Boston Gear: successful with new Klüber gear oil

Running-in lubrication of large gear drives

Klüber and REACH

The right compressor oil for each gas

Research project on sintered metal plain bearings
Klübersynth UH1 6-460 increases Boston Gear’s productivity
Specialty lubricant provides PAG technology, performance and H1 certification for the food-processing and pharmaceutical industries

Running-in lubrication
Decisive for the service life of large gear drives

Klüber and REACH
The new European chemicals regulation

It’s the gas flow that counts
Reliable operation of oil-injected rotary-screw process gas compressors through selection of the right lubricating oil

Optimized tribology in sintered metal plain bearings
Joint research project of GKN and Klüber Lubrication at the Westsächsische Hochschule Zwickau

Versatile in the long term
For free-wheeling bearings, rolling bearings, linear guides …

A truly wholesome solution
Manufacture of aluminum packages

Effective operation
of needles and sinkers
“What are the strengths of Klüber?” This is a question I was recently asked by a journalist during an interview. A question which is of course also of great interest to you, our customers. It is for this reason that I would like to briefly recount my answer. Maybe, some of the issues I mentioned will come as a surprise to you – even if you know our company.

First of all, Klüber Lubrication is a company that takes great pride in working very closely with our customers. Klüber therefore possesses profound knowledge and experiences that are embraced throughout numerous levels of operations, such as through our expert consulting services for each individual application, our R&D programs, or during the testing or manufacturing of our lubricants. We use our knowledge and expertise to build superior relationships with our customers. We have copious resources for R&D and testing; pioneering product developments and creative ideas mark all of Klüber’s history as a company. Also, Klüber’s business is built on maximum quality. This is true, of course, for our specialty lubricants, which Klüber makes in 14 modern production plants worldwide.

But we extend our quality focus also to our consulting service, industry tools and the competence of the people who work for us.

You will read about some of the many ways in which these strengths can be of use to you in this edition of Tribojournal, such as Klüber’s activities with REACH, or our expertise in gas compressor lubrication, or vital aspects to be aware of when commissioning new large gear drives or new specialty lubricants. Please read on to find out how Klüber can offer you added value for your operations.

I wish you interesting reading,

Karsten Grüne
There are many considerations for a company trying to penetrate the food packaging industry. Industrial and commercial standards need to be satisfied. These include sanitation, safety and meeting H1 certification (lubricants that are suitable for incidental, technically unavoidable contact with food products). For Boston Gear, these factors were critical to achieving success in the overall food industry.

Boston Gear serves many industrial markets, including food processing, packaging, machinery and material handling. The company provides products ranging from worm gears to variable speed drives to clutches, bearings, shaft accessories and fluid power solutions. Since Boston Gear components are used in a wide range of original equipment and machinery, it is critical for end-use industry standards to be met.

In addition to these standards, equipment needs to be reliable and efficient, with significant uptime and little downtime between regular services. “As plant operating costs continue to spiral upward, a natural tendency is to cut back on maintenance staff and operating costs,” said Ralph Whitley, director of engineering for Boston Gear. “The less maintenance staff a plant has, the less likely equipment will be properly serviced at the specified intervals. The equipment design hurdle is to ‘design out’ frequent maintenance and obtain maximum operating hours between service intervals.”

“Our job was to evaluate various performance parameters of the lubricant,” said Whitley. “H1 was just one piece of the puzzle. We also needed to assess any other effects through extensive lab testing.” The end result demonstrated that Klübersynth UH1 6-460 outperformed the other products under test in every area. “I was just looking to see that the lubricant did not hurt the product and instead we found im-
improvement in our operating temperatures and efficiency,” said Whitley.

**Power reserves**

Regardless of the gearbox manufacturer, all gearbox suppliers face the possibility of the “end users” pushing the product past the design intent limits. Boston Gear had experienced borderline application problems with these gearboxes, which consequently were running inefficiently and hotter than normal. “Although Boston Gear didn’t think it could resolve this ‘misapplied’ issue,” Whitley said, “Klüber helped us regain some of the otherwise borderline type applications.” Whitley continued, “Our same gearboxes that were operating at elevated temperatures and lower efficiencies are now improved. When compared to polyalphaolefin (PAO), this polyglycol oil really shines. The gearboxes are now running cooler and there is less power required to operate the system to obtain the same amount of work.”

With machines operating at lower temperatures, it translates into a safer work environment with a much lower risk of employees being lightly burned by touching the external surfaces of speed reducers. Additionally, there is also less power consumption and lower operating costs when units operate more efficiently.

“Some of the biggest benefits of this product are that it’s thermally stable, it has H1 certification and has a low coefficient of friction,” said Mark Crombie, manager of application engineering at Klüber Lubrication North America L.P. “Now, OEMs only have to use one product, rather than inventorying more than one lubricant. It covers many applications.”

The oil was developed especially for the lubrication of worm gears with their pronounced sliding friction and can be used in gearboxes in every industry arena. This lubricant also has a much longer service life than standard lubricants, due to the oil’s excellent ageing and oxidation resistance and good viscosity temperature behavior.
Focus on efficiency

“It’s important to use high-quality lubricants, because they translate into better operating efficiencies of various pieces of equipment,” said Whitley. “In the case of worm gear speed reducers, where sliding friction is high, the PAG lubricants minimize the sliding friction to a manageable level, allowing efficient use of power and lower operating temperatures. There are also fewer oil changes, which means lower operating costs.”

Since Boston Gear’s test results were all positive, it also decided to share the benefits of Klübersynth UH1 6-460 with its customers.

Support for customers

Two to three months prior to changing over to the product themselves, Boston Gear educated its customers by providing them with information sheets, highlighting the features and benefits of the UH1 6-460. Boston Gear began using the new lubricant in March 2006, and, since then, approximately 85 percent of its customers have made the switch.

Boston Gear’s gearboxes feature a label noting the machines should be refilled with the same product. As an additional service to its customers, Boston Gear will sell Klübersynth UH1 6-460 in container sizes matching the application.

A leader in power transmission products, Boston Gear is achieving its goals. “Our sales are beginning to penetrate the food market with success,” said Whitley. This is due, in part, to the regular maintenance of and high-quality lubricant being used in Boston Gear’s gearboxes. “We plan on staying very close to Klüber,” continued Whitley. “We want to stay as innovative as Klüber and be part of what’s next.”
Running-in lubrication

Decisive for the service life of large gear drives

Running-in lubrication of new gear drives mainly serves the purpose of reducing surface roughness and improving the contact ratio of tooth flanks. Due to the special additives, running-in lubricants cause a controlled minimum of chemical/corrosive wear at the tooth flanks. Such intentional wear is controlled through the amount of lubricant used and the time it is allowed to act on the component.

During the running-in process the tooth flank surfaces are smoothened, thus creating optimum conditions for the prevention of pitting and other damage. As the high pressures occurring during initial operation entail the risk of scoring damage, the running-in lubricants contain highly effective EP additives to counteract this effect. Our experience has shown that a gear’s rolling strength and scuffing load capacity are substantially improved if flank roughness is reduced and the effective contact ratio increased.

The change in surface roughness caused by running-in has a direct influence on the lubricating film thickness required for a reliable operation. The so-called Lambda value is an acknowledged measurable describing the ratio of the lubricant film thickness divided by the average surface roughness of the gear. If Lambda is greater than 2, the tooth flanks are completely separated by the lubricant film; if Lambda is between 0.7 and 2, the gear is operating under mixed friction conditions, i.e. metal-to-metal contact may occur between the mating tooth surfaces. Practical experience has shown that the Lambda value is 10 times higher.

Large gear drives play a major role in cement production processes. Therefore, reliability and operational safety requirements of the drives are particularly stringent. In consequence, it is of utmost importance that their lubrication be specifically geared to the design characteristics, operating and ambient conditions of the drives. Prior to starting operation, both spur and helical gear drives have to undergo running-in lubrication, irrespective of the lubrication method used. The result of a running-in process has a decisive influence on the operating performance and the lifetime of the drive.
after running-in lubrication, meaning that separation of the tooth flanks is much improved.

In the following, we will show the main points to be taken into consideration when performing a running-in lubrication with graphitic or transparent lubricants.

### Preparation of running-in lubrication

Running-in lubrication is subject to the prior approval by the manufacturer of the drive or the operator. The new drive has to be covered completely with the priming lubricant before the running-in. This lubricant protects the gear teeth against corrosion until the drive is put into service. Furthermore, the priming lubricant provides the drive with initial lubrication during and after the assembly and prevents a metal-to-metal contact of the tooth flanks owing to the high percentage of solid lubricant. Initial damage, which may be caused by dry running and might lead on to flank damage during operation later, is prevented as well. The priming lubricant helps to avoid critical operating conditions during the first operating hours while the automatic lubricant spray devices take some time until a uniform and load-carrying lubricant film has formed.

Pinions and gear rim should be aligned such that there is an average load-bearing area of at least 60% across the tooth height, width, and over the whole circumference of the pinion and gear rim, otherwise there is an increasing danger that the partial overloading of the tooth flanks may cause damage like initial pitting or local scuffing, which might aggravate severely during subsequent operation. Running-in lubrication is not capable of compensating for an insufficient alignment of pinions and gear rim.

Running-in lubricants containing graphite smoothen the tooth flanks through a minimum of chemical/corrosive wear, and transparent products through physical/mechanical material removal. The running-in process is initiated when starting the drive, i.e. the tooth flanks are at first only lubricated with the running-in product. There are different types of drive lubrication. For the specific consumption quantities (g/cm-hour) and the overall quantity of the running-in lubricant please refer to the lubricant manufacturer’s specifications.

### Running-in with automatic spray lubrication

Prior to starting the running-in process, the automatic spraying equipment should be set to quasi-permanent operation with short pauses and the throughput volume indicated. The spray pattern should be checked and, if necessary, corrected. Spraying should commence before the drive starts running. Ideally, start the running-in at low machine load and raise it step by step. For drives that need to be run at full load from the start, “forced running-in lubrication” is a viable option.

The total amount of lubricant needed for the running-in depends on the type of machine and the size of the drive, normally it is between 180 and 540 kg (one to three drums). The running-in procedure should never be discontinued prematurely because no more running-in lubricant is available. Especially with spray lubrication, we recommend providing three drums of transparent or two drums of graphite-containing running-in lubricant. Running-in is completed when the tooth flanks are smooth and the contact ratio is sufficient. For spray lubrication Klüber Lubrication offers the graphitic black lubricant GRAFLOSCON B-SG 00 Ultra as

### Table 1: Film thickness calculation for gear rim and pinion drive of a mill

<table>
<thead>
<tr>
<th>Product</th>
<th>Operating temperature of tooth flank (°C)</th>
<th>Kin. viscosity at temperature $\nu$ mm²/s</th>
<th>Flank roughness $R_a$ (µm)</th>
<th>Film thickness $h_c$ (µm)</th>
<th>Lambda $\lambda$</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLASFLOSCON C-SG 0 ULTRA</td>
<td>60</td>
<td>680</td>
<td>199.4</td>
<td>40</td>
<td>2.53</td>
</tr>
<tr>
<td>GLASFLOSCON C-SG 0 ULTRA</td>
<td>60</td>
<td>680</td>
<td>202.4</td>
<td>40</td>
<td>2.55</td>
</tr>
<tr>
<td>KLÜBERFLUID C-F 3 ULTRA</td>
<td>60</td>
<td>16,500</td>
<td>3,812.0</td>
<td>500</td>
<td>19.9</td>
</tr>
<tr>
<td>KLÜBERFLUID C-F 3 ULTRA</td>
<td>60</td>
<td>16,500</td>
<td>3,877.0</td>
<td>500</td>
<td>20.2</td>
</tr>
</tbody>
</table>

$\nu = \text{Difference results from the VT diagram and the computer calculation}$

$R_a = \text{Average peak-to-valley height acc. to DIN 4768 sheet 1, arithmetic average height of all profile ordinates } y \text{ after eliminating form errors and waviness, } R_a \text{ value varies between 1/3 and 1/7 of the } R_z \text{ value (DIN 4767)}$

$h_c = \text{Lubricant film thickness in the pitch circle (maximum value)}$

$$\lambda = \frac{h_c}{R_a^{2/3} + R_a^{2/3}}$$

$\lambda < 0.7 \Rightarrow \text{Dry friction/boundary lubrication (no EHD)}$

$0.7 < \lambda < 2.0 \Rightarrow \text{Mixed friction (partially EDH)}$

$\lambda > 2.0 \Rightarrow \text{Fluid friction/hydrodynamic lubrication (full EHD)}$
well as the transparent Klüberfluid B-F 2 Ultra, which is also suitable for running-in with immersion lubrication.

Running-in with immersion lubrication

Fill sufficient lubricant into the bath until the teeth or the paddle elements are fully immersed. After starting the drive, the lubricant level has to be monitored. Normally, the lubricant level drops considerably because of the amount of lubricant carried away by the teeth. To avoid starved lubrication, the bath should be refilled to attain a level where the teeth are maximally half, or the paddle elements fully immersed.

Lubricant losses during the running-in process can be compensated for by refilling running-in lubricant or operating lubricant (if compatible), depending on the result achieved so far. As soon as the tooth flanks are properly run in, i.e. flanks are bright and smooth, the operating lubricant can be filled in. If tool marks are still visible or the tooth flanks are still not smooth enough, more running-in lubricant should be added. The running-in lubricant should be fully replaced by the operating lubricant after a maximum of 7,000 operating hours. For running-in with immersion lubrication, one bath fill is needed plus a refill quantity of at least one 180 kg drum. Klüber Lubrication offers the graphite-containing lubricant Klüberfluid B-F 1 Ultra or the transparent lubricant Klüberfluid B-F 2 Ultra for this method.

Maximized reliability for lower costs: who can offer you that?

Klüber can! No matter whether you’re a manufacturer or an operator of wind power facilities, Klüber is a partner you can depend on – all over the world. The result of our intensive R&D work is comprehensively convincing: for each and every requirement, Klüber offers the appropriate lubricant, reassuringly produced to Klüber’s high standard of quality. This means maximized reliability. Reduced friction ensures reduced wear and tear, higher efficiency, extended component lifetimes and lower operating costs.

If you, too, want to have the right lubricant, fit for purpose, just get in touch with us – we’ll be pleased to advise you.
Running-in with stepwise increase of load

New gear drives should not be operated under full load from the start because with many drives the contact ratio is initially too low. Instead, they should be run in according to a predetermined load/time schedule, with the transition to the next stage only being made when a specific contact ratio has been reached. The actual load steps, however, can only be determined on the basis of the operating instructions of the drive and machine manufacturers. The running-in process is completed when at 90 to 100 % load the tooth flanks have become sufficiently smooth and the contact ratio attained is sufficient for continuous operation under full load. Drives whose tooth flanks already have a good surface quality, a high contact ratio and a good load distribution in the beginning can be run in without stepwise increasing of the load.

Evaluation of tooth flank smoothing

Smoothing of tooth flanks has a decisive effect on the operating performance of a drive because properly smoothed tooth flanks require a far lower lubricating film thickness to completely separate the tooth flanks. This is a
phenomenon that is well known from working with a microscope: the object slides are extremely smooth, so a single drop of water is enough to separate them completely. To evaluate the smoothing effect, the surface roughness before and after running-in is compared. However, measurements are not performed for this purpose, but the operator simply inspects the drive visually, maybe using the finger-nail test or similar methods. The RUGO test may also be used, which compares reference roughnesses with that of the tooth flanks under test. The trained eye will be able to correctly assess the progressing smoothness of the flanks and determine when the running-in can be considered complete. Starting with a residual roughness of approx. $R_a 4$ to $6 \mu m$, a smoothness of approx. $R_a 0.5$ to $2 \mu m$ can be attained. The possible flank correction is rather limited, namely to approx. $R_a 10 \mu m$ in total. If high machining tolerances have left the drives with high roughness values, these can only be corrected by factors within this narrow range.

**Overall evaluation**

The running-in process is result-oriented, which means that the engineer carrying out the inspection will determine when the processes is completed. During running-in, temperatures and vibration should be regularly measured, and the drive be monitored by experienced staff. For the detection of uneven load distribution over the tooth flanks, touch-free temperature measurement by means of an infrared thermometer has proven an excellent method that can be performed while the drive is running under load. A temperature difference of more than $5 K$ – measured over the entire flank width from face to face – indicates an uneven load distribution, which might require realignment of the gears or some other correction. When the temperature difference falls below $5 K$, this is a clear indicator of even axial load distribution, i.e. the load-carrying ratio across the width of the tooth flanks is satisfactory.

The load-carrying ratio across the tooth height can only be assessed by visual inspection since infrared temperature measurement along the teeth is not possible during operation. If the vibration of, for example, the pinion pedestal bearing in a tubular mill decreases, this indicates that the roughness has been reduced and hence better separation of the flanks is attained. If this is confirmed in an inspection, the running-in process can be terminated. Vibration measurement on the pedestal bearings supporting the pinion shaft of kiln drives is normally not possible as their vibration is normally very slow (less than $1 \text{mm/s}$) and therefore beyond the range of the measuring instruments.

**Summary**

The result of the running-in determines to a considerable extent the service life and the operational behavior of new large gear drives. The drives should be carefully aligned and offer a load-carrying ratio of over 60 percent to start with in order to enable effective running-in. During the running-in, the load-carrying ratio can then be increased to a desirable 80 to 85 percent through intentional wear of small dimensions.
Klüber and REACH

The new European chemicals regulation REACH, which came into effect on June 1, 2007, means a substantially new approach in the EU’s policy on chemical substances. Its effects are felt not only in the chemical sector but in many fields of industry, trade and services as well. There is widespread uncertainty as to the consequences of REACH, as well as the new tasks and challenges it will bring.

In preparation for the launch of REACH, Klüber Lubrication has benefited from having gathered a lot of related experience in the past. The conformity of our lubricants with legal regulations, as well as their ability to meet customers’ requirements, has always been a matter of paramount importance to Klüber. Ten years ago, “Material Compliance Management” (MCM) was set up, an internal department dedicated specifically to dealing with these complex legal subjects. The specialists of MCM have experience with the registration of substances under international laws and have been working on REACH for six years. Klüber is actively involved in several REACH work groups dealing with lubricants, e.g. at ELGI, the European Lubricating Grease Institute, at ATIEL, the Technical Association of the European Lubricants Industry, in the VSI, the German Association of the Lubricant Industry e.V., in the German Association of the Middle-class Oil Companies (UNITI) and many other organizations.

The implementation of REACH is handled by our experts in an international network, and in close cooperation with our customers and supplier.

To our knowledge to date
- we trust that all our raw materials will be pre-registered and
- we are not using any substances of concern subject to the authorization requirement

Our goal is to have all uses of our lubricants registered.

You will find further information on Klüber and REACH on our website www.klueber.com under “Service”.

Should you have any questions or require additional information regarding REACH pertaining to Klüber lubricants, our MCM specialists would be happy to answer any inquiries you may have. Please send an e-mail to REACH@klueber.com.
It’s the gas flow that counts

Reliable operation of oil-injected rotary-screw process gas compressors through selection of the right lubricating oil

The question which lubricating oil to use in a rotary-screw process gas compressor is decisive not only for reliable machine operation but also for the profitability of the processing plant as a whole. Frequent problems in such compressors are high wear, deposits, sludge formation and corrosion, which may all lead to extra downtime and high production loss. This article explains the criteria to be taken into account when choosing a compressor lubricant.

Which lubricating oil is best suited? What happens when the process gas and the lubricant meet in the compressor? These and other important questions tend to arise when process gas compressors are commissioned and lubricated for the first time or after downtime of a compressor already in service. The following real-life examples show that a sound understanding of chemical processes and some practical experience are required to satisfactorily answer all of these questions.

Oil-injected rotary-screw compressors

Depending on the requirements made on volume flow and pressure, a variety of process gas compressor types are used in many different areas of industry. Turbo-compressors, reciprocating compressors and rotary-screw compressors are the most commonly found types in industry. Their application areas are mainly in the oil and gas industry as well as the chemical and petrochemical industry – wherever gases are compressed and processed.

Lubrication varies greatly for the different compressor types. In turbo-compressors, the lubricating oil is required only for the lubrication of the
bearings and has no or little contact with the process gas. The lubrication of oil-injected rotary-screw and reciprocating compressors is more challenging. Here, the lubricating oil is injected directly into the compression chamber, sometimes under extreme operating conditions, to lubricate, seal and, above all, cool down the pistons or rotors. In rotary-screw compressors, in particular, the 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 compressors. Because of this particular requirement, this article will in the following deal with oil-injected rotary screw compressors only.

Apart from varying impurities in the air, air compressors simply compress a well-known gas – ambient air. Gas compressors, however, 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. Whilst 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.

Those are the problems – but what needs to be observed in selecting the correct lubricating oil for a gas compressor with a defined gas flow?
Typical problems and solutions

A. 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 higher 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:

Pressure: The higher the compression, the higher the tendency of the gas to be dissolved in the oil.

Temperature: The higher the compression temperature, the lower the tendency of the gas to be dissolved in the oil.

Polarity of oil and gas: As a rule, polar gases have a higher tendency to be dissolved in polar lubricating oils than in homopolar oils, and vice versa, homopolar gases are more easily dissolved in homopolar oils than in polar oils.

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 C₇H₈, are more easily dissolved than “light” ones, such as methane CH₄ or propane C₃H₈.

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

The gas flow (indicators in Mol %) to be compressed is:

- 20.0 % Methane CH₄
- 9.0 % Ethane C₂H₆
- 22.0 % Butane C₄
- 26.0 % Propane C₃H₈
- 0.5 % C₈+

The compressor used is a rotary-screw compressor with oil injection system. The gas mixture is compressed from 0.5 to 6.0 bar at a temperature of approx. 95 °C. To lubricate the bearings, the compressor manufacturer stipulates a minimum oil viscosity of 10 mm²/s at an oil temperature of 70 °C, and for rotor lubrication a viscosity of at least 8.5 mm²/s at 95 °C oil temperature. Ambient temperatures are between 0 °C and 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 viscosity sufficient to ensure reliable long-term operation of the compressor?

Fig. 2: Schematic viscosity curve of a polyglycol oil compared with a mineral oil when compressing a hydrocarbon gas mixture
Software can help

An answer to all these questions can be obtained by using a special calculation programme 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. Klüber has a software for this complex calculation. 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 150 mm²/s to approx. 62 mm²/s at a temperature of 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 80 °C to prevent condensation of the heavy hydrocarbons (C₆+).

If an ISO VG 150 mineral oil were to be used for this application, problems would be imminent. Fig. 2 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.

B. 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 90 °C. The oil vapour 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 others, on the evaporation stability of the lubricating oil. As compared to synthetic oils, conventional mineral oils are characterised by a higher vapour 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 – however, with the same reason, as will be explained in the following section.

C. 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.

Figure 3 compares the oil vapour content in the gas flow for various lubricating oils. In extensive tests, the oil vapour content in a compressed air flow was measured and recorded over a period of 80 hours. 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 optimised, thus increasing reliability and long-term efficiency and effectiveness of the entire process.

---

**Fig. 3: Characteristic of oil vapor content in a rotary-screw compressor – measured in the compressed air flow after the oil separator and filter section**
D. 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 specialise in this area 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.

E. 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 colourful 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 colour. 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 realised 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 a 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 rotary-screw compressors has a great impact on the reliability and profitability of the entire process plant. The lubricant supplier should, therefore, be able to provide more than just the right lubricant. Thanks to extensive and detailed chemical know-how, a great deal of practical experience and specially designed lubricating oils, a 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.

clean gears clean hands

Dipl.-Ing. (FH) Holger Körber
Technical Consulting and International Sales
Leader Global Expert Team Gas Compressors
Klüber Lubrication München KG
Holger.Koerber@klueber.com

Of course – thanks to transparent adhesive lubricants made by Klüber.

The high-performance adhesive lubricants of the Klüberfluid C-F Ultra series take the grime out of girth gear lubrication: they are transparent and free from graphite. Application is easy and tooth flank inspection is possible even while the drive is in motion. As consumption is low, you will reduce your disposal and storage costs, no cleaning is required before inspection and there’s less need for maintenance. So to reduce your costs in one clean sweep, give us a call.

See also article on page 7
Today’s power transmission designs require machine elements of utmost precision covering a wide temperature range and combining low noise with low friction coefficients. Long service life and reliable, maintenance-free operation are the main demands made on the components that are, for example, used in the automotive industry. Depending on the application in which a component is used, e.g. in window lifter or windshield wiper motors, or in fans, the requirements may vary greatly with either extremely high or very low speeds. In addition, there can be alternating or oscillating bearing movements. To meet all the required parameters, a design comprising a bearing and shaft in combination with a high-performance lubricant has established itself, over the course of many years, as a very successful solution. The use of sintered metal plain bearings composed of different base substances, densities and pore structures permits impregnation with the most suitable lubricant for every application.

1. Background of the cooperation

To gain more precise tribological knowledge on sintered bearing applications than is currently available, GKN Sinter Metals and Klüber Lubrication München KG decided to embark on a joint project with the Westsächsische Hochschule Zwickau. The objective was the tribological optimization of the running properties through analysis of the components involved with the aim of transferring the results into series applications. The first step was to design a test station which could simulate the typical application parameters seen in practical service conditions, such as load, temperature, speed, required life time, etc. Then, the maximum and minimum parameters were continuously extended to investigate and gain a greater insight into the possible limiting values. In this context, experimental tests were carried out on the “tribosystem” of the sintered bearing and shaft. The test results were influenced to a great degree by the type of lubricant
applied, its base oil viscosity, the additives and the entire lubrication concept, e.g. whether an impregnating oil or impregnating fluid was used.

2. Test rig design

The test station consists of four independently operating test rigs of identical design. Figure 1 shows a sectional view of the configuration of a sintered bearing test rig. The main components of the test rig, the housing (11, 12) and the electric motor (15) are aligned and assembled on a base plate (18). The test specimens are a shaft (10) and a spherical sintered bearing (4). The shaft is held by two deep groove ball bearings (8) and driven by an electric motor via a coupling (19). The sintered bearing is pressed into the spherical housing (3) by a clamp (5).

A spacer (6) ensures that the specified axial load is applied during assembly. A pressure spring (7) applies the load to the retaining ring (1), which then transfers the radial load to the sintered bearing via the rolling bearing (2). The pressure spring is pre-loaded using a hexagonal screw (16). A distance sleeve (17) limits spring deflection. The test rig is equipped with a heating system; the individual test specimens can be heated separately using a heating coil to the specified testing temperature, which was 120 °C or 130 °C for the tests carried out so far.

2.1 Description of the test procedure

The test consists of a loaded and a load relief stage. The duration of the loaded stage is two hours. The subsequent load relief stage lasts one hour. The test shaft speed during this stage is \( n_w = 0 \). Four identical fans are used to cool down the test rig housings with ambient air.

The sintered plain bearings are subjected to different loads and temperatures in order to simulate varying operating conditions. A frequency transformer ensures infinitely variable setting of electric motor speed (and thus also test shaft speed) up to \( n_w = 10,000 \text{ rpm} \). The specific surface pressure of the sintered bearings during the test runs is \( p = 0.5 \text{ N/mm}^2 \) to \( 5 \text{ N/mm}^2 \).

2.2 Test rig and peripheral equipment

During a single test run, trials can be carried out simultaneously with four sintered bearings on the four independently operating identical test rigs (Fig. 2). The specified operating parameters, including specific surface pressure, can be set individually for each test rig. Test shaft speed, however, cannot be controlled independently, as the speed of the electric motors is set by a frequency transformer. Thermal elements are used to measure the temperature at the sintered bearings. The heating coils are automatically supplied with electricity through a closed-loop control system until the specified upper cut-off temperature is reached. If the temperature drops below the lower threshold value after cut-off, a relay switches on the electricity supply again. If the temperature of a sintered bearing rises above a defined cut-off value due to internal heat dissipation, the affected test rig switches off automatically.

Miniature compressive force sensors are used to record frictional force during the tests. Similarly to the cut-off parameters for temperature regulation, the frictional force measurements are compared with the defined threshold.
value and the test rig is stopped as soon as the specified value is exceeded. All the measured data of force and temperature are prepared for further processing on PCs with the aid of an Almemo measuring unit and the AMR WinControl software. Upon completion of the tests, the test results are evaluated using Microsoft Excel. The evaluation results are illustrated in appropriate diagrams plotting frictional force, the coefficient of friction and temperature as a function of time.

3. Evaluation

To accelerate the tests and obtain results in the shortest possible time, the operating parameters were set as close as possible to the upper thermal and mechanical load limits. To further intensify the test conditions, the trials were carried out in start-stop operation mode.

Excess of the upper temperature limit of 145 °C was defined as the failure criterion. The upper limit for the frictional force was 48 N. Thus blockage of the bearings and damage of the measuring unit in case of excessive increase of frictional force was prevented.

The test bearing used was a spherical type with an internal diameter of 8 mm, a ball diameter of 16 mm and a length of 11 mm. The materials used were sintered bronze Sint-B50 and sintered steel Sint-B10. The bearings were impregnated with the Klüber lubricants CONSTANT OY 68, Klübersynth DB 2-68, Klüberalfa DH 3-100 and CONSTANT GLY 2100. All four products are well established in the automotive industry.

All in all, the team carried out 21 tests under different test conditions. With the initially selected parameters for specific surface pressure (1 or 2 N/mm², respectively) and a speed of 3,000 rpm, running times of above 1,000 hours were always achieved, at which point the tests were discontinued. The aforementioned conditions correspond to a pv-value of 1.26 or 2.52 N/mm² x m/s, respectively. The majority of the sintered bearing applications in the automotive industry (fan motors and actuators, window lifter and windscreen wiper motors etc.) operate within this load range. At normal ambient temperature this result could, therefore, be expected. These tests, however, were performed under far more demanding conditions (e.g. at a temperature of 120 °C), and high running times were still achieved in almost all test runs.

In order to reduce testing time, speed was increased to 6,000 or 8,000 rpm and the specific surface pressure was raised up to 4 N/mm². In the extreme, these conditions would lead to a pv-value of over 13 N/mm² x m/s, which is far above the usual application range of sintered plain bearings. This helped to reduce bearing lifetime significantly below the 1,000 hour mark, but now there were considerable variations (from ten to several hundred hours), which made the comparability of lubricant performance virtually impossible.

The bearings and the pertinent shafts were analyzed by the team after the tests. The main reasons for failure were as follows: The lubricant additives were partially used up, the lubricants had begun to oxidize and in some cases carbonized oil was found. All these phenomena subsequently led to wear, scoring and ultimately failure of the overloaded bearings.

Fig. 3: Comparison between a new and a used sintered bearing impregnating fluid
4. Analysis of a used sintered metal bearing oil

4.1 Oil analysis

The changes and/or decomposition of the additives contained in a sintered bearing impregnating oil can be detected by analyzing the remaining oil in the sintered bearing via infrared spectroscopy.

For this purpose, the oil first needs to be extracted using a suitable solvent, which is then evaporated from the oil in a rotary evaporator. The extracted oil is examined in an FTIR (Fourier Transform Infrared) analysis, in which additives and impurities can be detected.

Fig. 3 shows the comparison of the two spectra of CONSTANT GLY 2100, an impregnating fluid with a synthetic hydrocarbon base oil and lithium soap thickener. The chart illustrates the following differences between the new fluid (red) and the used fluid (black): The additional band with a peak maximum at 1,737 cm⁻¹ clearly suggests the presence of an impurity containing ester oil. The absence of both bands at 1,580 cm⁻¹ and 1,560 cm⁻¹ is a clear sign that there is no lithium soap remaining in the analyzed lubricant. The absence of both bands at 1,609 cm⁻¹ and 1,518 cm⁻¹ indicates that the antioxidant used in the product has been completely decomposed and, therefore, oxidation resistance of the analyzed lubricant is very limited.

4.2 Component analysis

The surface of the shaft depicted in Fig. 4 shows a considerable reaction layer of additives originating from the impregnating fluid CONSTANT GLY 2100. These could well be corrosion protection additives which have decomposed due to the high speed of 8,000 min⁻¹ and a period of prolonged service to form deposits on the shaft surface.

The shaft shown in Fig. 5 displays barely any reaction layers compared to Fig. 5, as in this test the sintered bearing has been impregnated with a different lubricant (Klübersynth DB 2-68) and the speed was only 3,000 rpm.

5 Summary

Depending on the operating conditions, sintered metal plain bearings impregnated with different impregnating oils achieved service lives which are similar to those attained in real-life applications. Moreover, the tests confirmed that the service life of sintered bearings can be increased through the use of ageing-resistant impregnating oils. Impregnation with impregnating fluids, such as CONSTANT GLY 2100, also has a positive effect on the service life of a sintered bearing. Low friction coefficients, which can be achieved by using lubricants with a good viscosity-temperature behavior, improve wear protection characteristics and thus permit longer component service life. Visual inspection of bearing raceways and test shafts is in line with the results of the used lubricant analysis. The results achieved on the test station confirm long-standing practical experience and offer a well-founded basis for further development work to optimize the tribosystems concerned, for example to meet the continuously rising demands and enhanced operating conditions in the automotive industry.
Today’s linear guide systems are expected to meet ever increasing requirements in terms of precision and repeatability, load bearing capacity and shock resistance, but also resistance to wear and media and a reduced need for maintenance. This calls for lubrication solutions offering improved performance. The new synthetic special grease Klübersynth BM 44-42 was developed by Klüber Lubrication specifically for linear guides, free-wheeling bearings and rolling bearings operating to the stringent requirements mentioned above.

With its good adhesion to the friction point this special grease is predestined for long-term lubrication, even in open bearing applications or bearings with a rotating outer ring, where it reduces the need for maintenance considerably. The grease’s low starting torque enables problem-free operation and lower energy consumption also at low temperatures. Its optimized oil release and special anti-wear additives promise a longer component life.

Good compatibility with sealing materials and other lubricants as well as the grease’s wide service temperature range from −40 °C to +140 °C, with peaks up to +180 °C, allow Klübersynth BM 44-42 to be used in a wide range of applications, also where reliable lifetime lubrication over a wide temperature range is required. Besides in linear guides, the product may be used in various automotive applications, i.e. wherever the idling and shifting of free-wheels or overrunning clutches involving rolling bearings is expected to take place reliably and with a minimum of wear – for example in brakes or other applications of the drive-by-wire technology.

When making food packages of aluminum foil by means of rolling and deep-drawing, the lubricant plays a major role. Special rolling oils are used to carry off the heat and protect the aluminum surfaces. They also serve for preventing the thin foil from sticking together when rolled onto a coil. But before the actual deep-drawing starts, the lubricant must be completely removed from the material so as not to come into contact with the food product. This is normally a complex and expensive process. Klüber Lubrication offers specialty lubricants PARALIQ P 68 and PARALIQ 91, which are capable of eliminating this cleaning process. First, because they do their job, as described above, even when applied in minimal quantities or in a diluted form; secondly, because they are approved for occasional contact with food products.

PARALIQ P 68 has been tried and tested in numerous oil-lubricated friction points in the food-processing and pharmaceuticals industry, e.g. gears, bearings, chains, spindles and joints. PARALIQ 91 was specifically developed for use as a baking and mould release agent in the baking and confectionery industry. Both oils comply with DIN V 10517 “Lubricants Suitable for Use with Foodstuffs” and are registered as NSF H1, PARALIQ 91 is also registered as 3H. NSF H1 and 3H lubricants are suitable for occasional contact with food products which may be inevitable in this process. They are neutral in taste and odor and are decomposed by humans if small quantities are consumed. In the manufacturing of aluminum foil packages, special oils for use throughout the process chain may help to reduce costs and increase process reliability.
Yes, I want to become a regular reader of Tribojournal. The subscription is free of charge and can be terminated any time.

Please send me Tribojournal in  

German  English  Spanish  French

I found the article ticked below particularly interesting. Please send me information on Klüber service or special lubricants used in this context.

☐ Klübersynth UH1 6-460 increases Boston Gear’s productivity
☐ Running-in lubrication of large gear drives
☐ It's the gas flow that counts
☐ Optimized tribology in sintered metal plain bearings

☐ Klüber and REACH
☐ Klübersynth BM 44-42 for free-wheels, rolling bearings, linear guides
☐ PARALIQ P 68, PARALIQ 91 for manufacture of aluminum packages
☐ Klüberplex BEM 41-141 for all bearings in wind power stations
☐ Needle and sinker oils

Reader Service

Sender:

Name

Company

Dept.

Street

Place

Phone

Fax

E-mail
Until now, the producers of wind power stations have had to use greases from a variety of manufacturers in order to meet the specific requirements of the various bearings involved. This was due to the different rpms, stresses, sizes and functions of main, generator, azimuth and pitch bearings, and resulted in a high financial outlay for the operators concerned in terms of inventories and grease disposal procedures, plus of course the ever-present risk of confusing lubricants. Now all of the requirements of these individual bearing lubrication points are covered by a single product: Klüberplex BEM 41-141, a specialty lubricant for rolling and plain bearings operating under high loads, has been designed for:

- main bearings, which with their low rpms are subjected to high loads and vibrations,
- generator bearings, which have to cope with high rpms and high temperatures,
- pitch and azimuth bearings, which besides high loads are also subjected to oscillating movements and vibration.

"Klüberplex BEM 41-141 is in no way a compromise. This specialty grease meets and exceeds all the current requirements specified by the OEMs for bearings and wind power stations, and by the operators as well", explains Peter Mages, Industry Group Manager at Klüber Lubrication München KG.

The wide service temperature range, good pumping and metering behavior in central lubrication systems, and the equally good grease distribution and oil release ensure trouble-free operation of the wind power stations. High wear protection even under vibrations extends the bearings’ lifetime. Klüberplex BEM 41-141 also prevents costly standstill damage. Taken overall, the number of necessary standstills is reduced, for a perceptible increase in productivity levels. In addition, repair and spare-part costs for the operator are downsized, as are the costs for disposing of used greases. The new lubricant possesses good compatibility with elastomer seal materials in common use and mixes excellently with other greases, which makes lubricant changeover a whole lot easier.
Effective operation
of needles and sinkers

Klüber’s range of high-performance needle and sinker oils for all kinds of circular, flat-bed and hosiery knitting machines has been enhanced. The newly developed Madol Supreme series will now be available to Klüber’s customers worldwide.

These special oils support a reliable knitting machine operation under difficult ambient and operating conditions such as, particularly high or low air humidity, temperature or speed.

They reduce friction as well as the cylinder temperature, which in turn enables a longer life of the machines elements. At the same time, they do not affect the materials with which they come into contact – yarns, knitwear as well as the plastics and paints used on the machines. These special oils offer wear and corrosion protection, leading to longer machine component life and lower maintenance costs.

Numerous knitting machine OEMs have successfully utilized the Madol Supreme series of oils for first fill operations, resulting in lube chart inclusion and approval.

With high-performance needle and sinker oils, the maintenance costs for knitting machines can be reduced.
We are where you are.
Klüber Lubrication – the world market leader
in specialty lubricants

• subsidiaries in over 30 countries
• more than 1,500 staff
• products available worldwide

Klüber Lubrication offers expert tribological solutions. Through our worldwide presence, we meet customers’ needs reliably and on time. We supply tailor-made specialty lubricants to customers from nearly all branches of industry and around the world – oils, greases, bonded coatings, pastes, dry lubricants and many more. Over 75 years of experience, industry-specific know-how, and exceptional test facilities all help to optimize our solutions.