ICR article draft
What's inside counts

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Ball mills require frequent attention in terms of their wear parts. The appropriate selection of mill internals not only protects the mill shell, saving on costly repairs, but in some cases, improves mill performance.

Ball mill internals can play a key role in a preventative maintenance programme. Crucially, mill internals protect the mill shell. Furthermore, mill lining plates are subject to wear which in turn can lead to adverse operating conditions. For example, one of the most abrasive processes that the mill has to endure is the processing of fresh feed. If the mill is filled with too low a ball charge or the mill is run without sufficient feed, wear will occur quickly.

Manufacturers of mill internals focus on installing the right equipment in the right place at the right time to improve mill performance. They also aim to provide quality equipment with an acceptable lifetime to the cement producer. Therefore, providing protection to the mill is a subtle compromise between replacing the internals at the right time and choosing the right or best-available equipment.

Protection or performance?

Return on investment (ROI) and payback are a key part of evaluating the replacement of equipment. But first, a distinction must be made between equipment that improves the grinding process and that which solely protects.

While internal mill parts such as feed end liners, drying chamber lifting plates, transfer diaphragms between the drying and grinding chambers, central discharge diaphragms for raw material double-rotator mills and outlet diaphragms (see Figure 1) are all important, they do not improve mill performance significantly. However, the correct type of lining, intermediate diaphragm and grinding media can offer performance gains.

Mill linings

First chamber

In a typical two-chamber ball mill (see Figure 1), the first chamber crushes material to prepare it for the second or finishing chamber. Generally, a maximum of five per cent of rejects on a 3mm sieve is good enough to be processed in the second chamber. To achieve this, between 8-12kWh/t of specific power consumption is required. A good lining of the first chamber is essential in achieving this objective as it helps to improve the lifting effect of the ball charge.

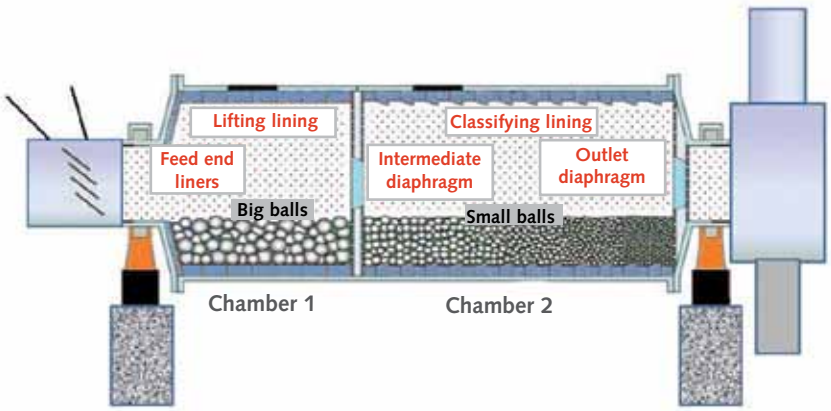

Figure 1: a typical two-chamber ball mill

With a sufficient lifting effect, the impact of the ball as it falls will be powerful enough to break the large material. However, the balls should not be raised too much to avoid wear and breakage. The dead zone (ie, the area where grinding media barely moves), is also reduced with an adequate lining. Figure 2 shows the areas of movement of the media.

There are many types of lifting linings including the step lining (see Figure 3), which is probably the most common.

The second chamber

The second or finishing chamber of a ball mill requires a classifying lining (see Figure 4) in the majority of cases if there is to be a gain in grinding efficiency. One of the most-often used lining types, classifying linings are designed to help the largest grinding media remain at the entrance of the second chamber. This enables coarse material to be subjected to higher impact forces than friction or attrition work.

At the end of the second chamber, the material is much finer when it arrives at the base of the outlet diaphragm. This means that more of the material is flowing through the compartment. It, therefore, needs attrition to produce the final product rather than the impact forces that are required in the earlier parts of the mill. The classifying lining is used to 'grade' the balls from large, at the inlet, to small, at

Figure 2: movement of the balls in the mill

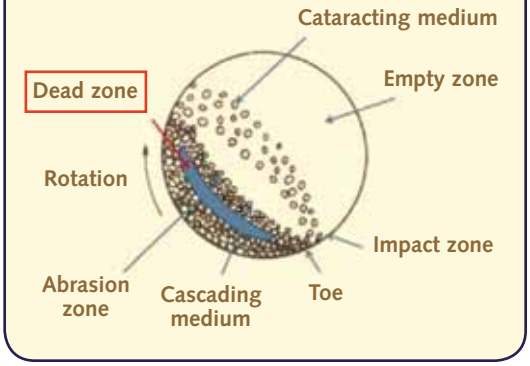

Figure 3: ball mill step lining

Figure 4: classifying liner

the outlet in the second chamber.

The benefits of classifying linings have been shown in laboratory tests. In these tests, it was found beneficial to grind the fine material with a single dimension of media rather than a mixture of sizes. Smaller media sizes improved mill performance and the production of fine cement particles.

The installation of a classifying lining in the second chamber can result in a performance improvement of up to 10 per cent. Such a lining will be only fully effective where the composition of ball sizes has a large range, ie 15-60mm.

In single-chamber mills, following a semi-finished pregrinding system, a classifying lining is often not necessary.

Intermediate diaphragms

Intermediate diaphragms are mechanical units that separate the various chambers of a mill and prevent the passage of grinding media from one chamber to the other. While single and double diaphragms exists, the flow control diaphragm (FCD) merits particular attention in terms of improving mill performance. The FCD adjusts the level of material of the first chamber.

The lack of material is a recurrent issue in the first chamber (see Figure 5). This is caused by high ventilation or a very coarse ball charge. Laboratory tests have shown that the optimum efficiency is achieved when the ratio weight of material/weight of balls is around 18 per cent, ie the material comes to rest at a level on top of the balls (see Figure 6). There exists three types of FCDs, with three kinds of control devices as shown in Figure 7:

- adjustable ring
- adjustable scoops
- adjustable lifters.

FCDs can deliver up to five per cent additional grinding efficiency.

Grinding media

While grinding media are not exactly a mill internal, they are important in the grinding process. The composition of the ball charge depends on various factors such as:

- mill diameter
- mill length
- ratio length/diameter

Table 1: mill internals and their potential performance improvement

Internals list	*Type*	*Subtype*	*Location*	*Protective function*	*Process function*	*Process improvement*	*Production increase (%)*	*Energy savings (%)*
Feed end liners	-	-	Mill entrance	Yes	No	No	-	-
Linings	Plates with lifter	-	Drying chamber	Yes	Yes	No		
	Lifting linings	-	Chamber 1	Yes	Yes	Yes	0-5	0-5
	Lifting-classifying linings	-	Monochamber	Yes	Yes	±		
	Classifying linings	-	Chamber 2	Yes	Yes	Yes	0-10	0-10
	Non-classifying linings	-	Chamber 2	Yes	Yes	±		
Diaphragms	Transfer diaphragms		Drying chamber	±	No	No		
	Intermediate diaphragms	Single	Chamber 1-2	No	No	No		
		Double	Chamber 1-2	No	No	No		
		Flow control	Chamber 1-2	No	Yes	Yes	0-5	0-5
	Central discharge diaphragms		Chamber 1-2	No	No	No		
	Outlet diaphragms		Mill outlet	No	No	No		
Grinding media	Big balls	-	Chamber 1	No	Yes	Yes	0-12	0-15
	Small balls	-	Chamber 2	No	Yes	Yes		
	Cylpebs (Boulpebs)	-	Chamber 2	No	Yes	±		
	(Filling degree)	-						

- mill speed
- types of linings
- mill circuit
- type of separator
- grindability of the fresh feed
- moisture content
- granulometry of the fresh feed
- hardness of the fresh feed
- product fineness.

The study of the composition of the ball charge is probably one of the most complex exercises for a comminution expert: each case is different and the empirical side remains important.

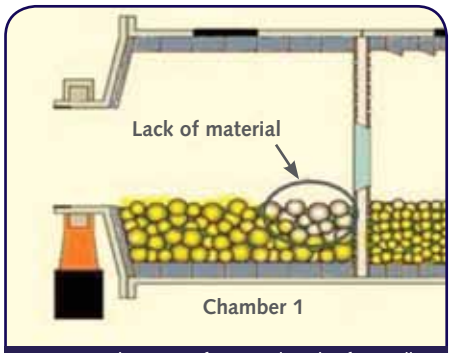

Figure 5: a shortage of material in the first mill chamber causes excessive wear on mill internals

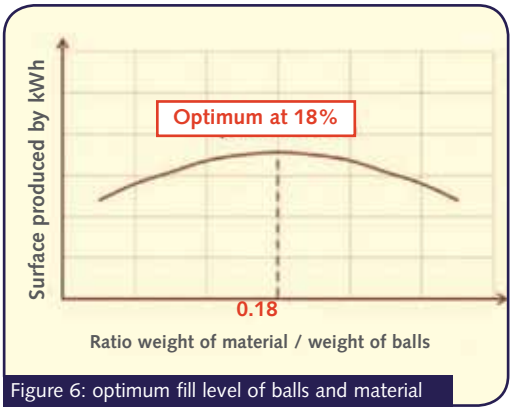

Figure 6: optimum fill level of balls and material

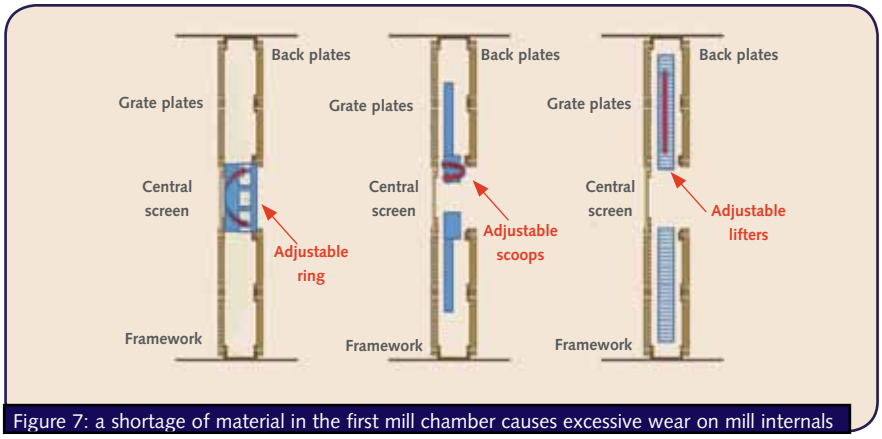

Figure 7: a shortage of material in the first mill chamber causes excessive wear on mill internals

Efficient running

Mill internals play a key part in keeping grinding equipment running efficiently and some internals can actively contribute to improving mill performance. Table 1 summarises the potential performance improvements. The ROI of installing suitable mill internals can be relatively fast. It is estimated that the limit payback is more or less two years.