Ball mill optimisation

As grinding accounts for a sizeable share in a cement plant's power consumption, optimisation of grinding equipment such as ball mills can provide significant cost and CO_2 emission benefits to the cement producer.

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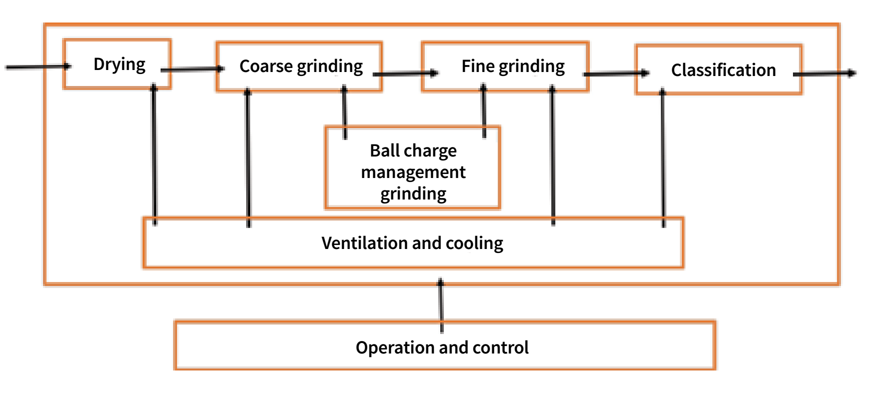
There are currently several energy-efficient grinding systems available for the cement and mineral industry, including vertical roller mills (VRM), high-pressure grinding units (HPGR) or simple roller presses, as well as the most traditional type of installation: ball mills, combined in circuit with an air classification system of varying generations and sophistications.

Depending on the local market situation and product portfolio, VRMs are the most common solution to grind raw materials and cement. Roller presses are used mainly in combination with a ball mill for cement grinding applications and as finished product grinding units, as well as raw ingredient grinding equipment in mineral applications.

This paper will focus on the ball mill grinding process, its tools and optimisation possibilities (see Figure 1). The ball mill comminution process has a high electrical energy consumption, especially when those systems are in combination with first- or second-generation classifiers. This is particularly relevant in terms of the requirement to control CO_2 emissions and therefore, energy consumption.

This provides the opportunity for a considerable optimisation drive as more than 60 per cent of electrical energy consumption is used for grinding. In optimising the process, the grinding tools will have a significant impact on lower production costs as well as maintenance costs.

Figure 1: ball mill communition process chain

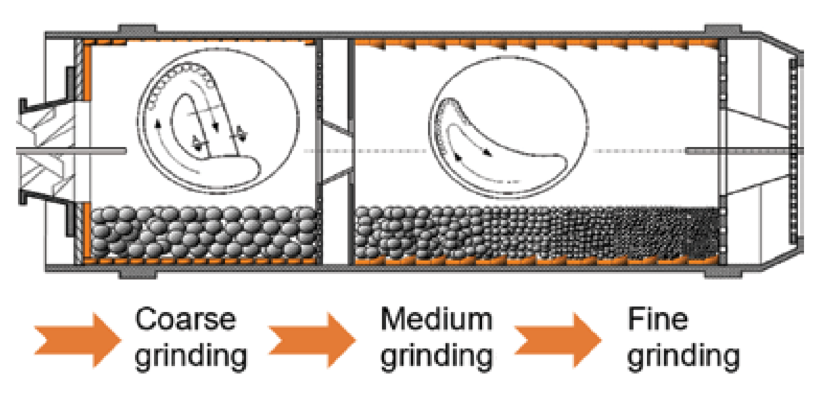


Ball mills and grinding tools

Cement ball mills are typically two-chamber mills (Figure 2), where the first chamber has larger media with lifting liners installed, providing the coarse grinding stage, whereas, in the second chamber, medium and fine grinding is carried out with smaller media and classifying liners.

Therefore, the grinding tools in a ball mill process are the different types of liners and media sizes applied for each process step. All these factors need to be adjusted to local process requirements to optimise operation and lower production costs.

Figure 2: ball mill tools and comminution process



In many of Holzinger Consulting's client visits, the company needs to discuss with maintenance teams when to exchange liners, where the thickness is still sufficient to protect the shell. It is crucial to point out that shell protection is only one function of the mill liner. It also needs to optimise the grinding process.

Clinker grain sizes depend on pre-crusher settings but are in some cases still up to 50mm when fed to the ball mill and therefore, it is necessary to adjust the grinding tools accordingly. The more that alternative fuels are used in the clinker production process, the finer and hence better the clinker becomes for the ball milling process. However, this requires rethinking the application of installed tools to optimise energy utilisation in the mill.

Therefore, different suppliers have developed liner systems with flexible adaptation and adjustment possibilities for the required intensity of the comminution process. Together with ball charge composition, both tools – liners and media – can be optimally adjusted for the application. They can then fulfil the

Figure 3: the lifting effect of different liners

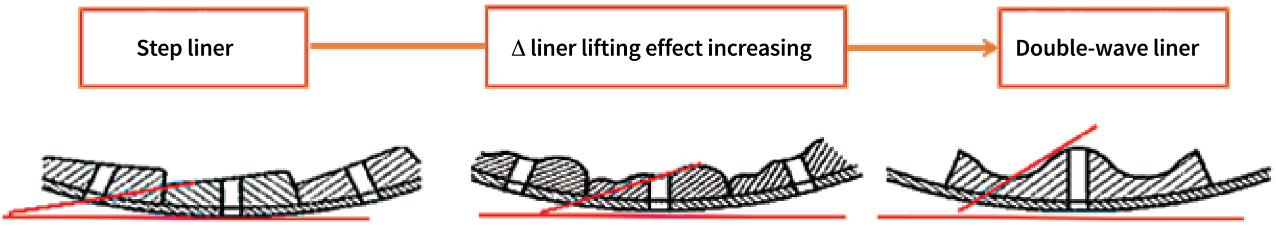
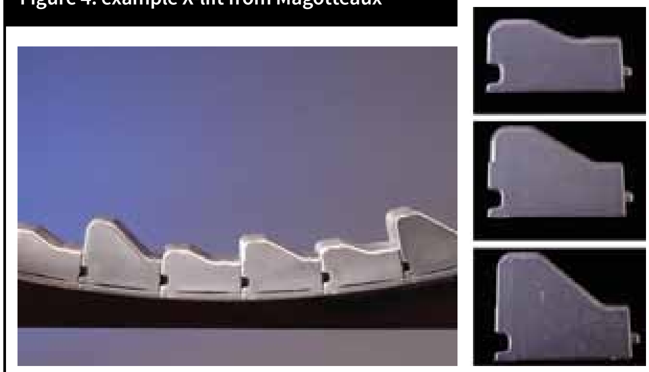


Figure 4: example X-lift from Magotteaux



aim of delivering a target mill discharge size at the end of the chamber, with a maximum residue of five per cent >2mm. This is a standard limit and is practically known to guarantee the coarsest grain to be <6mm – a standard discharge slot size of an intermediate diaphragm. In this case, no slot blockages are expected and the material is ready to enter the next comminution step.

As balls and liners wear over time, the comminution process can be adjusted by applying a more intensive ball charge, typically involving a higher proportion of ϕ90mm balls, which compensates for lifting losses with a reduced active liner height. If 2mm residues eventually increase, more and more grains will block the slots so maintenance teams have to start cleaning. This is always an indication that the process is not properly adjusted and optimised.

Retaining material in the mill with diaphragms until the comminution process is finished is not an optimal process adjustment to deal with the effects of slot blockage, as material levels in the second chamber – where >70 per cent of the grinding energy is consumed – fall.

In many mills inspected by Holzinger Consulting, the second chamber is starved of material due to incorrect diaphragm transport settings. It is also commonplace, because of increasing efforts for diaphragm cleaning, that maintenance teams increase slot sizes to avoid these blockages. Therefore, the impact on the grinding process can mostly be evaluated by analysing the second chamber, which is often contaminated with too high a proportion of large grains. These cannot be ground by an unadjusted ball charge and as a result, mill performance is yet again reduced.

As shown in Figure 1, all these small, interlinked process steps need to be adjusted to achieve optimal ball mill performance.

Analysing the grinding process regularly – a minimum once per year – gives process engineers the necessary feedback on what kind of measures to apply. By not matching targets, with too high a proportion of residues, it becomes increasingly necessary to work on comminution as follows:

- Check maximum feed size of fresh feed: if >50mm, adjust the crushing unit accordingly. The finer the better!
- Check liner conditions: if h <50 per cent x h_0, replace the liners.
- Check 'aggressivity' of ball charge: if there is a low share of 90mm media, increase the proportion of 90mm.
- Check filling level of the first chamber: if below maximum, increase the level.

Case study

The following example shows the impact of such an evaluation when basics are not respected.

Base situation

Before Holzinger Consulting's evaluation the ball mill had an average production rate of 190tph with a specific electrical energy consumption of 35.5kWh/t. Its operational issues included:

- oversized limestone
- worn-out lifting liners with liner thickness decreasing from 80 to 20mm
- low-quality media.

Following evaluation and as part of the optimisation of the ball mill, the following recommended measures were carried out:

- The feed size was adapted to the mill.
- The first chamber liners were replaced.
- The grinding media in both chambers were replaced and adapted to match the expectations of the grinding progress curve in each chamber.

As a result, the production rate went from a previous 190tph to 235tph, a ~20 per cent increase, with a resultant specific energy reduction from 35.5kWh/t to 29.8kWh/t, representing a ~16 per cent drop in energy consumption.

The importance of second chamber optimisation

It is also important to evaluate the grinding efficiency and ball charge efficiency for a

Figure 5: first chamber grinding process evaluation

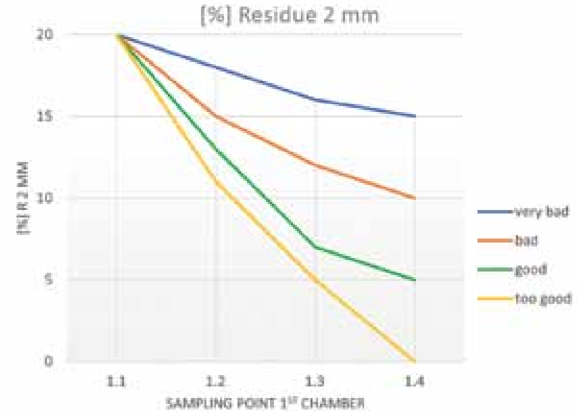


Figure 6: over-sized material in the first chamber

Figure 7: low-quality media in the first chamber

Figure 8: worn-out lifting liners

Figure 9: low-quality media in the second chamber

Figure 10: evaluation of fine grinding in the second chamber

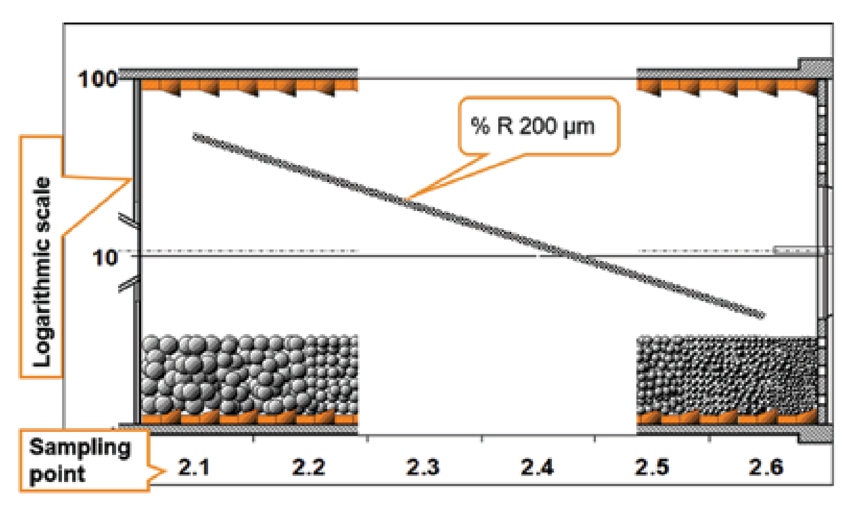
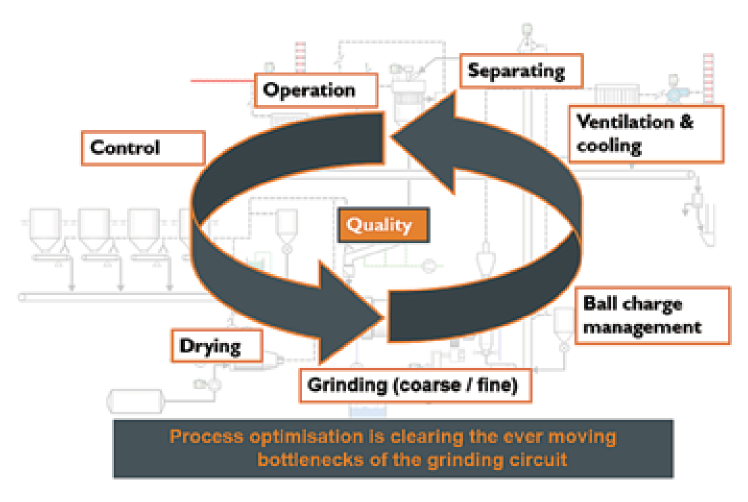


Figure 11: process optimisation in a grinding system



given situation by taking samples along the mill axis in the second chamber. We can then measure the material fineness evolution of nominated grain sizes, starting from around 2mm, down to 45µm by drawing such graphs, as shown in Figure 10. If, for all different particle sizes, a continuous evolution is seen, as well as steadily increasing Blaine values, the ball charge is working properly and no action is required.

In reality, the situation more often shows a different graph, where sections are flattening out, no grinding is taking place or even worse, larger grain sizes are accumulating in the charge. In the first case – as shown by flat sections of grinding progress curves – the ball charge needs to be modified either at the chamber inlet or at the exit accordingly.

The size reduction target in a second ball mill chamber generally requires – depending on the desired size reduction – bigger media at the chamber inlet and smaller sizes towards the mill outlet. To fulfil this requirement, the industry has developed so-called classifying liners in a variety of shapes and designs. The task of the liner is to influence the ball charge movement such that larger balls accumulate more towards the mill inlet and the smaller sizes respectively, more towards the mill outlet.

Therefore, in the case of some types of liner, the available fill volume for a given media charge will be higher, thus accommodating an increased media mass and resulting in a higher production rate. These types of liners ensure that the mill shell is also protected and that the ball charge achieves a more effective tumbling movement down to its core.

In this second chamber so-called cascade grinding takes place, where particles are ground by attrition, as a result of multiple impacts of the tumbling media.

Therefore, the second-chamber performance qualification for optimal usage depends on whether the grinding progress is effective over the whole chamber length as well as on whether enough material is being fed into the chamber to fully utilise the applied energy. Optimally, the material level should be in the range of 20-50mm above the ball charge.

If these guidelines are respected and considered, process engineers at site should be occupied during the year by the challenge of identifying and clearing the bottlenecks of their systems. ■