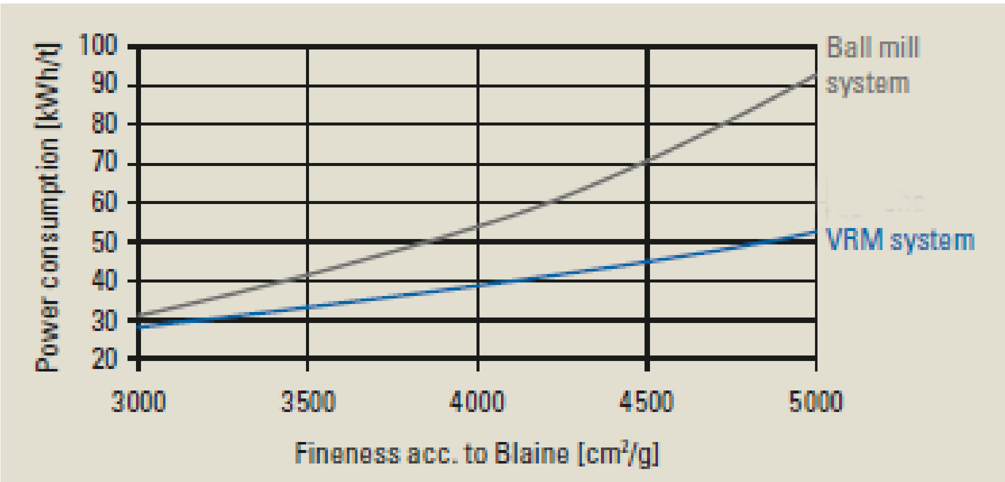
Cement grinding in the vertical roller mill meets the requirements of the market

Cement production typically requires the grinding of three separate types of material during the process: the raw materials and coal before the **rotary kiln**, and the final cement product once firing is complete and the clinker cooled. Looking back on a century or more, ball mill systems were used for all three grinding stages, but the development of more energy efficient vertical roller mills led to their replacement. Initially, this focused on grinding coal and the cement raw materials, with the adoption of vertical roller mills for cement product grinding – with its finer grinding requirements – coming more recently, in the late 1990s. The main reason for the delay in uptake of VRM technology for cement grinding was the concerns of producers that their product qualities would not meet market requirements, specifically in three key areas: water demand, strength development and setting times. Over the past 15 years, however, it could be demonstrated that these concerns are unfounded, and that the quality of cement obtained from VRM grinding is as good as, or in some cases better than, that produced in a ball mill. In consequence, most of the world's major cement producers now use vertical roller mills for cement grinding with no hesitation.

1. Introduction

There is no question that **vertical roller mills** offer significant advantages over ball mills in terms of their energy efficiency. As noted in the following chart : the specific power consumption of a ball mill is higher than that of a vertical roller mill carrying out the same operations by a factor of between 1.5 and 2, depending on the degree of optimisation of the ball mill.



2. Grinding system options

Nowadays, cement producers have the option for using a range of different systems for cement grinding. A comprehensive list of all the available options would certainly include traditional ball mill systems, high-pressure grinding rolls in every kind of design types and their various combinations with ball mills and, of course, vertical roller mills. All of these systems treat the material to be ground differently, in that the actual grinding needed to achieve the desired characteristics varies from one to the other. The following chart illustrates schematically some possible alternative flow sheets using vertical roller mill and **ball mills**. With the focus here being on ball mills and vertical roller mills..

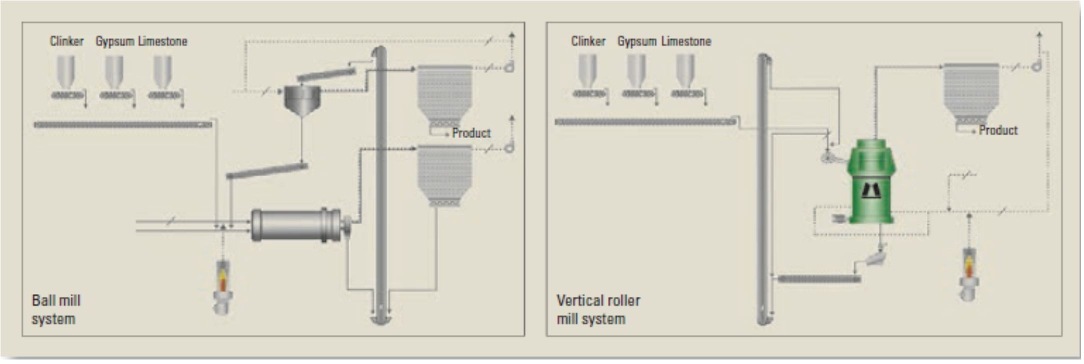


Table1 shows some comparative performance parameters for the two systems when used for grinding cement. It has to be remembered that there are major differences in the mechanism of grinding between vertical roller mill and ball mills, in terms of how grinding occurs, the residence time, the level of repeat grinding and recirculation factors, among others. In a vertical roller mill, comminution occurs by pressure and shear forces that are introduced via the grinding rollers. In ball mills, comminution is mainly done by impact, with the grinding balls being lifted up by the rotating shell, and then dropped back onto the charge and other balls.

Table 1: Comparative performance parameters for the two systems when used for grinding cement

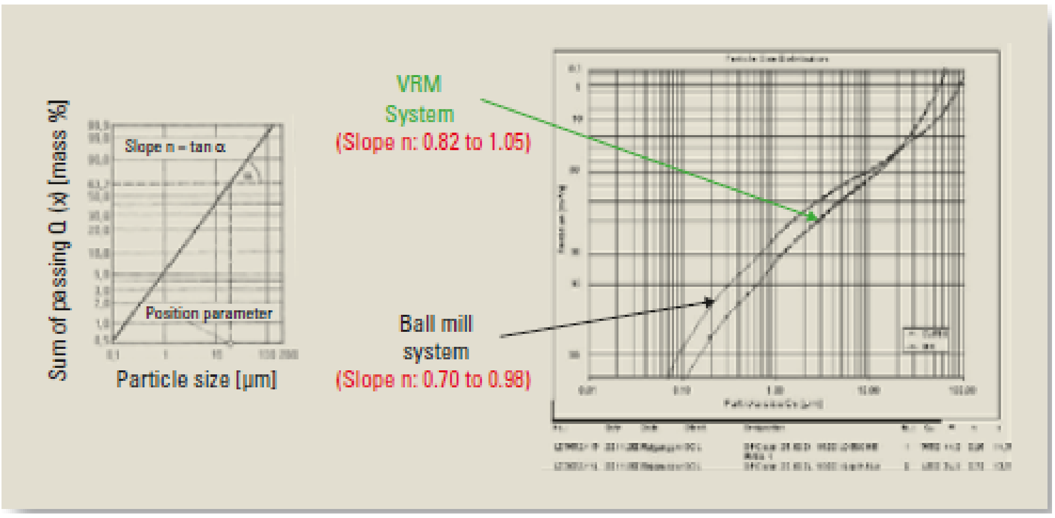
Characteristics	Ball mill (closed circuit)	Vertical roller mill
Comminution by	Impact and attrition	Pressure and shear forces
Residence time [min]	20 to 30	< 1
Crushings before separation	∞	1 to 3
Circulation factor	2 to 3	6 to 20
Wear rate [g/t]	~ 50	3 to 6

There is some attrition as well. There is also a major difference in terms of the average residence time – the time the material particles remain in the mill system before they leave the classifier as product. Including both grinding in the mill body and a circulation factor, the residence time for a VRM is less than one minute, while particles can remain within a ball mill system for 20 to 30 minutes. Individual cement particles will be ground from one to three times in a vertical roller mills before being offered to the classifier, whereas repeat grinding in a ball mill is virtually uncountable because of the grinding mechanism. Finally, while a ball mill will have a recirculation factor of 2 to 3, these increases between 6 to 20 for a vertical roller mill, depending on the pressure height, the grinding tools configuration, the grind ability of the material and the required product fineness.

4 .Particle size distribution

The particle size distribution of cement is usually plotted on the known RRSB diagram.

The following chart shows size distribution curves for cements produced by grinding in VRMs and in ball mills. The inclination of each curve, the slope 'n', is measured at the positioning parameter that represents the particle diameter at which the residue, in terms of mass, is 36.8 %. A higher 'n-'value produces a steeper curve, whereas the lower the slope, the more fine and over-ground particles are in the finished product at a constant Blaine value, measured in cm2/g. Fig. 4 shows that in this case, 'n' for the VRM cement system is steeper than for a cement produced in a ball mill. This is caused by the higher proportion of fine (over-ground) material present in the ball mill cement, which in turn reflects the greater number of impacts and the inherent inefficiency of ball mill grinding. In more general terms, a typical particle size distribution for a ball mill system in closed-circuit operation with a high efficiency, third-generation classifier would be between 0.75 and 0.98. The equivalent would be between 0.82 and 1.05 in vertical roller mill system. These ranges may differ when different types of laser sizes are used. The area of concern in the past was that the steeper particle size distribution for VRM cements would lead, for example, to their having higher water demand and lower early strength development. This could, of course, generate problems, especially in precast concrete manufacturing with its sophisticated production processes regarding cycle and stripping times. The question then has to be asked as to the reason for the different slopes in the particle size distribution diagrams. Firstly, and as explained above, the different grinding behavior of the vertical roller and ball mill systems means that particles remain in a ball mill system for about 20 to 30 minutes before they leave the classifier as product. They are impacted repeatedly during that time, with the result that some particles are ground more than necessary. By contrast, the limited amount of grinding for each particle in the VRM system before classification avoids any unnecessary over-grinding.

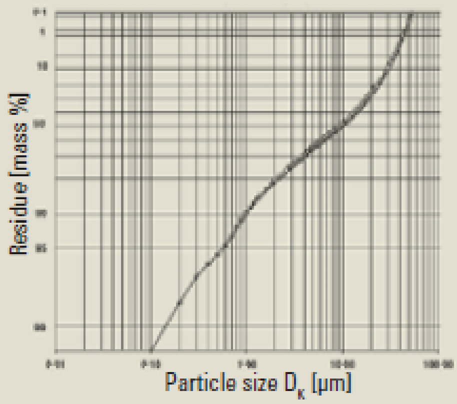


Different particle size distributions

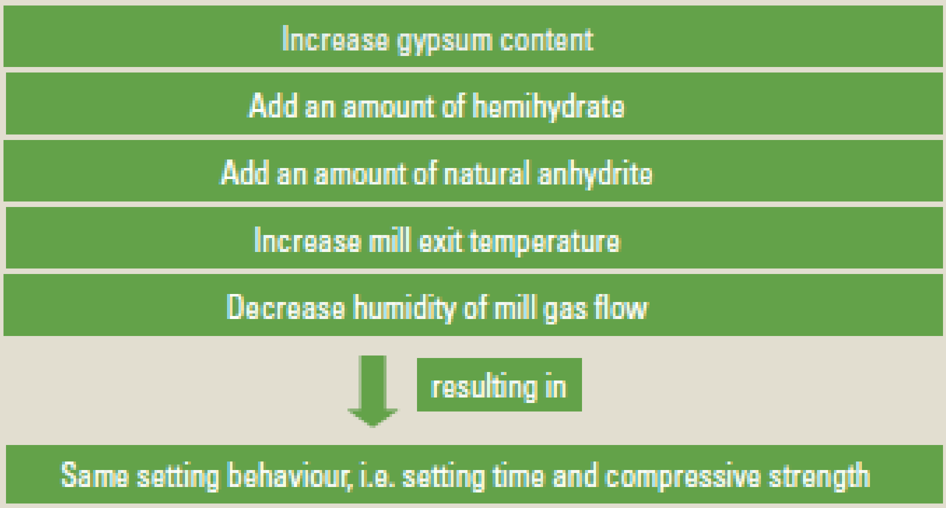
5 Particle shape considerations

Differences in particle shape have been another area in which vertical roller mill systems have been the subject of scrutiny. The suggestion was made that cement particles coming out of a ball mill are always much rounder then those coming out of a VRM, which are more shallow and elongated. This again, together with fewer fine particles, would result in increased water demand for the cement paste. The roundness or circularity of the particles can be determined by optical methods such as image analyses. Within those measurements, particle shapes are described with values of between 1 and 0. A value of 1 indicates a particle that is perfectly spherical, and as the value approaches 0, it indicates an increasingly elongated, shallow polygon. Following chart illustrates the particle size distribution of cement with a product fineness of about 4 100 g/cm2 acc. to Blaine. This shows that the size of the smallest particle is about 0.1 µm and the size of the largest particle is about 52 µm for this particular cement. In general, while a wide variety of cements are ground to different finenesses, the largest particles are usually between 45 and 55 µm. In addition, 95 % of all the cement particles are below 45 µm in size, again depending on the final product fineness and the slope of the particle size distribution curve.

Technical properties			
Mill	Unit	VRM	BM
Separator		LSKS	O-SEPA
Density	g/cm³	3.164	3.152
Blaine	cm²/g	4258	4095
Slope n	-	0.93	0.92
Position parameter d'	µm	11.7	12.6
Water demand (Standard consistency)	%	28	28.5



6. Gypsum dehydration optimization



Gypsum is mainly added to cement to act as setting regulator, with the precise amount and type of gypsum being chosen in relation to its solubility and the individual clinker. A producer will work out the correct proportion and type of sulphate to be used through product optimisation in order to meet optimal requirements. The energy input into the mill and the hot gases will heat the cement, with the gypsum being partially dried and converted to hemihydrate, so-called bassanite or plaster. Mixed together with water, hemihydrate dissolves better than gypsum, so the dilution is more reactive in regulating the cement set. Partial dehydration is intended within the milling process, but if it exceeds or under runs a certain value, it can result in accelerated setting behaviour. This in turn can lead to problems such as with the workability of the cement paste. As the retention time in ball mills is 20 to 30 times greater than in vertical roller mills, the cement is exposed to the hot gas atmosphere for much longer. In addition, ball mills use much more energy than vertical roller mills in order to grind the same amount of cement, with this additional energy heating the material even further. Because of this, the particle temperatures at the exit from ball mills operated without water cooling are usually about 30 °C higher than those experienced with vertical roller mills. Therefore, if the same cement recipe is ground in both mills, paste from cement ground in a vertical roller mill will exhibit different setting behaviour and strength development during hardening. This is because the gypsum is dried more intensively in a ball mill system, resulting in the formation of more hemihydrate and hence higher sulphate solubility. Of course, commissioning any new mill requires the system to be optimised, including adjusting the amounts of gypsum and the other additives needed to achieve the required setting and strengthening behaviour. The same applies when changing from a ball mill system to a vertical roller mill system, when the operator needs to increase slightly the amount of gypsum put into the cement, or substitutes the gypsum to increase the solubility by hemihydrate or anhydrite. Other optimisation measures include increasing the mill exit temperature and/or reducing the moisture content of the mill gas flow, both of which will enhance the drying process of the added gypsum. As summarised in the chart these are standard process optimisation procedures that can also be used to ensure that the cements produced in vertical roller mills have comparable setting times and compressive strength development to those from ball mills. Because it is partly true that cement produced in a vertical roller mill has lower gypsum dehydration, this can be adjusted through standard process optimisation.