Focus on:
Plastics and lubricants

Further topics:
High performance under extreme conditions
Reliability at sub-zero temperatures in refrigeration compressors
Tailor-made package for food-processing industry

Lubrication is our world
The chemistry has to be right
Speciality oils for extruder gears help save costs and increase operational reliability

Save costs – increase performance – solve problems
Bonded coatings improve friction and wear behavior of plastic components

Lube & Seal, a combination ensuring reliable function in power transmission technology
Lubricant and radial shaft seal from a single source

High performance under extreme conditions
Faster, higher, further – PFPE lubricants push performance limits

Hot stuff
High-temperature grease offers new performance range

Reliability at sub-zero temperatures
New generation of refrigeration compressor oils enables lower operating costs throughout the refrigeration cycle

Exhibitions: Platforms for contacts
Tailor-made
Product and service package for the food-processing in industry

Reader Service

New brochures

Professional tips and hints
Customer training made by Klüber

Fit for the future
Longer automotive component life attained with new special grease
Innovation is today more in demand than ever. It is generally regarded as the prerequisite for the competitiveness and long-term success of a company in ever more contested and internationalized markets. On the other hand, the term ‘innovation’ appears to be somewhat overused, it has often become a mere buzzword and leaves much space for interpretation. So let’s have a closer look to get it clear what we’re talking about.

Klüber Lubrications offers its customers innovation – and has done so even before the word was on everyone’s lips. Already the company founder Theodor Klüber had solutions to very specific problems of customers in mind. In the early 1950ies, he began with the development of speciality lubricants – although his existing business with mineral oil products and petrol was flourishing – because he was foresighted enough to realize the industry’s oncoming demand for such products. And there are many more examples of creative ideas and pioneering products to be found in the 77 years of our company’s history. The trendy label ‘innovation’, however, has not been attached to each and every item. So not every innovation is recognized as such at first glance!

The range of innovations we offer you – even without that label – and, even more important, what these novelties from Klüber Lubrication can contribute to your success, is outlined in this edition of Tribojournal. There is, for example, our Lube & Seal concept, a development partnership for power transmission applications aiming at optimized service lives and tightness of seals. Or take KLASS, the Klüber Lubrication Asset Support Service helping all kinds of industrial operations to attain profitability and quality goals in all kinds of industrial operations, the food-processing industry being the example referred to in this edition.

I wish you interesting reading!

Claus Langgartner

Claus Langgartner
Speaker of the Board,
Klüber Lubrication München KG
The chemistry has to be right

Speciality oils for extruder gears help save costs and increase operational reliability

Extruder output is steadily being maximised in extrusion and compounding. At the same time, operators are trying to minimise their investments on process technology and operation. Technological advances in recent years in screws and drives have doubled the throughput performance of extruders. As a result, the requirements on the entire power train are changing. On one hand, the gears are becoming more compact and less expensive. On the other, the torque, temperature and loads in extruder gears have increased as efficiency has improved.

As designs have become more compact, the quantity of oil in the gears has decreased. Nevertheless, the best possible build-up of lubricating film must be guaranteed for every drive operating mode. While in the past the gears were actually over-dimensioned for operation, the new generation of extruder gears frequently work non-stop under full load. Such conditions push mineral oils to the limit of their performance.

When so-called high-torque and high-speed extruder gears are being designed, choosing the right oil has become a major factor that influences added value and long-term operational stability. Synthetic oil grades offer many advantages here.

Unique features of extruder gears

Extruder gears come particularly under strain at the last pair of gears and on the thrust bearings on account of high torque and longitudinal thrust. Twin-screw extruders additionally have less design space on account of the small distances between the axes of the screws. As a result, there are limits imposed on the design of the last gear train and the splitting of forces between the individual screws. Synthetic oils afford a means of designing wear prevention into the drives as they are being developed.

At high longitudinal screw pressure, high forces act on the thrust bearings. Twin-screw extruders are for this reason fitted with tandem bearings arranged in line. A circulating lubricating system lubricates these bearings with oil. The viscosity of the lubricating oil has to be determined on the basis of the expected operating conditions at the last pair of gears and on the thrust bearing assembly. The most common viscosity classes for extruder gears are ISO VG 220, ISO VG 320 and ISO VG 460. In a cold start, the oil must be soft enough to be pumpable and at the same time viscous enough to form a lubricating film. Synthetic oils offer the necessary performance spectrum.
Good selection matters

Mineral oils are mixtures of hydrocarbons of different molecular structure. These structures influence their physical characteristics. For this reason, performance characteristics within the group of mineral oils differ, too. Synthetic oils are derived from polyglycol, polyalphaolefin and esters. The tribological advantages of synthetic oils over mineral oils include:

- high thermal and oxidation stability
- less change in viscosity over the temperature profile
- lower friction values at the gear teeth
- high wear protection in bearings and gears
- good load carrying capacity in bearings and gears, and
- low residue formation.

From the diversity of synthetic base oils and with an in-depth know-how of chemical additives, it is possible to develop synthetic oils that offer technical advantages for specific requirements. In this regard, it is important that the chemistry of the oils be taken into account when the gears are being designed. By using synthetic oils, the extruder operator can save energy in the power transmission and enhance the operational reliability of the extruder while requiring less oil changes. All in all, costs will be reduced and the availability of the plant may be increased.

Saving energy

In recent years, extruder manufacturers have paid increasing attention to the reduction of energy losses in power transmission. This is a further argument speaking in favour of synthetic oils with their higher efficiency.

Gear efficiency can be substantially improved by using oils based on polyalphaolefins, esters and polyglycols. Tribological studies have shown that different friction coefficients are attained at identical operating conditions:

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>Friction Coefficient µ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oils</td>
<td>0.039 µ</td>
</tr>
<tr>
<td>Polyalphaolefins, ester</td>
<td>0.022 µ</td>
</tr>
<tr>
<td>Polyglycol oils</td>
<td>0.011 µ</td>
</tr>
</tbody>
</table>

These friction values and the results of efficiency studies were used to establish the power loss occurring with the various oils:

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>Power Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oils</td>
<td>approx. 2%</td>
</tr>
<tr>
<td>Polyalphaolefins, ester</td>
<td>approx. 1.6% to 1.7%</td>
</tr>
<tr>
<td>Polyglycol oils</td>
<td>approx. 1.45%</td>
</tr>
</tbody>
</table>

Evaluation reveals a substantial reduction in power loss in the case of synthetic specialty oils.

In a multi-stage extruder gear, this seemingly low improvement leads to a measurable decrease in power consumption. For example, an extruder drive lubricated with polyglycol oil has a power loss of around 13,500 kW at a rating of 150 kW and an annual operating time of 6000 hours. By comparison, the power loss for a drive operated with mineral oil is around 18,000 kW. This difference translates into substantial savings potential on energy costs.

Longer lifetime

The better frictional performance of the synthetic oils causes less frictional heat to be generated in the contact zone and hence the lubricating film. At the same time, these oils have a higher thermal stability. For these two reasons, they age more slowly than mineral oils. Also, less stress is placed on existing oil cooling systems. Oil life can be extended up to five-fold. In practice, the oil-change interval for
mineral oils is 10,000 operating hours in a standard extruder drive with an operating temperature of 70 °C. Synthetic oils have service lives of up to 40,000 operating hours, and in some cases the values are even higher. Analysing used oil offers additional security when oil-change intervals are being determined. As a result, numerous oil changes can be dispensed with, along with the associated outlay. To an extent depending on the maintenance intervals for the whole unit, this can also translate to higher availability of the extrusion equipment.

Wear reduction

Gear manufacturers instruct operators on the oil viscosities to be used. The right oil viscosity ensures that a lubricating film forms also under load. However, viscosity changes with temperature to a stronger or lesser degree, which is described by the viscosity index. This change is more pronounced in mineral oils than in synthetic oils. The higher the viscosity index, the lower is the change in viscosity across the temperature range for the drive. When the temperature in the gear changes, the oil viscosity and the conditions for continuous build-up of lubricating film also change. In the long-term, therefore, a high viscosity index equates to lower wear.

Viscosity indexes of different base oils

<table>
<thead>
<tr>
<th>Base Oil</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oils</td>
<td>80 to 100</td>
</tr>
<tr>
<td>Polyalphaolefins</td>
<td>130 to 150</td>
</tr>
<tr>
<td>Ester oils</td>
<td>140 to 175</td>
</tr>
<tr>
<td>Polyglycol oils</td>
<td>150 to 270</td>
</tr>
</tbody>
</table>

Besides the higher load-carrying capacity of synthetic oils, their lesser tendency towards residue formation plays also a major role. Mineral oils that are operated continuously at their limits generate solid ageing residues that increase wear.

Compatibility

Synthetic oils need to be chemically compatible with radial shaft seals, sight glasses, and interior coatings if leaks are to be avoided. The synthetic oils approved by gear manufacturers have frequently been tested for their interactions with the corresponding plastics and coatings.

In extruder gears, the fitted radial shaft seals are primarily made of the elastomers NBR and FKM. Synthetic hydrocarbons (polyalphaolefins) are usually compatible with these types of seals. In the meanwhile, intensive fundamental research
conducted in conjunction with producers of radial shaft seals has also led to the approval of ester and polyglycol oils. The compatibility is tested both statically and dynamically in order that a harmonised system of lubricating oil and elastomer seals may be offered. This makes it much easier to decide to switch from mineral oils to synthetic oils. In cases of doubt, individual studies by the oil manufacturer can provide security for the customer.

The Lube & Seal cooperation between Klüber Lubrication and Simrit offers the additional benefit of increasing the seal life. (Read also the article on page 15.)

**Maintenance – living values**

Synthetic oils, and polyglycols in particular, help operators working in a 24/7 production mode with their long-term maintenance strategies:

- safeguarding plant availability
- initiating preventive maintenance measures
- increasing operational reliability
- increasing productivity
- increasing machine life

**Cost/benefit ratio**

The pure purchase costs per litre of synthetic oil, especially for specialties, may be higher than those of mineral oil. However, when viewed over the entire lifetime of the equipment, the operating costs are much lower on account of the aforementioned technical advantages of synthetic specialty oils over mineral oils. Costs for oil change and oil disposal are reduced due to the longer oil change intervals. Furthermore, the right synthetic oil can help to save energy costs and reduce wear in the machinery. Klüber Lubrication will be pleased to conduct detailed cost-benefit analyses together with the customer.

**Your benefit:**

- Less wear
- Higher efficiency
- Higher drive torque

**leading to**

- longer oil change intervals
- less maintenance and repairs
- energy savings
- lower operating costs

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Fig. 4: Possible oil change intervals

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[Image of Dipl. Ing. (FH) Sebastian Homborg]
Together with two major OEMs from the plastics industry, Klüber Lubrication has conducted extensive field tests. They showed that large extruder gears lubricated with the polyglycol special oil Klübersynth GH 6-220 run longer at lower cost than with the previously used mineral oil.

Companies involved:
Thielenhaus Technologies GmbH, Wuppertal; Business Unit Köllmann Gear, a leading German manufacturer of single-worm extruder gears
Kiefel Extrusion GmbH, Worms, a leading German manufacturer of plastic processing technology, especially of blow moulding machines

Test description
- Seven-layer blow moulding machine with seven extruders
- Two extruders fitted with single type of gears, max. power 56 kW
- One set of gears filled with previously used mineral oil
- A second set of gears fitted with polyglycol-resistant materials (inner paint and seal), filled with Klübersynth GH 6-220 (polyglycol)
- Measurement of oil sump temperature at identical load on both gears. Lower oil sump temperature indicates that less friction heat is being generated in the gears. By means of the WTPlus program of FVA (Research Association for Power Transmission Engineering), these measured data can be used for calculating the gears’ efficiency. In combination with the experience gained in practice, the oil sump temperature also allows conclusions on equipment life. The measurements are made with a specifically calibrated sensor (measuring uncertainty 0.14 °C).
- Oil sump temperature is compared with ambient temperatures of the individual gears.

Results
The oil sump temperature of the set of gears lubricated with the polyglycol oil was 2.8 °C lower at the operating point than that of the gears filled with mineral oil. To enable a direct conclusion on the efficiency, the efficiency under full-load conditions was determined (WTPlus program by FVA). The calculated efficiency attained with Klübersynth GH 6-220 was 97.168 %, i.e. 0.434 % above that of mineral oil.

Benefit: cost reduction
For mineral oils in extruder gears, an oil change is recommended every 6000 operating hours. Due to the oil sump temperature measured in the test, the oil change interval can be much extended for Klübersynth GH 6-220, namely to 20,000 operating hours.

For gears operating under less than full load, this constitutes a major benefit in terms of less costs for buying and storing oil and for maintenance. In gears operating under full load, energy costs are also reduced.

For the gears under test, for example, a yearly cost benefit of approx. 500 Euro can be generated. For the blow moulding plant as a whole, this would mean savings of up to 3,000 Euro per year, amounting to up to 15,000 Euro in five years.
Longer service life with bonded coatings from Klüber

Squeaking noises, high friction losses and wear - if you work with plastic parts that are subject to high loads, you know these problems all too well. But this needn’t be so: our Klübertop bonded coatings offer a clean, reliable and flexible alternative to traditional lubrication. Even in parts where regular relubrication is either not possible or very problematic, friction can be dramatically reduced, particle emission limited and component life significantly extended. A soft-feel effect, a modifiable surface structure and individual coloring enable you to design your components the way you wish. And the smooth planning and execution of your individual solution is ensured through the able assistance of our experts. Just call us, and together we will prolong component life with bonded coatings made by Klüber.

For more, see feature article on page 10
Save costs – increase performance – solve problems

**Bonded coatings improve friction and wear behavior of plastic components**

The use of plastic components for applications that are subject to tribological stress is becoming more popular, e.g. in the automotive industry. Thus, higher demands are made on the friction and wear behavior of such materials. One way of optimizing the performance of a component is to incorporate lubricating substances into the plastic. Of course, traditional lubrication with greases or oils is also suitable for many applications. An alternative method is the application of wear and friction reducing bonded coatings. The advantages and possibilities offered by such bonded coatings are explained in this article.

The incorporation of lubricating substances in polymer materials is state-of-the-art. Besides solid lubricants like MoS₂, wax, PTFE fibers, powders or other lubricating polymer particles, oils can also be used as fluid lubricants. Greases and oils continue to be used for subsequently minimizing friction, wear or noise behavior of plastic components. In this context, dry lubrication by means of bonded coatings is an efficient, though not fully utilized, alternative to the aforementioned methods of minimizing friction and wear on plastic components.

**Minimizing friction and wear**

The following table allows an evaluation by comparing the use of bonded coatings for plastic components with incorporated and traditional lubrication (Fig. 1).

The advantages of bonded coatings are obvious. Besides clean and low-maintenance lubrication, the individualized

<table>
<thead>
<tr>
<th>Lubrication method</th>
<th>Cleanliness</th>
<th>Maintenance</th>
<th>Impairment of material</th>
<th>Functionality, lifetime lubrication</th>
<th>Adaptability to problem</th>
<th>Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Integrated lubrication</td>
<td>++</td>
<td>++</td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2) Subsequent lubrication with grease, oil etc.</td>
<td>– –</td>
<td>– –</td>
<td>–/o</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>3) Dry lubrication with bonded coating</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>–</td>
</tr>
</tbody>
</table>

Fig. 1
selection of the suitable product for the specific application can be mentioned in this context. Especially in the case of problems occurring suddenly during use, like elevated wear or creaking and squeaking noises of unfavorable material combinations, a bonded coating can solve the problem in a quick and uncomplicated way. The use of bonded coatings is recommended when dry lubrication at low to medium loads is required and/or if a problem has to be solved quickly with the currently used plastic.

**Composition and functionality of bonded coatings**

The performance of a bonded coating in terms of chemical stability is determined by the binder. State-of-the-art binders include physically hardening resins, highly cross-linked single or multi-component resins based on polyurethane, acrylate or phenol/epoxide. Suitable cross-linking agents are isocyanate, melamines or silanes. Because elastic components deform when exposed to mechanical load, the binder has to show adequate elasticity. Short-chain and hard binders may break under load and cause premature wear. To achieve optimum lubricating properties, solid lubricants like polytetrafluoroethylene (PTFE), MoS2, graphite and waxes are used alone or in combination.

A fluid consistency is obtained by using organic solvents or water. Due to tightened ecological regulations, in terms of exhaust air purification for the use of lacquers and chemical substances, there is an increasing trend towards water-miscible bonded coatings.

**Selection criteria**

The selection of a bonded coating is not only determined by its functionality. When coating polymer materials, the thermal stability of the material must also be taken into consideration. Thermosensitive materials like ABS or POM, for example, can only be coated with bonded coatings which harden at low temperatures. In the case of thermally stable polymer materials like PPS or PEEK, a much wider range of high-performance, thermosetting bonded coatings is available.

**Bonded coatings have a lot to offer**

Bonded coatings can significantly increase the functionality of polymer materials. This is illustrated in the following examples:

- **A) Better friction behavior**
  
  Bonded coatings reduce the dispersion of friction values and the friction of the plastic by up to 70% (Fig. 2), and at the same time minimize undesired stick-slip.

  At different temperatures the friction behavior of the bonded coating may change in a positive or negative way (Fig. 3). The decisive factors are the softening point of the binder matrix, its basic hardness and the solid lubricant used.

  Bonded coatings can have a positive effect on the friction behavior of plastics and even adjust the friction coefficient to the required standard. The decisive factors are the type and quantity of solid lubricant used.

  ![Fig. 2: Comparison of friction behavior of uncoated and coated plastic determined on the UTI friction and wear test rig (see Fig. 7a). Reference: PA 66 40% GF uncoated/H1/, bonded coating /H2/](image)

  ![Fig. 3: Frictional behavior of different bonded coatings at room temperature and 100 °C /H3/ determined on UTI friction and wear test rig; Hertz pressure (-) 186 N/mm²](image)
The friction behavior of a bonded coating is relatively independent of the modification of the individual type of plastic. Therefore, bonded coatings cannot only reduce friction but also standardize the friction behavior of different types of plastics (Fig. 4).

**B) Wear on the opposing body**

In the case of fiber-reinforced plastics, in particular, wear may occur on the opposing body when subjected to friction. A bonded coating can eliminate wear (Fig. 5).

**C) Longer lifetime**

Under high dynamical loads the bonded coating can act as a sacrificial layer for the polymer material and thus significantly delay wear on the component (Fig. 6). Decisive factors for the wear resistance of a bonded coating are the type of binder and solid lubricant used as well as the pigment volume concentration.

The UTI test rig (Fig. 7a) and the OGP test rig (Fig. 7b) serve to examine the friction and wear behavior of oscillating sliding partners.

In both cases the flat body fixed on the running surface oscillates against a stationary opposing body. Unlike the UTI test rig/H5/ working with a low stroke of 5 mm and a ball as opposing body, the oscillating plate test rig OGP uses a variable geometry of the opposing body. Ball, line or area geometries can be used. The sliding distance is also considerably longer with a stroke of 50 mm.

**D) Surface roughness to measure**

Proper selection of the filler used for the bonded coating allows modification of the surface structure of a plastic (Fig. 8). In this way, the bonded coating has a positive effect on the appearance and tribological behavior of a component as well as on how it feels to the touch.
Factors influencing the performance of bonded coatings

Besides the chemical composition of a bonded coating there are other factors which have a great effect on its performance. The surface polarity or energy of the polymer materials plays a major role in both the wetting of the substrate and the adhesion of the bonded coating. The higher the surface energy of the plastic, the better its coatability (Fig. 9).

Plasma pretreatment increases the surface energy of the plastic by embedding oxygen molecules and thus creates a considerably better basis for good adhesion of the bonded coating. The higher the adhesion of the bonded coating on the polymer material, the better the performance to be expected under dynamic loads (Fig. 10).

Plastics with already improved sliding properties should not be provided with an additional coating because the adhesion of the bonded coating will probably be insufficient. Another important parameter in achieving optimum sliding surfaces is the method used to apply the bonded coating. State-of-the-art coating of large components is spraying by means of compressed air, electrostatics or HVLP (High Volume Low Pressure) spray guns. For small components, application by means of spray drum or immersion centrifugue is used. The selection of the suitable application method is primarily determined by the requirements, the component geometry, the size and the economic efficiency. Coating can be performed by contract coating companies.
Summary

Bonded coatings not only solve tribological problems – which often do not arise until series application – in a quick and clean way, but also offer new possibilities of modifying the surface of plastics. To achieve the optimum performance of a bonded coating, the adhesion to the substrate as well as the application method is of major importance in addition to functional requirements. Based on the variety of raw materials and the range of different bonded coatings offered by Klüber Lubrication, users of plastic components can choose a combination suitable to improve performance in their applications. This also offers new business opportunities to coating companies.

Fig. 10: Friction and wear curves of a bonded coating with and without plasma pretreatment (reference: K1)

Benefits for your application

- Longer component life
- Minimized noise through prevention of stick-slip
- Better process security
- Less maintenance
- Easy modification of surfaces
- Color or UV coding of components

References

/H1/ – /H5/ HSG-IMAT, Stuttgart, Arbeitskreis Gleitlacke
/K1/ Klüber Lubrication München KG, OGP-test rig
/K2/ Klüber Lubrication München KG, Internal tests

Units

f Friction coefficient
[N] Assembly force
T Temperature °C
t Time h
Lube & Seal, a combination ensuring reliable function in power transmission technology

Lubricant and radial shaft seal from a single source

Freudenberg Simrit and Klüber Lubrication, worldwide leading manufacturers of radial shaft seals and speciality lubricants, respectively, have combined the know-how in their specific fields to create the Lube & Seal concept, which is synonymous with comprehensive technological competence. With this concept, both companies offer development partnerships for the power transmission industry, aiming at providing comprehensive solutions with optimally tuned combinations of seals and lubricants from a single source. With Lube & Seal, the reliability of machines and drive units can be considerably improved and their lifetime extended. Furthermore, design and R&D engineers have a single contact person with whom to cooperate for the development of a tested high-end solution.

Reliable radial shaft seals (Fig. 1) are a key component in many industrial gears and can impact service life, machine availability, the need for maintenance, as well as the quality and hence the image a machine supplier has with his customers. The technical requirements for the seal are clearly defined: it is expected to reliably ensure tightness for a long time even while subject to severe physical, tribological and chemical stress. A decisive factor for the durability of a seal is the reaction of the sealing material to the lubricant used, which has received little attention in the design of gears and the development of gear oils.

Since 2004, DIN 51517 has been expanded to include the interaction of these two chemical worlds. The specification of this DIN standard stipulates a compatibility test between the lubricant and NBR 28, a reference elastomer. Unfortunately this test does not reflect real-life conditions and is therefore not really helpful in seal and lubricant selection. The elastomers used in practice are normally different from the reference elastomer in the standard. For this reason, gear oils that have been tested and approved in accordance with this DIN are not always suit-
preventing abrasion and wear. However, it works only if the lubricant and the sealing lip elastomer are compatible. If they are not, decomposition or hardening of the sealing lip may be the consequence, due to depolymerization or carbon build-up.

To reduce friction and wear to a minimum and maximize component life, the seal and the lubricant must form a functional unit. At the same time, the tribological system must be designed with a view to preventing running-in damage to the shaft (Fig. 3 a).

The lubricant must meet several requirements: it should form a separating film in the bearing, the teeth, and at the sealing lip to reduce damage to the friction bodies which may consist of various materials. It should reduce friction and increase the gears’ efficiency, improve the dissipation of heat, and protect the components against corrosion. High-performance lubricants can meet all of these requirements and substantially extend the service life and efficiency of drive units.

The importance of looking into all aspects of the tribosystem becomes obvious through an analysis of cost distribution. Both the sealing ring and the lubricant account for very little of the manufacturing cost of a drive unit. When analyzing complaints, however, e.g. those regarding gears, it becomes apparent that inadequately designed seals cause a high proportion of equipment failures. If the tribosystem formed by seal and lubricant is not optimized for its particular application, leakage or even total breakdown of a drive unit may be the consequence. In a nutshell: these classical C components clearly serve an A function! While lifetime designs are the daily bread of engineers they have nothing but personal experience to fall back on when selecting seals. An unlucky choice of this component can have severe conse-

Fig. 1: Lube & Seal caters for the three tribo-systems present in gears: teeth, bearings and sealing lip.

Fig. 2: A radial shaft sealing ring works like a small pump transporting lubricant or gas to below the sealing edge and back to the oil reservoir. This ensures sufficient lubrication between shaft and sealing lip, preventing abrasion and wear.

C components safeguard A function

The importance of looking into all aspects of the tribosystem becomes obvious through an analysis of cost distribution. Both the sealing ring and the lubricant account for very little of the manufacturing cost of a drive unit. When analyzing complaints, however, e.g. those regarding gears, it becomes apparent that inadequately designed seals cause a high proportion of equipment failures. If the tribosystem formed by seal and lubricant is not optimized for its particular application, leakage or even total breakdown of a drive unit may be the consequence. In a nutshell: these classical C components clearly serve an A function! While lifetime designs are the daily bread of engineers they have nothing but personal experience to fall back on when selecting seals. An unlucky choice of this component can have severe conse-
quences for the user as well as for the warranty obligations and image of the manufacturer.

Lube & Seal offers R&D and design engineers for drive technology as well as their purchasers the first opportunity to use an accurately tuned and tested seal-lubricant system. A team jointly set up by Simrit and Klüber Lubrication has pooled their combined know-how for seals and speciality lubricants. This Lube & Seal team supplies radial shaft seals and lubricants from a single source and offers comprehensive services in all matters regarding this highly complex tribological system. The specialists on the team deal with the system as a whole, which consists of the three individual tribo-systems

- gear teeth – lubricant
- bearings – lubricant
- sealing lip – shaft – lubricant.

The objective of the Lube & Seal approach is to minimize the failure rate over the unit’s lifetime to ensure that a failure occurs only when the definite wear or age limit of the lubricant is reached. Lube & Seal is aimed at substantially widening the ‘bathtub’ curve describing the failure rate (Fig. 4).

**Tested comprehensive solution offers high reliability**

The Lube & Seal team achieves this objective through innovation: specialty lubricants from Klüber coupled with seals of the latest design and materials by Simrit. Once a particular combination of seal and lubricant has been developed, it is tested in the lab or the drive unit provided by the manufacturer. These tests include standard tests as well as dynamic tests specifically designed for the expected operating time, operating temperature and shaft speed of the drive unit. 240 h DIN tests, low-temperature tests, low-temperature torque tests, friction or temperature measurements can be performed directly at the seal lip. Of course, the duration of long-term tests depends on the requirements in practice, and lubricant condition analyses are also made.

All this ensures that the solution that is eventually chosen has been thoroughly tested and offers the user a maximum of reliability and durability. Since this approach looks at the system as a whole, development times are reduced, which in turn results in competitive edge for the manufacturer of the drive system. Due to their systematic development, these solutions enable much more accurate estimates for warranties.
Fig. 4: The objective of the Lube & Seal approach is to minimize the failure rate over the unit’s lifetime to ensure that a failure occurs only when the definite wear or age limit of the lubricant is reached. Lube & Seal is aimed at substantially widening the “bathtub” curve describing the failure rate.

Practical experience

In a project conducted with a customer, the lifetime of a radial shaft seal (elastomer 75 FKM 170055) used in combination with Klübersynth GH 6-220 (polyglycol oil) was extended to 20,000 operating hours – a reproducible success! The unit was a worm gear unit with a drive shaft operating at a maximum speed of 1750 rpm.

All in all, Lube & Seal means better reliability due to longer equipment life, less failure for the users of drive systems, and a higher quality for the manufacturer. This is especially true for high-end long-life solutions operating at high rpm and high peripheral speeds, or under particular environmental conditions; Lube & Seal offers the support of a development partnership that makes the ambitious objectives of gear manufacturers attainable.

Your benefit:

- Reliable operation of the system as the lubricant is optimally tuned to suit the sealing ring and the drive systems
- Longer component life due to low friction and wear
- Competitive edge and cost savings due to reduced development times
- Better estimates for warranties
High performance under extreme conditions

Faster, higher, further – PFPE lubricants push performance limits

In contrast to all other fully synthetic lubricants, PFPE oils do not contain any carbonhydrogen bonds. Where these bonds are absent, most known chemical ageing processes are prevented, and this is exactly the reason why products based on PFPE score over other lubricants in terms chemical and thermal stability. PFPE oils can cover applications at temperature ranges from below – 80 °C to far above 300 °C. Extreme ambient conditions and contact with aggressive media do not normally affect the performance of PFPE lubricants. Especially at high temperatures, PFPE lubricants live significantly longer than “traditional” products in many applications.

Frequently, there is no economically viable alternative when long lubricant lives are required under extreme or strongly fluctuating operating conditions, the influence of chemicals or changing pressure. The longer lubricant life and extended maintenance intervals more than compensate for the higher material costs.

In the box on page 21, the benefits of PFPE lubricants are summarized.

“Only constantly increasing productivity and innovations ensure business success and competitiveness in the global market.” These or similar lines introduce many a paper dealing with the economic framework in which today’s machine building sector exists. For bearings and guides this means operating under higher loads and temperatures, at higher speeds and with longer maintenance intervals. Consequently, the lubricants are expected to work under more taxing conditions than before. Under extreme operating conditions, lubricants based on perfluorinated polyethers (PFPE) often offer the best solutions from both a technical and economical aspect: they make an effective contribution to meeting the tightening requirements in terms of speed and productivity. Looking at a few key parameters can make lubricant selection much easier.
The success of PFPE products began roughly four decades ago when the BARRIERTA® brand was introduced. This new product class was the first to enable long-term lubrication at temperatures greatly exceeding 200 °C. In some applications, e.g. in the manufacture of corrugated cardboard, the benefits attained were so striking that the very design of the corrugating roller with its complex oil circulation system could be changed. Today, most corrugating rollers operate with PFPE-greased bearings at temperatures up to 200 °C. As a recent development, PFPE lubricants with an NSF-H1 approval for use in the food-processing industry are also available. This is a fundamental step towards new and innovative machine designs in this branch of industry.

Which PFPE lubricant for which requirements?

The range of PFPE lubricants, especially greases, has continuously grown over the past few years. While there used to be only a limited number of mostly standardized multi-purpose products, today OEMs and operators can choose from a vast array of PFPE greases with different properties. But what are the characteristics that help the user determine “what’s what” and compare various products? Besides manufacturers’ recommendations, there are three major criteria that may be used for the various fields of application: the type and viscosity of the oil, the type of thickener and the additives.

Influence of base oil and base oil viscosity

For the manufacture of PFPE greases, different base oil types with different viscosities and viscosity indexes are used, depending on the application. The viscosity index describes to what degree the viscosity of the fluid decreases with rising temperature. As guidance values, Klüber Lubrication always states the viscosity of its greases at 40 °C and 100 °C. This makes it easier for the user to compare the various products. For applications at very high temperatures there is a rule of thumb saying that the viscosity of a grease should not fall below 20 mm²/s at 100 °C. Such greases will not suffer excessive evaporation losses of the oil, which in turn safeguards a sufficient lubricant film and thus prevents premature wear. If the lubricated component is also regularly exposed to low temperatures, or if high speeds must be allowed for, a lower viscosity is normally recommended, namely one not exceeding 200 m²/s at 40 °C. Klüber Lubrication provides specific data for each product.
A decisive factor: the thickener type

Most PFPE greases are thickened with PTFE (polytetrafluoroethylene), which suitably complements these high-quality oils and offers good lubricating characteristics in its own right. However, not all PTFEs are the same. Different degrees of grinding and different chemical chain lengths lead to a variety of product characteristics. Therefore, PFPE/PTFE greases can have different compositions and be manufactured in different ways to suit varying requirement profiles; consequently, they may be found in high-speed bearings in electric motors as well as in the shut-off valves of chemical containers. Problems of incompatibility with seals or sensitive materials are extremely rare. Furthermore, some PFPE/PTFE greases are permitted for use in the food-processing industry.

At permanent temperatures above 260 °C, mineral thickeners such as aerosil or inorganic solid lubricants should be given preference since the upper temperature limit of PTFE thickeners is exceeded. PFPE greases with metal-soap thickeners are more rare, not least because of their comparatively limited temperature hardness. However, products with metal-soap thickeners are more easily removed from surfaces with the aid of conventional cleaning agents, which makes them more compatible with painting processes.

Additives provide corrosion protection

PFPE lubricants normally have a good load-carrying capacity. When containing a suitable additive, they can also offer good protection against corrosion. But not all PFPE lubricants were designed with an anticorrosive effect in mind. Users should therefore make sure to use products with suitable additives when choosing lubricants for applications in corrosive environments, e.g. where humidity cannot be prevented.

Summary

Before opting for a particular PFPE grease, the user should check if a product made specifically for the purpose of the application might not offer additional value compared with a standardized multi-purpose PFPE grease. A rough assessment of the product concept, by means of the mentioned criteria, as well as of the grease’s key data narrows down the choice. It then makes sense to request application-specific consulting for product selection. Klüber Lubrication offers on-site practical support during testing and putting into operation of the lubricant. If product selection is guided in this way, savings and higher efficiency can be reached reliably in a short time.

Benefits of PFPE greases

- Long operating times
  - at high operating temperatures (300 °C and above)
  - at pronounced temperature fluctuations above 200 °C
  - in the presence of aggressive media
- Flexible uses
  - due to excellent compatibility with many materials
  - due to excellent compatibility with seals
- High degree of safety
  - contain no toxic substances
  - are not flammable
High-temperature grease offers new performance range

Where there’s a baking oven, there’s heat – whether at home or in a factory. If an oven can be operated conveniently and without problems does not least depend on lubricants, for instance those used in the ball and roller bearings or linear guides of the baking tray extension mechanism.

Klüberalfa HPX 93-1202 is a new special grease with NSF H1 approval for applications in the food-processing industry. Operating temperatures up to 300 °C pose no problem, not even in the long term. Previously used greases usually went along with a loss of performance due to lubricant starvation, while Klüberalfa HPX 93-1202 has a base oil with a particularly low evaporation rate, ensuring lubricity over an extremely long period of time. The enduring lubricity enables guide mechanisms in ovens to run smoothly and with good dampening for a long time, too. This marks an increase in performance which the manufacturers of household or industrial ovens can market as a longer service life of their components and equipment.

For more information, use the reader service on page 29.
Reliability at sub-zero temperatures

New generation of refrigeration compressor oils enables lower operating costs throughout the refrigeration cycle

The intense contact between the ammonia and the lubricating oil in refrigeration compressors constitutes a great challenge. The unsaturated hydrocarbons and the sulphur compounds contained in mineral oils may react with the aggressive refrigerant ammonia. Due to this chemical reaction the oil gradually becomes darker until, eventually, it turns black. The reaction products, which are insoluble in the oil, remain in the compressor or the refrigeration cycle (mainly in the evaporator and the condenser) as residues or sludge. These residues may bring down refrigeration plant efficiency (due to reduced heat transfer in the heat exchangers) and noticeably affect operational reliability. Experience shows that blackening and acidification of the oil can be accelerated in particular by the presence of air and water in the refrigeration cycle (up to 3 % of water is possible). In addition to that, abrasive wear caused by oil sludge may directly attack various compressor components. Also, the oil filter and separator are under increased strain and are more susceptible to clogging. All this leads to a reduced lifetime of the components, a drop in efficiency and increased operating costs.

"Cleaned" oil prevents sludge formation

A solution can be found in the use of hydrogenated mineral oils or synthetic lubricating oils. Klüber has taken the mineral oil route with Klüber Summit RHT-68, a lubricating oil on the basis of a paraffinic, hydrogenated mineral oil developed for use in ammonia refrigeration plants with evaporator temperatures down to –35 °C. The hydrogenation of the base oil (also called "hydrotreating") removes unsaturated and sulphur compounds from the oil. Thus, the oil is being "cleaned" and becomes less reactive with ammonia. Changing from a naphthenic mineral oil to this type of oil constitutes no problem at all.

The same goes for Klüber Summit RPA-68, a fully synthetic lubricating oil on the basis of polyalphaolefin and alkylbenzene. This oil was developed especially for low evaporator temperatures down to –53 °C when, due to their high pour point, mineral oils are no longer capable of flowing. Finally, Klüber Summit R-200, is not only suitable for use with ammonia, but can also be applied in combination with CO₂, propane or butane. As a fully synthetic lubricating oil on the basis of polyalphaolefin, it is NSF registered for use in the food processing industry and is suitable for evaporator temperatures down to –50 °C.

Both synthetic products contain very chemically stable base oils. Their high resistance to reaction with ammonia prevents blackening of the oils, a phenomenon that is very common with conventional mineral oils, and undesirable residue formation in the evaporator, thus avoiding unplanned downtime and increasing the efficiency of the entire refrigeration plant.

Whether a refrigeration compressor is used in a brewery, an ice rink or for air conditioning: its lubrication has a major effect on the reliability and the efficiency of the refrigeration plant as a whole. The widely used naphthene-based mineral oils do not always meet the stringent requirements of today: used in smaller quantities than previously, they have to withstand higher temperatures, higher pressures and shorter recirculation cycles. At the same time, compressor operators call for longer maintenance intervals in order to reduce costs. Especially developed refrigeration compressor oils ensure the reliable operation of ammonia refrigeration compressors and help to reduce operating costs. With the aid of in-depth consulting, oil analyses and hands-on support, oil changeover can be made without problems.
Reducing oil consumption

The quantity of oil carried over from the compression chamber into the refrigeration cycle, the so-called oil carry-over, depends, among others, on the evaporation tendency (vapor pressure) of the oil at the relevant discharge temperature (sometimes clearly above 100 °C). A high oil carry-over, caused by the comparatively high evaporation rate of a naphthenic mineral oil, may lead to excessive oil consumption and increased maintenance requirements due to frequent oil top-up. Both phenomena lead to increased operating costs. Here, too, hydrogenated or fully synthetic oils offer a satisfactory solution: Highly refined, chemically stable base oils clearly reduce oil carry-over as compared to conventional mineral oils, thus contributing to a reduction in oil consumption of the compressor. A practical example illustrates the potential savings: A refrigeration compressor charged with 200 l of mineral oil operated for around 7,000 service hours per year. The operator had to replenish around 300 l of oil per year, about 1.5 times the filling quantity. When changing to a hydrogenated mineral oil, the refill quantity was reduced by up to 70 %.

Extending oil change intervals

As it is the low-molecular constituents of the mineral oil which evaporate the fastest in the compression chamber, oil viscosity gradually increases over a period of time. Apart from the viscosity increase, blackening of the oil and sludge and residue formation may be other reasons for excessive ageing of the oil. All this inevitably leads to frequent oil changes, which interrupt normal operation and can be very costly.
Highly refined and specially formulated mineral and synthetic oils do not contain these volatile oil constituents. Therefore, oil viscosity remains stable over a long period of time, permitting oil change intervals that are up to four or five times longer. The operator of a refrigeration compressor which was lubricated with naphthenic oil (ISO VG 68) measured a viscosity increase of the oil from 68 to 105 mm²/s after only 2,000 service hours. Changing over to synthetic oil enabled him to extend oil lifetime to six times that of the mineral oil fill.

Oil changeover without losses

Despite the undeniable advantages offered by synthetic oils, there is still a lot of uncertainty regarding changeover to these oils, for example regarding compatibility with seals. Naphthenic oils often cause seals to swell, while some synthetic oils, in particular PAOs (polyalphaolefins) have the contrary effect and may lead to seal shrinkage. Especially in ammonia refrigeration compressors where neoprene seals are often used, leakage may occur following changeover from a naphthenic lubricating oil to a PAO. In this instance, Klüber Lubrication offers a special oil, which considerably simplifies changeover: The PAO used is mixed with alkylbenzene, where the shrinking effect of one constituent is neutralized by the swelling effect of the other, achieving a neutral behavior towards sealing materials. Greater care has to be taken when changing from a naphthenic oil to a pure PAO with seal shrinking effect. Pure PAOs, such as the one used for Klüber Summit R 200, may cause a seal which has swollen in contact with the naphthenic oil to shrink, which may lead to leakage at O-rings in the housing or at face and shaft sealing rings. When changing over to Klüber Summit R 200 (one reason to choose this product may be its NSF approval for the food processing industry), operators are advised to renew any O-rings, face seals or shaft sealing rings.

Hands-on support

Klüber Lubrication offers tailor-made lubricants for refrigeration compressors and, on request, also provides support for oil changeover. The first step con-
sists in a detailed analysis of the oil presently used, which gives an indication as to the current state of the refrigeration plant and may highlight “hidden” problems. Once the best solution for the particular customer has been determined, a service team can assist in the oil changeover on the plant. The procedure depends largely on the degree of oil contamination and/or the compressor. Usually it is sufficient to simply drain the oil, replace filters and oil separators and to remove any residual oil from the pipes, housings and filters before filling with the new oil. For heavily contaminated screw compressors, Klüber offers an oil-based cleaning concentrate which is added to the compressor oil in a 10 % concentration 60 hours before the planned oil change. The compressor continues to operate during these 60 hours, and residues and deposits are dissolved by the cleaning agent. The compressor does not have to be dismantled for cleaning.

Also, after the changeover to new oil, Klüber Lubrication can provide further support. Together with the customer, Klüber Lubrication’s specialists can inspect used oil samples at regular intervals. Should any problems occur, the situation is analyzed and countermeasures can be taken immediately. Always, the objective is to reduce maintenance costs and achieve the best possible availability and reliability of a refrigeration plant.

Summary

Changing over from naphthenic mineral oils to the new generation of hydrogenated mineral oils and fully synthetic lubricating oils offers many advantages. In many cases, these lubricants enable untroubled and reliable operation of refrigeration compressors without frequent interruptions due to unavoidable cleaning or maintenance. Worn parts are replaced less frequently and filter costs are reduced. Oil change intervals, on the other hand, become up to six times longer and oil consumption decreases by as much as 70 %. And last but not least, due to the absence of oil-related residues, the efficiency of the refrigeration plant as a whole should increase. A successful changeover, however, requires a high degree of experience and know-how. Therefore, Klüber Lubrication offers the customers comprehensive consulting, provides tailor-made solutions and supports them during the entire changeover period.

Benefits for refrigeration plant operators

- Low oil consumption due to special oils resistant to evaporation – reduction by 50 to 90 % compared with mineral oils
- Oil change intervals up to five times longer due to constant viscosity
- Reliable operation and high efficiency of the refrigeration compressor as no reaction with ammonia takes place and hence residue and sludge formation is prevented
Exhibitions: Platforms for contacts

Use these opportunities for a personal talk:
We look forward to meeting you at our stand, for example at the

Texmac
17 to 20 January 2007
New Delhi, India

SAMULEGNO
8 to 12 February 2007
Pordenone, Italy

Graphispag
19 to 25 February 2007
Barcelona, Spain

VenMec
2 to 5 March 2007
Padova, Italy

CFIA
6 to 8 March 2007
Rennes, France

MAINTENANCE
28 to 29 March 2007
Antwerp, Belgium

Hannover Fair
16 to 20 April 2007
Hannover, Germany

ARMINERA
2 to 5 May 2007
Buenos Aires, Argentina

EWEC
7 to 10 May 2007
Milan, Italy

Use these opportunities for a personal talk:
We look forward to meeting you at our stand, for example at the

Fispal
May 2007
São Paulo, SP – Brazil

EMO
17 to 22 September 2007
Hannover, Germany

IBIE
International Baking Industry Exposition (IBIE)
7 to 10 October 2007
Orlando, FL – USA

Process Expo
15 to 17 October 2007
Las Vegas, NV – USA

Worldwide Food Expo
24 to 27 October 2007
Chicago, IL – USA

K 2007
24 to 31 October 2007
Düsseldorf, Germany

TOKYO MOTOR SHOW
26 October to 11 November 2007
Chiba, Japan

SAE
November 2007
São Paulo, SP - Brazil

SEMICON JAPAN
5 to 7 December 2007
Chiba, Japan

You will find a comprehensive overview of exhibitions attended by Klüber under www.klueber.com / News / Exhibitions etc. – just click and have a look!
In the food-processing industry, lubrication not only influences operating costs and productivity, but the integrity of the food product as well. Particularly challenging for many companies in this field is the addition of increased food safety processes which have been introduced by governments and authorities. The international ISO standard 22000 “Management Systems for Food Safety”, for example, defines activities enabling an organization to safeguard food safety throughout all process stages until the food product reaches the consumer. This requires staff training, audits and so-called PRP (prerequisite programmes) as well as documented GMP (good manufacturing practice).

With KLASS, the Klüber Lubrication Asset Support Service, Klüber offers a comprehensive package of lubricants and services for companies in the food, beverages and pharmaceutical industries, supporting them in a wide variety of tasks and requirements. For example, lubrication audits that include risk analyses for all critical control points (HACCP = Hazard Analysis and Critical Control Points) may be conducted along with lubrication workshops that introduce staff members to the topic and heighten the awareness of the importance of good lubrication. Finally, KLASS can be a valuable contribution to both higher productivity and reduced energy and operating costs.

The elements of KLASS are selected and implemented according to individual requirements:

- Lubricant application consulting to select a suitable lubricant
- Support with HACCP analysis (HACCP = Hazard Analysis and Critical Control Points) for legally sound production and consumer protection
- Friction point inspection by service engineers and tribological analyses for optimised lubricant selection and relubrication intervals
- Support with stockkeeping and documentation (best practice)
- Lube point management software, Klüber Maintenance System, for effective maintenance planning and reporting
- On-site customised training programs and seminars
- Comprehensive range of NSF H1 specialty lubricants for all kinds of applications
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Please send me information on Klüber service or special lubricants used in this context.

- The chemistry has to be right
- Save costs – increase performance – solve problems
- Lube & Seal, a combination ensuring reliable function in power
- High performance under extreme conditions
- Hot stuff
- Reliability at sub-zero temperatures
- Product and service package for the food-processing industry
- Brochure “Lubrication of large gear drives”
- Brochure “At home on the Seven Seas …”
- Training
- Fit for the future

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New brochures

*Klüber know-how shown in black on white*

Background information with a lot of references to practice can be found in the newly edited brochure “Lubrication of large gear drives”. Besides the contents already known from the previous edition, the new brochure now also offers comprehensive solutions for all operating modes of two different lubrication concepts: that with ‘black’ products containing graphite as well as that with transparent products without. With its 72 pages, the brochure is a tribological guide manual provided by Klüber Lubrication for those whose job is the reliable operation of large gear drives.

Lubrication solutions for maritime and off-shore industries is the topic of the new brochure “At home on the Seven Seas ...”. Whether reduction gears on ships, winch drives, process gas compressors or twist locks – all aggregates and components common to this sector are examined under aspects of lubrication. On 28 pages, you will learn which speciality lubricants your highly loaded components need to operate without problems. And how you can reduce your operating costs.

Professional tips and hints

*Customer training made by Klüber*

How do I find the lubricant that’s best for my machines? Can I optimize my design by using a special lubricant? How can I save costs by using the right lubricant? There are answers to questions like these: in seminars of one or two days duration, experts from Klüber Lubrication explain everything you need to know in terms of lubrication; you will be shown the latest developments and gain inside knowledge. Seminar topics range from basics of tribology to the latest trends in maintenance or different fields of lubricant application.

Any special wishes are highly welcome – if requested, Klüber Lubrication also organizes individually tailored seminars at the customer’s site. This has been done, for instance, at the premises of a major lubrication equipment OEM in September, where trends and developments in the lubrication of large gear-rim/pinion drives were discussed. Another example is a worldwide leading bearing OEM, where Klüber trained R&D engineers on various lubricant concepts as part of a Tech Day program.

Klüber’s seminars cross not only technical borders with ease. They are also offered wherever there are customers of Klüber – in other words: worldwide.

Please make use of our reader service on page 29 to obtain further information on our seminars.
Fit for the future

Longer automotive component life attained with new special grease

Absolute reliability of performance is a must for any safety-related component in cars. This requirement does of course extend to the lubricants they contain. Developing a lubricant for future-oriented technologies, i.e. one that meets expectations like 20 years of service life, thermal stability up to 180 °C, with still much higher peaks, as well as an excellent pressure absorption capacity, poses quite a challenge in a sector of industry where pricing is also a sensitive issue. With Klübersynth BR 46-82, Klüber Lubrication has overcome the gap between seemingly irreconcilable objectives: a powerful low- and high-temperature grease for drive-by-wire components in cars.

The silicone-free special grease can cope with permanent temperatures of 180 °C, and short-term peaks up to 250 °C, while also ensuring smooth running at temperatures far below zero. Further characteristics of this newly developed product are good wear protection in steel/steel friction pairings, compatibility with EPDM and miscibility with brake fluids. Klübersynth BR 46-82 is therefore a first-choice product when it comes to the long-term lubrication of numerous components such as ball screws, rolling bearings, vertically mounted needle bearings and gears. It allows several lube points of a component like the brake unit to be made fit for the future with a single grease.

For more detailed information, please use the reader service on page 29.