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Tribojournal 01 2011

- Seaworthy and eco-friendly
- Worm gears becoming more efficient
- Optimised friction coefficients for the automotive industry
- Antiwear layers for rolling bearings

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An eco-friendly alternative
Klüber Lubrication develops readily biodegradable, non-toxic gear oil for rudder propellers and thrusters

Simply more efficient
High-performance polyglycol gear oils help increase the efficiency of worm gears and reduce the consumption of resources

KlüberComp Lube Technology - Gear oils for extreme requirements
The perfect match
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News

We thank the companies Rolls-Royce Marine, Freudenberg Simmeringe GmbH & Co. KG and KRONES AG for their kind support and provision of pictures.
Push the limits, act sustainably

Dear reader

Sustainability is a ubiquitous buzzword. There is no doubt: the significance of preserving our environment via careful use of resources cannot be overestimated. However, I hear more and more comments indicating that people are becoming tired of sustainability as a subject. Talking less and doing more is a great solution to this situation. Klüber Lubrication is doing quite a lot in this regard. We’re driven by the question of how we can support you, our customers, in the efficient use, saving and protection of resources.

Pushing the limits of efficiency and performance is what our development specialists and customer service colleagues are working on. This is how new, innovative solutions are found, e.g. speciality lubricants like our high-performance gear oils which not only reduce energy consumption owing to improved efficiency, but which also increase component lifetime up to ten-fold as less wear of gear teeth occurs. Our compressor oils also help to reduce energy consumption considerably. A brewery with three production lines can save approx. 225 000 kilowatt hours each year when using high-performance synthetic compressor and gear oils. This improves their carbon footprint by more than 100 tons. Energy-efficient operation is also provided by lubricants especially developed for automotive components, where they contribute to fuel savings or rapidly biodegradable high-performance oils for rudder propellers and thrusters which help to make major sea routes cleaner.

If you wish to learn more on the application examples highlighted, please refer to this edition of Tribojournal. Our experts will also explain how these achievements were obtained. I wish you interesting reading

Claus Langgartner
Speaker of the Board
Klüber Lubrication München KG
An eco-friendly alternative
Klüber Lubrication develops readily biodegradable, non-toxic gear oil for rudder propellers and thrusters

All vessels of a certain size today are manoeuvred by propeller units and thrusters of different designs. Depending on the size of the vessel, these propulsion units may be filled with up to 8,000 litres of oil. During normal operation, oil may leak into the sea through the propeller seals even when they are well-maintained. Oil leakage can also occur due to wear and tear, accidents or faulty handling. While the effect of an individual leakage may be small, the total oil contamination in the seas worldwide amounts to several million litres per year. As shipping traffic is increasing, this constitutes a growing potential problem for the environment.

For this reason, many ship-owners call for eco-compatible alternatives to today’s mineral oil-based lubricants. A solution that would satisfy all requirements has not been available for gears in thrusters and rudder propellers so far. In terms of technical performance, any alternative must be at least equal to mineral oils, while at the same time being compatible with the propeller shaft seals – a considerable challenge for lubricant development engineers. In close cooperation with the elastomer and seal manufacturers Simrit and Merkel Freudenberg, Klüber Lubrication successfully developed a readily biodegradable and non-toxic gear oil1 meeting these special high requirements.

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1 Biodegradability according to OECD 301 F: > 60 % within 10 days
Acute toxicity according to OECD 201 (EC50): > 1000 mg/l, 202 (EC50): > 1000 mg/l and 203 (LC50): > 1000 mg/l
Container ships, bulk carriers, harbour tugs and cruise ships have one thing in common: reliable function of their propeller units is essential for their manoeuvrability. This requires reliable sealing of the propeller shaft against the sea as even small quantities of water in the lubricating oil can drastically reduce shaft bearing life and cause propeller failure, especially in rudder propellers and thrusters. Special seals are fitted to reliably prevent water from entering the propeller unit.

Leakages cannot always be avoided

Likewise, propeller shaft seals serve for preventing oil from leaking into the sea. This, however, cannot be fully avoided, even with good maintenance, as seals can never be completely tight: the sealing lip must be lubricated to keep wear on sealing lip and bushing as low as possible; therefore, small oil quantities always leak through the sealing lip. Depending on the size of the propeller and the seal condition, the total leak quantity can add up to several litres per day. Accidents increase the risk of leakage, for example when a steel cable trawling a fishing net is pulled under the sealing lip as it gets caught in the ship’s propeller, which can lead to a leakage of several thousand litres of oil into the sea.

Creeping contamination of the seas

Some seas and rivers are already polluted today, particularly in coastal regions with high industrial density, in sea ports and highly frequented shipping routes, which is in part due to lubricants leaking into the sea from ships. They are slowly degraded by microorganisms living in the seawater. Hydrocarbons and additives, which are contained in mineral oil-based products, are particularly harmful for bacteria, algae, fish and mammals; the substances can deposit and accumulate in their organisms.

Environmental risks will increase with increasing marine traffic unless suitable measures are taken to prevent and reduce marine pollution, which is also caused by lubricants leaking into the sea. More stringent guidelines for the protection of the seas can also entail legal consequences for ship-owners and this has encouraged a demand for eco-friendly alternatives to the mineral oil-based products commonly used today.

Readily biodegradable lubricants are an option to reduce pollution of the seas
Major challenges for eco-friendly alternatives

Using readily biodegradable gear oils instead of mineral oils is a sizable contribution to preventing pollution of the seas and their inhabitants, as microorganisms can quickly decompose them into carbon dioxide, water and biomass. The biodegradability of mineral oils shown in the OECD 301 F test is approx. 20%. The new gear oil from Klüber, by comparison, shows a biodegradability of 80%.

However, readily biodegradable gear oils must comply with certain requirements in order to be considered an alternative to mineral oils, particularly in terms of performance. They must ensure excellent lubrication and fulfil all requirements of bearing, tooth flank and sealing lip lubrication. Moreover, the oil must be compatible with the elastomer seals used.

When looking for readily biodegradable oils, ester oils or low-viscous polyethylene glycols may be considered, however these oils must be chosen with great care as they might otherwise affect the characteristics of the elastomer seal used. Damage or premature seal failure would be the consequence. For fixed-pitch and controllable-pitch propellers, alternative readily-biodegradable oils are already available, e.g. Klüberbio RM 2-150, or the newly developed Klüberbio RM 2-100. However, a reliable alternative to mineral oil to satisfy the considerably higher lubrication requirements of gears in thrusters or rudder propellers has so far not been available.

Passed with flying colours

To meet the special requirements of thrusters and rudder propellers, Klüber Lubrication developed a gear oil and launched it under the name Klübersynth EG 2-150:

- The additive-treated special oil is based on a synthetic, biodegradable and non-toxic ester oil. Its rapid biodegradability in the presence of bacteria has been proven according to the OECD 301 F test. Further tests (OECD 201, 202, 203) have shown that Klüberbio EG 2-150 is non-toxic towards algae, shellfish and fish.

- It complies with all tribological requirements of high-performance gear oils and the requirements of leading manufacturers of thrusters and rudder propellers.

- Klüberbio EG 2-150 successfully passed a dynamic endurance test on original propeller shaft seals by an international leading manufacturer.

A strong partnership

In the development of the new gear oil, Klüber worked in close cooperation with its affiliated companies Simrit and Merkel Freudenberg Fluidtechnik, both leading suppliers of shaft seals and profiled seals to the maritime industry. Like Klüber Lubrication, these two companies belong to the Freudenberg Group. Together, the three sister companies are therefore in a unique position to match elastomers and lubricating oils for the taxing requirements of propeller and thruster manufacturers as well as for ship-owners.2

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2 We recommend checking compatibility of oil and radial shaft seal with the manufacturer of the thrusters or rudder propellers.
Close cooperation between manufacturers of lubricants and seals facilitates systematic solutions.

The result of their cooperation is a tailor-made, environmentally-friendly combination of radial shaft seal and lubricant for increased reliability and lifetime to reduce costs for downtime and repair. As Klübersynth EG 2-150 is a synthetic oil, its lifetime is three to four times longer than that of mineral oil under comparable operating conditions. As Klübersynth EG 2-150 is miscible with mineral oil, trouble-free changeover to the new oil is possible and existing sealing systems\(^2\) can continue to be used.

Speciality lubricants for optimum results.

For critical marine applications such as anchor-handling winches, pulleys or propeller shafts subject to arctic cold, tropical storms or saltwater spray, Klüber Lubrication has developed the right products, also for jobs requiring environmentally-friendly solutions. Many of them were developed in close collaboration with leading OEMs. Our high-performance lubricants have been ensuring trouble-free component and system function for decades. They extend component lifetime and service intervals to save your money.

Speciality lubricants made by Klüber Lubrication: 80 years of experience and professional services to aid your success.

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your global specialist
The concepts of sustainability and energy efficiency are gaining importance in power transmission engineering. More than ever, manufacturers are looking for ways to reduce raw material consumption and attain a lower energy consumption and hence a better CO₂ balance. This can be done by making machines more efficient, extending the lifetime of components as well as maintenance intervals. The added benefit of such measures is a reduction of operating costs.

High-performance polyglycol gear oils help increase the efficiency of worm gears and reduce the consumption of resources. The increase of gear efficiency harbours a frequently overlooked potential for increasing the efficiency of a machine as a whole. A very direct and effective way of increasing power transmission efficiency – which goes along with excellent wear protection – is a changeover from mineral-oil-based to synthetic lubricants.

Synthetic lubricants, e.g. based on poly-alphaolefin, ester or polyglycol oils, have proven to reduce energy costs and in addition extend the service life of gears. The possible extent of efficiency increase, however, depends on the type of gears: while gears featuring a low percentage of sliding friction, such as spur or bevel gears, offer a relatively low potential, gears with a high percentage of sliding friction enable considerable improvements.

A particularly positive effect can be noted when worm gears are switched over to polyglycol oil: their efficiency has been increased by up to 35 percent. In addition, their lifetime can be extended up to tenfold. A conversion to synthetic oils offers an
enormous potential for savings especially in facilities where a large number of gears are operated – for example in logistics centres, filling stations, breweries or airports. The example in the box illustrates how several million Euros can be saved at a large airport.

Tribological factors are decisive in attaining the maximum performance of a machine and its components. When choosing a lubricant for a gearbox or machine, therefore, design engineers should be aware of the characteristics of the various types of lubricants and know how to use them.

While, as a rule, synthetic special lubricants tend to be more expensive than mineral oils in terms of the sales price, they pay off after a short time when taking into account efficiency, oil change intervals, oil consumption and the longer lifetime of lubricated components. With such lubricants, gear manufacturers offer their customers the added benefit of lower operating costs.

Airports offer enormous potential for savings

A large airport may utilise more than 20,000 gear units, for example in conveyor belts and escalators. Approximately 15,000 of them may be spur- and bevel gears with a mean power of 5 kW, and another 5000 worm gears with a mean power of 15 kW. With some 4000 operating hours a year and a utilisation rate of 40 percent, total power consumption is at approximately 240 GWh. Replacing a mineral oil by a polyglycol special oil will increase the efficiency of all gears by roughly 5.25 percent on average. The power saved thus totals 12.6 GWh – this is the annual power consumption of approx. 3 000 private households. 12.6 GWh, that’s 12,600 MWh – leading, based on Germany’s average mix of energy sources encompassing fossil fuels, nuclear power and renewables, to the emission of more than 8500 tons of CO₂*. Based on an energy price of 9.5 cent per kWh, more than a million Euros can be saved this way.

* Source: CARMA (www.carma.org), 2008
A hint that polyglycol oils offer the best wear protection to worm gears is already included in DIN 3996 on the design of cylindrical worm gears. They can help to extend the lifetime of a worm gearbox significantly compared with a mineral oil. The examination of the wear behaviour of various polyglycol gear oils made by Klüber Lubrication performed on Klüber's worm gear test rig shows that with these high-performance gear oils wear is even lower than what DIN 3996 stipulates gear designers should assume for gears lubricated with polyglycol products. This shows that the use of a high-performance polyglycol oil made by Klüber Lubrication rather than a standard polyglycol oil enables an even more significant reduction of wear. Consequently, the worm wheel survives longer with the same load, or the output torque can be increased without dimensional changes. Additional benefits for machine operators are cost savings due to longer maintenance intervals, a lower risk of equipment failure and minimised downtime.

Tested and proven

Applied to the effect a lubricant provides in worm gears, the aspects of sustainability and energy efficiency can be translated into the wear behaviour and the efficiency of a gearbox. Reduced wear means longer service life of components, which has a consequential effect on the exploitation of resources as less raw material is required to make new components to replace the old ones. Higher gear efficiency has a direct effect on the amount of energy consumed.

On a worm gear test rig developed by Klüber Lubrication specifically for the purpose, the influence gear oils have on the wear and efficiency behaviour in heavily loaded worm gears is examined under real-life conditions. Both the speed and the torque of the worm can be measured on this test rig. This is correlated to the worm wheel output torque to calculate the total efficiency of the gear unit. Wear on the worm wheel is measured by determining the weight loss and the abrasion of the tooth flanks occurring during operation. Various temperature values are also measured in the standard version of this test, namely oil sump temperature, mass temperature of the worm shaft, casing temperature and ambient temperature.

Minimising wear

A hint that polyglycol oils offer the best wear protection to worm gears is already included in DIN 3996 on the design of cylindrical worm gears. They can help to extend the lifetime of a worm gearbox significantly compared with a mineral oil. The examination of the wear behaviour of various polyglycol gear oils made by Klüber Lubrication performed on Klüber's worm gear test rig shows that with these high-performance gear oils wear is even lower than what DIN 3996 stipulates gear designers should assume for gears lubricated with polyglycol products.

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Maximum efficiency

Maximum energy efficiency of a gear unit means that it produces the highest possible output power for a given input power. The energy lost in the process manifests itself in the form of heat, for example in bearings, O-ring seals or gear wheels. As gear efficiency increases, its temperature will go down. This has a number of positive effects: a decreasing temperature not only extends the oil life, but the service life of seals as well. This in turn reduces the risk of leakage. Another benefit is that fans or air conditioners in production facilities might be switched off, which is another contributor to lower energy costs and a better CO\textsubscript{2} balance.

According to DIN 3996, the efficiency of gears in mesh is influenced by, among other factors, the oil’s basic friction coefficient. Consequently, oils with a low friction coefficient offer potential for increasing gear efficiency. Similar to their wear characteristics, polyglycol oils show a lower friction coefficient than other base oils. Suitable additives can help to further improve the friction coefficient of a polyglycol. Fig. 3 shows a comparison of various polyglycol oils. The basic friction coefficients determined for Klübersynth GH 6 and Klübersynth UH1 6 are clearly below the figures to be assumed for polyglycol oils according to DIN 3996.

The described effects of higher efficiency make themselves strongly felt in the energy balance of facilities operating several hundred gearboxes. This is shown in detail in the example of a large airport (p. 9).

Conclusion

The changeover from mineral-oil-based to synthetic gear oils is a simple and highly effective way of minimising wear and improving energy efficiency. The extent of optimisation possible depends on the individual gear type. Best results are obtained where polyglycol oils are used in worm gears. Additional potential for improvement is offered by polyglycol oils based on special formulations and containing specific additives: such lubricants enable even longer gear and machine life as well as a lower energy consumption for a given output power.

The result is savings both in terms of financial resources and raw materials. Besides these savings, operators enjoy the benefit of a much better CO\textsubscript{2} balance in their operations.

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Under the umbrella of „KlüberComp Lube Technology“, we have combined our expertise in gear oils. This concept takes into account tribological requirements such as scuffing or micropitting resistance, wear and fatigue protection in rolling bearings, but also the challenges of material pairings such as steel/plastic, steel/elastomer or steel/bronze. Developed in close cooperation with leading OEMs, we have tuned our gear oils to specific material pairings and loads with the aid of sophisticated additive packages. All gear oil series - no matter if based on mineral, ester, polyalphaolefin or polyglycol oil - have been subjected to numerous tests on Klüber’s in-house test rigs in order to attain a maximum of performance.

Besides the development of high-performance products, high manufacturing standards worldwide and numerous additional services are also part of the KlüberComp Lube Technology program. The latter include thorough consultation for product selection and application, used-oil analyses and the optimisation of applications as well as customer-specific training and basic seminars.

This enables gear manufacturers and users to make full use of the know-how available at Klüber Lubrication and thus to optimise the operational reliability of their gears and machinery and reduce their costs.

We have compiled comprehensive information on KlüberComp Lube Technology in a folder. You will find it for download in German or English on our website www.klueber.com under Service > Brochures > Components.

KlüberComp Lube Technology – Gear oils for extreme requirements
The perfect match
Influence of gear oils on the sealing and friction behaviour of radial shaft seals

In power transmission engineering, the sealing system plays a vital role. Many factors influence the performance and lifetime of this complex tribological system consisting of the seal, lubricant and shaft surface. According to recent findings, the role of the lubricant is particularly important. Under the project name Lube&Seal, the two Freudenberg companies Simmerringe and Klüber Lubrication work in close cooperation with users to create tailor-made solutions for increased performance and reliable lifetime predictions for this critical system.

Selecting the right radial shaft seal is the possible influence the lubricant itself may have on the seal material, besides load, speed, temperature, and lifetime requirements. Gear oils are classified as standard oils according to the standard DIN 51 517/03 and therefore comply with considerable protection requirements against fretting and rolling bearing wear. Elastomer compatibility under static conditions is only considered as a next step. However, practical experience has shown that this is not enough to fulfill the multiple industry requirements regarding seal reliability and lifetime under operational conditions.

Composition of industrial gear oils
Industrial gear oils normally consist of mineral or synthetic base oil. The base oil percentage is 85 – 98 %, complemented by additives (see figure 1). In Germany, 70 to 80 % of gears are currently lubricated with mineral oil while the remaining 20 to 30 % are lubricated with synthetic gear oils.

Figure 1: Gear oil composition

<table>
<thead>
<tr>
<th>Base oil</th>
<th>Gear oil</th>
<th>Additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oil</td>
<td></td>
<td>Corrosion protection</td>
</tr>
<tr>
<td>Paraffin-base</td>
<td>Synthetic oil</td>
<td>Ageing protection</td>
</tr>
<tr>
<td>Naphthene-base</td>
<td>Polyglycols</td>
<td>Anti-foam</td>
</tr>
<tr>
<td></td>
<td>Polyalphaolefins</td>
<td>Anti-wear (AW)</td>
</tr>
<tr>
<td></td>
<td>Ester</td>
<td>Extreme pressure (EP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Viscosity index improver</td>
</tr>
</tbody>
</table>
Mineral oils have been traditionally proven as the basis for gear oils for decades. Additives normally dissolve very well in these base oils. Elastomer compatibility is predominantly influenced by the additives selected.

Polyalphaolefins (PAO) are the most commonly used base oils for synthetic gear oils. They show better viscosity-temperature behaviour, very good low-temperature characteristics and can improve friction reduction. Unlike mineral oils, elastomer compatibility with polyalphaolefin oils is influenced by the combination of base oils and additives.

Polyglycols (PAG) are another important group of synthetic gear oils. They also show good viscosity-temperature behaviour, good low-temperature characteristics and a high potential for friction reduction improvement. As with mineral oils, elastomer compatibility is achieved through additivation.

Synthetic esters also show good viscosity-temperature behaviour and good low-temperature properties with a potential for friction reduction improvement. Unlike mineral oils, elastomer compatibility is influenced by the different ester oil types and the additives used.

Radial shaft seal materials

Seals are normally made of rubber-like materials, called elastomers. These are long-chain molecules combined with additives which provide the specific and technical properties of the material. Sealing materials based on NBR and FKM are, apart from few exceptions, the proven preferred sealing materials used in industrial gear applications.

NBR - Butadiene-acrylonitrile rubber: NBR materials show good swelling resistance in hydrocarbons, high resistance to hot water and inorganic acids and bases. However, when exposed to benzene, chlorinated hydrocarbons, esters, polar solvents and polyglycol ether brake liquids, considerable swelling occurs.

FKM – Fluorinated rubber: FKM materials show high temperature resistance, high chemical stability and good swelling resistance in hydrocarbons. Like NBR materials, FKM materials also tend to swell considerably when exposed to polar solvents and flame-resistant hydraulic fluids.

Interactions in the tribological system

The functionality of a radial shaft seal primarily depends on its geometry and the elastomer material.

Radial shaft seals work like a small pump transporting liquids, gases or dirt particles around it through the sealing edge (see figures 2 and 3).

This effect is also used to pump very small leakages back into the area to be sealed. This intentional unmeasurable leakage is required for reliable lubrication and function of the radial shaft seal and has a considerable influence on its service life.
Leak-free sealing of the rotating shaft is ensured by the pressure of the sealing lip on the shaft. This force generates asymmetric pressure distribution on the shaft dependent on the design of the sealing lip angle and tension spring space, which, together with the elastic material properties, causes the pump effect.

Due to the pressing force, the rotating speed of the shaft and other factors, considerable heat is generated under the shaft seal’s sealing edge. There is permanent interaction between the sealing material and the lubricant caused by the very strong shearing forces combined with atmospheric oxygen. It is therefore critical that the combination of shaft seal, lubricant and shaft surface finish be optimised to ensure trouble-free operation.

Elastomer compatibility

Static Freudenberg test modelled after DIN ISO 1817
When selecting a sealing material, in addition to the operational temperature range, the chemical and physical resistance of the sealing material to the lubricant to be used must be considered.

The behaviour of rubber-like materials towards liquids is tested according to DIN ISO 1817 in the specific medium or in standardised testing liquids.

To determine static elastomer compatibility, S2 standard test pieces and discs are punched from a 2 mm test sheet and stored in the test medium. To achieve better correspondence between static and dynamic test results and practical conditions, Freudenberg increased the test duration for mineral oils from 168 h to 1008 h. After being immersed in the test medium, the test pieces are inspected with regard to changes in hardness, tensile strength and ultimate elongation according to DIN 53504. Volume changes are determined according to DIN ISO 1817.

The standard static compatibility tests were traditionally used for lubricant approvals, but it is now more representative to conduct dynamic seal testing as well.

Dynamic oil compatibility test following DIN 3761
To analyse compatibility on original components under largely realistic conditions Freudenberg and Friedr. Flender AG developed a testing programme. This dynamic seal testing is undertaken on DIN-standard test benches.

The radial shaft seals used are analysed by measuring the relevant functional parameters and by visual inspection (see table 1, page 17). To attain approval, the variation compared to the original measurements is decisive. Visual inspection results are based on experimental values.

Friction reduction
The friction between the seal and shaft is an important indicator of the expected seal lifetime. It should be kept as low as possible as the friction heat generated by the sealing system influences both gear efficiency and lubricant temperature. Temperature increases of only 10 K halve the lifetime of both the radial shaft seal and gear oil.

The Lube&Seal cooperation therefore focuses on determining the frictional moment, or power loss, for all seal/lubricant combinations as a function of the speed, temperature, lubricant additives and viscosity.
Initial findings on the influence of lubricant additives prove that different additives in the same base oil can considerably influence the frictional moment and the temperature in the shaft seal’s sealing zone (figure 5). The example below shows that the frictional moment and temperature are considerably higher with lubricant PAG 1 than with lubricant PAG 2 over the entire speed range regardless of the oil sump temperature.

Energy and CO₂ emission reduction

Basic research projects have shown that the right combination of radial shaft seal (material/shape) and lubricant can lead to considerable friction reduction.

Rough calculations deliver the following figures:
Assumption: Typical industrial gearbox with three seals, operating time 5,000 hrs p.a.
- Power loss using standard radial shaft seals approx. 90 W
- Power loss using optimised standard radial shaft seals approx. 60 W

The potential in energy-saving for an entire installation leads to a remarkable potential reduction of CO₂ emissions: a gear manufacturer making one million gearboxes per year could contribute to the reduction of industrial CO₂ emissions by users by approx. 25 tonnes CO₂ p.a. simply through changing oil and seals (1 kW corresponds to average carbon dioxide emissions of approx. 500 g).

Conclusion

Industry requirements regarding tightness and reliability of radial shaft seals are ever-increasing. Elastomer compatibility of the lubricant is, besides speed and temperature, of particular importance if these increased requirements are to be met.

Practical experience has shown that the traditional purely static elastomer compatibility testing is not sufficient. Dynamic seal testing is thus indispensable as only these tests allow reliable conclusions on the long-term behaviour of the shaft/seal tribo-system under lubricant exposure.

If the combination of radial shaft seal, shaft and lubricant is ideal, seal lifetime can increase three-fold and friction at the sealing lip can be reduced by up to 30%. As a consequence of this optimisation, considerable CO₂ emission reductions are possible.

However, the complex interaction between lubricant and sealing material must be thoroughly investigated to realise these reductions.

Freudenberg is meeting this challenge with its Lube&Seal cooperation.
### Table 1: Limit values after dynamic test

<table>
<thead>
<tr>
<th>Test parameter</th>
<th>Unit</th>
<th>Test passed at</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage</td>
<td>ml</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sealing time</td>
<td>h</td>
<td>1008</td>
<td>1008</td>
</tr>
<tr>
<td>Width of running mark at the seal edge</td>
<td>mm</td>
<td>≤ 0.5</td>
<td>≤ 0.4</td>
</tr>
<tr>
<td>Depth of shaft run-in</td>
<td>μm</td>
<td>≤ 5</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Radial force with tension spring 1/2</td>
<td>%</td>
<td>+10 to −45</td>
<td>+10 to −35</td>
</tr>
<tr>
<td>Contact ratio with tension spring 1</td>
<td>mm</td>
<td>≤ −0.6</td>
<td>≤ −0.5</td>
</tr>
<tr>
<td>Contact ratio without tension spring 1</td>
<td>mm</td>
<td>≤ −0.7</td>
<td></td>
</tr>
<tr>
<td>Visual inspection of the sealing lip:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discolouration of running mark</td>
<td></td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Carbon build-up</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hardening</td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Fissuring</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Blistering</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wear of the seal edge / flange groove</td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Chemical attacks</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wear of the seal edge / flange groove</td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Residuals on shaft</td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Rating: none = 1, low = 2, distinct = 3, strong = 4, very strong = 5

### Comparison of friction moment / temperature, BAUM3X7 35-52-7, medium temperature 80 °C

![Friction moment vs Temperature Graph](image)

**Figure 5:** Influence of additives on an FKM seal, Ø 35 mm
Automotive challenges
New lubricant developments amplify design options

One of the major challenges in automotive design is the reduction of fuel consumption by increasing the efficiency of individual components as well as reducing the total weight of the vehicles. In cooperation with renowned automotive suppliers, Klüber Lubrication was able to develop a range of innovative speciality lubricants tailored for optimum interaction with modern automotive components.

A focal issue in this context is the increasing use of plastic materials in vehicles. Innovative plastic components that have to function trouble-free in the long term even under extreme conditions in motor vehicles harbour special requirements for lubricants: The plastic and the lubricant may interact in such a way that a wrong combination of substances can cause substantial damage. For this reason, Klüber Lubrication is carrying out intensive research investigating the interaction of lubricants and plastics.

Another important factor is the energy consumption of the individual vehicle components. Klüber Lubrication offers speciality lubricants that help to attain a high degree of energy efficiency through optimised friction. Where such lubricants with an optimised friction coefficient are used, energy consumption can be reduced – an additional aspect for design engineers working on a reduction of the total energy consumption in vehicles.

Compatibility with elastomers and plastics

Klübersynth MR 96-31 is a special grease developed by Klüber Lubrication that is compatible with numerous non-polar polymers such as PP or PE, elastomers such as EPDM, and polar polymers such as POM, PA 66 or NBR. Due to this compatibility, components consisting of friction bodies made from different materials can be developed. Klübersynth MR 96-31 offers reliable
Protection against wear over a wide temperature range from -40 to +120 °C, ensures smooth motion, dampens noise and reduces vibration. These characteristics make it an obvious choice for numerous vehicle components, e.g. slideways, small gears, window lifter modules, etc.

Saving fuel as efficiency is increased

Klübersynth BM 44-42 is a highly adhesive synthetic long-term grease for components subject to high wear loads. While it has been developed to ensure low wear in idling operation and a reliable engagement and disengagement of freewheels and over-ride clutches running on rolling bearings, Klübersynth BM 44-42 is also capable of enabling a considerably higher efficiency in rolling bearings in electro-mechanical steering systems and clutch actuators. With its optimised oil release and specific antiwear additives, this special grease enables longer component life and a reduction of maintenance. Its service temperature range is -40 to +140 °C.

New hybrid grease helps save costs

Klübersynth BHP 72-102 was developed for the lifetime lubrication of heavily loaded friction points in components located near the car engine, which are therefore often exposed to alternating temperatures from -40 °C to +200 °C - for example in viscous coupling bearings, belt tensioners, radiator fans and related applications. Furthermore, this high-temperature lubricant is used for release bearings in cars using alternative forms of drive power such as hybrid engines. Klübersynth BHP 72-102 is based on new, patented hybrid grease technology and enables longer runtimes as well as lower grease consumption costs than conventional lubricants.

Grease for low driving power

BARRIERTA KM 192 is a high-temperature grease for the long-term lubrication of rolling or plain bearings where low driving power and long-term stability under varying ambient conditions are required. It may be used, for example, as a high-temperature grease for bearings in dual clutch gearboxes. At the same time, BARRIERTA KM 192 has good low-temperature characteristics. It remains therefore sufficiently smooth at extremely low temperatures so as to prevent low-torque drives from being overloaded. BARRIERTA KM 192 is also compatible with a wide range of plastics and elastomers. It may therefore be used for the lubrication of valve actuators and seals, for example in EGR systems. In such applications, the grease ensures long runtimes combined with low noise and a low friction coefficient.
Reducing operating costs and improving CO₂ footprint in the food-processing industry
High potential in compressor and gear operation - example of a brewery

The production, storage and filling of beer in large quantities requires extremely high amounts of energy, resulting in high operating costs for breweries. Enormous potential for energy savings lies in the operation of refrigeration compressors, air compressors and gearboxes, as their energy footprint can be improved considerably by using state-of-the-art speciality lubricants.

“Reducing energy consumption is an important concern of equipment manufacturers and operators, as energy costs make up a significant part of their total operating costs”, says Manjesh Babu, Market Manager Food Processing Industry at Klüber Lubrication München KG. “However, energy not only incurs costs for the user; energy generation is also one of the main sources of climate-damaging CO₂ emissions. Reducing the energy consumption of a brewery is therefore also a marked contribution to environmental protection.”

The brewery example below with three production lines shows the high potential for energy savings in the operation of compressors and gearboxes. Typically, refrigeration compressor power in operation is 200 kW, air compressor power is 300 kW and gear power 450 kW. After the changeover to state-of-the-art speciality lubricants, efficiency increases between 0.5 and 15 percent can be proven, depending on the type of equipment. The energy savings can add up to 224,400 kWh, which is equivalent to more than € 20,000 per year, taking 9.4 cents per kWh as a basis (see table "Potential savings in a brewery"). Changeover to appropriate speciality lubricants is easy and pays off after a short while.

Saving costs with synthetic compressor oils

The energy consumption by compressors constitutes a sizeable proportion of operating costs. By reducing friction and offering better gap sealing, a synthetic compressor oil based on a suitable formulation can contribute both to a higher volumetric efficiency and a reduction of energy consumption. Less than one percent of the operating costs of a compressor are attributable to the compressor oil purchase. While synthetic compressor oils are more expensive to buy than conventional oils, they turn out to be more cost-efficient when considering overall compressor operation costs.
The operation of refrigeration compressors also benefits from the use of high-performance products. Klüber Summit R series synthetic refrigeration compressor oils, for example, enable refrigerators to operate with high efficiency due to reduced residues and oil carryover. With these oils, refrigerators can be used for a wide range of applications with evaporator temperatures down to -50 °C.

Both Klüber Summit FG oils and Klüber Summit R oils are registered as NSF H1 and certified according to ISO 21469, making them obvious choices for use in the food and pharmaceutical industries.

### Potential savings in a brewery

<table>
<thead>
<tr>
<th>Component</th>
<th>Power output</th>
<th>Operating time</th>
<th>Energy consumption</th>
<th>Potential savings</th>
<th>Energy savings</th>
<th>Savings in Euros</th>
<th>Improvement of CO₂ footprint*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigeration compressors</td>
<td>200 kW</td>
<td>8,760 h</td>
<td>1,752 MWh</td>
<td>approx. 5 %</td>
<td>87.6 MWh</td>
<td>8,520.00</td>
<td>39.2 t</td>
</tr>
<tr>
<td>Air compressors</td>
<td>300 kW</td>
<td>6,000 h</td>
<td>1,800 MWh</td>
<td>approx. 4 %</td>
<td>72.0 MWh</td>
<td>6,800.00</td>
<td>32.2 t</td>
</tr>
<tr>
<td>Gears</td>
<td>450 kW</td>
<td>6,000 h</td>
<td>2,700 MWh</td>
<td>approx. 2.4 %</td>
<td>64.8 MWh</td>
<td>6,100.00</td>
<td>29.1 t</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>224.4 MWh</td>
<td>21,150.00</td>
<td>100.5 t</td>
</tr>
</tbody>
</table>

All values apply to one year at an average energy cost of 0.094 Euros/kWh

* 447 kg/MWh on average, depending on regional mix of energy resources; source: CARMA 2008

### CO₂ emission per MWh of energy generated per region:

<table>
<thead>
<tr>
<th>Continent</th>
<th>CO₂ in tons</th>
<th>MWh of energy</th>
<th>kg of CO₂ / MWh of energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>5,750,000,128</td>
<td>8,030,000,128</td>
<td>716</td>
</tr>
<tr>
<td>North America</td>
<td>3,089,999,872</td>
<td>5,139,999,744</td>
<td>602</td>
</tr>
<tr>
<td>Europe</td>
<td>1,880,000,000</td>
<td>4,220,000,000</td>
<td>447</td>
</tr>
<tr>
<td>Germany</td>
<td>429,000,000</td>
<td>636,000,000</td>
<td>676</td>
</tr>
<tr>
<td>Africa</td>
<td>335,000,000</td>
<td>518,000,000</td>
<td>647</td>
</tr>
<tr>
<td>Oceania</td>
<td>235,000,000</td>
<td>273,000,000</td>
<td>859</td>
</tr>
<tr>
<td>South America</td>
<td>139,000,000</td>
<td>874,000,000</td>
<td>159</td>
</tr>
</tbody>
</table>

All data provided refer to the results attained with the mix of energy resources used in each of the stated regions (fossil fuels, nuclear power, hydrodynamic and other renewable sources of energy). Source: CARMA (www.carma.org), 2008.

A lot of energy is needed before a decent pint can be enjoyed.
Speciality lubricants for refrigeration compressors and gears offer a high potential for savings.

**Gear oils for the food industry**

Synthetic gear oils made by Klüber Lubrication also contribute to high process reliability and reduced energy consumption and are likewise registered as NSF H1 and certified according to ISO 21469 and hence permitted for use in the food and pharmaceutical industries. As their synthetic base oils are extremely resistant to ageing and oxidation, these lubricants offer a much longer service life and can increase gear efficiency considerably. Their good viscosity-temperature behaviour means that in many applications a single viscosity grade can be used for both high and low-temperature applications.

Klüberoil 4 UH1…N oils are gear oils for normal temperature use and normal loads that even enable lifetime lubrication in certain applications. For high temperatures and high loads, the use of Klübersynth UH1 6 oils is preferred as the optimised friction behaviour of the polyglycol base oil reduces power loss and clearly improves gear efficiency. Klüber Lubrication also offers a fluid grease, Klübersynth UH1 14-1600, enabling a good supply of lubricant to the friction point due to the soft consistency. The special thickener provides good adhesion and corrosion protection, thus enabling longer component life.

**For a lower CO₂ footprint**

The positive effects are not limited to savings in operating costs alone. If energy consumption is reduced, the carbon footprint of a brewery improves. Approximately 447 kg of carbon dioxide is emitted in Europe on average per megawatt hour, depending on the regional energy mix of fossil fuels, nuclear energy and renewable energies. If the brewery described above saves 224,400 kWh, its carbon footprint improves by more than 100 tons of carbon dioxide per year.

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Rolling bearings and other machine elements can be subject to unfavourable lubrication conditions due to mixed friction occurring during operation. Extreme pressure (EP) and antiwear (AW) additives have been added to lubricants for years in order to prevent excessive wear of the friction elements. When solid bodies contact and temperature increases as a consequence, the additives react and form a so-called tribolayer on the surfaces they are meant to protect. The effect of such additives depends on the conditions existing on the interacting surfaces.

A number of tests are conducted to determine the additives’ reactivity under various kinds of motion. For this purpose, several surface-active additives are tested under motion conditions such as oscillating-sliding, oscillating-rolling-sliding and continuously sliding.

As a result, strengths and weaknesses of additive groups under the tested contact conditions are identified as well as the extent to which the test benches used are suitable for the evaluation of additives. This provides valuable insight for the development of new rolling bearing lubricants.
Analysis results are set in relation to the test conditions, test results, additive properties and reaction layers. Several groups of active substances are used as additives, e.g. phosphate antiwear additives, sulphurised extreme-pressure additives and phosphorus-sulphur compounds. The results explain the effect of lubricants in rolling bearings and provide valuable support for their development.

Methodology

A decisive factor for antiwear additives forming a tribolayer is the energy input onto the interacting surfaces. Under standard test conditions on the same test rig, the energy input should ideally be constant. To be able to compare additives with regard to their wear protection capacity and formation of tribolayers under differing motion conditions, i.e. on various test rigs, the energy input into the friction point must be the same on each device. Speeds, loads, geometries and contact temperatures are therefore analysed and energy input is set to a constant level. The various types of motion on the test equipment selected are oscillating-sliding (SRV), continuously sliding (pin-on-disc testing) and oscillating-rolling-sliding (KLM FAB test).

The lubricants used for testing consist of two different base oils containing the additives to be tested. As a first step, additive reaction to the test conditions is measured, e.g. by referring to friction force, electric contact resistance and amount of wear. The next step is to rank the additives according to their measurement results.

Furthermore, the causes of friction and wear reduction were investigated in surface analyses, providing information on the structure, thickness and resistance of the tribolayers and assuring the comparability of measurements and analysis results. The aim of this is to underpin and enhance the validity of measurements in order to be able to interpret future measurements without having to conduct surface analyses.

Additives and their properties

The effect of EP additives is to form sufficiently resistant reaction layers on metal surfaces under high temperatures, loads and speeds whenever natural oxide layers are abraded. These layers also prevent metal/metal contact in the event of occasional ruptures in the hydrodynamic lubricating film. Many additives of this type can also smooth surface roughness peaks, which further enhances the formation of a hydrodynamic lubricant film - of course this means temporarily greater wear during operation.

Fig. 1: Results attained with additives on the four-ball tester for different base oils. The overview shows the desired effect of the additives in oil under the existing testing conditions. The arrows show how additives improve with base oil 2 compared with base oil 1.
To have the capability to form such layers, EP additives must show thermal resistance on the one hand and the capacity for physisorption and chemisorption on the other hand. These properties do not solely depend on the nature of chemically active elements, but also on the structure of the additive molecules, their decomposability, the degree of activity of the decomposition products and the chemical activity of the metals of the friction bodies. The metals’ reaction partners are mostly sulphur compounds \([1-3]\). The characteristic of these chemicals is the direct bonding of the active elements to the metal atoms, leading e.g. to the formation of iron sulphide \([4]\). The antiwear effect depends directly on the sulphur content in the additive. The sulphur content, however, is always a compromise of reactivity (corrosive attack) and stability (e.g. thermally) \([5]\).

Other than sulphur-containing additives, those with phosphorus do not cause corrosion, even in high concentration, especially in contact with brass. As their antiewear mechanisms, reaction times and film thicknesses differ from those of sulphurised ones, phosphorus compounds as antiwear additives cannot be replaced by sulphur-containing additives. Additives containing phosphorus prove particularly strong when used at very slow sliding speeds and on rough surfaces \([6]\), \([7]\). Incorporating sulphur in the molecules of phosphor-containing AW additives leads to higher thermal stability and load-carrying capacity \([7]\). It is often impossible to draw a strict distinction between AW and EP additives, as many substances have both properties \([1], [7]\).

**Should one prefer additives with EP or AW properties?**

The wear protection characteristics of additives are tested by means of the four-ball tester (DIN 51350) \([8]\). The long-term wear resistance test serves to test the AW effect of additives, i.e. how quickly and permanently an additive can form reaction layers and protect surfaces. The result is the diameter of the wear scar. The four-ball test also classifies additives with regard to their suitability as EP additives by testing the scuffing load capacity of the tribolayer formed by them under stepwise loads. The non-seizure load is significant for the evaluation rather than the actual wear scar diameter.

In Fig. 1, we see the four-ball test results of various additives and whether their EP or AW properties prevail. It would be impossible to use a non-additivated lubricant for this purpose; so it cannot serve as a reference in the diagram. A wide range of additives were tested. The four-ball tester appears to be an appropriate tool to differentiate EP and AW properties. Additives were tested...
with two different base oils. In Fig. 1, we clearly see that sulphurised additives have better AW properties in base oil 2 than in base oil 1. The effect of different oils on phosphor-containing additives is less pronounced.

Results

To create suitable testing conditions on the test rigs, additives were mixed with the base oils in a percentage of 1% in each case. The test results and measurement equipment differ due to the varying scope of the test rigs.

Type of stress applied and the additives’ function

Friction coefficient and contact resistance under oscillating-sliding stress at the oscillation friction wear test rig (SRV) were documented for each lubricant. As expected, the non-additivated lubricant showed the highest friction coefficient Figure 3). As can be seen in Figure 4, contact resistance could not be measured, either. These results provide us with an answer to the question whether measuring contact resistance serves to verify either the formation of a reaction layer or a separating hydrodynamic lubricating film. A separating lubricating film would be identifiable as the cause for the resistance after a very short time in all three cases.

As this is not the case, the occurrence of contact resistance hints towards the formation of a reaction layer.

The high friction coefficient and non-measurable contact resistance which were identified during the test with pure base oil indicate solid body contact without a separating layer for wear protection. The additives showed a more or less pronounced friction-reducing effect. The SRV tester indicated a constant friction coefficient already after approx. five minutes. Although the oils contained different additives, no fluctuations in the friction behaviour were detected.

The contact resistance results over time in Fig. 3 show two additive substances forming an effective reaction layer relatively quickly. After twelve minutes, contact resistance is up to its maximum. At the same time, friction coefficient results become constant. There is a balance between stress and reaction of the lubricant.

The most striking properties were encountered with an additive which reduced friction on the one hand and did not cause the formation of contact resistance on the other. This can be explained by the strong effect of sulphurised EP additives: as they form iron sulphide, they can in fact conduct an electric current without forming resistance. This indicates that, even if no resistance is measurable, a reaction layer may have formed.

Test duration in percent was set to a standard value in order to be able to compare test results obtained with an additive under constant energy input. Fig. 4 shows the test results of an additivated lubricant subject to various types of stress.
In case of the tested additive, the formation of a measurable reaction layer is to be expected primarily under oscillating-sliding stress. After 20% of the running time, a fully formed reaction layer can be expected. This result also reflects the results of the measurement of the friction coefficient. When tested on the KLM-FAB test bench under oscillating-rolling-sliding stress, activation of the additive began slowly only after half of the running time had elapsed, after which high resistance values could be measured, meaning that good wear protection is also likely to be achieved in this case.

**Outlook**

Klüber Lubrication uses the tests and analyses illustrated as tools to develop lubricants containing additives for customer-specific applications. The effects of the additives are fully utilised, additive synergies are used and the concentration of active agents is tuned for an optimum effect. In addition to straightforward functional requirements, this enables additives to be used to optimise wear protection thereby reducing the consumption of resources, with a view to environmental aspects.

**Bibliography**

1. Sommer, K.: Reaktionsschichtbildung im Mischreibungsgebiet langsamaufender Wälzlager; Staatliche Materialprüfungsanstalt Universität Stuttgart; Diss 1997
2. Pass, F.: Die Wirkungsweise der Schmieradditive; paper held at GfT in Essen; 1969
5. Dunklen, H.; Kolitz, L.; Mayer, R.: Zeitschrift für Chemie; 24(4) volume, December 1984, issue 12; ISSN 044-2402
8. DIN 51350: Prüfung im Shell-Vierkugel-Apparat, Allgemeine Arbeitsgrundlagen; January 1977; Beuth-Verlag

**Tribojournal** 1/2011
New cleaning spray for the food and pharmaceutical industries eliminating oil, grease, resin and adhesive

Klüber Lubrication presents its first surface cleaner and degreaser for the food and pharmaceutical industries, Klüberfood NK 1 Z 8-001 Spray. The newly developed cleaning spray rapidly and thoroughly removes oils, greases and resins from metal and plastic surfaces. The cleaner also reliably removes adhesive residues, e.g. on labelling machines. Klüberfood NK 1 Z 8-001 has been registered by the NSF as K1 and K3 and therefore complies with FDA 21 CFR and is approved for use as an operating supply in the food, pharmaceutical and cosmetic industries. NSF registration letters are valid all over the world and confirm the suitability and compatibility of the operating supplies during audits. Therefore, they constitute important compliance documents.

Klüberfood NK 1 Z 8-001 Spray does not contain extremely flammable propellants like butane or propane, but uses a VOC-neutral propellant obtained in a non-polluting way instead. The additional benefit of this propellant is that the active substance content in the spray could be more than doubled, i.e. a very little quantity of the spray is sufficient for a good cleaning effect.

Chain lubrication with cleaning effect

Klüber Lubrication launches Klübersynth CHM 2-100, a new high-temperature chain oil for drive, lift and conveyor chains. Among the special oil’s distinctive features are its thermal stability and low residue formation as well as the capacity to dissolve existing residues. Klübersynth CHM 2-100 therefore overcomes the problem of conventional chain oils which evaporate under high temperatures and form lacquer-type residues. These residues impede the supply of fresh oil to the friction points and increase friction. This in turn leads to higher energy consumption and increased chain wear.

With Klübersynth CHM 2-100, maintenance intervals can be extended, downtime reduced and the plant’s energy efficiency increased. At the same time, the new chain oil contributes significantly to preserving the chains’ value.

Klübersynth CHM 2-100 can be used for all drive, lift and conveyor chains at high temperatures up to approx. 250 °C and can be applied, for example, in coating installations (radiators, white goods), in the insulating materials industry (glass and rock wool), in conveyors (automotive industry) and driers (gypsum boards). Klübersynth CHM 2-100 is NSF H2-registered and thus suitable for use in areas in the food-processing industry where direct contact with the food products can be excluded.
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