a compressor and separated from the oil once again as pressure drops, which usually manifests itself in the formation of foam.

In this context, the following rule applies: the better the solubility of the gas in the lubricant, the more significant the viscosity reduction of the oil. The solubility of gases into lubricating oils depends largely on the following factors:

Holger Körber is Industry Group Manager at Klüber Lubrication München KG.

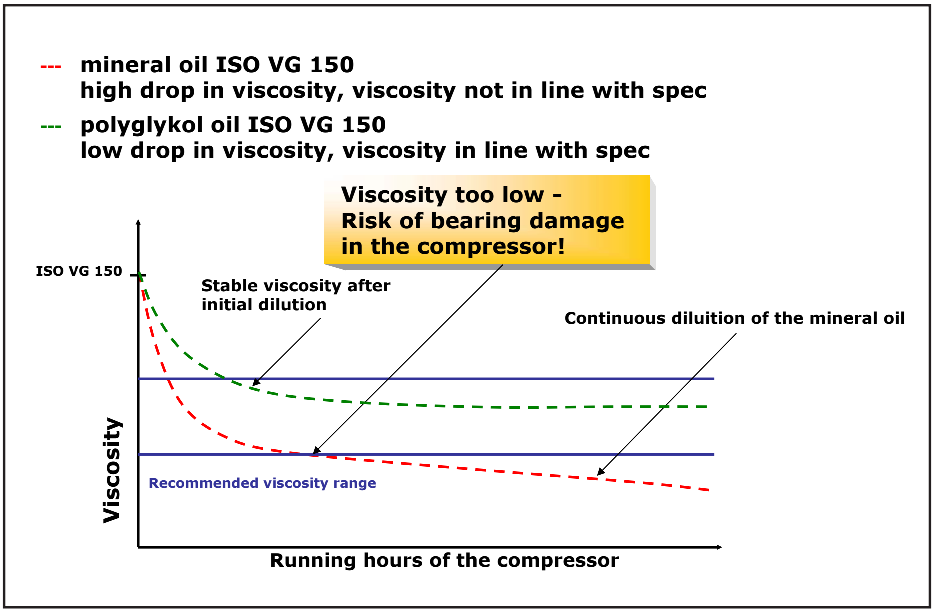
■ **Rotary screw compressor in a sound proof housing in a refinery.**

1. Pressure: the higher the compression, the higher the tendency of the gas to be dissolved in the oil.
2. Temperature: the higher the compression temperature, the lower the tendency of the gas to be dissolved in the oil.
3. Polarity of oil and gas: as a rule, polar gases have a higher tendency to be dissolved in polar lubricating oils than homopolar gases, and vice versa, homopolar gases are more easily dissolved in homopolar oils than in polar oils.
4. Molecular weight of the gas: the higher the molecular weight of the gas, the higher its tendency to be dissolved in the oil and the higher the drop in oil viscosity. "Heavy" hydrocarbons, such as toluene C_7H_8, are more easily dissolved than "light" ones, such as methane CH_4 or propane C_3H_8.

The following example should provide a better understanding of this phenomenon.

The gas flow (indications in Mol %) to be compressed is 20.0% Methane CH_4; 9.0% Ethane C_2H_6; 22.0% Butane C_4; 26.0 % Propane C_3H_8; 13.0% C_5; 5.5% C_6; 4.0% C_7; 0.5% C_8+.

The compressor used is an oil-injected rotary screw compressor. The gas mixture is compressed from 7.25 to 87 psi (0.5 to 6.0 bar) at a temperature of approximately. 205°F (95°C). To lubricate the bearings, the compressor manufacturer stipulates a minimum oil viscosity of 0.015 in.^{2}/s (10 mm^2/s) at an oil temperature of 158°F (70°C), and for rotor lubrication a viscosity of at least 0.013 in.^{2}/s (8.5 mm^2/s) at 205°F (95°C) oil temperature. Ambient temperatures are between 32°F (0°C) and 113°F (45°C). The questions are: which lubricating oil is best suited for this type of gas mixture? What is the oil viscosity under its operating conditions once the gas has dissolved in the oil? Is the remaining vis-



■ **Figure 1. Viscosity curves of a polyglycol oil and a mineral oil for the compression of a hydrocarbon gas mixture.**

cosity sufficient to ensure reliable long-term operation of the compressor?

An answer to all these questions can be obtained by using a special calculation program for determining the solubility of each gas contained in the gas flow in the lubricating oil. The benefit is a precise forecast of oil viscosity under operating conditions and, hence, a stable lubricating film as well as reassurance for the responsible operators when commissioning and operating the compressor. The software for this complex calculation is available only from a specialist lubricant manufacturer like Klüber. It is based on years of hands-on experience, extensive calculations and many online viscosity measurements on operational gas compressors.

The solution for the above example was to use a polyglycol oil with a viscosity of ISO VG 150. During operation, the viscosity drops from 0.23 sq.in. (150 mm^2/s) to approx. 0.09 sq.in. (62 mm^2/s) at a temperature of 104°F (40°C). The viscosity attained at operating temperature is sufficient to ensure reliable lubrication of the compressor. The compressor should be operated with a final compression temperature of over 176°F (80°C) to prevent condensation of the heavy hydrocarbons (C6+).

If an ISO VG 150 mineral oil would be used for this application, problems would be imminent. Figure 1 reveals the decisive difference: it shows the viscosity curves of the polyglycol oil and the mineral oil for the gas flow to be compressed. As mineral oils are homopolar and dissolve homopolar hydrocarbon gases quite easily, the viscosity of the mineral oil drops much faster and considerably lower than that of the polar polyglycol oil. Moreover, there is no gas saturation point in the oil. During operation, the viscosity keeps dropping and eventually falls below the stipulated viscosity requirements. Wear protection is insufficient, and the compressor bearings or even the rotors may be susceptible to damage. The consequences are downtime of the compressor, and often of the entire process chain, resulting in high productivity losses.

Calculation of viscosity under operating conditions is essential to ensure long-term reliable operation of a compressor. Therefore, a lubricant specialist should be consulted to assist in the selection of the correct lubricating oil.

High Oil Consumption of the Compressor

Often, oil-injected screw compressors consume a relatively large amount of oil, which manifests itself in high oil re-fill quantities, resulting in increased maintenance and operating costs. Moreover, excessive oil consumption in a compressor may cause the formation of oil deposits in downstream components or damage the process catalysts.

For many processes, the specified maximum permissible oil content in the process gas is becoming stricter, a fact which should be considered when selecting the oil.

Quite often, the oil itself is the reason for relatively high oil consumption. If the oil is injected into a rotary screw compressor, it is not only used for lubrication, but also for the cooling of the gas flow. Some lubricating oils evaporate at the compressor operating temperatures, which may often be above 194°F (90°C). The oil vapor is carried along with the gas flow and — as opposed to the oil droplets in the gas flow — not collected by the oil separator. Hence, oil consumption depends, among other things, on the evaporation stability of the lubricating oil. As compared to synthetic oils, conventional mineral oils are characterized by a higher vapor pressure — i.e., they evaporate more easily — and thus lead to higher oil consumption.

Apart from the evaporation rate of the oil, its absorption in the gas flow also plays an important role. Oil molecules may be absorbed by the compressed gas and carried along with the gas flow. Here, the same rule applies as for solubility: homopolar oils are absorbed far easier by homopolar gases than polar oils and vice versa. Once oil has been absorbed into the gas flow, it will not be collected by the oil separator.

The effects of absorption and evaporation show that oil consumption of a compressor can be influenced by selecting the correct lubricating oil.

Some process gas compressor operators are interested mainly in oil refill quantities, while others would rather know the oil content in the compressed gas flow. Different interests with the same reason.

High Oil Vapor Content in the Gas Flow

Many industrial processes — in particular the compression of helium and nitrogen — will permit only very low oil content in the compressed gas flow. In this context, besides the effectiveness of the oil separator, the tendency of the lubricating oil to evaporate plays an important role. High oil consumption of the compressor usually goes hand in hand with high quantities of oil being carried along with the gas flow.

In extensive tests, the oil vapor content in a compressed air flow was measured and recorded over a period of 80 hours.

■ Oil container of a process gas compressor, covered with greenish sludge from reactions between the lubricating oil and the process gas.

There are variations around the factor 20 between specially developed synthetic oils and conventional mineral oils.

These measurements prove that by using specially developed compressor oils, the oil absorption into the gas flow can be reduced and the purity of the gas flow optimized, thus increasing reliability and long-term efficiency and effectiveness of the entire process.

Damage to the Process Catalyst

In many industrial processes, there are catalysts downstream from the compressor, which play an important role in the further processing of the gas flow. Traces of lubricating oil contained in the compressed gas flow may reduce the efficiency of those catalysts or even destroy them. This phenomenon is called “catalyst poisoning.”

In order to avoid this, the amount of oil in the gas flow should be as low as possible and the type of oil used should not be detrimental to the catalysts. Mineral oils, for example, contain unsaturated hydrocarbons and sulphur compounds, which may damage the catalyst. Some additives may also cause negative reactions, which may, in the longer term, lead to further damage.

To be on the safe side, special lubricating oils should be used, which, ideally, have been approved by the catalyst manufacturers, such as UOP. Lubricant manufacturers who specialize in this area, as Klüber, can offer suitable oils. The base oils and additives contained in their special lubricants have been carefully selected to ensure compatibility, in particular with the catalyst materials. These oils ensure reliable process operation and long and efficient operation of the catalysts.

Deposits in the Compressor

As mentioned before, process gases consist of a wide variety of gas mixtures. In the compressor, the individual components of these mixtures are in close contact with the lubricating oil injected into the compression chamber. Just as there are many different gas mixtures, lubricating oils may consist of different base oil types and additives. The lubricating oil, the additives and the gas flow together make up a colorful mixture of all sorts of different chemical elements. Hence, selection of the correct oil plays a decisive role when it comes to avoiding the formation of undesirable deposits.

This real-life example illustrates the extreme effects this may have:

In this particular case, the oil used for injection lubrication of a process gas rotary screw compressor was unsuitable for the gas flow. During the first 500 operating hours, the oil changed to a greenish color. Control of the compressor was lost, as the slide valve for volume flow control had stopped functioning. Shortly afterwards the current consumption of the drive motor increased and the compressor cut out.

When the oil container was opened, the operators soon realized why the compressor had stopped working: the screws and the entire oil system were covered in green sludge. The compressor had to be dismantled and sent back to the manufacturer for manual cleaning and repair. Obviously, the resulting downtime cost for the operator was immense. What can be done to prevent the formation of deposits? This requires a lot of experience and in-depth and detailed chemical know-how. Reactive gases may react with additives or unsaturated hydrocarbons contained in mineral oils, which may lead to the formation of many different reaction products. Possible consequences are acidification of the oil, precipitation, sludge formation and clogging of valves and other components.

Therefore, when selecting lubricating oil for a specific gas flow it is essential to consider the possible reactions. Often the gas flow contains aggressive components and potential hazards need to be assessed prior to the selection of the oil. What could happen, what could be the results and what can be done to ensure effective monitoring during compressor operation? Consideration of all these questions will provide us with the optimum solution, thus saving the operator any unwanted surprises, aggravation, downtime and repair costs. Particularly in these cases, the practical experience of the lubricant supplier is vital in achieving the right conclusions.

Summary

Selection of the correct lubricant for oil-injected process gas screw-type compressors has a great impact on the reliability and profitability of the entire process plant. Thanks to extensive and detailed chemical know-how, a great deal of practical experience and specially designed lubricating oils, the lubricant specialist today is able to check and predict the effects of the gas flow on the lubricant. The costs for a tailor-made service package including in-depth consulting, gas flow analyses, on-site support and the lubricating oil will pay off, even if only one short, unplanned downtime period can be avoided. In many cases, such a partnership between OEM, operator and lubricant specialist, over a period of time, offers significant potential to increase productivity of the entire process plant. ■