
COMING
FULL CIRCLE

Nicolas Costa, NOVEXA, Christoph Muschaweck, DALOG, and Nicolas David and Dr Eva-Maria Mautner, Klüber Lubrication, provide an innovative approach to maximising the lifetime of gears in the cement plant, using circular maintenance management.

Large girth gear drives have proven effective in plant engineering for many decades and their reliability and operational safety is of the utmost importance. Given the total cost of such equipment as well as its impact on production performance, cement manufacturers must adopt the right maintenance strategy for each life stage of a gear. Four maintenance strategies can be distinguished:

- Curative: Repair after damage to return to normal operation.
- Preventive: Perform routine maintenance for sustainable operation.
- Predictive: Minimise unplanned shutdown.
- Proactive: Implement a Total Productive Management (TPM) system for continuous improvement.

All of these strategies should be applied at the right time and with the right resources in terms of people, the system used, and organisational aspects, to deliver a high return on investment.

How does one make the right decision?

Maintenance managers must often reconcile the views of internal experts and third parties with conflicting interests.

For the sake of efficient readability, Klüber Lubrication (global leader in speciality lubricants), NOVEXA (global leader in on-site machining) and DALOG (global leader in condition monitoring) have united in this article to explain how to maximise the lifetime and performance of the gear for peace of mind.

Machine monitoring

An objective machine health assessment of the drive system builds the foundation for a cost efficient TPM system (Figure 1). The goal is to prevent any unwanted surprises during the operation and plan maintenance interventions based on the condition of the drive. Online condition monitoring systems can give detailed information about the health of the machine in real time. Their main task is the early failure detection of wear and cracks at bearings and gears. In addition, it is possible to detect even slight changes in the gear meshing to evaluate the effects of repair works (e.g. repair lubricants, reprofiling). Conventional vibration analysis at low speeds generally fails to detect vibrations issued from a faulty bearing due to its low energy, high and variable loading conditions and to the noisy environment generated by other mechanical components of low speed machines such as gearing systems.

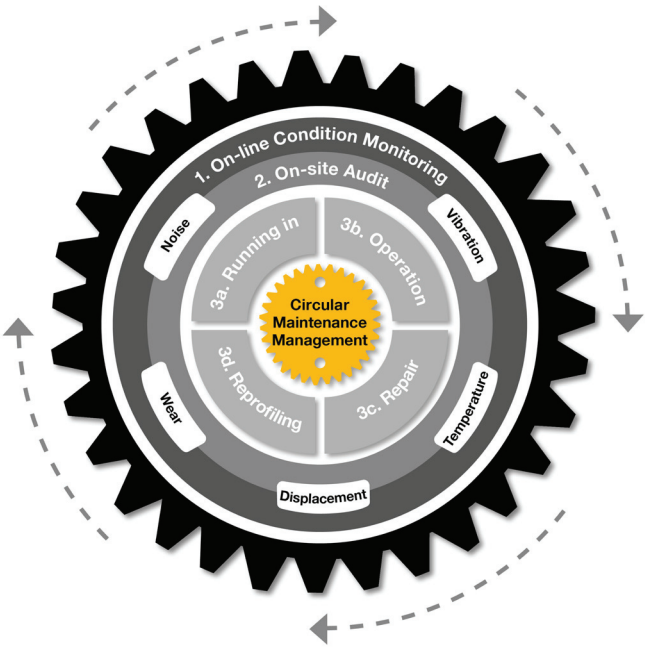

Figure 1. Open gear circular maintenance management.

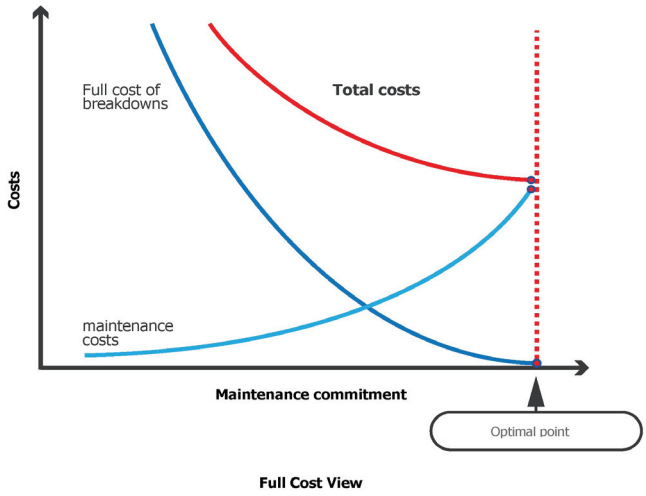

Figure 2. Plants benefit from less unplanned stoppages and a minimisation of consequential damage.

DALOG uses a combination of acceleration and speed sensors with a high performance online condition monitoring system to detect early stage failures at low speed girth gears and bearings. The data logger system must be able to sample the signals at a high rate and perform signal filtering. The output of the DALOG system is in the form of intuitive component related indicators (e.g. pinion bearing indicators) that can be visualised on the operator screen in a reliability software package and in the cloud to give access to all interested stakeholders. This provides time to act and plan. Plants benefit from fewer unplanned stoppages and minimal consequential damage (Figure 2).

The assessment of the failure is backed by experts in the DALOG Diagnostic Centre. Besides detecting the failure, their job is to evaluate its criticality and determine consequential actions. Many failures can be rectified before they turn into a bigger problem. Klüber Lubrication and NOVEXA can quickly intervene and verify the findings of DALOG with an on-site inspection.

Field inspection

Visual inspection is inseparable from the accurate establishing of a diagnosis on a girth gear. Regardless of the warning mechanisms available to a maintenance team, only an on-site inspection will allow the detected fault to be confirmed or not confirmed.

Vibration and temperature are indicators of the proper functioning of equipment, but they are also warning indicators that allow on-site audits to be planned when the warning thresholds are reached. In itself, DALOG's expertise and the level of technology they can develop makes it possible to ensure technical monitoring of the equipment and to react as quickly as possible.

For example, a recurring speed variation detected on a gear by a sensor should trigger an immediate visual inspection. This variation may be caused by excessive deformation of the tooth profiles due to a high wear rate. By reacting as quickly as possible, from the first warning signals, wear management is better controlled, and maintenance costs and the risks of unexpected shutdown are reduced.

A complete inspection of the girth gear must take into account several parameters, including:

- Lubrication conditions (quality, consumption, lubricant distribution, lubrication system, etc.).
- Meshing conditions (root clearance, contact pattern, pinion and gear alignment, etc.).
- Gear surface faults (pitting, spalling, scuffing, etc.).
- Vibration measurements.
- Temperature measurements.
- The kinematic wear state (bearing clearances, pinion/gear box alignment, etc.).

The on-site inspections carried out by Klüber Lubrication and NOVEXA are complementary as they combine all the parameters of an inspection. If these two types of inspections share common parameters (vibrations, load distribution, temperatures), Klüber Lubrication inspections are more oriented towards the analysis of lubrication conditions, whereas NOVEXA inspections are focused on the inspection of gears and shaft geometry.

The right lubrication and correct gear geometry (including correct alignment setting) are two essential parameters in the efficient monitoring of a piece of equipment. Without the right lubrication, equipment wear progression will be rapid and exponential. Likewise, without good meshing conditions ensuring sufficient load distribution, equipment lubrication while meshing will not operate optimally.

From running-in to repair

Large girth gear drives are ubiquitous in cement processing. The reliability and operational safety of the drives, and in consequence their lubrication, is of the utmost importance. Functional reliability and damage-free operation of large gear drives highly depends on the correct lubrication. Outstanding gear protection starts long before the actual first revolution, i.e. during transportation, storage and assembly, and accompanies the gear set over its entire lifetime. To ensure optimum lubrication at all life stages, Klüber Lubrication has developed a systematic four-step lubrication method for large gear drives, which has been known for many years under the name ‘A-B-C-D system lubrication’ (Figure 3).

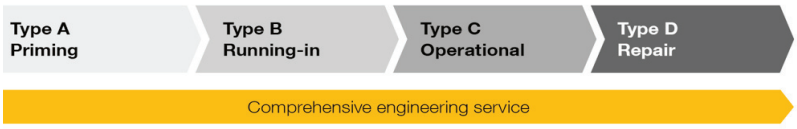

Figure 3. A-B-C-D system lubrication.

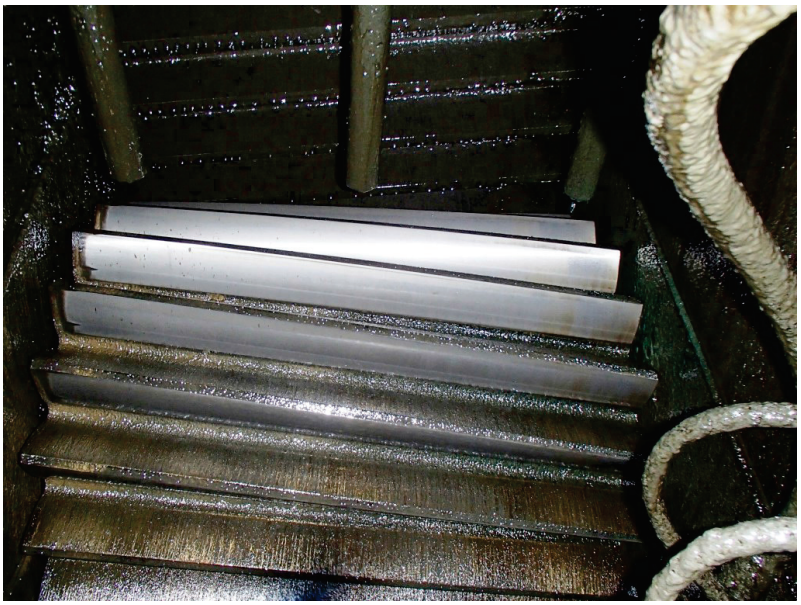

Figure 4. Pinion/girth gear with transparent open gear lubricants – inspection and documentation made easy with strobe light or high-resolution digital camera while running.

Priming lubricants protect the tooth flanks in the first life stage from damage during storage and initial alignment of the gears. Lubricants can be applied manually by brush or spatula. Running-in lubricants are applied to new gear drives or after repair lubrication. Due to their special additives, they cause a controlled, minimum amount of chemical wear. Thereby, they improve the surface condition by smoothening rough surfaces and enlarging the contact pattern. Both reduce the possibility of gear damage in subsequent stages. During the regular operation of a large girth gear drive, operational lubricants are the lubricants of choice. They are modern adhesive lubricants tailored to suit the operational conditions of girth gear drives. They meet all extreme pressure requirements of gear drives at very low consumption rates while keeping up wear protection. Hereby, two different lubricant technologies are distinguished.

High viscosity fluids

To meet the demands of large girth gear drives, Klüber Lubrication invented a range of transparent open gear lubricants. With a wide range of available viscosities, the Klüberfluid C-F Ultra series can be used in spray, circulation, and immersion systems in all climates. The modern high-viscosity fluids offer low consumption in combination with the best gear protection. Inspections can be conducted easily with a strobe light or a high-resolution digital camera while running the gear drive (Figure 4).

Gear greases containing solid lubricant

These open gear lubricants are based on soaps and mineral or semi-synthetic base oils with solid lubricants. They offer operating reliability in different environments around the world. Furthermore, these lubricants are the first choice if cost efficiency is a target. Another advantage is to visualise the contact pattern easily by the contrast with the gear material.

Flank surfaces often become damaged for a variety of reasons, which can lead to an inadequate contact pattern. To prevent breakdowns, Klüber Lubrication has a solution to repair the gear while remaining in operation under full load. Repair lubricants re-condition the tooth flank surface (Figure 5). They incrementally and evenly remove asperities, scratches and scorings to improve the contact pattern and to avoid peak loads. Even pittings and plastic deformation can be smoothened up to a certain level.

However, when the tooth flank damage is too excessive, chemical smoothening is often no longer sufficient and a mechanical intervention is required (in order to restore the initial involute profile and right meshing conditions) as load and lubricant distribution and lubricant circulation deteriorate. This condition is present, for instance, if profile deformation, vibration level and/or temperature difference between fixed bearing and loose bearing side, on pinion and/or girth gear exceed certain levels. In such critical situations, the reprofiling is one of the few applicable options.

Reprofiling

Even though the wear speed and lifespan of an open gear can be managed, mechanical wear is inevitable. Year after year, pinion and gear wear out due to metal to metal contact during meshing. Gear profiles are slowly deteriorating, thus creating similar wear on each tooth. Pinion/gear wear always shows in the form of:

- A pinion root step.
- A recess below the pitch diameter area.
- A hump on the tooth's head, above the pitch diameter area.

This profile deformation generates modifications in the meshing conditions and contact ratio. When wear reaches a critical level, one can also notice:

- An excessive vibration level.
- In some cases, and without intervention: appearance of fatigue cracks with risk of tooth breakage.

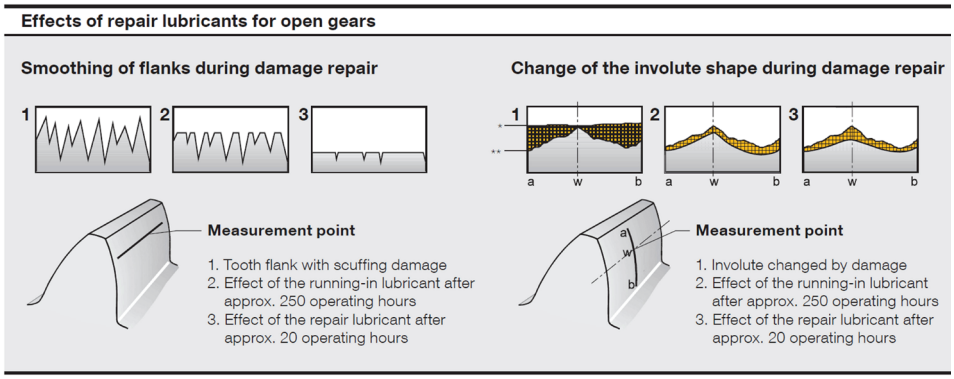

Figure 5. Repair lubricants are not applicable when profile deformation is excessive.

Figure 6. Profile deformation before intervention: 4.7 mm (left) and profile deformation after reprofiling by NOVEXA: accuracy 0.07 mm (right).

The replacement or reversal of damaged gears (when possible) is not the only available option. An intervention called 'reprofiling' represents an alternative solution (assuming that the remaining thickness is sufficient) which is faster and

substantially less expensive than replacement or reversal.

During the last 20 years, NOVEXA has developed a unique reprofiling method which allows, in a few days only and without dismantling the gear, the original gear's involute profile to be restored, with a machining accuracy of 0.07 mm.

This on-site machining technique is specially recommended in cases of pinion replacement on a worn gear. Many clients do not take into account the girth gear's wear when replacing their pinion. In such situations, at restarting, meshing conditions are totally disturbed, and the contact pattern is very poor due to the incompatibility between the profiles of the new pinion and worn gear. This situation often generates very high vibrations coupled with shocks during rotation (mainly on mills which have an elevated rotation speed). As long as the profiles of the pinions and gears are not matched, vibrations will remain. The pinion's wear speed will drastically increase until the pinion's wear level reaches that of the gear so that their profiles will finally match. By this time, the pinion's wear will be almost as high as it was before its replacement and the customer will face the same issues as before. In some cases, when the gear's maximum wear level does not exceed 0.5% of the module (i.e. 0.15 mm for a module of 30), a chemical running in process by a running-in lubricant can be carried out. Otherwise, only a mechanical reprofiling intervention on the girth gear will allow the perfect involute profiles to be restored and bring about a sustainable solution (Figure 6).

After a reprofiling intervention including setting and alignment, all meshing conditions will have to be maintained in their optimal state by means of perfect lubrication conditions and permanent remote monitoring in order to have optimised running conditions for many years.

Summary

'Circular Maintenance Management' is a holistic approach to get the best out of rotary tubes in a more lasting and transparent way without the risk of unexpected shutdown. Beside the long-term gain of performance, this solution offers a large saving potential, making the payoff extremely attractive.

- Cost of production: A reduction of energy consumption exceeding 3% through proper lubrication can be achieved and demonstrated using big data algorithms. A long-term reduction of lubricant consumption exceeding 50% against a commodity lubricant can be achieved without the risk of damage for the gear.
- Cost of maintenance: Remote monitoring and field inspection make the status of the large gear transparent and predictive. The system triggers ahead of time the need for inspection, repair, reprofiling or replacement to avoid costly emergency solutions. It also offers large possibilities for automation like condition-based lubrication systems to make Industry 4.0 a reality.
- Cost of unexpected shutdown: This is likely to exceed €0.5 to 1 million combining the cost of replacement of the gear (purchasing cost and installation), the loss of production (lead time until installation of the new gear) and various additional costs (labour, third parties and others).

With the combined competencies of Klüber Lubrication, NOVEXA and DALOG, cement manufacturers are offered an innovative approach to maintenance management. The combination of machine monitoring, onsite inspection, repair lubrication and reprofiling helps to reduce costs, makes maintenance more efficient and thus supports the attainment of sustainability goals. ■

About the authors

Nicolas Costa is Development Manager at NOVEXA. He holds a Master's Degree of Strategy and Economic Intelligence from Toulouse Business School and a Degree in Management from Cergy-Pontoise University. Nicolas Costa was Project Manager for XCase application deployment, the remote monitoring application for gear wear developed by NOVEXA.

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