Light Metals 2013 *Edited by: Barry Sadler*
TMS (The Minerals, Metals & Materials Society), 2013

THE PROCESSING OF HIGH QUARTZ BAUXITE

Edgar Gasafi[1], Alessio Scarsella[1], Vladimir Hartman[1], Hans. W. Schmidt[1]

1 Outotec GmbH, Ludwig-Erhard-Strasse 21, 61440 Oberursel, Germany

Keywords: "Alumina Refinery, Bayer Process, Bauxite, Quartz, Sand"

Abstract

Low-grade bauxite refers to bauxite that is high in silica, which is present as kaolin, or quartz, and therefore requires different approaches for processing. With digestion of gibbsitic bauxites the quartz would remain largely undissolved. The nature and hardness of Quartz with respect to other minerals in bauxite will suggest that coarse size fractions will have high quartz content. Whilst designing an alumina refinery designers need to pay special attention to high quartz content slurries as they are abrasive, in addition the non-homogeneity of the resultant mud will mean that the quartz rich particles will settle faster causing segregation within settlers and washers resulting in poor operation. Two options were considered to deal with high quartz bauxite, upstream physical separation during the beneficiation process, or physical separation post bauxite digestion. This paper seeks to explore design and operational considerations whilst designing a greenfield refinery for high quartz content bauxite.

Introduction

Knowledge of vast bauxite resources in Indonesia has been known since the late 1940's (1), since then Indonesian bauxite exploration and exportation industry has arguably become one of the most important sources of bauxite in South East Asia supplying feedstock to a number of refineries in China. The highly publicised mining laws being introduced has meant that many of the bauxite mining and export licence holders have had to consider the next step in the integrated chain aluminium – alumina refining.

High levels of quartz can result in major operational problems in alumina refining

- Quartz attack in digestion resulting in increased alumina and caustic losses (predominant at beohmitic digestion temperatures)
- Segregation between the quartz and mud in mud separation and mud washing stages, resulting in unstable underflow densities and poor wash efficiencies
- Quartz in a moving slurry is abraisive by nature resulting in increased wear around particular fittings such as tees and valves.

Two main pathways deal with the processing of high quartz bauxite. The first of these methods is to soley rely on upstream beneficiation at the bauxite mine where the quartz is physically separated by classifiying and rejecting ore below a given cut (2), (3). This method can marginally enrich the available alumina whilst also reducing total silica also but adds to the associated bauxite mining costs as the run of mine significantly increases and the reject bauxite needs to be disposed of.

The second pathway is to seek a compromise between beneficiation and downstream processing. The most advantageous way of doing this is separating quartz physically from mud after the bauxite has been depleted of alumina bearing material.

This paper seeks to highlight some of the characteristics in the design process associated with the downstream separation of quartz from mud.

The Bayer Process

The Bayer process is a highly integrated process involving grinding, digestion, clarification, precipitation and calcination. Initially ground bauxite is dissolved (digested) at an elevated temperature in a concentrated caustic. In a following separation step the other components of the bauxite which do not digest are separated by a thickening and security filtration step, subsequently washed and then stored as red mud. The alumina rich solution is cooled and aluminium tri-hydrate is precipitated from the solution. The now alumina depleted caustic solution undergoes evaporation thus increasing the caustic concentration and recycled back to digestion, thus closing the '*Bayer Wheel*'. The aluminium tri-hydrate is filtered, washed and finally thermally treated resulting in calcined aluminium oxide as product (Figure 1).

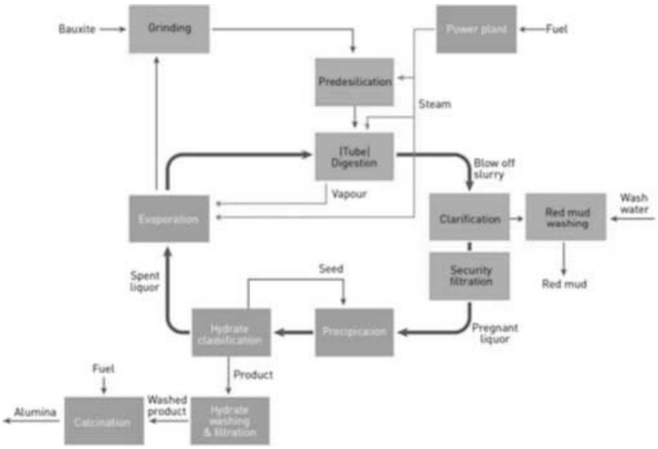

Figure 1: The Bayer Wheel

Bauxite Specification

Bauxite from four sites was characterised with the intention to refine. Illustrated in Figure 2 is the composition of four different bauxite samples taken from four different sites inIndonesia. The results show the unusally high total silica between 20 to 30% and low to moderate levels of reactive silica between 2 to 4 %.

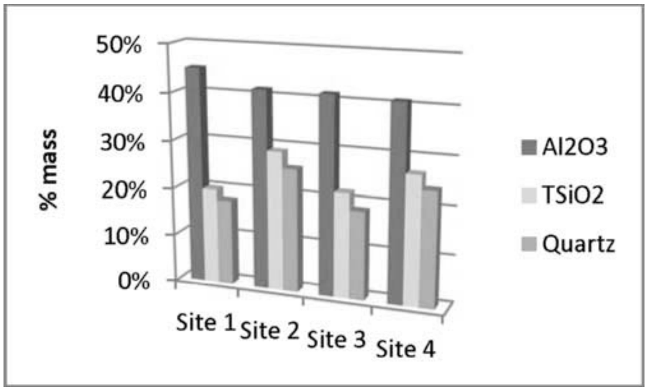

Figure 2: Bauxite composition

Laboratory tests revealed that the majority of the available alumina is gibbsitic, and that the majority of the tri hydrate alumina could be extracted at tempreatures associated with low temperature digestion (135 – 150° C). The associated soda losses correlated with alumino silicate formation due to the reactive silica, implied that the quartz remained largely inert.

Characteristics of mud from digested bauxite

A pre-defined blend of the above bauxites (Figure 2) was subjected to a pre-desilication and digestion bomb test, with the following three analyses performed:

- XRF of the oxide constituents of the mud at given sieve intervals
- Wet composition analysis of mud with the aim to determine the quartz content
- Segregation characteristics of the resultant mud under typical Bayer settler conditions

The results of the chemical make up of the mud versus sieve size are illustrated in Figure 3. The majority of aluminium, iron and titanium is restricted to the 19 μm size bin. The silica bearing materials are highly distributed in the larger size bins (=> 178 μm) which can be associated to quartz. Relatively high quantities of silica are also present in the sub 19 μm size bin, this possibly can be attributed to formation sodium alumina silicate during the pre-desilication process. Similarly in Figure 4, the total silica and quartz distributions are compared showing that 90% of the quartz in the mud is distributed above the 72 μm region.

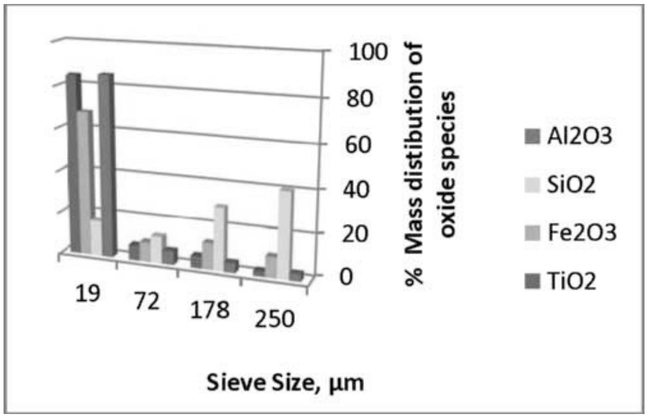

Figure 3: Oxide versus sieve size in a resultant mud from blended bauxite.

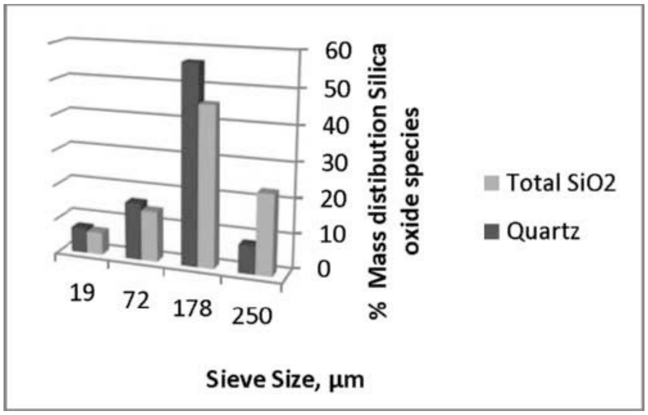

Figure 4: Total silica and quartz versus sieve size in resultant mud from a blended bauxite.

The resultant mud from the pre-desilication followed by bomb testwork was diluted with a synthetic makeup of washer overflow so as to simulate settler conditions in the Bayer process. The Bayer solution of liquor and mud was left to settle for 30 seconds exactly without the addition of flocculant in order to observe the characteristics of segregation. Figure 5 and Figure 6 represent the particle size distributions of the suspended mud slurry before and after the segregation test, which clearly show the distinct change in distribution.

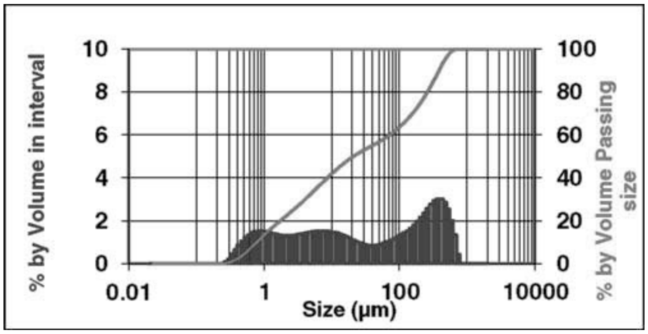

Figure 5: Particle size distribution of mud before decantation

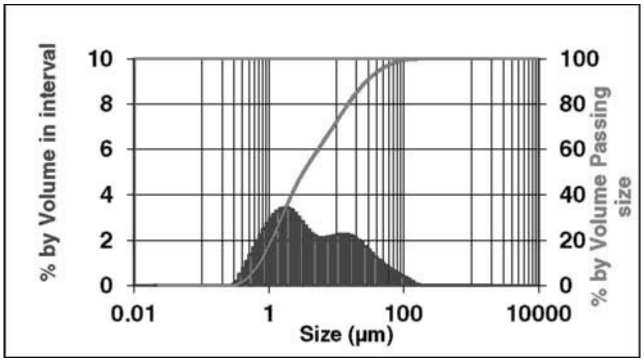

Figure 6: Particle size distribution of mud after decantation

Table 1 is the direct comparison of the size distributions, further highlighting segregation of the non-homogeneous nature of the solid phase.

Table 1: D_{10}, D_{50} and D_{90} of mud before and after decantation

Size, µm	Before	After
D_{10}	0,8	0,7
D_{50}	21,1	3,2
D_{90}	387,1	27,5

Development of continuous quartz separation process

The above results demonstrate the non homogeneous nature of resultant mud from the investigated bauxite, and the dependence of the quartz content as a function of sieve size. These characteristics and the bench scale segregation test results as illustrated in Figure 5 and Figure 6 show how difficult it would be to effective perform conventional mud separation and mud washing as normally used in the Bayer process.
In order to effectively process such a mud and caustic recovery industrial partitioning of the mud post digestion and prior to mud separation and washing is required.

Figure 7 is an example of such a process. Normally mud from blow off slurry is thickened via settlers and counter currently washed with water through a number of washers placed in series. Processing a mud from a high quartz bauxite requires a dedicated intermediate process between digestion and mud separation. The partitioning of quartz from the mud is best done via batteries of hydrocyclones, where the fine and now quartz depleted mud in the cyclone overflow is then processed conventionally through a counter current washer train.

The coarse quartz underflow slurry is counter currently washed through a series of three mechanical classifiers in order to recover caustic and alumina so as it can be re-introduced back into the Bayer circuit. The classifiers can either be rake or spiral. Other refineries which process high quartz bauxite also use a similar approach (4).

This option is preferred to a dedicated counter current decantation circuit with wash water due to the fact that further partitioning between the coarse and fine material can occur, and due to the reduced capital requirements. The drawback of the selection of rake classifiers over dedicated washers is they do not yield the high wash efficiency that washers may have through modern feedwell or static mixing design (5).

The washed and separated sand is either sent for disposal or commercial sale (subject to local market conditions). The separated sand can be used in the construction industry, reuse options include the manufacturing of bricks, the utilization as road base, fill material, embankment, the production of geopolymers or the utilization as concrete aggregates (6).

An alternative design is the use of static mixers (either dedicated vessels or in line mixers) as the quartz is being separated from one mechanical classifier to the next, this ensures improved wash efficiencies.

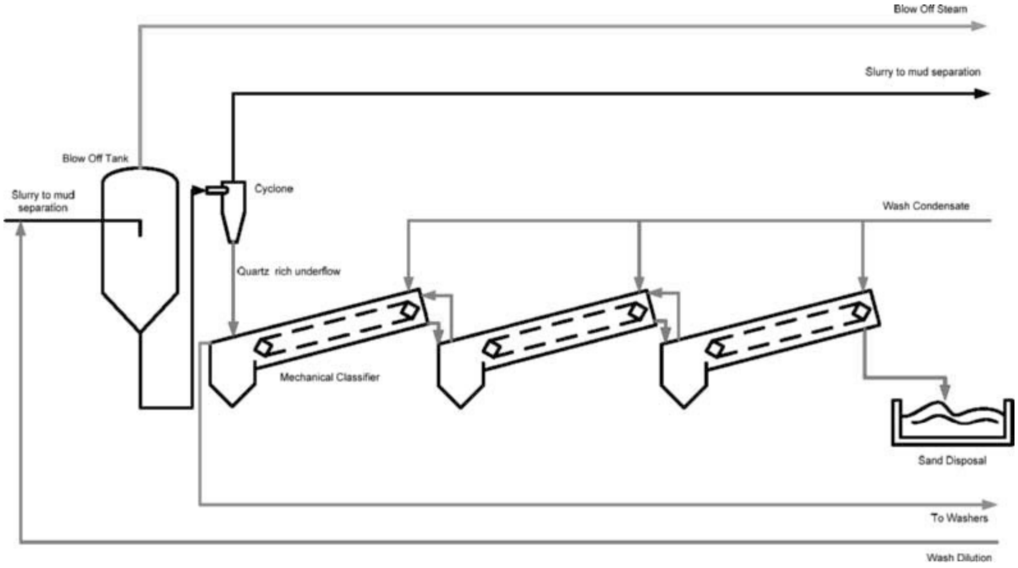

Figure 7: Process flowsheet of a post digestion three stage quartz removal from a Bayer mud

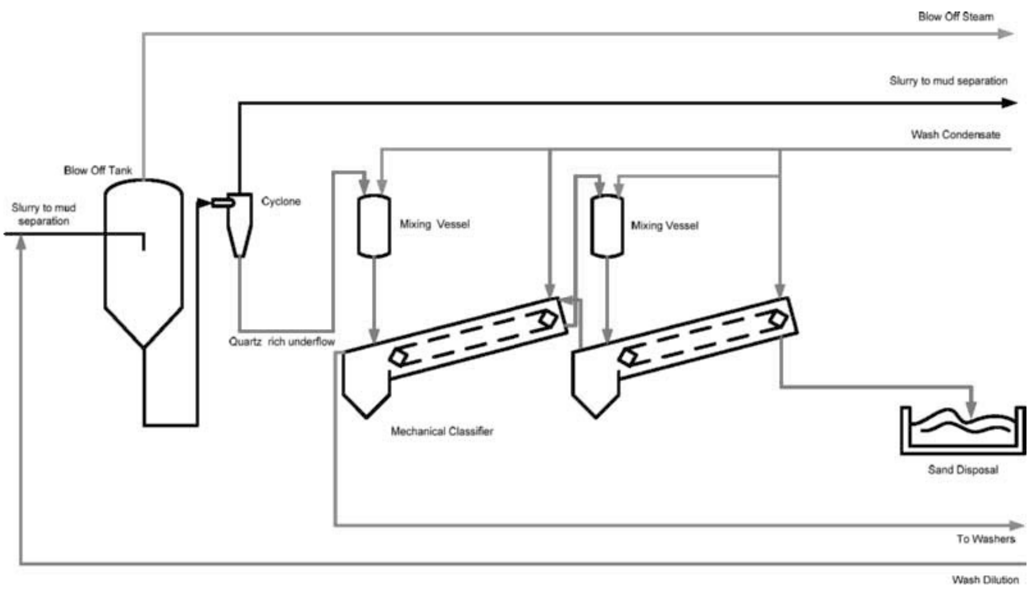

Figure 8: Process flowsheet of a post digestion quartz two stage removal from a Bayer mud with mixing vessels

Due to the '*step wise*' orientated partition curve associated with mechanical classifiers and the addition of static mixers the new flowsheet can allow for a reduction in mechanical classifiers from three to two resulting in a 15 % reduction in capital expenditure for the quartz separation plant. Such a flowsheet is illustrated in Figure 8.

Generic Design and Decision Making Process for application of quartz removal plant in an alumina refinery

From the above paragraphs one can deduce a simple selection and design methodology which is highlighted in Figure 9. XRF, XRD and wet chemical analysis determine the bauxite head assay, which will in turn the quartz content. It is then at the discretion of the design engineers to deem whether the bauxite is a high quartz or not and whether a conventional Bayer process without a dedicated separation plant is needed. This sort of decision is not to be taken likely and requires many years of operating experience. If the bauxite is deemed high in quartz, then appropriate pre-desilication followed by digestion bomb tests should take place followed by a sieve size composition analysis of the mud. Process engineers actually designing the Bayer process should have developed a completely integrated model in parallel with a stand alone particle balance model of the quartz separation plant only.

The inputs of the plant model shall feed into the particle balance model together with the sieve composition analysis. Results from the particle balance model can then be re-incorporated into the plant model, so as to correctly define the underflow density of the cyclone battery and that the exact mud compositions and quartz compositions between each mechanical classifier can be calculated. One to two iterations has been found to be sufficient to proceed with the extraction of process information for the next stages of plant design.

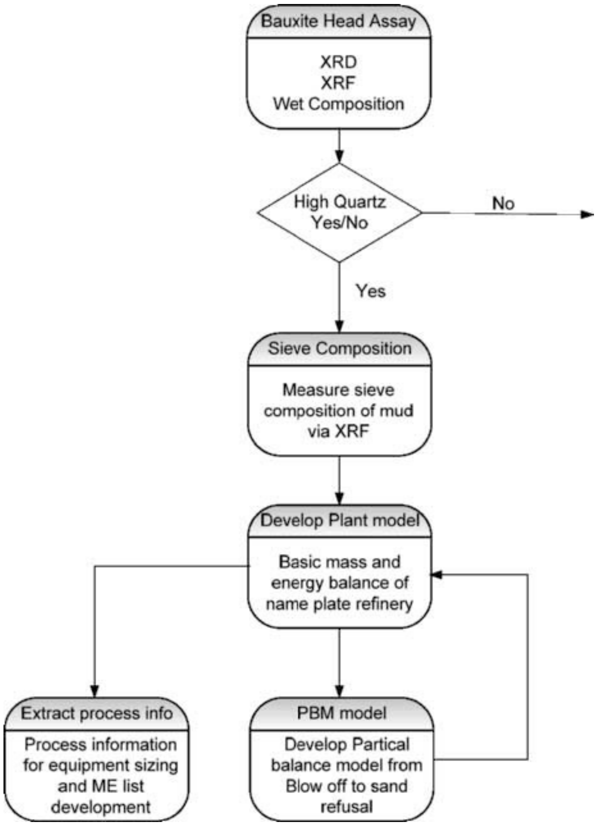

Figure 9: Decision tree for the development of the quartz separation plant

Conclusion

The investigated bauxite is extremely high in silica, however the gibbsitic nature of the available alumina and the high quartz content means that it can be used as suitable feedstock for the production of smelter grade alumina. Use of the conventional Bayer process is not well suited and would constitute major operational and possibly even maintenance problems in mud separation and washing. Upstream beneficiation can help alleviate some of these problems but will not eradicate them without observing huge bauxite mining costs on a per tonne basis. An alternative is to perform post quartz separation from the digested bauxite once the valuable aluminium has been extracted; this requires a dedicated quartz separation and caustic recovery plant.

The above paper describes not only the composition of a high silica high quartz bauxite and its associated mud, but also the fractional composition of the mud versus different sieve sizes. The noted difficulties and operating an alumina refinery with high levels of quartz are known, however by exploiting the specific characteristics of the mud a flow sheet can be developed to remove large quantities of the quartz.

References

1. *The Geology of Indondesia.* Van Bemmelen, R.S. 1949, Economic Geology, S. 265.

2. *Beneficiation of high Quartz content Bauxite from Los Pijiguaos.* Rousseaux, J., Verschuur, H., Flores, P., Buntenbach, S., Donhauser, F. 2006, Light Metals, S. 47-52.

3. *The Processing of High Silica Bauxites - Review of Existing Operations and Potential Processes.* Smith, P. 2009, Hydrometallurgy, S. 162-176.

4. *Potential Improvements of Bauxite Atmospheric Digestion Circuit.* Suss A., Ivanushkin N., Paromova I., Lapin A., Panov A., Gabrielian T., Snurnitzyna S., Martynyuk T. s.l. : Light Metals, TMS, 2008.

5. *Feedwell Design for Alumina Thickeners and Clarifiers – where to next?* Henriksson, B., Scarsella, A., Missalla., M. Goa : ICSOBA, I nternational Seminar on Bauxite Residue, 2011.

6. Jitsangiam, P. *Performance, evaluation, and enhancement of red sand for road bases, embankments, and seawall fills. Phd thesis.* s.l. : Curtin University of Technology., 2007.