FOCUSING ON THE FACTORS FOR SUCCESS

Dr. Caroline Woywadt, Gebr. Pfeiffer, discusses the various factors that can impact the performance of VRMs and explains how operators can achieve optimum efficiency from their equipment.

For decades, vertical roller mills have been in use in the cement industry for the grinding of cement raw material and coal. Since the 1980s, this mill type has also been used for combined or separate grinding of cement clinker and additives. During the last three decades, the number of installations for grinding cement and blast furnace slag has increased significantly.

The MPS mill has been used for decades for the grinding of materials such as cement raw material, cement clinker, solid fuels, gypsum, and limestone, etc. Due to the trend towards increasing capacities of individual grinding plants, the MVR mill was developed in the early 2000s and has been in industrial operation since 2006. This mill has since become well established for large units with an installed drive power of nearly 12 MW as well as compact systems known as ready2grind plants.

More than 100 such mills are currently in operation or in order execution.

Figure 1 shows the geographic distribution of plants with MVR mills.

Design feature comparison

The design features of the MVR mill differ from the well-known MPS mill mainly in the areas of grinding element geometry, roller suspension and the number of rollers.

The MVR roller mill is characterised by four or six grinding rollers and the use of flat grinding table liners. A roller module consists of the roller with cylindrical roller tyre, roller axle, roller arm, support pedestal and the hydraulic power input. In conjunction with the flat grinding table liner geometry, this type of roller suspension system achieves a parallel grinding gap between roller and table liner at any time. This has a positive effect on the vibration level of the mill and the energy input into the grinding bed.

All machine parts that are relevant in terms of fluid dynamics, such as the hot gas channel, nozzle ring, SLS high-efficiency classifier and material feed, are of the same design as the parts that have been proven to be successful in the well-established MPS mills.

The combination of three process steps in one system – drying, grinding, separating – makes the mill very versatile with regard to handling dry and moist feed materials, grinding to a very high fineness, and creating the product properties required by the different market areas.

Figure 1. World map with MVR mills.

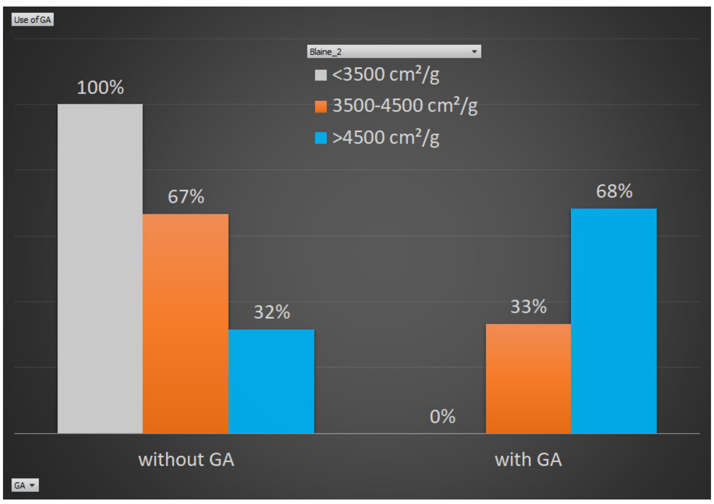

Figure 2. Use of grinding aids (GA) at different product finenesses.

Performance of the VRM

The performance of a vertical roller mill is defined by a required throughput at a required fineness, paired with a low specific thermal and electric energy consumption. For cement grinding, the required product quality is the most important target, together with the aforementioned points. Some areas in general need special attention: Feed uniformity, metal detection and extraction, and preventive maintenance to name just a few. The levers to pull for a well performing vertical roller mill are operational parameters such as table speed, gas flow, working pressure and mechanical adjustments such as dam ring height and covering the nozzle ring. A smooth and stable mill operation with reduced or zero water spray is possible with a VRM, hence the ability to grind without external heat depends on the feed moisture of the material.

When it comes to composite cements, the versatility of vertical roller mills is impressive. These mills are very flexible when it comes to the grinding of different materials, such as: Clinker, limestone, GBFS, pozzolana, fly ash, bottom ash, etc., with a wide range of properties. When moist materials are included in the feed mix, a heated rotary lock will be installed. When dry and already quite fine materials are used, an additional feeding point is provided at the classifier housing.

When producing composite cements, the decision between the use of inter- or separate-grinding is often a point of discussion. The MVR mill is able to switch from inter-grinding to separate grinding depending on the client's needs without any changes to the mill internals. Properties of, for example, GBFS and fly ash vary widely. In line with the required product properties, it has to be taken into consideration that inter-grinding can result in finer fractions containing either very little or no GBFS or fly ash. Depending on the reactivity of GBFS, the mode of production can be achieved with inter-grinding as well with separate grinding of the single components.

Operational experiences show that plants tend to grind clinker and GBFS together if GBFS is available with a good reactivity. One advantage of inter-grinding is the formation of a stable grinding bed due to clinker and GBFS granulometries which interact positively. If the GBFS needs to be ground to a high fineness due to lower reactivity, separate grinding might be a better way to achieve the overall required properties of slag cements.

MVR mills can be operated in both ways. For example, an MVR 6700 C-6 installed in Algeria produces limestone-composite cement by inter- and separate-grinding of limestone and CEM I. The limestone is pre-ground in the raw material mill MVR 6000 R-6. Feed material to the MVR 6700 C-6 is clinker and gypsum. The pre-ground limestone is injected into the classifier outlet and is homogenised with the CEM I in the filter and during transport to the product silos. Table 1 shows the performance results of inter- and separate-grinding.

Cement grinding

Over the past decades, the vertical roller mill has replaced many ball mill grinding systems. The first MPS mill for cement was ordered in 1979 and remains in operation today. With the development of the MVR mill, the duty series has been changed for cement raw material and cement grinding from type MPS to MVR mill. Nearly 70 MVR mills for cement grinding are currently in operation or under order execution.

Achieving the same quality of cement produced in ball mills was essential for the success of the vertical roller mill. Originally, the goal was to achieve the same or similar particle size distribution (PSD). Today, however, it is clear that the PSD is not the only factor to impact the properties of the finished product.

Product quality is impacted by feed material properties and the physical properties of the ground cement. The clinker and its chemistry, especially the C3A-content and its sourcing, suggesting potential moisture, mean that prehydration is a main factor for the product quality.

The sulfate agent needs a balanced proportion of di-hydrate, hemi-hydrate and anhydrite. As a VRM has a significantly higher energy efficiency than a ball mill, much less heat is put into the grinding process. As a result, the dehydration degree of the sulfate agent is lower. The lower hemi-hydrate or plaster content can be compensated for by the addition of more gypsum (within the limit according to relevant standards), by the addition of a more reactive form of gypsum, or by the addition of more heat to the system. By installing the G4C® system with a separate hammer mill and hot gas generator to partially calcine the gypsum, the hemi-hydrate content can be controlled exactly for each clinker that is used. This is made possible by setting the outlet temperature of the hammer mill to adjust the proportion of hemi-hydrate.

An additional factor impacting cement properties is the choice of supplementary cementitious materials (SCMs) or clinker replacement materials (CRMs). These materials influence grindability and operational behaviour, and reactivity.[1] In many countries, limestone is the most easily available supplemental material. Limestone dilutes the clinker content of the cement and impacts strength development. If natural pozzolana is available, the hydraulic properties are advantageous for cement products.[2]

The performance of a vertical roller mill can also be impacted by grinding aids (GA). Today, grinding aids are very common – not only for increasing production, but also for enhancing cement properties, such as early strength increase, workability, etc. MVR mills can be operated without grinding aids, but adding grinding aids can support their performance. The general application of grinding

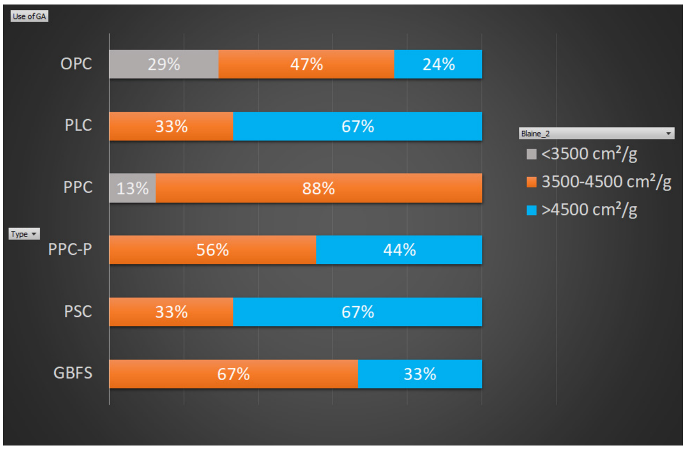

Figure 3. Fineness of different cement types ground in an MVR mill.

Table 1. CEM II/A-L and CEM I produced in MVR 6700 C-6.

	Limestone cement	OPC 2	OPC 1
Limestone injection (feeding point at duct to filter)	18 %	0 %	0 %
Feed to mill (only Clinker and Gypsum)	280 tph	240 tph	345 tph
Total output	330 tph	240 tph	345 tph
Fineness	4700 Blaine 4.0% R45 µm	4800 Blaine 3.0 % R32 µm	3875 Blaine 2.5% R45 µm
SPC mill coupling	17.6 kWh/t	24.5 kWh/t	18.7 kWh/t

aids depends strongly on the operating company and the region in which the plant is located. Other factors include the cement type and the fineness of the product.

Figure 2 shows the use of grinding aids for different types of cement produced in MVR mills. In this evaluation, all operating MVR mills for cement and all different products ground are included (this is also true for the data in Figure 3).

Cements with a fineness of less than 3500 cm^2/g are generally ground without grinding aids, for fineness ranging between 3500 and 4500 cm^2/g, one-third is ground with grinding aids, and for high fineness cement, more than two-thirds are ground with the application of grinding aids.

Figure 3 shows the fineness for cementitious products ground in MVR mills. The types are divided into OPC, GBFS (blast furnace slag), PLC (limestone-cement), PSC (slag-cement), PPC (flyash-cement), and PPC-P (composite-cement with pozzolan). Cements with more than one SCM are classified according to the SCM with the highest proportion. Only OPC and PPC are ground to a fineness of less than 3500 cm^2/g; the major proportion of cements are ground in the range between 3500 and 4500 cm^2/g. More than one-third of the products of high fineness (> 4500 Blaine) are ground to 5000 cm^2/g and higher. This reflects both the necessity of higher fineness for SCMs in order to achieve sufficient reactivity in the later application, and also the fact that OPC can be easily ground to a fineness of more than 5000 cm^2/g in MVR mills.

An important factor in the characterisation of cement properties is strength development in combination with setting times. National standards define the procedure for testing. Due to differences in those standards, the results of compressive strength development are not comparable to each other. Gebr. Pfeiffer has its own mortar laboratory and collects samples from operating MPS and MVR mills to characterise cement product properties. To ensure the reliability of results, the laboratory participates in annual round robin tests (ATIHL[3] and BE CERT[4]). The procedure for sample preparation, proportions for cement, sand and water are in accordance to EN 196-1.

The properties of several cements produced in MPS and MVR mills are listed in Table 2. Nearly all OPC/CEM I products

Table 2. Properties of exemplary cements produced in MVR and MPS mills.

Cement type acc. EN 197-1 Strength in acc. to EN 196-1 Normal consistency NC in acc. to EN 196-3	Blaine in cm^2/g	NC in %	2d in MPa	7d in MPa	28d in MPa
CEM I	3680	-	27.7	46.3	60.2
CEM I	5050	-	36.9	52.6	63.3
CEM I	4780	26.5	35.2	47.9	60.1
CEM I (3% Limestone)	5070	29.6	33.8	48.9	59.5
CEM I (3% Limestone)	5150	30.5	37.6	50.4	60.8
CEM I	5000	-	35.1	51.2	61.8
CEM I (5% Limestone)	3800	25.4	27.7	48.2	61.8
CEM I (0.5% Limestone)	3500	26.0	24.3	37.2	48.2
CEM I (5% Limestone)	4900	25.5	33.0	-	63.0
CEM II/A-L (17.5% Limestone)	4400	-	27.2	46.2	60.4
CEM II/B-P (28% Pozzolana)	4180	28.0	22.0	33.6	47.7
CEM II/B-M (12% Limestone, 12% Pozzolana, 2% Flyash)	4140	-	20.0	40.9	57.2
CEM II/A-M (6% Limestone, 6% Pozzolana)	5130	-	29.4	43.9	56.3
CEM II/B-S (23% GBFS, 4% Limestone)	4610	28.0	30.2	45.6	57.3
CEM III/A (45% GBFS)	4450	29.5	17.0	-	52.0
CEM III/B (70% GBFS)	5500	30.6	27.7	-	51.7

have developed a 28-day strength of 60 MPa or higher. High 28-day strength figures are achieved as well, with a product fineness of less than 4000 cm^2/g.

Early strength after two days is clearly impacted by clinker quality and, for composite cements, the type of composite is an additional factor. The composite cements achieve high 28-day strengths. Products need to be ground finely enough due to composites in order to achieve the required strength level. The given normal consistency figures have been determined in accordance with EN 196-3 and demonstrate that the workability of products from MVR mills meets the demands of industry. Custom specific adjustments have been made in many cases during the commissioning of MVR mills, for example: PSD adaptation, sulfate agent selection, or the use of the G4C® system to get precise plaster-content. These results show that cements ground in vertical roller mills are clearly on the same level compared to cements ground in ball mills.

Conclusion and outlook

Many factors affect the performance of a vertical roller mill. The feed material is the basis for the product quality and has a fundamental impact on operational behaviour. With customised PSD adjustment and sulfate agent matching, the required cement properties for all types of cement can be produced in MVR mills. With digitalisation and continuous technological improvement in MVR mills, continued progress towards client demands for sustainability and efficiency can be made. ■

References

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About the author

Dr Caroline Woywadt has been Director – Process Technology at Gebr. Pfeiffer since 2011. After graduating from RWTH Aachen, Germany, with a degree in Mineral Processing and a PhD in the field of grinding, she worked as a Process and Quality Control Manager at cement grinding plants in Germany and Poland, as well as a Product Manager for grinding products.