Grinding options for slag and pozzolan

While the use of supplementary cementitious materials is increasingly popular, the use of granulated blastfurnace slag and pozzolans presents extra challenges to the grinding process. A careful assessment of grinding options available is key to efficient grinding operations.

■ *by **Frank Benavides** and **Russell Reimer**, PEC Consulting Group LLC, USA*

The increasing pressure to use supplementary cementitious materials (SCMs) favours granulated blastfurnace slag (GBS) and pozzolans. However, these materials present high levels of moisture and abrasiveness, requiring grinding systems designed to deal with these properties. Therefore, it is important to evaluate which grinding system best serves the purpose.

GBS is a byproduct of steel manufacturing, mostly consisting of CaO, SiO_2, Al_2O_3 and MgO, with CaO and SiO_2 composing the largest share. Lesser components like Fe_2O_3 comprise the rest. As the number of blastfurnaces has decreased in steel manufacturing and are mostly located in the in the northeast and midwest USA, many US cement manufacturers import slag. The main benefit of slag cement (Type IS) is the effectiveness in mitigating alkali-silica reaction (ASR) by binding alkalis in the concrete hydration reaction.[1] Some cement mixes can be made without clinker, furthering the usefulness of GBS in reducing CO_2 emissions.

Pozzolanic materials such as volcanic ash or pumice, calcined kaolin, fly ash and diatomaceous earth are reactive aluminosilicates. Fly ash is the easiest to access from storage areas at coal-fired power plants. However, due to the closure of coal-fired power plants, this resource is dwindling.

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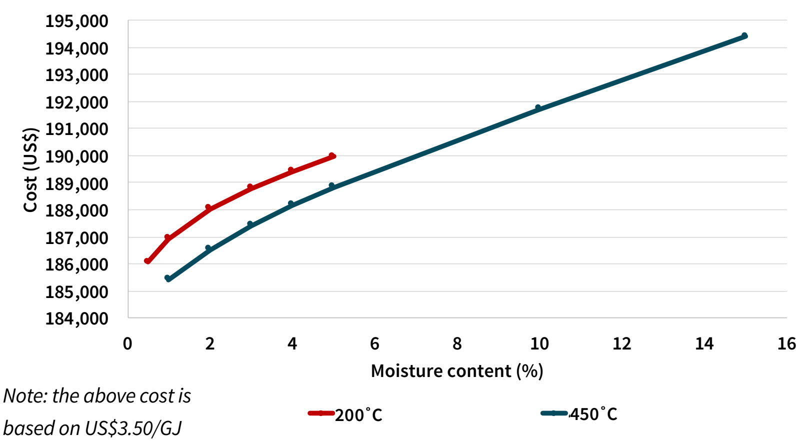
Figure 1: annual cost of operating a hot gas generator for drying materials



Note: the above cost is based on US$3.50/GJ

Comminution overview

Comminution theory focusses on the relationship between energy input and the particle size produced from a given feed size.[2] The most common breakage methods are impact and attrition, mostly by ball mills. This compares with the compression mechanism, as well as attrition, utilised in both high-pressure grinding rolls (HPGRs) and vertical roller mills (VRMs).

The Bond Ball Mill Work Index (BBMWi) is widely used to measure the grindability of a mineral in kWh/t.[2] In reference to clinker grinding, the following are typical

Table 1: typical properties of feed materials[3]

Material	Appearance	Grain size/ fineness (mm)	Moisture content (%)
Clinker	Hard, abrasive	<30	dry
Granulated blastfurnace slag	Vitreous, abrasive	<5	≤15
Gypsum	Mainly hard, REA* – soft and sticky	<50	10-25
Limestone	Hard	<50	5-10
Pozzolan, trass	Hard or soft	10-50	≤25
Fly ash – moist	Sticky	Lumpy	<25
Fly ash – dry	Powder	2000-5500cm^2/g	Dry

** Gypsum from the flue gas desulphurisation plants*

Table 2: example of wear life on FLSmidth's OK Mill

Product	Multiplication factor on current high-chrome installed segments	Estimated campaign wear life (h)
Cement	2.5	16,000
Slag	2	6400
Raw material	2	12,800

Source: FLSmidth OK PRO Plus Ceramic Wear Segments Brochure

energy requirements:[1]

- ball mill: 38kWh/t
- HPGR plus ball mill: 30-34kWh/t
- VRM: 28-32kWh/t.

Grinding is a very energy intensive process that accounts for a significant amount of production costs.[7] This is why advances in classifier technology have been vital in increasing production efficiency. Since GBS and pozzolan require a large surface area for reactivity, the fineness of the ground material plays a critical role, thus the efficiency of the classifier is essential.

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Drying methods

Minerals to be processed may have a high initial moisture content (see Table 1), but undercover storage can reduce moisture before entering the grinding process. If moisture levels are too high for mills to grind at reasonable production levels, drying is required ahead of the mill. VRMs are more suited for drying compared to other types of mills. A VRM can grind and dry minerals with 15 per cent moisture.[5] A ball mill may handle around five per cent moisture, but higher moisture levels will require a separate dryer ahead of the mill. Drying can also be performed by eeding directly to the classifier and adding hot gases to the classifier.

Figure 1 shows the annual cost for drying raw materials with a hot gas generator.

GBS devitrifies at approximately 700˚C, thereby losing its hydraulic properties and thus excessive temperatures should be avoided.[4] Pozzolans such as kaolin clay have temperature dependencies as well that will need to be fully understood before processing.

Vertical roller mills

VRMs have been gaining popularity in new projects as energy consumption can be up to 40 per cent less than that of ball mills,[6] in addition to allowing materials with a higher moisture content than competing grinding systems. Many advances in VRM technology have been made for clinker and slag grinding as well as for the production of pozzolanic blended cements.[7]

Technologies such as the ROKSH separator from FLSmidth also provide higher drying capacity for wet materials.[8] Other separation technology, like the Loesche LDC Series and Gebr Pfeiffer SLS classifiers, can reduce fineness down to 10µm [3,6]

The abrasiveness of GBS and pozzolan requires high wear-resistant liners. For VRMs grinding very abrasive materials, such as slag, hard-facing is an economical alternative to changing wear parts and is suitable for high-chrome castings, optimising the grinding process and saving refurbishment costs.[8]

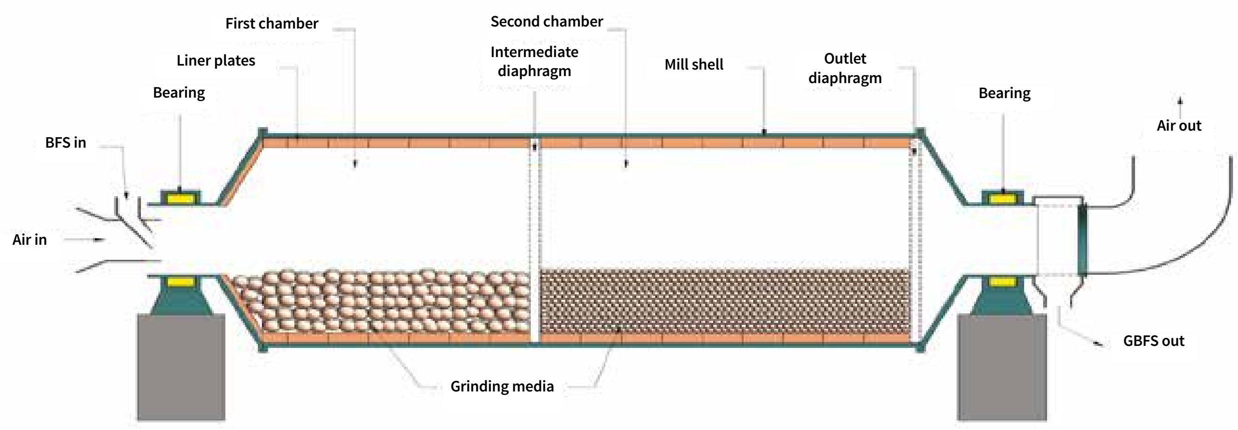
Innovations in material science have also led to a reduction in the loss of weight of wear parts, increasing their lifespan and reducing shipping costs. While welded liners can be used many times, ceramic liners provide double the amount of life.[9] Some companies, such as FLSmidth, are pursuing ceramics. The life of ceramic wear segments is shown in Table 2.

Ball mills

The ball mill (see Figure 2) still constitutes many of the existing grinding systems in place today. Disadvantages are higher energy consumption levels and higher decibel levels when compared with other grinding systems.[7] Advantages are ease of operation and lower capital investment cost.[2]

Ball mills have undergone considerable

Figure 2: typical ball mill arrangement



"If moisture levels are too high for mills to grind at reasonable production levels, drying is required ahead of the mill. VRMs are more suited for drying compared to other types of mills. A VRM can grind and dry minerals with 15 per cent moisture.[5]"

change in the last few decades with trends of increased mill sizes, high efficiency separators and innovative internal designs.[7] The efficiency and output are primarily dictated by ball charge for coarse and fine grinding optimisation. This has been accomplished mostly in part by internal designs on the maximum angular lift and the accurate trajectory of the ball charge.[7]

The relationship between production, ball charge loading (in per cent) and kWh should be observed carefully as these factors are pivotal and not mutually exclusive.[7] The ball size is dictated by the hardness of the material and its feed size distribution.

Grinding aids in a ball mill can greatly impact production costs.[7] Three major aspects are the decrease in "pack-set" (agglomeration of mineral coating on the media), increase flowability, and moisture reduction in the feedstock.[7]

High-pressure grinding rolls

High-pressure grinding rolls (HPGR) technology was first utilised in the grinding of clinker and raw material in the mid-1980s and quickly proved be an economical choice in the comminution process.[10] The HPGR compresses the material into a "cake" that includes both fines and coarse material, which later needs to be deagglomerated by a hammer mill, ball mill or a V-separator (see Figure 3).

A HPGR can reduce energy consumption when working as a pre-grinder ahead of a ball mill, with savings of around 1.8-2.5kWh/t for clinker and 2.5-3.8kWh/t for GBS.[10]

Conclusion

To reduce the clinker factor while still developing concrete strength requirements, the use of slag and pozzolans has proven to be very effective in lowering costs and overall positivity to the environment. ■

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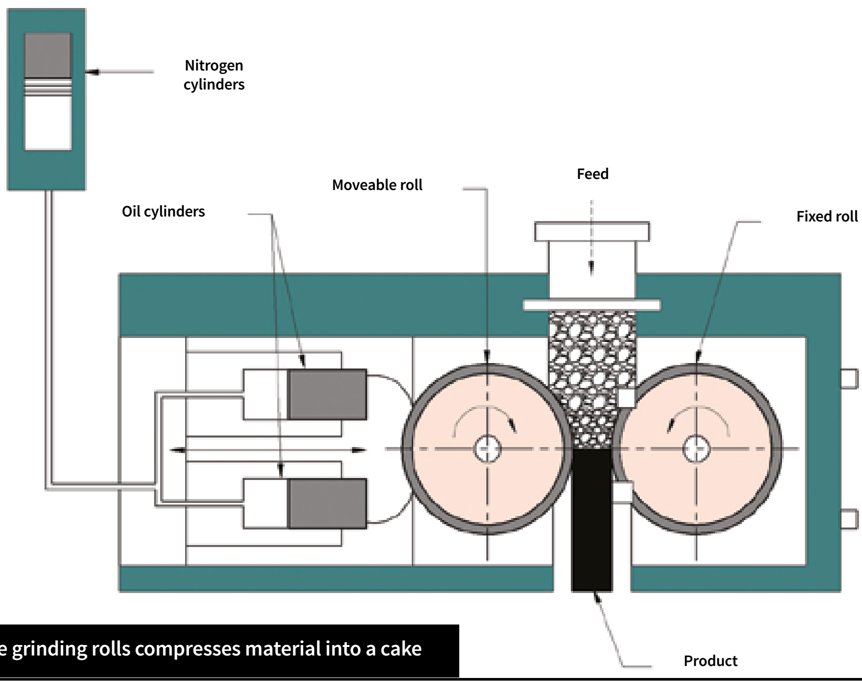

Figure 3: High-pressure grinding rolls compresses material into a cake