Best practice lubrication for increased kiln uptime

Increasing kiln uptime and output is a major goal for many cement plants to increase profits. When optimising these KPIs, plants usually identify the root causes of why the performance deviates from the targets. A common reason for performance shortcomings is kiln support roller bearings (KSRBs) issues that force operators to slow down production or stop the kiln operation altogether. While inadequate lubrication can be one reason for problems with KSRBs, cleverly-chosen lubrication practices can also be highly effective measures to mitigate or completely avoid certain problems.

■ by **Klüber Lubrication GmbH & Co KG**, Germany

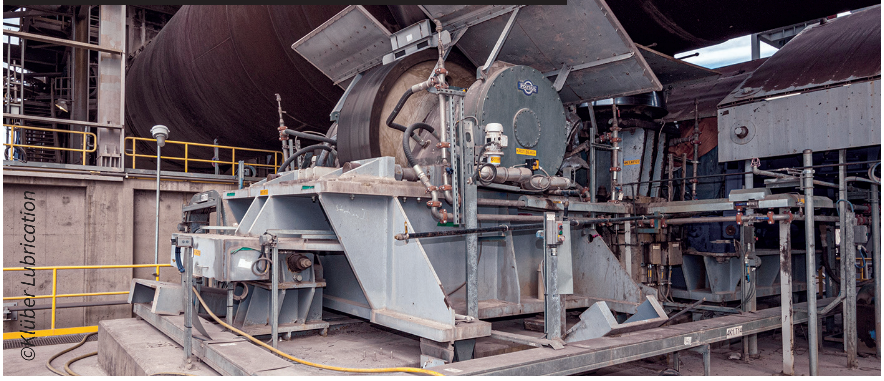
To benefit from cleverly-selected lubrication practices for increased uptime and output of kilns, it is important to understand some common lubrication-related challenges for kiln support roller bearings (KSRBs). These can include:

- overheating of bearing and oil due to abnormally high friction from unbalanced loads or overloads (eg, due to skewing or kiln upgrades)
- no perfect hydrodynamic lubrication due to slow rotational speeds causing metal-to-metal contact (eg, during start-up or at slow operational speeds)
- wear due to lubricant starvation at friction points because the viscosity of the lubricant is too high (eg, during start-up or when there is excessive cooling of the oil)
- use of lubricants that are not compatible with bearing materials or not miscible with other lubricants in use (eg, during troubleshooting)
- significant wear because of ultra-fast viscosity reductions of standard lubricants in case of overheating (eg, skewing, hot temperatures in summer).

Overview of best practices

There are several lubrication best practices that help address these challenges and contribute to increased kiln uptime and output. Three such best practices are:

1. increase viscosity of mineral oil
2. switch from mineral to synthetic polyalphaolefine (PAO) or polyglycol (PAG) oil
3. switch from low to high performance oil of the same type.



Increasing kiln uptime and output with three best practices for effective lubrication of kiln support roller bearings

Best practice 1

Increase viscosity of mineral oil

The standard lubricant recommendation of many kiln original equipment manufacturers (OEMs) is a mineral oil with an ISO viscosity grade of 460 or 680. This means the oil has a viscosity of 460 or 680mm²/s at 40˚C. This is usually an adequate choice for normal operating conditions at which the bearing and the oil have a temperature of around 45-55˚C. However, if the temperature of the bearing and the oil rise, the viscosity of the oil drops. This results in a thinner lubricant film and thus less protection from metal-to-metal contact that can cause wear and, in severe conditions, lead to the overheating of a bearing itself.

To counteract mildly increased temperatures that may not be caused by a problem but simply by constantly elevated temperatures (eg, hot climates), operators may chose to increase the viscosity by one grade (eg, from ISO viscosity grade 460 to 680) to operate more closely at the specified viscosity of the OEMs.

Table 1 compares how a mineral oil at ISO viscosity grades 460, 680 and 1000 changes its viscosity within a temperature range of -20 to 120 °C. The reference viscosity is given at 40˚C. As temperatures increase, the viscosity drops. As temperatures decrease, the viscosity increases. This relationship is summarised in the Viscosity Index (VI): the higher the VI, the less pronounced the changes of the viscosity in relation to changes in the temperature. Table 1 shows that an ISO VG 460 mineral oil provides a viscosity of 460mm²/s at 40˚C but only a viscosity of 147mm²/s at 60˚C. This means a 50 per cent increase in temperature results in an almost 70 per cent loss of viscosity and lubricant film thickness. Knowing that normal operating conditions are often well above 40˚C, operators may increase the viscosity by one grade. Using an ISO VG 680 oil instead would provide a

Table 1: changes of different viscosities of same base oil at different temperatures

Temperature (˚C)	Mineral		Mineral		Mineral
	Klüberoil GEM 1-460 N viscosity (mm²/s)		Klüberoil GEM 1-680 N viscosity (mm²/s)		Klüberoil GEM 1-1000 N viscosity (mm²/s)
-10	55,559		116,171		203,336
0	15,569		29,637		49,783
10	5255		9242		14,948
20	2068		3401		5313
30	925		1435		2174
40	460	+48% →	680	+47% →	1000
50	250		355		508
60	147	+37% →	201	+39% →	280
70	92		121		166
80	60	+30% →	78	+35% →	105
90	42		53		69
100	30		37		48

Source: Klüber Lubrication

Table 2: changes of same viscosity of different base oils changes at different temperatures

Temperature (˚C)	Mineral		Polyalphaolefine (PAO)		Polyglycole (PAG)
	Klüberoil GEM 1-460 N viscosity (mm²/s)		Klübersynth MEG 4-460 viscosity (mm²/s)		Klübersynth GH 6-460 viscosity (mm²/s)
-10	55,559		12,442		6479
0	15,569		5422		3385
10	5255		2609		1894
20	2068		1366		1124
30	925		768		703
40	460		460		460
50	250		291		313
60	147	+31% →	192	+15% →	220
70	92		132		160
80	60	+57% →	94	+27% →	119
90	42		69		91
100	30		53		71

Source: Klüber Lubrication

viscosity of 241mm²/s at 60˚C compared to a viscosity of 147mm²/s using the lower grade. This provides roughly a 60 per cent higher lubricant film thickness and better protection from friction.

Whilst this approach provides increased protection at mildly elevated temperatures, it comes with one significant disadvantage: the viscosity of the oil may be too high if the bearing is operating at normal conditions, or after the kiln has been shut down for a while and the bearing and oil have cooled off. This can compromise the flow behaviour of the oil and result in a lack of sufficient lubricant at the friction point. This can be particularly severe in colder climates.

Best practice 2

Switch from mineral to synthetic PAO or PAG oil

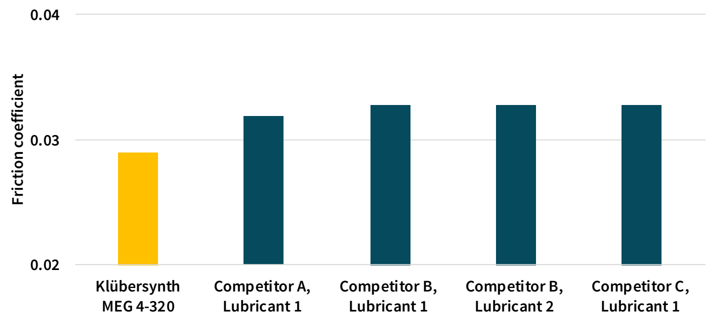
Increasing the viscosity of a mineral oil is one option to ensure better wear protection for KSRBs, but it comes with potential disadvantages as outlined before. A far more effective and versatile approach is switching from a mineral-based oil to a synthetic oil on a PAO or PAG basis.

The higher VI of these oils, especially PAGs, is far better suited for the operating conditions and the occasional overheating of kiln support roller bearings than a mineral oil. The reason is that the synthetic oils ensure a viscosity of the oil as close as possible to the specified target viscosity in case of temperature changes.

Table 2 compares how the same viscosity grade (460mm²/s) of the three different base oils changes within a temperature range of -20˚C to 120˚C. It shows that all three oils have the same reference viscosity at 40˚C but as temperatures increase, the viscosity changes of the different base oils vary greatly. The PAO- and PAG-based oils do not only offer a much higher viscosity than the mineral oil at higher temperatures but also less deviation from the viscosity specified by the OEMs to ensure an optimal lubricant film thicknesses in the friction point of the bearing.

Figure 1: same viscosities of same base oils can have different friction properties

All oils PAO, ISO VG 320 – mean EHD frictdion (traction curve) at 40-120˚C at 2.5m/s. Measured on Mini Traction Machine (MTM), 2022



Source: Klüber Lubrication

Operators can benefit in three ways from the higher VI of PAO and PAG oils:

- higher viscosity at elevated temperatures (thicker lubricant film and better wear protection)
- lower viscosities at low temperatures (better flow behaviour of lubricant at start up)
- viscosity closest to OEM specifications independent of operating temperature.

When operators are looking to make use of the benefits of PAO or PAG oils, it is important to be aware that these are fundamentally different chemistries. PAO oils are miscible with mineral oils and compatible with most materials commonly used in KSRBs (eg, metal/steel, paints, seals). PAGs are not miscible with any other oil type and may not be compatible with select materials of the bearings. There may be further differences between PAGs from different manufacturers. Therefore, it is strongly suggested to consult a lubrication partner who can advise on the correct use and understands the compatibilities of its own PAGs and the material pairings of the specific OEM equipment on site.

Best practice 3

Switch from low to high performance oil of the same type

Switching between viscosities and base oils is one approach to enhance operating conditions. Another one is switching from low to high performance oils of the same type. This approach can be very effective because not all oils are created equal. Oils of the same base oil and the same ISO viscosity grade can have very different performance features.

Typical differences that can exist between two different PAO oils are:

- viscosity-temperature behaviour (viscosity index)
- friction reduction properties (friction coefficients)
- wear protection.

Figure 1 illustrates the differences in the friction coefficient between three different PAO oils. It shows that there can be considerable differences despite using the same base oil at the same viscosity. The reason for this is the difference in additives and their concentrations in the oil.

Figure 2 shows differences in the wear protection between two different PAO oils. The results are taken from a worm gear test rig where a bronze worm wheel meshes with a steel wheel for 300h at variable speeds and torques at a standard of 350rpm and 300Nm, respectively. Bronze/steel pairings are common material pairings in the KSRBs of some OEMs and the results of the test show that these materials experience very different wear rates depending on lubricant choice.

Spanish cement plant case study

A cement plant in Spain was experiencing severe overheating of its KSRBs when using a mineral oil VG 320. Not only was the viscosity of the oil below the OEM's specification, but the mineral oil could also not hold up to the hot temperatures of the bearing which reached up to 100˚C during the summer.

The heat caused the viscosity of the mineral oil to drop severely, no longer protecting from metal-to-metal contact, resulting in wear, and contributing further to the overheating of the bearing. It also caused the oil to oxidate which created black residues on the bearing.

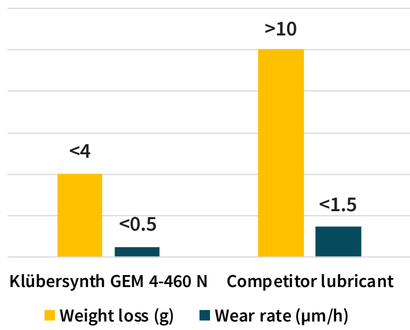
As a result, the plant slowed down the kiln turning speed which reduced production output by 30tph. The time needed to return to normal output was 16h. Over one year, nine such interventions were necessary. In four cases the complete oil volume of 1400l needed to be replaced which caused 5600l/annum of unplanned, additional oil demand.

Supported by Klüber Lubrication, the operator exchanged the old oil with Klübersynth GEM 4-680. This implied an increase in viscosity of two ISO grades which provided a higher lubricant film thickness. It also meant a switch from mineral oil to synthetic PAO, ensuring less viscosity losses in case of overheating and better high temperature stability, resulting in no oxidation or residues. It also doubled the oil lifetime. The benefits of the project include:

- better protection of the bearing from thicker lubricant film and lower coefficient of friction
- avoided risk of bearing failure from damages caused by carbon residues
- extension of oil life by a factor of four, thereby reducing oil waste and the need for manual oil changes
- unplanned oil changes avoided
- avoidance of lost production value of EUR146,000 per annum and a return on investment (ROI) of 440 per cent. ■

Figure 2: same viscosities of same base oils can have different wear protection

Both oils PAO, ISO VG 460 – weight loss and wear rate of different PAO oils, tested on worm gear test rig



Source: Klüber Lubrication