DRIVE SELECTION FOR LARGE LOESCHE VERTICAL ROLLER MILLS

ANTRIEBSWAHL FÜR GROSSE VERTIKAL ROLLENMÜHLEN DER BAHART LOESCHE
Rising demand from the cement industry for ever greater mill capacities is having implications for the drive systems that have been used up to now. With conventional drive solutions reaching their limits, the world’s leading gearbox manufacturers are developing new systems that can offer realistic alternatives for the higher-capacity mills that are now being ordered and delivered. This article looks at how Loesche undertook the evaluation of the best gearbox system for a new, high-capacity vertical roller mill, and explains the thinking behind the decisions made. After a summary of the most important functions of the drive for a vertical roller mill, its design and design limitations, there is a detailed comparison, using a real project, to select the best available drive system.

SUMMARY


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Drive selection for large Loesche vertical roller mills
Antriebsauswahl für große Vertikal-Rollenmühlen der Bauart Loesche

1 A background to drives of vertical roller mills

The drive of a vertical roller mill – essentially the mill gearbox – has to fulfill two tasks: The first is to reduce the speed of the electric motor to the selected mill speed and to transmit the torque created by the motor. Secondly, the gearbox has to transmit the grinding forces generated by the grinding rollers, from the mill table, through the gearbox, into the mill foundation.

Today, most mills are equipped with bevel planetary gearbox-es that are driven by a single electric motor, with two-stages used for drive outputs of up to 1 500 kW. The first stage consists of a bevel gear that changes the direction of the input rotation from horizontal to vertical, with a planetary stage needed for the final speed reduction to 20 to 35 rpm, depending on the size of the mill. For higher capacities, a second planetary stage is added to handle the increased torque requirement at the mill table. Fig. 1 shows a schematic of a three-stage bevel-planetary-planetary gearbox. The bevel gear stage changes the direction from horizontal to vertical, with the two planetary stages transmitting the drive torque to the grinding table.

The big design challenge for these gearboxes is mainly the first (bevel) stage, through which the full motor power is transferred to the gearbox. The bearing arrangement of the input shaft is always critical, as the power is introduced at high rotational speeds of about 990 rpm. For power inputs greater than 4 000 kW, a sleeve bearing arrangement is essential, since these are designed for higher loads and are basically wear-free.

This is only true as long as the lubrication system works perfectly, which is quite a task since the system is responsible not only for actual lubrication, but also for removing heat generated in the bearings. If the lubrication system does not work properly, catastrophic bearing failure will occur.

The next challenge is the bevel gear, and especially the bevel gear wheel. The bevel gear transmits the full torque into the planetary stage through a single contact point in order to withstand the forces generated. The bevel pinion and gear are hardened and machined to the highest standards. Mid-size bevel wheels can be manufactured nearly trouble-free today. Hardening involves heating the part to a certain temperature, followed by rapid cooling, with the bevel wheel held in a form in order to avoid deformation. The aim is to achieve gear teeth that are hard on the flanks but still ductile in the centre, with surface hardening reaching a depth of 1.5 to 2.0 mm. Final machining of the teeth to the correct profile takes place after the piece has been cooled.

However, larger bevel gears would need to be cooled without being fixed in position, and that substantially increases the risk of deformation. In fact, this might be enough to mean that the full depth of the hardened layer would have to be taken off during the final machining, rendering the gear useless and requiring a new part to be made – which in turn could have a serious effect on the delivery schedule of the gearbox hence on the completion date for the whole mill.

By contrast, the other gearbox components, such as the planetary stages, have proved to be technically mature. Looking only at Loesche’s mill population of about 2000 units, nearly 800 of those have been supplied with such conventional drives. In the rare cases of gearbox issues, none of them was related to a problem within one of the planetary stages.

Nonetheless, it must be believed that the first bevel stage, with its high-speed input shaft and sophisticated bearing and cooling arrangement, will not work reliably over a certain power limit. The same goes for the bevel gear because it transmits a torque through a single contact point, and because of the manufacturing limitations described above. Hence Loesche does not recommend using a conventional gearbox on mills using more than 7 800 kW motor power.

2 The need for larger drive units

Without question, the capacity and drive power requirements of cement- and slag-grinding mills has been steadily increased. For example, in 2006 mill capacities of about 220 t/h equated to 5 500 kW of maximum power demand. Nine years later, in 2015, the maximum mill throughput had increased to around 500 t/h with
The question is, what systems are available that can cope with these new demands? When developing new drive concepts, Loesche requires its drive manufacturers to meet certain performance targets. Newly developed systems have to be highly efficient and cost-effective, and have to be able to handle at least 13 MW of transmitted power with reserve capacity for maybe up to 16 MW. However, they also need to be designed in such a way as to avoid – wherever possible – components that have created major challenges in the past on conventional drive systems. Ideally, that would include omitting bevel gears with their high-speed input shafts.

In addition, accessibility and maintenance should be easier, while active redundancy is a big bonus. The external dimensions of new drive systems are also very important, and new systems should be designed so that they can be retrofitted directly to existing mills without the need for extra foundations.

In response, drive suppliers have developed a number of new concepts, three of which are discussed here. One option is the EMPP drive, developed by Flender/Siemens, or MAAG’s CEM drive. Both systems follow a similar design concept, having completely eliminated the first high-speed bevel gear stage and replaced it with an in-built electric motor. The concept also includes two planetary stages, the drive torque supplied by the motor being introduced directly into the first planetary stage. In addition, the gearbox housing has been designed so that it can be retrofitted to existing mills in place of a conventional gearbox.

As an alternative, the Flender/Siemens’ MultipleDrive concept divides the drive power needed between three and six smaller drive trains, depending upon the required capacity, that drive a common girth gear connected to the grinding table. Each individual drive train consists of a motor and a three-stage bevel-helical gearbox. However, the system is not suitable for retrofit applications.

Thirdly, the COPE (COmpact Planetary Electric) drive, developed by Renk, is driven by up to eight individual drives, distributing the torque evenly to a central gear wheel that drives a single standard planetary stage inside the gearbox. As with the EMPP and CEM drives, the COPE drive is exchangeable with conventional gearboxes.

3 Drive selection

Now it seems necessary to discuss the advantages and disadvantages of each system for large mills. Firstly it is necessary to state that all the available systems have been developed by the best gearbox suppliers in the world. All of them will fulfill, in one way or another, the demands of the cement industry, and all are available for driving a Loesche mill. However, as a mill supplier, the company has a duty to recommend not only a suitable drive system, but the best available drive system for any particular application.

Looking at a project that is currently on the company’s books, the task was to select a cement mill and a suitable drive to produce a cement with the quality of OPC and a variety of CEM II cements. The mill capacities requested by the client varied between 445 t/h at 3 200 Blaine for the OPC and 485 t/h at 3 400 cm²/g Blaine for the CEM II-type cement.

Specifying the mill was straightforward in this case, with the client’s requirements being handled by a mill type LM 72.4+4 CS. This mill type has a grinding track diameter of 7.2 m and is equipped with the patented design of four pairs of grinding and support rollers. The necessary drive power of 10 000 kW was also easy to calculate. Then came the process of selecting a drive system to deliver that power from the electric motor or motors to the grinding table. A conventional drive system was set as the baseline for the comparison, in the full knowledge that it would not be chosen as the preferred solution here because of the shortcomings identified above. The newly developed options selected for evaluation were the concept of a Flender/Siemens EMPP or MAAG CEM drive with an in-built motor, the Flender/Siemens MultipleDrive system, involving four drive units with a power rating of 2 500 kW each, and the Renk COPE system with eight, 1 250 kW drive units. Schematics of all these drive options are shown in Fig. 2.

The process used an evaluation matrix, comparing all theoretically available options against certain target criteria. The mechanical target criteria considered included:

- Avoidance of critical parts: How did the new solution manage to avoid the first high-speed input gear with its challenging bearing arrangement and one-tooth meshing?
- High efficiency: What level of losses could be expected?
- Active redundancy: Did the system allow for production to continue even if certain parts needed repair?
- Quality of access: How much free space is available for maintenance, and how much space is taken up by the drive system, reducing access opportunities?
- Low maintenance: How easy is maintenance, and how long does it take?
- Low foundation demand: What are different foundation requirements, and how much space does each take up?
Rating involved a simple three-tier marking system: “High” – the target was well-achieved; “Average” – the target was achieved to an acceptable level; and “Low” – indicating that the target was not achieved.

4 Evaluating individual criteria

Taking each point in turn, in the Multiple-Drive system, the gearboxes still need a high-speed bevel gear stage. The EMPP/CEM drive completely eliminates the high-speed input shaft, compensating for it with an inbuilt motor, while the COPE drive also works without the bevel stage as the motors are mounted vertically, allowing a helical pinion to drive the central gear wheel of the planetary stage.

The next target was high efficiency. In a gearbox, losses are generated in each bearing and because of gear meshing. As a rule of thumb, there is about 1 % loss in a helical stage, 1 % in a single planetary stage and about 1.5 % in a bevel stage. Thus for a conventional bevel-planetary-planetary drive, there is a 3.5 % loss in efficiency, 1.5 % for the bevel stage and twice 1 % for the planetary stages, as shown in Fig. 3 and Table 1.

In comparison, the EMPP/CEM drive operates with two planetary stages (hence a 2 % efficiency loss), and the MultipleDrive is a three-stage bevel-helical-helical drive, so that the losses add up to 3.5 % – similar to the conventional drive (Table 2). The COPE drive consists of single helical and planetary stages, has a 2 % efficiency loss – or 43 % less than a conventional or MultipleDrive system.

In terms of active redundancy, this is not provided by either the conventional solution or the EMPP/CEM drives, since both systems are powered by a single drive motor. If it fails, the mill cannot operate.

By contrast, the MultipleDrive system uses three-to-six drive trains, driving the grinding table via a large common girth gear. If one unit fails, it can be uncoupled from the girth gear and operation can continue on a partial load level – a process that takes around eight hours to complete before the mill can be started again.

The COPE system also divides the required torque into up to eight drive units that drive the central gear wheel. Like the MultipleDrive, any of the drive units can easily be disconnected in the case of a failure, and the mill can start running again after about four to five hours of downtime. When looking at the redundancy efficiency, the question arises as to how the nominal motor power is selected for a given mill. Easily enough, this is the product of the grindability of the material to be ground in kWh/t with the required mill capacity in t/h, which gives the minimum motor power needed to achieve the throughput required. This is then modified by using a safety margin, typically around 15 %, to account for grindability fluctuations in the feed (Fig. 4).

Table 1: Detailed comparison – gearbox efficiency loss

<table>
<thead>
<tr>
<th>Gearbox stage</th>
<th>Efficiency loss (mechanical) [%]</th>
<th>Gearbox system</th>
<th>Number of stages</th>
<th>Efficiency loss (mechanical) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planetary stage</td>
<td>1.0</td>
<td>Conventional</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>Helical stage</td>
<td>1.0</td>
<td>EMPP/CEM Drive</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Bevel stage</td>
<td>1.5</td>
<td>MultipleDrive</td>
<td>3</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Figure 3: Detailed comparison – efficiency loss per stage

In the project described here, a 10 MW drive capacity was selected that included a 15 % reserve. For a MultipleDrive, the drive power would be supplied by four 2500 kW drive trains while the COPE drive would use eight drive units, each with a capacity of 1250 kW.

If the mill runs as assumed, meaning that the material grindability, the mixing ratio of the feed material and the required material fineness are as planned, the mill can operate at 100 % guaranteed capacity with about 8700 kW of drive power, equivalent to 10000 kW minus the calculated reserve.

If, however, one drive unit fails, with the MultipleDrive solution 7500 kW would still be available, so the mill could continue running with an 86 % capacity – a 14 % production loss. In the COPE system, each of the drive units has a power rating of 1250 kW, so, if one of these fails the available drive power still adds up to 8750 kW. That means that the mill could still produce at full capacity with no loss of production.

Figure 4: Selection of drive power and redundancy efficiency
5 Accessibility for maintenance

The more free access there is available around a mill, the easier it is to carry out routine inspections or maintenance. This could include service on the drive system itself, on the hydraulic system for the grinding rollers with its cylinders and bladder, or on the piston accumulators.

For a mill with a conventional gearbox, access is relatively clear around the lower part of the mill, only being hindered by the single drive motor. This allows adequate, comfortable space for inspection and maintenance. For the EMPP or CEM drive systems, access is even better, since the motor is built into the gearbox itself. On the other hand, the arrangement of the MultipleDrive system, using a number of drive motors each with its individual gearbox, severely restricts access around the whole circumference of the mill, so maintenance would clearly be much more difficult (Fig. 5).

With its drive units integral to the gearbox, the COPE drive provides as good access to the lower part as do the EMPP or CEM drives, and better than that available with a conventional drive (Fig. 6).

This leads on to maintenance requirements, and an understanding of what types of activity are necessary. The gearbox itself needs daily visual inspection to check for oil leaks and any other unusual features or noises. The lubrication system, with its pumps, filters, valves, oil-levels indicators and so on, also needs constant inspection and maintenance, with filters to be changed and oil analyses undertaken at regular intervals. Where slip-ring motors are used, regular maintenance includes the replacement of carbon brushes.

Comparing the different systems again, the conventional system has one gearbox, one motor (mostly slip-ring motors), and one lubrication unit to be maintained. In the EMPP/CEM system, the lubrications are similar to the conventional drive but the motor is maintenance-free, leading to the need for slightly less maintenance overall.

For the Multiple Drive system, each of the four individual motor-gearbox drives being considered for this project has its own lubrication unit, with another for the girth gear attached to the grinding table, making five in all. Thus its maintenance needs are much higher than for the conventional or EMPP/CEM systems.

Finally, the COPE system has one compact unit with up to eight individually attached drive units, with just one lubrication unit. Even though there are more motors than in a conventional system, these are asynchronous motors that are basically maintenance-free, with no carbon brushes for regular replacement. This means that the COPE drive has maintenance needs comparable to those of the EMPP/CEM systems, and somewhat less than for a conventional drive.

6 Construction considerations

The choice of drive system can have a significant effect on the size of the foundations to be installed. Suffice to say that the space requirement for the EMPP/CEM drive or the COPE system is the lowest, whereas the MultipleDrive system occupies the most foundation space because of its arrangement. Comparing the foundation footprint for a Loesche mill of the type LM 56.3+3 CS equipped with a COPE drive with a similar mill using the MultipleDrive system, it is clear that while the basic footprint in the centre (to support the grinding forces and the mill table) is exactly the same, the MultipleDrive system has to have larger extensions to carry the drive trains (Fig. 7).

7 Completing the evaluation

The results of the evaluation can be summarised as a matrix, shown in Table 2, using the “High,” “Average” and “Low” criteria as described earlier. For the avoidance of critical parts, the conventional drive as well as the MultipleDrive system that retain some form of high-speed bevel gear were ranked “Low”; while the EMPP/CEM and COPE drives achieved “High”.

In terms of efficiency, the 3.5 % loss for the conventional and MultipleDrive was rated as “Average”, and hence an acceptable level, with the 2 % loss achieved by the EMPP/CEM and COPE systems ranked as “High”. The MultipleDrive and COPE fulfilled requirements for active redundancy, so were both rated “High”; whereas the conventional and EMPP/CEM drive systems were rated “Low” as no redundancy option is available.
This could include service on the drive. The more free access there is available to the grinding rollers with its cylinders and to the grinding table, making five in all. Thus its maintenance needs are much higher than for the conventional or EMPP/CEM systems.

Comparing the different systems again, the conventional MultipleDrive system, using a number of drives, and better than that available with the EMPP/CEM systems, access is even better, since the own lubrication unit, with another for the girth gear attached to the grinding table. For a mill with a conventional gearbox, the lubrications are similar to the conventional drive in that respect, as well as for its low foundation demand, a ranking shared with the EMPP/CEM systems. The MultipleDrive System could only score “Low” in both areas as it has the highest maintenance requirement and is in need of the largest foundation.

It became apparent that – for this specific application – the Renk COPE drive system scored the highest marks in all the target criteria, hence represents the best available drive system. Therefore the Loesche company recommended a 10 MW COPE drive for the mill type according to Fig. 8.

## 8 Systems in operation

Having only been introduced in 2013, Renk’s COPE drive is yet not in operation. However, since the concept only uses industry-proven parts, with the company’s reputation as a leading drive-system supplier, a number of clients have already selected the system.

The first mill to be equipped with a COPE drive is a cement mill LM 70.4+4 CS, which has a drive capacity of 8 800 kW supplied by eight, 1 100 kW drive units. The company is also supplying a mill of the type LM 53.3+3 CS for cement grinding with 4 600 kW of total drive power transferred by eight 575 kW drive units.

Further orders have included a mill LM 72.5 CS for raw-materials grinding and a cement mill LM 72.4+4 CS. These huge machines are equipped with a ø 7.2 m grinding table and five grinding rollers for the raw-material unit, and four grinding rollers plus four support rollers for the cement mill. Installed powers are 7 500 kW and 10 000 kW respectively, with the drive units for both mills using 1 250 kW motors.

For comparison, the first EMPP drive was installed for testing in a Loesche mill of midsize for nearly one year with good results, also the first CEM drive unit is already installed in a vertical roller mill, with a further five mills either in operation or under construction using the MultipleDrive system. It is the company’s conclusion that the Renk COPE drive concept has a straightforward design with a range of technical advantages.

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Table 2: Evaluation matrix

<table>
<thead>
<tr>
<th>Target criteria/Drive system</th>
<th>Avoidance of critical parts</th>
<th>High efficiency</th>
<th>Active redundancy</th>
<th>Good quality of access</th>
<th>Low maintenance</th>
<th>Low foundation demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional drive</td>
<td>Low</td>
<td>Average</td>
<td>Low</td>
<td>Average</td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td>Siemens EMPP/Maag CEM drive</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Siemens MultipleDrive</td>
<td>Low</td>
<td>Average</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Renk COPE drive</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Target achievement rating: High = well achieved, Average = acceptable level, Low = not or not sufficiently achieved

For quality of access, the ratings ranged from “Low” for the MultipleDrive, through “Average” for the conventional drive to “High” for the EMPP/CEM and COPE. The COPE drive also had the lowest maintenance needs, so achieved a “High” in that respect, as well as for its low foundation demand, a ranking shared with the EMPP/CEM systems. The MultipleDrive System could only score “Low” in both areas as it has the highest maintenance requirement and is in need of the largest foundation.

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In summary, the COPE drive has shown excellent performance in its early installations, with high quality of access, low maintenance requirements, and low foundation demands. The MultipleDrive system, while providing good access and maintenance, is limited by its higher foundation requirements. The conventional drive is the least versatile in terms of access and maintenance, but is readily available and proven in many applications. The EMPP/CEM systems offer a good balance between access, maintenance, and foundation requirements, but are not as flexible as the COPE drive.

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Figure 7: Low foundation demand

Figure 8: Selected mill type

Selected Loesche mill
- Mill type: LM 72.4+4 CS
- Table ø: 7.2 m
- Grinding rollers: 4
- Support rollers: 4
- Drive power: 10 000 kW

10 MW with COPE drive
Loesche – worldwide presence

Loesche is an export-oriented company run by the owner, which was established in 1906 in Berlin. Today the company is internationally active with subsidiaries, representatives and agencies worldwide.

Our engineers are constantly developing new ideas and individual concepts for grinding technologies and preparation processes for the benefit of our customers. Their competence is mainly due to our worldwide information management. This ensures that current knowledge and developments can also be used immediately for our own projects.

The services of our subsidiaries and agencies are of key importance for analysis, processing and solving specific project problems for our customers.

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