WEIGHING UP THE OPTIONS

Markus Burbach, Klüber Lubrication, reviews advances in open gear lubrication and provides a guide for choosing the right technology to optimise reliability and asset utilisation.

Over the last 100 years, different lubrication technologies for open gears have emerged, giving today's operators a wide choice. The variety of technologies and the number of different lubricants offered can make it challenging for operators to see the wood for the trees. As a result, the potential to optimise reliability, total cost of ownership and the lifetime of girth gears and pinions is not always exploited.

Until a few years ago, one could divide the lubrication technologies for open gears into three categories: asphaltics, solid containing greases and highly viscous oils. Over the last decade, innovative lubrication concepts have been introduced to the market. Therefore, a more differentiated categorisation is useful to help operators to identify the right technology for their goals:

- Asphaltics
- Solid containing greases (black)
- High-viscous oils/transparent fluids (based on mineral or synthetic hydrocarbon oils)
- Solid containing greases (white)
- Ultra-high-viscous oils/transparent fluids (based on Polyglycol oils)

Each technology has pros and cons (Figure 1) satisfying different needs operators may have depending on their maintenance strategy and practices. This article offers guidance on when to choose each technology.

Asphaltics

When to choose: The use of asphaltics is strongly discouraged for health and safety reasons and their poor housekeeping properties. Asphaltics are a by-product from the crude oil refining process and are also known as bituminous or residual compound lubricants. Despite considerable disadvantages, they are still used by some operators. The reason for this is that although they are basic formulated lubricants with little performance-improving additives, they can provide good gear protection thanks to their ultra-high viscosity. A high viscosity helps to build sufficient film thickness between tooth flanks, which protects them from wear, scuffing and pitting. However, asphaltics have many weaknesses that outweigh their few strengths and as a result they are unpopular in most parts of the world. They can be carcinogenic and are therefore banned by many countries. Due to their ultra-high viscosity, they require the use of a diluent to temporarily reduce viscosity in order to spray them onto gears. As a result, they feature a low viscosity at the time of application and seldom reach full viscosity during operation. The reason being, that the time it takes for the diluent to evaporate is far longer than the typical spray intervals. As a result, new diluted product is applied before full viscosity is reached, thus causing the evaporation cycle to start from the beginning. Therefore, the lubricant on the gear never reaches the desired viscosity that is meant to protect the gear. At the same time, the absence or low concentration of additives does not provide enough protection against wear whilst the viscosity is low. Another disadvantage is that diluent continues to evaporate if the equipment is stopped. This can lead to the spray nozzles of the lubrication system becoming clogged, which results in lubricant starvation once production is resumed. It can also lead to a build-up of solidified lubricant in the gear guard and tooth

	Asphaltics	**Solid containing greases (black)**	**High-viscous oils/ transparent fluids (mineral/synthetic hydrocarbon)**	**Solid containing greases (white)**	**High-viscous oils/ transparent fluids (Polyglycol)**
Working principle	Separation of gear tooth flanks supported by **ultra-high viscosity** of base oil.	Separation of gear tooth flanks mainly supported by **solid lubricants**.	Separation of gear tooth flanks supported by **very high viscosity** of base oil.	Separation of gear tooth flanks supported by **solid lubricants** and **very high viscosity** of base oil.	Separation of tooth flanks supported by **ultra-high viscosity** of base oil.
Solids containing	No	Yes	No	Yes	No
Viscosity	Ultra-high	Low	Very high	Very high	Ultra-high
Lubricant film	Very thick	Thin	Thick	Thick	Very thick
Lubrication regime	Mixed friction	Boundary friction	Mixed friction	Mixed friction	Mixed friction
Possible application	Spray	Spray	Spray/Bath	Spray/Bath	Spray
Key pros/cons pros cons	– Ultra-high viscosity provides good gear protection – Easy visualization of gear contact pattern – Contain solvents (need long time to reach full viscosity) – Poor housekeeping: solidification in gear root, gear guard, and spray nozzles – Tooth flank surfaces cannot be inspected during operation (black) – Can be carcinogenic	– Wide availability – Low viscosity causes highest friction and wear of gear – Powdery solids tend to clog spray nozzles – Tooth flank surfaces cannot be inspected during operation (black) – Poor housekeeping – Highest consumption – Graphite solids can wear out lubrication system parts	– High viscosity provides excellent gear protection – 3-7 x less wear than black greases resulting in much longer gear life (if use of lubricants from Klüber Lubrication) – Best visual inspection of tooth flank surfaces during operation (transparent) – No clogging of spray nozzles – Reduction of lubricant consumption by up to 50 % compared to black greases – Reduction of total lubricant cost by up 25 %	– High viscosity provides excellent gear protection – Very good visual inspections of tooth flank surfaces during operation (white appearance) – Best performance in presence of heavy dust contamination – No clogging of spray nozzles (Klüber Lubrication technology only) – Reduction of lubricant consumption by up to 60 % compared to black greases – Reduction of total lubricant cost by up 25 %	– Ultra-high viscosity provides best gear protection and lowest wear in the market supported by highest lubricant film thickness – Best visual inspection of tooth flank surfaces during operation (transparent) – No clogging of nozzles – Compatibility with seals/paints – Water can be absorbed and reduce viscosity
When to chose	Klüber Lubrication and many OEMs **discourage their use** for health and safety and poor housekeeping reasons.	Operators looking for the **lowest price per kg** rather than best profit impact.	Operators looking for the **best value for money and the best profit impact**.	Operators experiencing **excessive dust contamination** of open gears or when a lubricant that contains solids is preferred.	Operators looking for the **highest lubricant viscosity** on the market to achieve **unprecedented wear, scuffing and pitting protection**.

Figure 1. Technology evolution.

roots that are extremely difficult to clean. In light of these disadvantages, many lubricant suppliers specialised in open gear lubrication and OEMs strongly discourage the use of asphaltics.

Solid containing greases (black)

When to choose: Operators looking for the lowest price per kg rather than best profit impact.

Solid containing greases with a black appearance were developed in an attempt to overcome the disadvantages of asphaltics. Their base oil viscosity is far lower though and, as a result, open gears operate in a so-called boundary friction regime as shown in Figure 2 where metal-to-metal contact is the highest and wear, scuffing and pitting protection is the lowest of all friction regimes. To compensate for their low viscosity, solid lubricants such as graphite or molybdenum disulfide are added to provide additional protection of the gear and which cause the black appearance. Whilst these types of greases can support a satisfactory performance of the open gear (e.g. low vibrations, low temperature differentials across tooth flanks), the lifetime of the gear set will always be a few years shorter compared to a gear set that is lubricated with higher viscosity lubricants.

Due to their low viscosity, these greases require a significantly higher amount of lubricant to be applied on the gear than more advanced and higher viscosity lubricants. Whilst the price per kg may be lower than that of more advanced technologies, the total spend on consumption is typically higher and so is the cost for disposal due to a higher waste volume. This can mislead operators when trying to optimise their maintenance budgets. Just like asphaltics, these greases are black in appearance, which means that it is not possible to meaningfully inspect the condition of the gear tooth surface during operation or without cleaning it during shutdown. As a result, condition monitoring is very challenging and prediction of failures is hard, thus jeopardising reliability and uptime.

High-viscous oils/transparent fluids (based on mineral or synthetic hydrocarbon oils)

When to choose: Operators looking for the best value for money.

Transparent fluids were introduced to the market in the 1990s with Klüber Lubrication being one of the first lubricant manufactures to launch this technology through the Klüberfluid C-F Ultra Series. The development was driven by the recognition that the cement industry needs to improve equipment reliability and lifetime to reduce total cost of ownership and improve profitability. These lubricants have a much higher viscosity and as a result, a much better load carrying capacity than black greases. They offer better separation of the tooth flanks supported by a thicker lubricant film, both for slow running open gears on kilns or fast running open gears on mills. As a result, the gear flanks operate in a mixed friction regime where metal-to-metal contact is much less than in the boundary friction regime as is common with black greases that have a much lower viscosity.

The mixed friction regime as common for transparent fluids results in less wear (Figure 2). Less wear means pinion and girth gears maintain their original shape and mass for longer, leading to a longer life and a reduced

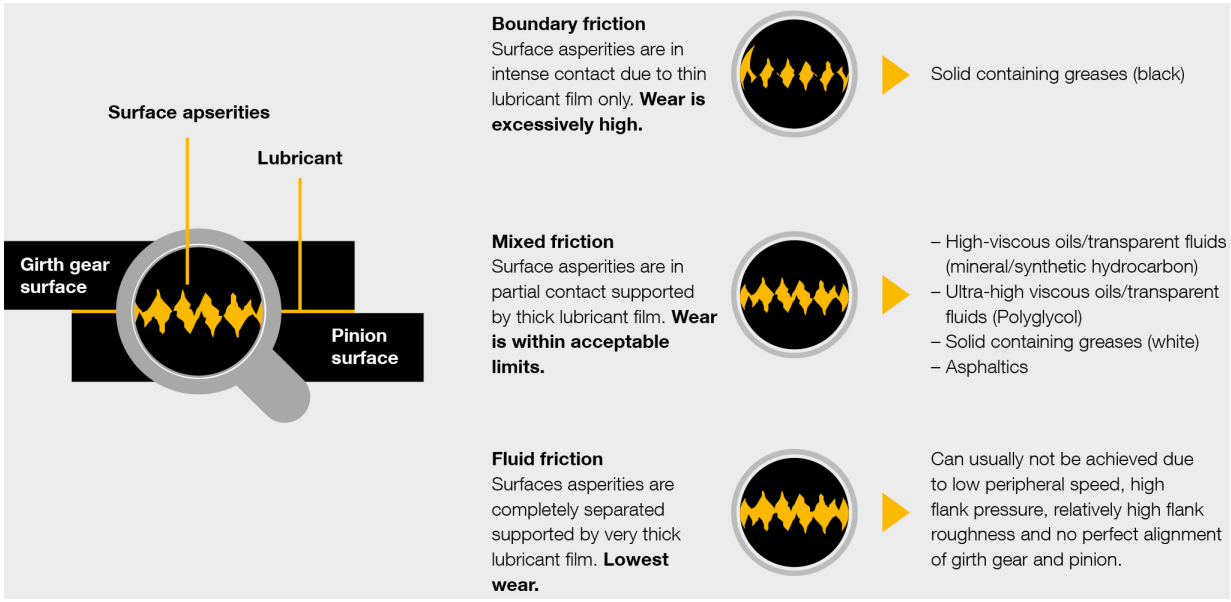
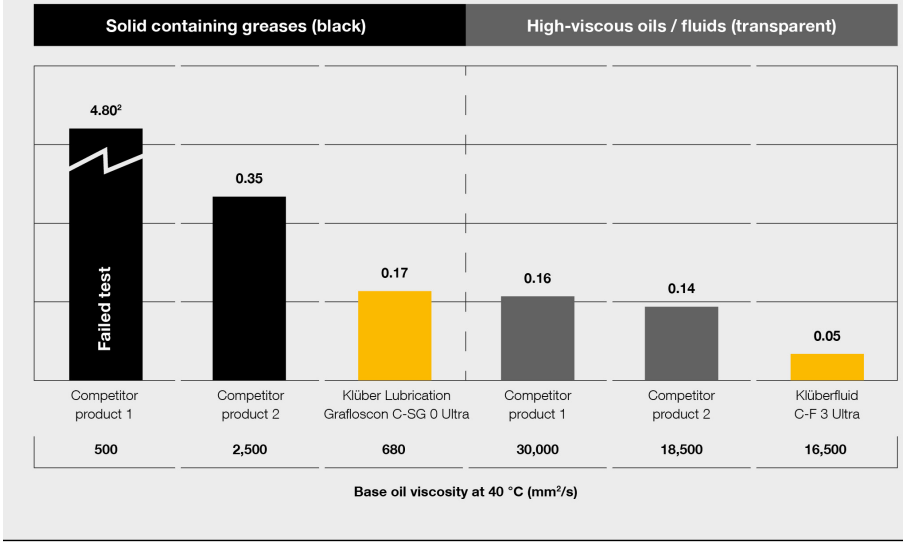


Figure 2. Relationship between lubricant film thickness, friction and wear.



Note: [1]Test results are based on a one-time measurement performed with a single batch of the product under review.
[2]Excessive mass load due to scuffing failure in load stage 12.

Figure 3. Specific mass loss (mg/kWh) as tested in FZG scuffing Test A/2.8/50' – The lower the value, the better.

risk of lower load carrying capacity, vibrations or localised stress that can result in gear failures. Aside from the improved protection of pinion and girth gear, the transparent nature of these lubricants allows for visual inspection of the tooth flank condition during operation. This allows for better insights into the condition of the gear, and if needed, to take corrective actions much earlier than would be possible if using black greases where one has to wait until shutdown for visual inspection.

The better lubricity and higher viscosity of this technology allows operators to reduce consumption by up to 50% compared to black, solid containing greases. It also provides more peace of mind as optimised lubricant consumption leads to less over lubrication. This often occurs when operators are unsure of adequate volumes and sometimes do not receive guidance and on-site support from their lubrication partners. The optimisation of the consumption usually overcompensates the higher price of this technology and results in an overall lubricant cost reduction of 20 – 25% compared to black greases. The much better gear protection, its impact on gear life and total cost of ownership combined with lower lubricant cost make this technology the preferred choice for operators who are looking for best in class maintenance practices and equipment protection.

Solid containing greases (white)

When to choose: Operators experiencing excessive dust contamination of their open gears or wanting to utilise the benefits of a high base oil viscosity combined with next generation solid lubricants.

White greases have been introduced to the market over the last ten years. Despite being greases, they utilise a similar concept to transparent fluids and use highly viscous base oils combined with advanced additives for best gear protection from wear, scuffing and pitting. They are also transparent in nature, albeit somewhat less than transparent fluids, and allow for visual condition inspection of gear flanks during operation. Additionally, they contain white solid lubricants, which can give them better performance characteristics in the case of cement dust contamination of the lubricant. The types of solid lubricants used in white greases differs to those used in black greases. Moreover, solid lubricant technologies differ substantially from one lubricant manufacturer to another and a generalisation is difficult. Klüber Lubrication uses a 'Solid Lube Integrated Base Fluid' (SLIBF) technology for its Klübersynth OA 98-15000 white open gear grease. In contrast to other white greases, the solids in this product are bound in the base oil, which avoids the undesired side effects commonly associated with solids in powder form, such as clogging of spray nozzles which can lead to unplanned downtime due to lubricant starvation and gear failure or the build-up of lubricant at gear tooth roots. Most importantly, Klübersynth OA 98-15000 provides enhanced gear protection in the case of cement dust ingress.

High-viscous oils/transparent fluids (based on polyglycol oils)

When to choose: Operators looking for the highest lubricant viscosity during operation to achieve enhanced wear, scuffing and pitting protection.

This technology represents the most advanced open gear lubrication available and was introduced by Klüber Lubrication in 2020. Polyglycol oils are known to offer the best anti-friction properties, especially when sliding friction is high as in open gears. This makes them an excellent choice for reducing friction in

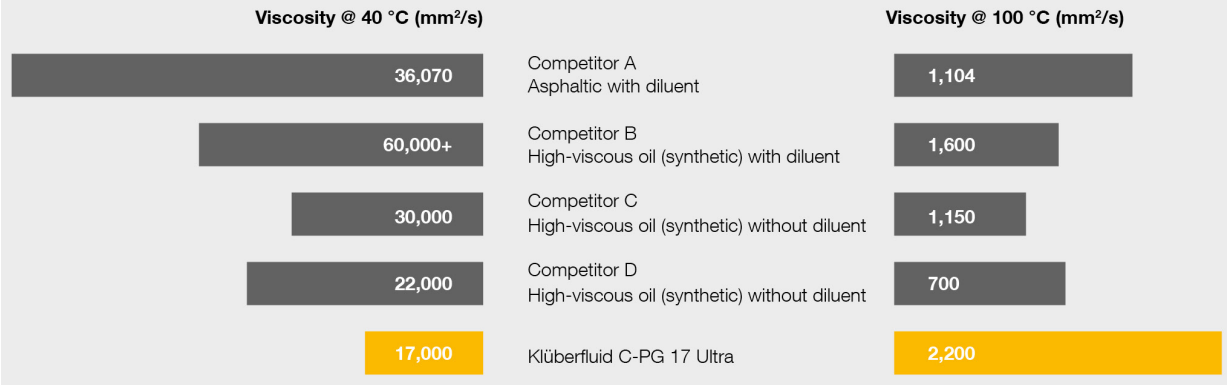


Figure 4. Comparison of base oil viscosity of different lubricant technologies at different temperatures.

order to avoid wear and scuffing. At the same time, Klübersynth C-PG 17 Ultra offers the highest viscosity available at 100˚C (Figure 3), which is an important indicator for determining the actual viscosity during operation at elevated temperatures. In fact, it provides operators with a higher viscosity at 100˚C than they could obtain from the outdated asphaltic technology whilst benefitting from all the advantages of modern lubricant concepts. This lubricant also works without diluents ensuring that its ultra-high viscosity works from the moment it is applied onto the gear.

Barriers to exploiting the potential of modern open gear lubricants

Operators may be hesitant to upgrade to advanced lubrication technologies even though they are eager to exploit the benefits associated with them and a need to maximise tooth flank life of pinion and girth gear. A common reason is that they experience a reliable operation of their mill or kiln now, which they do not want to jeopardise. Whilst this allows for stable operation in the short-term, they are likely to risk reliable operation in the medium-term and it will most definitely result in a much shorter gear life.

Understandably, some operators are anxious about making changes to their lubrication set-up. To ensure safe transitions, Klüber Lubrication's sales and service engineers accompany a changeover of lubricants. This is followed by regular onsite inspections to monitor gear contact and spray system patterns, tooth flank temperatures and vibrations. This provides operators with peace of mind that their gear and pinion are in good condition. In addition, during annual shutdown, the wear speed on the gear flanks can be measured to gauge the lower wear rates leading to an extended gear life resulting from advanced lubrication technologies.

An alternative to frequent on-site inspections is continuous remote condition monitoring of the girth gear that Klüber Lubrication offers in exclusive partnership with DALOG, a leader in remote condition monitoring solutions for the cement industry. This joint solution allows operators to define limits for performance indicators such as tooth flank temperatures and vibrations. When indicators reach a defined limit, operators and, if desired, their Klüber Lubrication service engineer are notified to inspect the equipment manually and take corrective actions. This is not only helpful during the changeover process from one lubricant to another but also when optimising lubricant consumption levels, or for detecting lubrication starvation in case of a spray system failure.

Summary

Asphaltics and black greases have served operators well for decades. Advanced open gear lubrication technologies offer operators the possibility of improving equipment reliability whilst significantly extending its lifetime, thus maximising asset utilisation. This allows operations and maintenance to a enter a more reliable and cost-efficient state. Operators do not need to accomplish such a transformation all by themselves. A strong lubrication partner can support them with regular on site presence for inspections, lubricant optimisation, staff training and implementation of digital condition monitoring solutions. ■

About the author

Markus Burbach is the Global Head of Cement at Klüber Lubrication. Prior to this role, he worked as Head of Marketing & Business Development North America for Klüber Lubrication in the United States where he was responsible for Marketing, Application Engineering, Technical Services and Product Management for the Klüber Lubrication and Summit brands.