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Cement grinding - a comparison between vertical roller mill and ball mill

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By Søren Worre Jørgensen, FLSmidth A/S, Denmark.




FLSmidth

MSc S. W. Jorgensen, FLSmidth A/S,
Copenhagen, Denmark

SUMMARY

Over the last three decades the vertical roller mill has become the preferred mill for grinding of raw materials. The grinding efficiency of the vertical roller mill combined with an ability to dry, grind and classify within a single unit gives the vertical roller mill a decided advantage over a ball mill system. However, despite these benefits applications of the vertical roller mill for cement grinding are less prevalent. The two-compartment ball mill, which operate in a closed circuit with a high efficiency separator, is thus still the most preferred arrangement for new cement grinding installations although the vertical roller mill now has emerged as a viable alternative to the ball mill system and has increased its share of the market for cement mills over the last decade. There are a number of explanations to this situation which relate to issues like cost and ease of operation, cost of installation, cost and ease of maintenance, product quality, versatility, etc. A comparison of vertical roller mill systems and ball mills systems for cement grinding has been prepared with reference to all these issues.

ZUSAMMENFASSUNG

In den letzten drei Jahren hat sich die Vertikal-Rollenmühle zur bevorzugten Mühle für das Mahlen von Rohmaterial entwickelt. Die Mahleffizienz von Vertikal-Rollenmühlen verbunden mit ihrer Eigenschaft zum Trocknen, Mahlen und Sichten in einer einzigen Anlage sind entscheidende Pluspunkte gegenüber Kugelmühlen. Trotz dieser Vorteile ist die Verwendung von Vertikal-Rollenmühlen für die Zementmahlung wesentlich weniger verbreitet. Die im Verbund mit einem Hochleistungssichter im geschlossenen Kreislauf arbeitende Zwei-Kammer-Kugelmühle ist immer noch die bevorzugte Anlage zum Mahlen von Zement, obwohl die Vertikal-Rollenmühle sich inzwischen zu einer echten Alternative entwickelt hat und ihren Marktanteil im Bereich der Zementmühlen während der letzten Dekade kontinuierlich steigern konnte. Dieser Sachverhalt kann durch eine Reihe von Punkten erklärt werden, wie z.B. Betriebskosten und Betriebsfreundlichkeit, Installationskosten, Instandhaltungskosten und Instandhaltungsfreundlichkeit, Produktqualität, Vielseitigkeit etc. Ein Vergleich zwischen Mahlanlagen mit Vertikal-Rollenmühle und Kugelmühle für die Zementmahlung wird unter Einbeziehung aller zuvor genannten Punkte durchgeführt.

(English provided by the author)

Cement grinding – a comparison between vertical roller mill and ball mill

Zementmahlung – ein Vergleich zwischen Vertikal-Rollenmühle und Kugelmühle

1 Introduction

About 110 years ago the Danish engineer M. Davidsen patented a pioneering invention in France which involved a tube mill with a charge of steel balls or flint pebbles for fine grinding of sand or cement. FLSmidth acquired the rights to his patent and started selling an improved version of this mill all over the world. For the cement industry the ball mill was really an epoch-making breakthrough as for almost 80 years it was the predominant mill for grinding raw materials and coal, and still today it is the mill most used for cement grinding.

Over the last three decades the vertical roller mill has become the preferred mill for grinding raw materials. The grinding efficiency of the vertical roller mill combined with the ability to dry, grind and classify within a single unit gives the vertical roller mill a decisive advantage over a ball mill. However, despite these benefits, applications of the vertical roller mill for cement grinding are less prevalent.

Figure 1: The grinding tools of an OK mill

The two-compartment ball mill operating in a closed circuit with a high efficiency separator is thus still the most preferred arrangement for new cement grinding installations although the vertical roller mill now has emerged as a viable alternative to the ball mill system and has increased its share of the market for cement mills over the last decade. There are a number of explanations for this situation, related to issues like cost and ease of operation, cost of installation, cost and ease of maintenance, product quality, versatility, etc. The following presents a comparison of the two mill systems with reference to these issues.

2 Grinding process

The grinding process in ball mills and vertical roller mills differs fundamentally. In a ball mill the comminution takes place by impact and attrition. The comminution in the vertical roller mill takes place by exposing a bed of material to a pressure sufficiently high to cause fracture of the individual particles in the bed, although the majority of the particles in the bed are considerably smaller than the thickness of the bed.

It is thus necessary that a stable and consistent grinding bed is formed between the rollers and the table of the vertical roller mill, which is able to sustain such a pressure without the material being squeezed away from the pressure zone. A stable grinding bed is usually easily obtained in raw material grinding in a vertical roller mill with a high efficiency separator. However, in cement grinding it becomes more difficult to form a stable grinding bed as

- cement is ground much finer than raw meal
- the feed to a cement mill is often completely dry and is significantly more difficult to grind than raw materials
- the requirements for the particle size distribution of the finished product are much more strict when grinding cement.

These differences between the grinding of cement and raw materials made it a serious challenge to obtain good performance for a vertical roller mill in cement grinding. Today, however, the so-called OK mill, a type of vertical roller mill produced by FLSmidth, has become an example of a mill design that has overcome the difficult grinding conditions associated with finish grinding of cement clinker and related products.

The OK mill was developed in Japan by Onoda Cement Co., Onoda Engineering and Consulting Co. and Kobe Steel in the early nineteen eighties. In 1993 F.L.Smidth-Fuller Engineering obtained a license to manufacture and market this mill.

With respect to forming a stable grinding bed the OK mill's patented roller and grinding table designs proved to be a major breakthrough. As shown in ❯ Fig. 1, the rollers of the OK mill are spherical in shape with a groove in the middle. The table is also curved forming a wedge-shaped compression and grinding zone between the rollers and the table. This dual-lobed design is an optimum for clinker grinding because it supplies two distinct grinding zones – a low pressure zone and a high pressure zone – as shown in ❯ Fig. 2.

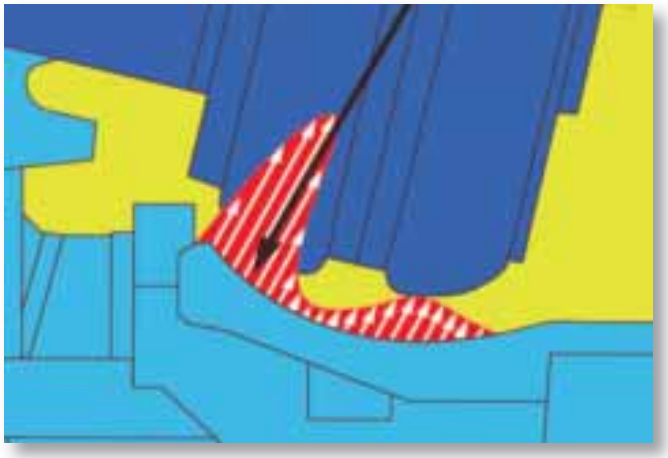

Figure 2: Radial pressure distribution in the stress zone of an OK mill

PROCESSING

The low-pressure area under the inner lobe de-aerates and consolidates the material to be ground. The proper grinding takes place in the high-pressure zone under the outer lobe. The groove in the middle of the roller facilitates de-aeration of the material without fluidising it.

In order to further ensure stable operation with little vibration the OK mill is provided with a high efficiency separator. This results in reduced internal circulation of fine material and a correspondingly higher feed rate. The material on the grinding track will thus become coarser and therefore less prone to fluidisation.

Industrial experience has proved that due to the design of the grinding parts and the high efficiency separator the OK mill (❯ Fig. 3) adequately addresses all the difficult grinding conditions associated with fine grinding of cement clinker and related products, enabling a high grinding efficiency and stable operation. However, despite the generally good performance of vertical roller mills used for grinding cement and related products this mill is still inferior to the ball mill in terms of sensitivity to variations of mill feed quality (fineness) and mill feed rate.

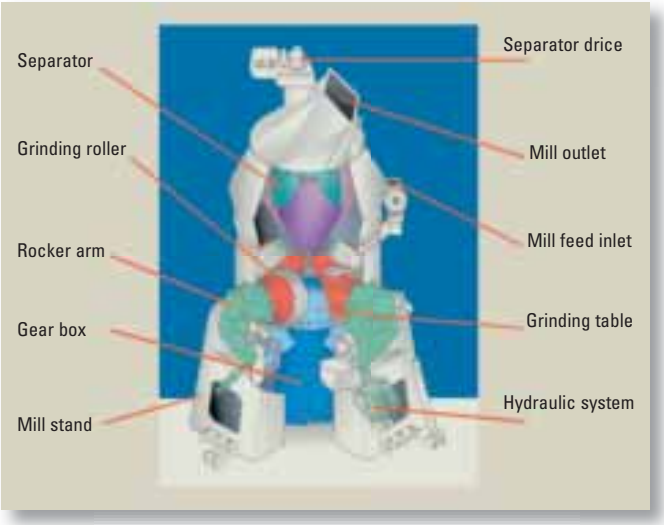

Figure 3: The OK mill in 3D representation

3 Product quality

The purpose of the mill system is to provide a product fineness that will result in the required reactivity and consequently the strength producing potential of the product – the cement. The fineness of cement is usually monitored by measuring the Blaine specific surface area or a sieve residue of the product. However, the effects of the mill system on the quality of the product are more complex than can be reflected by a Blaine value or a sieve residue. They include the following factors associated with the product:

- the particle size distribution,
- the degree of dehydration of the gypsum added to the cement,
- the prehydration and carbonation of the clinker minerals.

3.1 Particle Size Distribution

It is a characteristic of vertical roller mills that the energy input to the material per pass between roller and table is small, for which reason a large number of passes are required to obtain the necessary specific energy. This leads to a very high internal material circulation factor. High circulation factors invariably lead to steep particle size distribution curves if the separation process is efficient. It has therefore been necessary to adapt special measures to reduce the inclination of the particle size distribution curve in order to achieve a cement quality that is similar to the quality of cement ground in a ball mill. There are a number of ways of adjusting the inclination of the particle size distribution curve for cement ground in an OK mill.

Figure 4: The segment dam ring, easy to adjust in height

In order to reduce the circulation factor, the grinding track on the grinding table has an upward curved shape that helps to retain a certain minimum amount of material under the rollers. At the periphery the grinding table is further equipped with an adjustable dam ring (❯ Fig. 4). A higher dam ring will result in a thicker grinding bed corresponding to a longer retention time of the material on the grinding table. The material will thus receive a higher energy input before leaving the grinding table, resulting in a lower circulation factor via the separator and thus a particle size distribution curve with a lower inclination.

The grinding pressure also has an influence on the particle size distribution. The higher the grinding pressure, the higher the energy input per pass between roller and table, and the lower the circulation factor, and consequently the lower the inclination of the particle size distribution curve.

An example of the influence of the dam ring height and grinding pressure on the inclination of the particle size distribution curve is given in ❯ Fig. 5. The trend shown is quite typical, whereas the indicated figures may vary depending on – among other factors – the method of particle size analysis applied.

The ratio between mill airflow rate and separator speed also influences the particle size distribution. A lower air flow rate

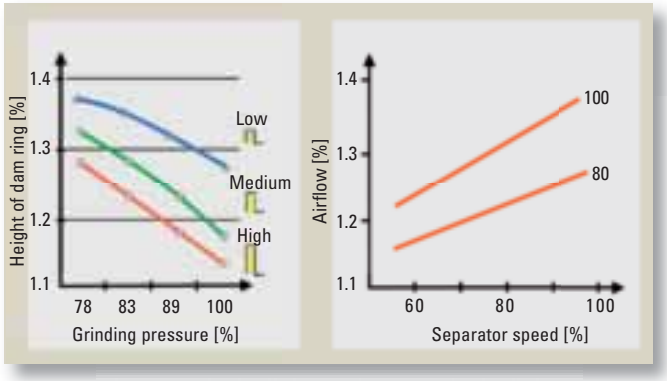

Figure 5: Dependence of the inclination in the RRSB diagram on the grinding pressure, classifier speed, dam ring height and air flow

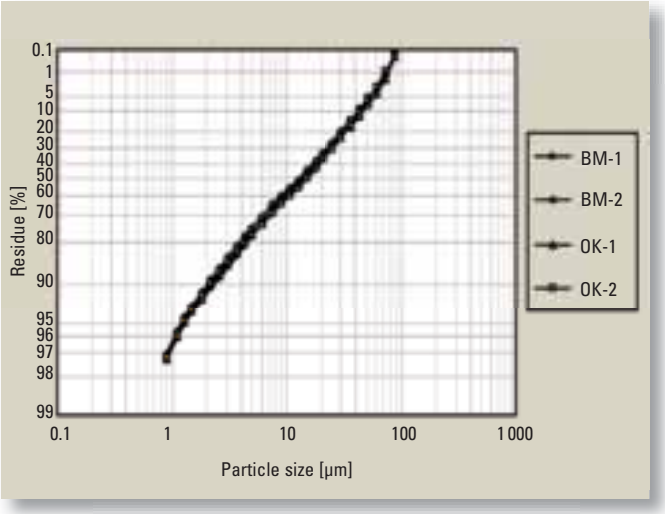

Figure 6: Comparison of the particle size distributions in the RRSB diagram of products ground in the ball mill and in the OK mill

will lead to a lower inclination of the particle size distribution curve. By these measures it has been possible to obtain particle size distributions for cement ground in OK mills similar to those for cement ground in ball mills (BM), as shown in ❯ Fig. 6. However, it should be noted that the operation to achieve a wide particle size distribution (low n-value) has a cost. The measures taken to achieve a low inclination of the PSD curve – i.e. a high dam ring, a high grinding pressure with unchanged feed rate, and a low airflow rate – all result in a lower grinding efficiency and consequently in a higher specific energy consumption than achieved with the mill optimised with a view to low energy consumption and a correspondingly steeper PSD curve.

3.2 Dehydration of the gypsum added to the cement

Heat will be generated and the cement will be heated up during the grinding process. The temperature of the cement leaving the mill will be dependent on the temperature of the materials (especially the clinker) fed to the mill and on features of the mill and the grinding process. It will typically be in the range from 90 to 120 °C. At this temperature level the water of crystallisation of the gypsum added to the mill will be partially lost, i.e. the gypsum will be partly dehydrated. This dehydration will increase the solubility of the gypsum and make it more effective as a retarder for the aluminate reaction in the cement and thus more effective in setting control. Another consequence is a general increase of the strength during the hardening of the cement. However, a too high content of dehydrated gypsum can lead to early precipitation of gypsum crystals between the cement grains in the paste and cause early stiffening (false set). Some dehydrating of gypsum is usually advantageous but a too high degree of dehydration (or too much dehydrated gypsum) can lead to problems.

As less grinding energy is used in producing a cement of a required fineness in an OK mill and the retention time in the mill is shorter, the product will not be heated up as much as in a ball mill. This means that a lower degree of dehydration of the gypsum must be anticipated. This may not be a problem if the gypsum is sufficiently reactive to control the setting reactions, which is normally the case. If, in special cases, this is not so then different measures may be applied to cope with the problem:

- addition of more gypsum (if it is possible within the SO_3-limit),
- increased dehydration of gypsum by adding more heat to the mill system,
- addition of a more reactive form of gypsum.

In order to ensure adequate dehydration of the gypsum, the layout of a vertical roller mill system (❯ Fig. 7) has provision for recirculation of hot mill exit gas to the inlet to maintain a proper temperature in the mill circuit. If there is cold clinker or wet additives in the mill feed material then more heat may be added to the mill system by an auxiliary hot air generator. If the temperature of the clinker fed to the mill is very high, the mill exit temperature controls a cold air damper at the air inlet to the mill or – in extreme cases – water injection into the mill.

3.3 Prehydration of the clinker minerals

Another chemical aspect to be considered in connection with cement grinding is the prehydration of cement particles that may take place during the grinding. The mois-

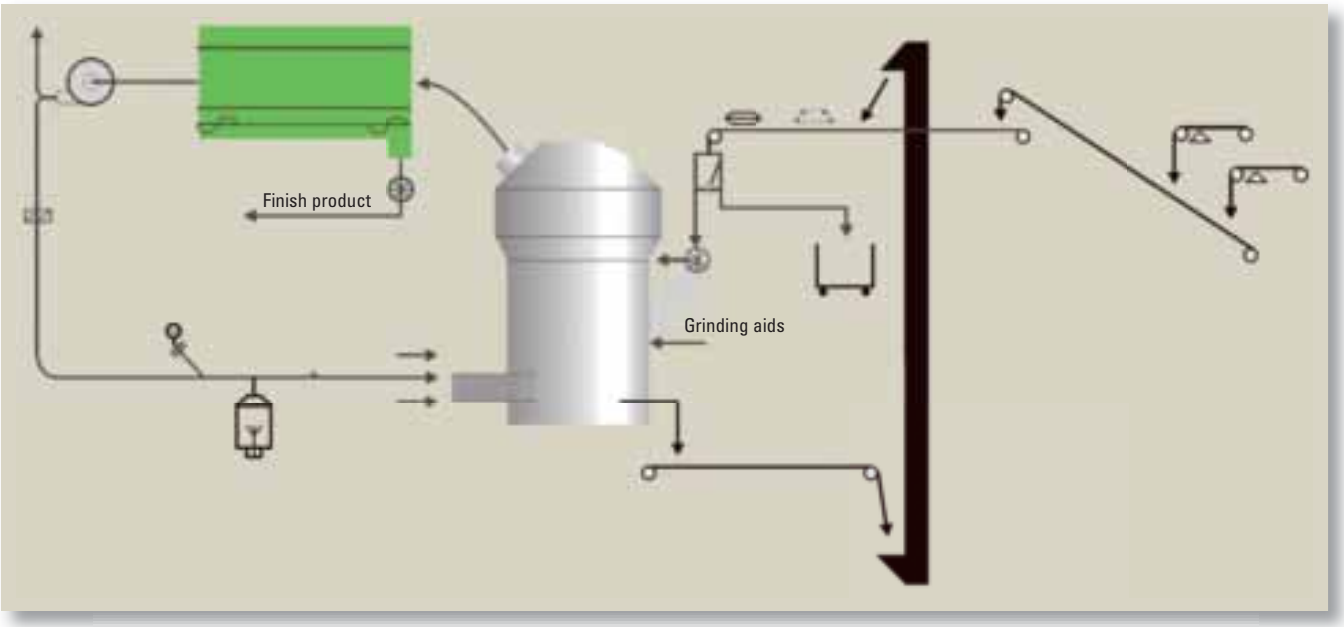

Figure 7: Flow sheet of a modern grinding plant with vertical roller mill for grinding clinker and slag

Table 1: Comparison of the products ground in OK and ball mills

Plant	Plant A		Plant B				Plant C	
Cement type	OPC		Blended				Blended	
Mill type	OK*)	BM**)	OK-1	OK-2	BM-1	BM-2	OK	BM
Fineness/PSD								
Blaine [cm²/g]	3770	3750	3990	3760	3990	4360	3850	4370
Residue 45 µm [%]	1.3	5.3	7.4	4.5	5.4	5.6	3.2	2.4
PSD/n-value	1.10	1.05	1.07	1.06	1.11	1.07	1.05	1.01
Dehydrate/Prehydration								
Gypsum [%]	2.0	0.1	2.5	4.0	2.0	2.0	3.5	4.0
Hemihydrate [%]	0.5	1.5	1.0	0.5	0.5	0.0	1.5	2.0
Prehydration [%]	0.15	0.25	-	-	-	-	0.20	0.29
Cement testing acc. to EN/ISO								
Water demand [%]	26.5	27.0	31.0	32.5	29.5	29.0	27.5	27.5
Initial set [h:min]	1:50	2:05	3:05	3:15	2:35	2:25	1:45	1:20
Final set [h:min]	2:40	2:50	4:00	4:20	3:20	3:10	2:30	2:30
Compr. strength 1d [MPa]	18.8	19.0	10.6	10.2	13.8	12.1	14.8	15.5
Compr. strength 2 d [MPa]	28.8	27.6	–	–	–	–	32.5	32.1
Compr. strength 3 d [MPa]	–	–	26.9	28.8	29.8	28.4	–	–
Compr. strength 7 d [MPa]	42.8	39.0	35.7	37.5	39.4	36.1	41.7	39.8
Compr. strength 28 d [MPa]	60.3	60.5	49.2	50.3	50.0	47.9	52.0	50.5

OK*); BM**) Ball mill is operating with close circuit

ture for prehydration can come from moisture in the feed materials, from internal cooling systems, and/or from dehydrating gypsum. The latter case mainly becomes a problem in connection with storage of hot cement in a silo. Prehydration of cement can, when exceeding a certain level, lead to reduced reactivity of the cement and thus longer setting times and reduced strengths, particularly early strengths. Prehydration can also enhance the tendency of false set in cement with a high content of dehydrated gypsum.

Prehydration is normally not as problematic in an OK mill as in ball mill systems where an internal water-cooling is often required. However, if cement is produced at a relatively high temperature and still contains a lot of gypsum that is not dehydrated, one should be aware of the problem of possible gypsum dehydration coupled with clinker prehydration which can take place during storage in the cement silos. If a problem of this kind is present, it can be remedied by one (or more) of the following options:

- Ensure that the cement is cooled to a lower temperature before it enters the silo.
- Ensure there is a higher dehydration level of the gypsum in the mill (see above).
- Replace part of the gypsum by natural anhydrite.

3.4 Comparisons of products from OK and ball mills

To get an impression of similarities or differences between cement products of the same composition but produced in OK and ball mills (BM) respectively, cement samples from plants having both types of mills producing the same product have been collected and tested. The ball mills in the plants where the tests took place were all closed circuit mills. The main results of the comparison are shown in ❯ Table 1.

One conclusion from the comparisons is that the quality of cements produced in OK mills is very similar to the quality of those produced in a ball mill grinding installation operating in closed circuit with a modern separator. For the OK mill products, there is a tendency towards a lower dehydration level of the gypsum in the cement and a steeper PSD, but generally the cements end up with very similar cementitious properties. Major differences found were typically caused by other non-mill-derived factors such as mix proportions of constituents in the product.

4 Cost of operation

4.1 Specific energy consumption

The most significant advantage of a vertical roller mill compared to a ball mill system is related to the specific consumption of electrical energy of the two systems. ❯ Table 2 shows

Table 2: Comparison of the specific electrical energy consumption based on performance figures from cement plants operating with OK and ball mills

Plant	AA		BB		CC		DD	
Cement type	OPC		OPC		OPC		Slag cement	
Type of mill	BM	OK	BM	OK	BM	OK	BM	OK
Fineness acc. Blaine [cm²/g]	3200	3200	3700	3700	3880	3900	3640	3640
Specific power consumption [kWh/t]								
Mill	32.5	22.2	39.2	21.1	35.2	18.3	34.4	17.2
Total	38.5	28.9	42.3	32.2	42.4	25.7	40.0	25.7

samples of performance figures from cement plants operating OK mills as well as ball mills (BM).

It appears from the table that the specific energy consumption of the OK mill system is 25 to 40 % lower than for a ball mill system. The benefit of the OK mill is in particular pronounced when grinding to a high fineness and/or when slag is included in the cement.

4.2 Grinding aid

For grinding OPC in a ball mill to a fineness of up to around 3600 cm^2/g (Blaine) grinding aids are usually not required and may not even be feasible in view of the cost of grinding aids. However, a vertical roller mill for cement grinding generally requires the use of grinding aids to achieve the most efficient operation with a stable grinding bed and a low level of vibrations. Vertical roller mills grinding an OPC of low fineness, i.e. around 3000 cm^2/g (Blaine), can operate without a grinding aid, but even when grinding to that low fineness, a grinding aid improves the output rate as well as the specific energy consumption. Recent experience has shown that water has an effect similar to that of a grinding aid. If conditions, i.e. the combination of clinker temperature, energy consumption and ambient temperature, allow or require water injection in the mill then part of the grinding aid may be replaced by water. The amount of grinding aid that can be replaced by water depends on the feed granulometry, the feed moisture and the product fineness.

The consumption of grinding aid when grinding OPC in a vertical roller mill is typically in the range from 100 to 300 g per tonne of cement. The ball mill system thus has an advantage compared to the vertical roller mill with respect to the use of a grinding aid for grinding of OPC.

A grinding aid is generally not required for grinding slag or slag cement in a vertical roller mill.

4.3 Fuel for control of mill outlet temperature

In order to ensure adequate dehydration of the gypsum when grinding OPC from cold clinker in a vertical roller mill, it may be necessary to use a hot air generator to provide sufficient heat to the grinding circuit. This will not usually be necessary with a ball mill due to its higher energy consumption, resulting in a sufficiently high temperature in the mill.

Grinding blended cement with wet additives may require supplementary heat from a hot air generator, regardless of whether the mill is a ball mill or a vertical roller mill. Obviously, in this case the vertical roller mill will also need more heat than the ball mill from the hot air generator. The examples shown in ❯ Table 3 indicate the fuel consumption for temperature control for the two mill systems when grinding OPC and a blended cement.

4.4 Water injection for temperature control

Water injection for temperature control is usually not required with a vertical roller mill. The heat generated by the grinding process is low due to the high grinding efficiency, all the air to the mill air inlet can be ambient air, and the air flow through a vertical roller mill is much higher than through a ball mill.

For a ball mill the heat generated by the grinding process is high and the air flow through the mill is relatively low. Most ball mills grinding OPC therefore operate with internal water cooling. The amount of water required is dependent not only on the clinker temperature but also on the operation of the separator. The separator circuit may be arranged for air cooling using from 0 to 100 % of ambient air for the process. Full air cooling in the ball mill separator, i.e. 100 % ambient air to the separator, will not only reduce the requirements for internal water cooling in the mill but will also make a powder cooler for the final product redundant.

Table 3: Comparison of specific fuel consumption for temperature control in OK and ball mills

Clinker temperature [°C]	Mill type	Hot air generator fuel consumption (kg oil per ton of cement)	
		OPC 95 % clinker 5 % gypsum 20 °C 8 % moisture 3200 cm^2/g (Blaine)	Blended cement 75 % clinker 5 % gypsum 20 °C 8 % moisture 20 % additives 20 °C 10 % moisture 4000 cm^2/g (Blaine)
30	Ball mill	0	1.3
	OK-mill	0.9	2.5
100	Ball mill	0	0.5
	OK-mill	0	1.4

5 Versatility

A vertical roller mill is a very versatile mill capable of grinding a wide range of products. The OK mill has proved suitable for grinding not only pure slag and Ordinary Portland Cement, but also blended cements with a wide range of additives such as slag, pozzolana, limestone and fly ash. Several OK mills grind two or more products alternately. Shifting from one product type to another is easy and with only a very short transition period. A decisive advantage of the vertical roller mill compared to a ball mill is its ability to dry feed materials, such as slag, with a high water content. Furthermore, the operational parameters of a vertical roller mill are easily adapted to suit alternative products. Even adjustment of the dam ring, should that be required, is an easy task compared to moving the diaphragm of a ball mill. With respect to versatility the vertical roller mill can thus be considered as superior to the ball mill.

6 Upgrading

Over the last two decades quite a large number of ball mill installations for cement grinding have been upgraded by installation of pre-grinders, mostly roller presses. Dependent on the complexity of the upgrade the system capacity may be increased by from about 30 to around 100 %. This option may not only be interesting as regards existing ball mill installations, but may even be taken into consideration in relation to new installations that are included in a two-phase investment program, i.e. a low capacity first phase engineered with a view to the second phase – a later upgrade.

Such a scenario is not applicable to a vertical roller mill system.

7 Maintenance of wearing parts

Wearing parts for a ball mill, i.e. grinding balls, liner plates and other mill internals are either very easy to maintain or they have a long lifetime. The grinding charge is simply maintained by adding more grinding balls to the mill as the mill charge becomes worn and the power consumption and the output capacity decrease. Liners and mill internals for the first compartment have typical lifetimes from at least two years (grate plates for the intermediate diaphragm) to around five years (shell liners). Parts for the second compartment last even longer, typically from around four years (outlet grates) to around nine years (shell liners).

The performance of a vertical roller mill will also deteriorate as a consequence of progressive wear of the grinding parts. This, however, is not only reflected in a reduced capacity, but also in a higher specific energy consumption and a higher level of mill vibrations. Work for remedying progressive wear of the grinding parts for an OK mill may involve reversal of roller segments, hardfacing of roller and table segments and/or eventually replacement of worn out parts. This work is obviously more complicated than just adding more balls to a ball mill.

However, the wear rate for grinding parts of an OK mill grinding OPC is fairly low and maintenance of wearing parts, i.e. reversal, hardfacing or replacement, can usually be scheduled to take place say once per year to follow the plant's kiln maintenance programme. The wear rate measured in grams per tonne of cement produced is much higher for a ball mill than for a vertical roller mill. However, the unit cost for wear parts for a ball mill is much lower than for a vertical roller mill.

For a ball mill grinding OPC to a fineness according to Blaine of 3200 to 3600 cm^2/g the cost of wear parts (ball, liners and mill internals) is typically € 0.15 to 0.20 per tonne of cement.

For an OK mill grinding a similar product, the cost of wear parts depends on the maintenance procedures, i.e. whether hardfacing is applied. If hardfacing is not applied the cost is the same as for a ball mill, i.e. € 0.15 to 0.20 per tonne of cement. If hardfacing is applied, the corresponding figure will be € 0.10 to 0.15 per tonne of cement.

Figure 8: View of a grinding plant with a ball mill that is enclosed in a building to reduce emissions

Figure 9: View of a grinding plant with an OK mill erected in the open

8 Costs of equipment and civil works

The total specific costs associated with a new mill system can be divided into:

- equipment,
- civil works,
- erection.

The relative equipment costs of the two alternative grinding systems depend on a number of factors such as the application, whether a separate drying facility is required for the ball mill, system capacity, requirements with respect to country of origin of the equipment and a number of other factors. The comparison of equipment costs outlined in the following is based on mills grinding OPC, i.e. without separate drying facilities for the ball mill, and with most of the equipment being of European origin. Relative equipment costs estimated on this basis are fairly constant irrespective of location of installation.

In contrast to equipment cost, the costs for civil works and erection show large regional variations. Furthermore, the specific details of building requirements vary from plant to plant. Predominant climatic and weather conditions will have a significant impact on the final building design, and ball mill and vertical roller mill installations have significantly different foundation and layout requirements.

In general, ball mill grinding systems are fully enclosed in a building regardless of geographic location or predominant weather conditions. The use of a building has as much to do with noise abatement as with protecting the equipment. The noise level of a ball mill is normally above 100 dBA. By enclosing the mill it is possible to achieve reliable control of noise emissions to the surrounding environment. ❯ Fig. 8 shows the exterior of a ball mill building. The size of the ball mill building when the system is fully enclosed will be dictated by the equipment footprint and elevation. The foundations for a ball mill system consist of multiple piers for the mill supports, drive, reducer and fan.

Vertical roller mills are not typically fully enclosed in a building (❯ Fig. 9). In many cases the mill is covered with a roof to protect the separator drive. The noise level from a vertical roller mill is significantly lower than from a ball mill, typically between 80 and 85 dBA, and does not require the same noise protection. In areas of high precipitation or extreme

weather conditions such as sub-freezing temperatures an enclosure may be required, but is not the norm. The equipment footprint for a vertical roller mill is more compact than a ball mill; there is only necessary a single foundation for the mill and one for the mill fan.

8.1 Comparison of relative prices

The price comparison comprises:

- A ball mill with side drive in closed circuit with a high efficiency separator enclosed in a building with an installed ball mill power of 7 430 kW and a throughput of 220 t/h.
- A vertical roller mill installed with a minimum of civil works, i.e. as shown in Fig. 9, with an installed mill power of 3 750 kW and a capacity of 204 t/h.

The comparisons are exclusive of mill feed arrangements, silo battery for mill feed materials, cement transport and cement silos, as these items are identical for the two systems. The weights and prices of ball mill and vertical roller mill systems are listed in ❯ Table 4.

It should be noted that grinding media make up around 40% of the weight of equipment procured and erected for the ball mill system, which explains why the unit cost for equipment and erection is significantly higher for the vertical roller mill system than for the ball mill system.

Since erection prices and price for civil work show large regional variations it is not possible to make a globally applicable comparison of total prices. However, ❯ Fig. 10 has been prepared on the basis of European prices for equipment and erection as well as civil works to give an example of the relative total prices. The prices for erection and civil works may be significantly lower in many countries.

9 Final remarks

Vertical roller mills and ball mills represent two clearly distinct technologies. However, almost identical cement properties that satisfy the cement user's demands can be achieved by the two mills if the operational parameters of the vertical roller mill are correctly adjusted. Nevertheless, the two types of mills have their distinctive merits.

The grinding efficiency of the vertical roller mill is combined with the ability to grind, classify and – if required – dry within a single unit. These merits give the vertical roller mill a decisive advantage over a ball mill. However, the grinding process applied in a vertical roller mill has the effect that the vertical roller mill is more sensitive to variations of mill feed quality and mill feed rate than a ball mill, which makes the ball mill easier to operate. Likewise, the ball mill has an advantage over a vertical roller mill in terms of ease of maintenance.

Table 4: Comparison of the weight and prices of ball mill and vertical roller mill systems

Grinding system with	Weight of equipment [%]	Price of equipment [%]	Price for civil engineering [%]	Price for erection [%]
Ball mill incl. grinding media	100	100	100	100
Vertical roller mill	93	135	73	126

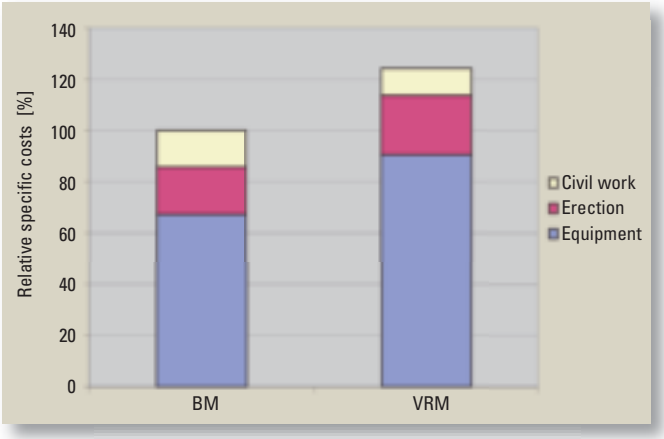

Figure 10: Comparison of the relative specific costs of a grinding plant with a ball mill and a vertical roller mill

Apart from the consumption of electrical energy, in which respect the vertical roller mill is superior to a ball mill, other factors, such as cost of grinding aid, cost of fuel for a hot air generator and cost of water for cooling, also affect the cost of operation – although to a lesser extent. The cost of maintenance is quite similar for the two mill systems and is therefore a factor of minor significance in a comparative evaluation of the two systems.

When compared to a ball mill a vertical roller mill is a very versatile mill suitable for, and easily adaptable to, a wide range of products. However, a ball mill can be upgraded to a higher capacity, which is not an option for a vertical roller mill. Although cost of erection and cost for civil works show large regional variations the total cost of installation is in most cases somewhat higher for a vertical roller mill system than for a ball mill system.

It appears that quite a number of factors should be taken into consideration when making a comparative evaluation of a vertical roller mill system and a ball mill system for cement grinding, although the cost of electrical energy and total installation costs may be the most significant. The significance of those factors may vary substantially depending on the location of the installation, so it is not possible to make a ranking order for the two grinding systems that is globally applicable. Such an evaluation must be made for the specific project while taking into consideration the fact that the effects of the various factors depend on local conditions and specific demands. ◀

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Please contact us for specific information or data that may relate to your interests.

DENMARK
FLSmidth A/S
Vigerslev Allé 77
DK-2500 Valby
Copenhagen
Tel: +45 - 36 18 10 00
Fax: +45 - 36 30 18 20
E-mail: info@flsmidth.com

USA
FLSmidth Inc.
2040 Avenue C
Bethlehem, PA 18017-2188
Tel: +1 - 610-264-6011
Tel: +1 - 800-523-9482
Fax: +1 - 610-264-6170
E-mail: info-us@flsmidth.com

INDIA
FLSmidth Ltd.
Capital Towers
180, Kodambakkam High Road
Nungambakkam
Chennai 600 034
Tel: +91 - 44-52-191234
Fax: +91 - 44-2827-9393
E-mail: indiainfo@flsmidth.com




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