AA04 - Bauxite Particle Size Requirements for the Bayer Process: Back to Basics

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Abstract

This paper examines the bauxite particle size requirements for the Bayer Process. A closed circuit Semi-Autogenous Grinding (SAG) mill with a hydrocyclone is considered to be the most suitable for a high bauxite throughput operation. SAG Mills do more than just grind, they tumble, separate, and size classify the feed through multiple size reduction steps (grate, trommel and hydrocyclone). The small aspect ratio (L/D ~ 0.5) and use of pulp lifters allows for the immediate removal of up to 35 % of the fine solids (< 2 mm) from the crushed feed. Lateritic bauxites are usually classified as soft, using the drop weight test hardness criteria (> 150), and have an exceptionally low specific energy (< 5 kWh/t) and explains the short residence time inside the mill. In the mill abrasion, attrition and chipping of the larger and harder bauxite particles takes place. Eventual breakage of these particles allows their removal. Very small differences in bauxite hardness or density, mainly through variability in the content of iron-containing hard-cap, can lead to an increased recirculating load. This also leads to a longer residence time, with the possibility of a build-up of a critical size inside the mill. When a new bauxite stockpile is reclaimed any small difference in size or hardness will impact on the established steady state grinding conditions. The shrinking core digestion model for aluminous particles in liquor is controlled by particle size, temperature, holding time, alumina and caustic concentrations. Alumina losses are usually found in the coarser size fractions and for this reason a finer grind will always achieve a higher extraction. The size distribution of the milled bauxite therefore becomes an important parameter and can influence the bauxite usage factor. Monitoring, care and maintenance of: crusher gaps, ball charge management, grate hole and mill liner wear, screen and trommel wear, hydrocyclone wear will all contribute towards improved particle size control.

Keywords: Ma'aden, crusher, mill, SAG, hydrocyclone.

1. Introduction

Alumina production is a high-tonnage, low-profit margin operation where alumina must be produced as cost effectively as possible. Milling targets a high tonnage throughput to produce a product with a particle size appropriate for the Bayer process. When necessary digestion temperatures and liquor characteristics can be adjusted to maximise dissolution of coarser particles. In a refinery the Alumina production is paramount and high liquor flow rates are critical for maximum productivity. This primary consideration may be at the expense of a reduced alumina extraction from the bauxite. Optimal particle sizes are also necessary for: pumpability, to avoid settling in pipes and tanks, and for high desilication and digestion rates.

The mill-types and configurations used for bauxite are usually limited to those detailed in Table 1, the choice of mill, size and number of mills will be based on experience, cost and

recommendations of the design engineers. High Pressure Grinding Rolls (HPGR) is rarely considered as lateritic bauxites are too soft to warrant this technology. Only for hard diasporitic bauxite, where digestion feed sizes of P80 -75 µm are required would it ever be considered. Rod and ball mills can readily handle bauxite on account of its very soft nature. However, it is the tonnage throughput and the product size that are the two critical factors that must be met in assessing the optimal mill design. Despite the simplicity of open circuit rod mills, the operation of numerous small mills has now become antiquated. Likewise, the 2-compartment combination mill is also considered outdated. For rod mills they constantly requires stoppage so that more rods can be recharged and tangled, and broken rods removed. More recently these mill options have been replaced by larger SAG mills that can treat a larger feed size and allows a higher tonnage throughput and requires reduced maintenance.

2. Mine-to-Digestion

Bauxite can be found in a number of different physical forms including: pisolitic, friable and hardcap. Each bauxite will have its own distinctive crushing and milling characteristics. Bauxite can be highly variable through the mine pit profile, both vertically and horizontally. Often large blocks from blasted or ripped bauxite can be upto 1–2 m^3 in size, and while present in only a small volume the process flow path must still consider these and be capable of crushing them to a suitable size for materials handling purposes, and to avoid damage to the conveyor belts. Improved blasting may be necessary if there are too many large blocks of hardcap. Crushing is achieved by a combination of steps that may include jaw crusher, sizer, rolls and hammer crushers. Open circuit and closed-circuit crushing circuits are operated, as well as multi-step crushing routes which are possibly used more often to maximise tonnage throughput. Crushing initially reduces the bauxite to a size that the mill can handle, and then the mill delivers a product size suitable for the refinery feed.

Milling of the crushed bauxite product (Table 2) takes place in caustic spent liquor at temperatures of ~ 75 °C and delivers a slurry for desilication and digestion. Bauxite is considered to be “soft” when using the drop-weight-test hardess criteria (~ 150) and is far softer than most other ores [1]. For this reason, bauxite has a low specific energy (< 5 kWh/t) and should have a short residence time inside a mill. A high open area on the mill grates allows the fine particles of bauxite to move as a slurry and immediately exit through the mill grate and mill trommel. The SAG mill with an installed pulp lifter is designed to promote rapid tonnage throughput. The larger and harder particles are retained and have a longer residence time in the mill requiring increased breakage before fully exiting through the mill grate. Modern SAG mills are considered to be the modern process route for bauxite processing and have minimal down time. The installation of a pulp lifter at the rear of the SAG mill are recommended for bauxite processing. This unit may consume over < 50 cm of the width of the mill yet justifies its installation as it enhances the ability of the mill to flush and pump out the finer size fractions (~ 35 % < 2 mm) in the rejected slurry and allows milling to focus on the larger and harder particles retained in the belly of the mill.

5. Conclusions

In the Bayer process the milled bauxite must be of a size appropriate for desilication and digestion purposes. Finer particles in digestion will always be preferable as the individual particles will dissolve and shrink more rapidly and release alumina into the liquor. This will help the rapid achievement of the target ratio and require a shorter residence time. Other process benefits of finer grinding include reduced abrasion / erosion in: pumps, valves, pipes and flash tanks. For coarsely ground bauxite the digestion temperature, TC, liquor ratio (A/C) and holding time become controlling parameters in digestion control. Alumina losses will occur in the coarser size fractions due to incomplete digestion. In a gibbsite-boehmite containing bauxite the coarser boehmite grains will always be the dominant alumina loss to the waste mud. Mine-to-Digestion studies where size reduction of the bauxite on its journey from blasting through to crushing, milling, desilication and to digestion will help identify and prioritise incremental improvement steps and help deliver a reduced particle size.

A coarse grind can be resorted to when quartz is present in the bauxite, this is to avoid wastage of energy during grinding and generation of reactive ultrafine quartz particles (<10 microns). Coarse quartz can be recovered after digestion using sand traps, rakes, screens and hydrocyclone washing circuits. For these reasons coarse milling can be tolerated as long as the refinery is initially designed around such bauxite feed characteristics.

Close circuit SAG mills are now considered to be the most suitable mill for processing soft bauxites and can handle a range of particle feed sizes and hardnesses. The small aspect ratio (L/D ~ 0.5) and the use of pulp lifters allows a rapid flushing out and separation of the finer particles (< 2 mm) from the crushed product, allowing grinding to focus on the remaining coarser and harder particles. SAG mills treating bauxite are often operated like ball mills, mainly on account of the soft nature of the bauxite and size of the crushed feed (< 10 cm). The actual sizes and number of mills used to deliver a selected particle size can be estimated using conventional bond ball calculators and JKSimMet modelling. Mill models can predict the size distribution of the mill product with reasonable accuracy.

Incremental improvements can also come from maintenance of key equipment which effects particle size, notably: lifter bar wear, grate hole wear, trommel wear, hydrocyclone and screen wear. Routine grind outs will also ensure the removal of larger hard and dense bauxite particles in the mill and also reduce any build up of the circulating load.

6. References

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