Optimum Grinding

Thomas Holzinger, Holzinger Consulting, discusses cement grinding system optimisation.

Introduction

The cement industry uses a wide range of different systems in raw material, coal, and cement grinding. While new plants mainly focus on highly energy-efficient systems, using roller comminution systems like vertical roller mills (VRMs) and high pressure grinding units (roller presses), less efficient ball mills and combined grinding systems (pre-grinder plus ball mill) are still widely used. Which option to install depends on the local cement market, the product portfolio and raw materials, as well as the relevant operational skills available to maintain such systems.

The industry is facing high volumes in every global market and cement pricing is driving producers to optimise their systems to peak performance. Rising electrical energy costs have created a trend to force plants to reduce their production costs by system and wear part strategy optimisation.

Raw material grinding

The current standard solution for raw material grinding is the VRM, offering the advantages of an efficient comminution system combined with a high drying capacity.

From the mineralogical and 'burnability' of raw meals, roller presses in finish-grinding mode should be considered as an alternative to VRMs. A prerequisite is that the raw mix moisture content should be below 8% and the clay content less than 6%. Due to better wear protection solutions for highly abrasive materials, roller presses are a viable alternative to VRMs.

Ball mills meanwhile, due to low electrical energy efficiency and limitations on drying capacity, play a minor role in new installations.

Cement grinding

In Table 1, three common cement grinding systems are compared on their electrical consumption for a typical 3500 Blaine ordinary portland cement (OPC).

Roller press finish-grinding systems, due to lower fan power demand compared to a VRM, exhibit a lower specific energy consumption.

The only restriction of such a system is the maximum roller size of 2.2 m with an installed motor power of 3400 kW, which is 2380 kW absorbable power, limiting production of a 3600 Blaine OPC cement to around 140 tph.

For the cement quality of a roller press finish-grinding system, studies show that for a standard type cement compared to VRM or ball mill, no differences could be observed. Only for fine cement types (>4500 Blaine), requiring high early strengths, did the roller press finish-grinding system achieve slightly lower strength performances.

Table 1. **Comparison of cement grinding systems for ordinary portland cement at 3500 Blaine, 4% limestone.**

		Ball mill	Combi grinding system	Finish grinding	
		Ball mill with cage rotor separator	Roller press in semi-finish mode and ball mill	VRM	Roller press
Spec.el Energy consumption mill motors	kWh/t	30	25	17	17
% at mill motor (ball mill 100%)	%	100	83	57	57
Spec.el. Energy consumption mill system	kWh/t	39	32	27	26
% department (ball mill 100%)	%	100	82	69	67

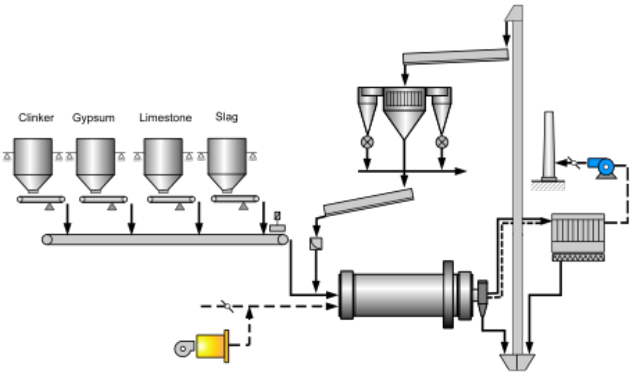

Figure 1. Shows a typical flowsheet for a ball mill installation.

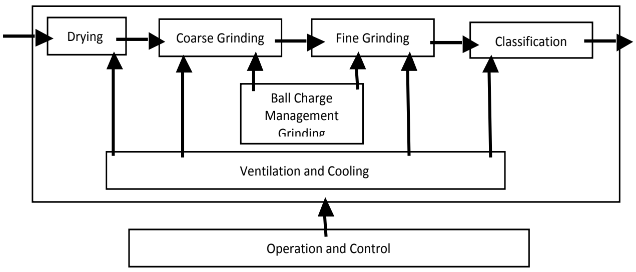

Figure 2. Ball mill production process chain.

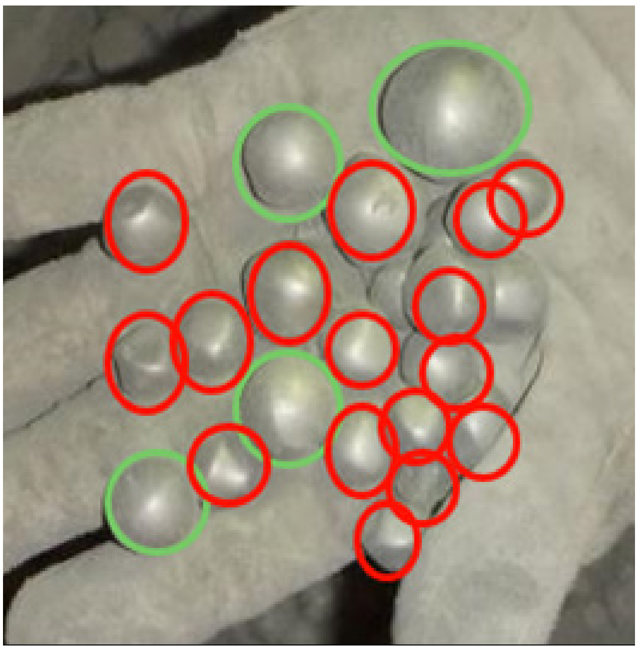

Figure 3. Worn out and deformed media from the second chamber.

Optimisation of grinding systems

To optimise grinding systems, it is important to understand the processes and what the equipment was originally designed for. Figure 1 shows the processes in the various systems. The following process steps are taking place in the system:

1. Drying.
2. Coarse grinding.
3. Fine grinding.
4. Cooling and mill ventilation.
5. Classification.
6. Mill operation and control.

To optimise a system, it must be considered that all these processes are interlinked and connected in a process chain, meaning that, focusing simply on one process, will not immediately achieve success. There is a production chain to be considered shown in Figure 2.

A typical process starting point to analyse a system for its efficiency is to carry out an audit, a 'health check' of the grinding system. A regular audit, performed at a minimum once a year, consists of the following two phases:

1. A system check of the running condition.
2. An equipment and system check in a stopped condition.

If everything is well prepared by all the involved departments (e.g. maintenance, quality, process, production) one or two days should be enough for all the activities.

It is crucial that the product is not changed during the audit and the mill must be stable during circuit sampling and performance data collection for at least 6 – 8 hours. Circuit stability means stable material flow (fresh feed and classifier rejects).

In running condition, material sampling (fresh feed, circuit samples, finished product), airflow measurements and, data recording are taking place (e.g. production rate, cement type and composition, fineness, energy consumption of mill motor etc). This data will later be evaluated and documented in terms of the following:

- Specific electrical energy of mill motor system.
- Circulating load and classification of efficiency.
- Dew point, critical temperature, and pressure.

During mill stopped condition, it is important to:

- Evaluate the grinding performance in both chambers along the mill.
- Examine the grinding tools (liner and media), check their filling level, and state in terms of wear and deformation.

If balls and liners are not in good condition, the mill suffers from efficiency loss, meaning electrical energy consumption and production costs will increase.

As an example of a trial on the influence of grinding media shape on mill performance, a twin grinding system is illustrated, which is identical in terms of installation, maintenance, and cement production.

The only difference is that one mill got a completely new ball charge in the second chamber, while the other mill was left with used deformed balls in the same general size composition (Figure 3).

Running both systems to their limits, the result was a clear difference in specific electrical energy consumption (SEEC) of about 5 kWh/t on mill motor power consumption at a mill motor total SEEC of 30 kWh/t. This results in a loss of 16%, simply due to completely deformed second chamber media.

In many site visits observed by the author, although plant operators have carried out ball sorting, mainly only ball classification was carried out.

Similar to the ball charge quality, the liner shape and condition has a major influence on mill efficiency, especially for the first chamber when the feed material is coarse (>30 mm) and hard to grind.

Besides grinding tool management and its process importance, the following checks are typically carried out.

Cooling and drying limitations

A simple heat balance indicates the limitations, is useful for the introduction of new products, and is used to highlight the limitations of the system in the event of a moisture increase of the feed material mix.

Mill ventilation

Besides limiting both the cooling or drying of the system, an under-ventilated mill (<1m/sec. above ball charge) also offers room for production increase by bringing the ventilation back to its design value of around 1.2 – 1.5 m/sec. above ball charge. If the dust from mill ventilation is directly mixed into the final product, the mentioned limitations are no longer valid.

Material levels in both chambers

Overloaded or underloaded mills also clearly show the potential to increase performance. In many cases, a low material level in the second chamber develops and results in a transport problem through the intermediate diaphragm.

Diaphragm blockages or missing/lacking proper metal extraction system

Especially in cement grinding systems, with kilns running at high AFR and using outside stored clinker, metal foreign bodies always find their way into the mill, creating operational and mill performance issues, increasing costs for regular cleaning.

Bucket elevator discharge lip

Bucket elevator power may also be a limitation on the system, especially when mill control systems are in place. If this lip is damaged or no longer in place, the increasing resistance causes recirculation in the bucket elevator, limiting the mill performance significantly.

Classifier performance and dynamic seal checks

A typical process check is to evaluate performance by assessing the Tromp curve of the classifier, which in combination with the feed-to-air ratio [kg/m^3] of the product can indicate an under-performing system or one with improvement potential. From a mechanical point of view, the dynamic seal is important, as it seriously influences system performance when no longer working correctly, resulting in coarse material bypass.

Mill control system

Having an automated mill control system in place should be a standard for all systems.

Combined grinding systems

Due to growing global cement markets in the years before 2008, many plants upgraded their existing ball mill systems with pre-grinders (HPGR, roller presses, or VRM pre-grinders) to increase cement production from about 30% to 100%, depending on the system installed.

As there are so many different systems installed and each has its own characteristics, this article will focus on a very common system for expansions, as shown in Figure 4.

This features a roller press together with a ball mill in a combi-grinding mode, where both systems already produce a finished product, but still have two classifiers. Another option in such a project would have been to replace the existing ball mill classifier with a bigger one suitable for both grinding systems.

In general, the aim is to understand such a system and the task of the pre-grinder. Compared to a simple ball mill installation, the roller press is in one sense substituting the pre-grinding part of the first chamber and, in another sense, replacing the finish grinding of the second mill. The ball mill is in first and most likely case, transformed into a single chamber mill where just finish-grinding takes place. Many installed systems still use two chambers, especially when roller press availability is low, due to incorrect operation or maintenance.

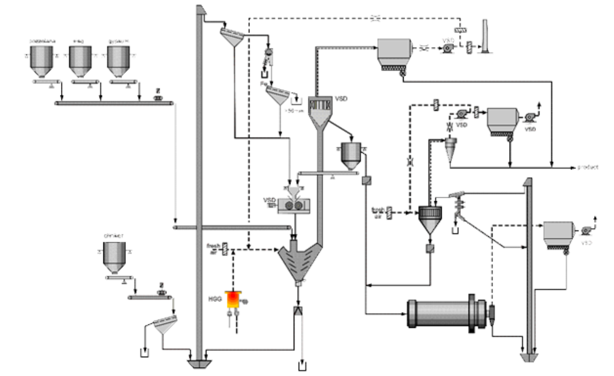

Figure 4. Flowsheet of a combined grinding system with roller press.

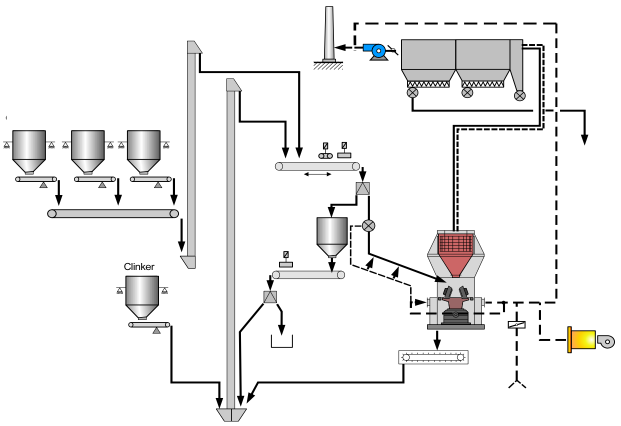

Figure 5. Typical VRM flowsheet for cement grinding.

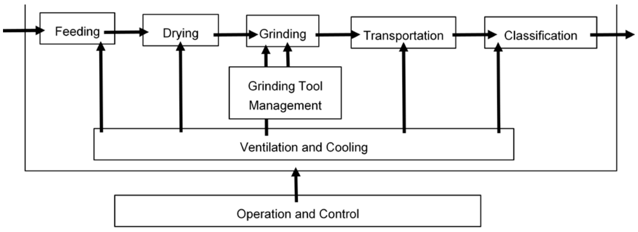

Figure 6. Production process chain for a VRM.

There are existing systems where no finished product is produced on the roller press classifier, but sent directly as feed material to the ball mill. These systems create good opportunities to increase system performance by modification. A completely new installation would use a short, one chamber mill (L/D <2), but existing mills, having been designed with L/D ratio >2.5, are commonly too long and have too much power available. Therefore, it is necessary to evaluate the modifications of the mill internals, ball charge composition, and filling level.

A major drawback of performance losses in such systems, is an inadequately working pre-grinder, where the wear strategy and used roller materials are not aligned. Having the ball mill adjusted for a certain feed size, the pre-grinder must provide a generally constant supply, considering that adapting the ball charge composition is not easily done without extra stoppage time and expense.

Finish grinding: VRM system

For raw material, as well as for fuel grinding, this is the most commonly used system.

For cement grinding, it is a very efficient system, which is currently widely installed. Due to the development of various multi-motor drive solutions by all major suppliers, big installations of up to 12 000 kW or more can be realised, achieving the highest production rates for a single grinding system.

In addition to the distinct advantages of such a system (including low specific electrical energy consumption, easy operation, and high drying/cooling capacity) there are also some disadvantages which have to be considered. Spare part costs are high, even when maintenance costs are lower than for ball mills, due to the fact that as a must, a separate reducer and one spare roller should be stocked onsite. The main reason for VRM stoppages is still mill vibration. When having gearboxes >3 MW installed, it is recommended to use gearbox protection systems, monitoring vibrations in the gearbox, to be alert to developing problems before critical damage occurs.

Figure 5 explains the processes in a VRM where there is optimisation potential and corrective measures can be performed.

Besides mechanical issues with the reclaimer, feed bins, and elevator, which may cause several stoppages ,significantly influencing system performance, the feed size of the material is also of great importance. As a rule, for VRMs, the feed material should always be <100 mm. Finer feeds, in terms of top size, also showed benefits in various tests on specific energy consumption, as well as in operation.

Producing finer feed at the crushers improved VRM-specific electrical energy consumption and the total electrical energy gain, due to the higher crusher specific electrical energy consumption and finer material. This was still positive for the plant's electrical energy consumption.

An important point here is not only to look at the coarsest particles but also at the fines. If the amount below 1 mm is more than 30%, mill stability will be adversely affected.

Too coarse feed material leads to the following:

- A reduction of production rate and increased specific energy.
- An unstable operation and stress to the reducer.

Whereas too fine feed mateiral causes the following:

- Mill stability problems.
- A decreased capacity.
- High water injection for mill stabilisation.

In the case of cement grinding, too high water injection will negatively influence cement performance in early strength losses. A general rule is to consider a maximum of around 2.5% of production rate and to keep the dew point at less than 55°C. Higher values will lead to reduced early strength of the final cement product.

It is of vital importance to have a stable and homogeneous mill feed particle size distribution for stable and optimal operation. The mill and its mechanical setup cannot easily handle any short-term variations in feed size, e.g. mill table dam-ring height, accumulator pressure or table speed, leading directly to mill stability problems and performance loss.

In raw material grinding, the drying capacity can be a limitation, leading to reduced mill production, which might be a limitation for the kiln and hence for clinker production.

The drying capacity can also be caused by a high false air intake, which most mills suffer from. High false air also means high fan power consumption, which can limit the production rate. It increases the electrical energy consumption of the mill fan leading to higher plant production costs.

Conclusion

The airflow inside a VRM is of significant importance to internal mill material transportation. A correct air velocity profile must be respected. The upward velocity throughout the mill height must always increase. Decreasing velocity could be due to incorrect mill internal design. Decreasing air velocity inside the mill body has the effect of increased internal material recirculation, causing an increased mill pressure drop, leading to reduced feed rates and high energy demand in the system.

For VRM systems, it is highly recommended to use automated mill control systems, considering all relevant parameters to guarantee maximised operation close to system limitations. For an operator, it is very difficult to follow all changing parameters on top of other tasks to be carried out during a shift.

Optimising such systems and running them to the edge of performance is a complex task. All departments must work closely together and understand what is relevant for good and stable operation of grinding systems.

Optimisation of grinding systems is not only the task of process operators but also of the plant management and its understanding of each department's requirements and how departments work together.

About the author

Thomas Holzinger has a Masters Degree from Leoben University, Austria, in Mining, Metallurgy & Materials. In his 20 years' experience in the fine grinding of minerals, he has worked for leading companies in corporate functions as a milling and classification expert and consultant. As a Lead Consultant for LafargeHolcim, he was mainly involved in plant design and performance analyses of plants and grinding systems throughout the world.