Fine Grinding

Mike Sumner and Keith Marsay, Grace, examine ball mill optimisation when grinding aids are used.

Many articles have been published on the use of grinding aids or cement additives to improve cement manufacturing economics by providing increased productivity and profitability. These chemical compounds are routinely used in the production of cement to increase the output and efficiency of the grinding process and to improve the performance, quality and handling of the finished cement.

Their utilisation has been steadily growing, with a significantly faster growth rate in the last 20 years. This has been due to advances in both the technology of cement additives and changes in the economic environment. The introduction of emissions trading for carbon dioxide has also caused a further increase in chemical additive technology application, as it is one of the ways to lower clinker content for constant cement performance, thereby lowering CO_2 emissions per t of cement.

It is clear that the appropriate application of grinding aids is just one of many tools that process engineers have at their disposal to enhance the efficiency of the grinding process. The process mechanisms of grinding aids have been previously described[1] and, rather than focusing on how they lead directly to enhanced grinding efficiency, this article looks at how these mechanisms provide an ability to maximise the outcome of the optimisation of both the circuit operation as well as the grinding media.

Ball mill grinding mechanisms

The action of grinding aids is largely explained by their influence on particle de-agglomeration and coating removal, improved dispersion in the separator with resulting sharper cut and lower bypass, and a reduction in the mill filling level. The latter is important, as in steady-state conditions there exists an optimum powder filling level in the mill relative to the media volume to ensure maximum grinding efficiency (i.e. an optimum steel-to-clinker ratio or retention time). This is widely believed to occur when approximately 85% of the media voidage is filled with material[2] (void filling can simply be defined as the volume of material being ground divided by the volume of void space within the media charge). However, in reality, the optimum circulating load results in a void filling somewhat above this, typically around 110 – 120%, as both higher total mill throughput (feed and rejects) and smaller grinding media sizes (specifically in chamber 2) result in an increase in void filling.

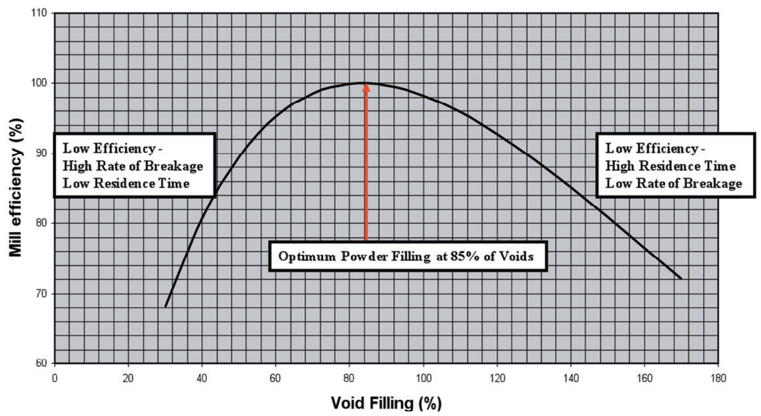

Figure 1. Influence of powder filling on mill efficiency.

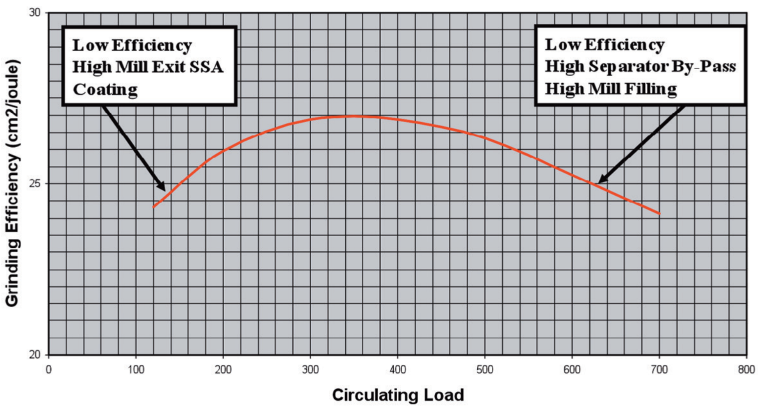

Figure 2. Influence of circulating load on grinding efficiency - example.

Circulating load optimisation

For any closed circuit ball mill system there is an optimum circulating load for maximum output and minimum kWh/t. Increasing circulating load is desirable as a means to reduce the in-mill fineness and thus reduce negative influences of fine particle agglomeration. However, the increase in total mill throughput has negative consequences of increased separator loading and, therefore, reduced separator efficiency, increased mill filling and, thus, reduced grinding efficiency (when above the optimum 85% of void filling). This optimum level needs to be established by experimentation for a given circuit and depends on a number of parameters, including: the mill diameter; separator efficiency; media sizes; chamber 1 performance; grinding aid, and mill ventilation airflow. The latter two are important and need to be considered together, as both are an important means to remove fines from the mill and avoid over-grinding. Mill ventilation is also important for mill cooling and dew-point temperature control.

The use of a grinding aid provides an increase in grinding efficiency due to its benefits of improved separation and reduced void filling. Furthermore, as a consequence of these mechanisms, the additive also creates an improved environment for the circuit optimisation. In simple terms, the additive allows the separator and the mill to function at a higher total throughput for the same efficiency and provides scope to further optimise the circuit at a higher circulating load.

The example in Table 1 summarises a series of tests made on an FLSmidth mill with a third generation Sepax separator and the use of small media in chamber 2 (i.e. 15 – 30 mm, mean size of 20 mm). In condition 1, the optimum circulating load was restricted by a high void filling, and forcing the circulating load (condition 2) to a higher level was not able to generate benefits. Condition 3 concerned the application of a traditional grinding aid at the existing optimum low circulating load, where the benefits of the additive were relatively moderate (6% gain). However the use of the additive created a new set of mill conditions, with reduced mill void filling, improved separator efficiency and reduced coating. This then provided an improved set of conditions more suited to achieve the benefits of a higher circulating load and the application of an additive (condition 4). Therefore, the application of the additive combined with the re-establishing of the optimum circulating load enabled a more substantial overall benefit: 15% in this case.

Chamber 2 media optimisation

Much has been reported concerning optimum media sizes and media grading for cement grinding in ball mills. One of the consistent conclusions has been that smaller media sizes are beneficial to the efficiency in the fine particle size range in cement grinding. In typical ball mill circuits the second chamber will benefit from a reduction in mean size, so long as a number of preconditions are met:

- Adequate chamber 1 material preparation (target 95% passing 1 mm).
- Not excessive coating of mill internals.
- Not excessive chamber 2 material filling (i.e. not a high void filling).

The studies of media size for optimum breakage were largely pioneered by Austin & Co. in the 1970s and 1980s. It is apparent that once particles are below 1 mm, larger ball sizes (i.e. above 25 mm) no longer provide the highest rate of breakage. Figure 3 is a summary of similar studies made in the former Blue Circle Research Division. For cement grinding, it means that once feed materials have been reduced in size to below 1 mm, small media of 15 – 25 mm are most appropriate as a means to increase grinding efficiency. So with good first chamber operation, the second chamber can be charged with small media to provide higher grinding efficiency.

In approximate terms, a reduction in mean size from 25 mm to 15 mm would be expected to provide a 20% increase in grinding efficiency. However, this assumes all other important parameters are constant. Unfortunately, in reality, this is not true, as the use of smaller media results in a significant increase in the total number of grinding elements (balls) and this in turn creates a higher resistance to material flow, resulting in a higher material filling level in the mill (higher void filling). If the void filling is above the optimum of 85%, then the grinding efficiency will reduce. This loss of efficiency is exacerbated if the media has a significant coating. During the previously mentioned work at the former Blue Circle Research Division, the influence of mean ball size (chamber 2) on void filling was also studied. For the reduction in mean ball size from 25 mm to 15 mm, the void filling increases in the range of 10 – 20%, with an associated reduction in grinding efficiency of some 5 – 7%. Hence, the net effect of the application of smaller media is compromised. In addition, if the media is heavily coated or if coarser material to be ground is present, then the efficiency of the smaller media is further reduced.

These factors often explain why the application of smaller media is not always able to demonstrate the expected improvements in grinding efficiency and the associated benefits in output and specific power consumption.

Fortunately, the application of a suitable grinding aid provides lower void filling and a reduction in agglomeration, with consequent reduced level of media coating. Thus, the success in applying smaller media sizes in the second chamber is greatly assisted by the use of a grinding aid.

Table 1. Tests made on an FLSmidth mill with a third generation Sepax separator and the use of small media in chamber 2

	Mill condition	Tph	Mill kW	kWh/t	C load (%)	Additive
1	Optimised circulating load	95	2950	31.1	150	None
2	High circulating load	94	2900	30.9	250	None
3	Grinding aid	100	2980	29.8	150	Grinding aid
4	Optimised circulating load	109	2950	27.1	250	Grinding aid

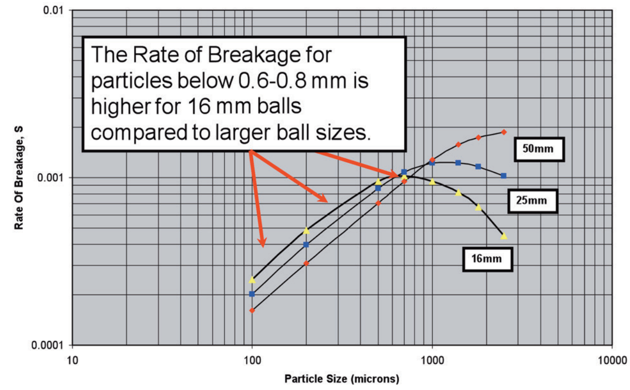

Figure 3. Relationship between particle size and breakage rate for ball sizes.

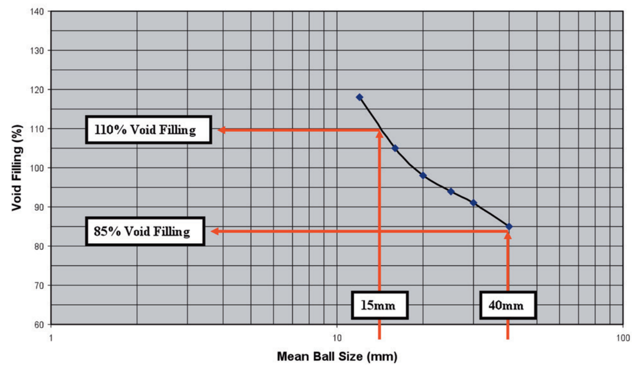

Figure 4. Influence of ball size on void filling.

Summary

The optimisation of cement ball mills requires careful attention to the many parameters involved and this includes the optimum circulating load and the application of smaller media in the fine grinding zone (typically chamber 2). The application of appropriate grinding aids or cement additives themselves can also provide significant benefits to process efficiency. However, it is evident from the mechanisms involved that these areas require a simultaneous optimisation approach if the maximum benefits of each are to be fully realised.

References

1. SUMNER, M. S., 'Modern Grinding Additive Technology', *International Cement Review* (November, 1993), pp. 72 – 73.
2. SHOJI, K., AUSTIN, L.G., SMAILA, F., BRAME, K. and LUCKIE, P.T., 'Further studies of ball and powder filling effects in ball milling', *Powder Technology 31* (1982), pp. 121 – 126.