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THE PRACTICE OF BAUXITE ORES PROCESSING

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ABSTRACT

Bauxite beneficiation is seldom done outside Brazil. In industrial scale, the ROM ore is fed directly to the alumina production plant. In Brazil, there is tradition and culture in doing it. MRN treats bauxite through scrubbing and desliming, while MSL uses a dense-medium separation (dinawhirlpool – DWP) circuit. CBA, in Itamarati de Minas, treats it by scrubbing and desliming, plus a heavy minerals separation in spiral concentrators complemented by high intensity magnetic separation. At Poços de Caldas, CBA also does optical sorting, and Mineração Rio Pomba, at Mercês, MG, uses jigs to separate coarse silica.

Reverse froth flotation of the silica present in the fine fraction of gnaissic ores, followed by magnetic separation of the depressed product, is being tested for both CBA's Miraí and Itamarati de Minas plants.

Authors discuss these ores' characteristics and those of their deposits as well as the suitability of the preparation unit operations, their difficulties and limitations, for those ores. This work still describes industrial practice for crushing, size separation in trommels, vibratory screens and cyclones, for gravity separation in jigs and Reichert spirals, complemented by magnetic separation of the light product, plus results from froth flotation testing in bench and pilot plant scale (reverse flotation plus magnetic separation for the depressed product).

KEYWORDS: bauxite, crushing, scrubbing, size separation, densitary separation, reverse froth flotation, magnetic separation.

1. INTRODUCTION

Apparently, bauxite preparation practice only exists in Brazil. In the other producing countries, they feed the richest ores directly to the refinery plant. Depending on the silica / available alumina ratio of the ores, poorer ores can be fed to specially designed refineries. In Brazil, bauxite preparation is a routine:

- Mineração Rio do Norte, in Oriximiná (PA), dresses bauxite via scrubbing, desliming in a complex cyclones circuit, and dewatering in vacuum filters (Reis, 2004);
- Mineração Santa Lucrécia, in Monte Dourado (PA), had a circuit to prepare ceramic grade bauxite via heavy media separation in dwp - dynawhirlpool separators (Sampaio & Neves, 2005);
- Omni Mining, in its Juriti project, is building a plant with 3 crushing stages (one recrusher), scrubbing, 4 screening stages, and 4 cycloning stages;
- Companhia Brasileira de Alumínio (CBA), in Poços de Caldas (MG), uses scrubbing, optical sorting and desliming in cyclones;
- CBA, in Itamarati de Minas, MG, scrubs, screens, deslimes and uses Reichert spirals and magnetic separation to recover bauxite from fines;
- Mineração Rio Pomba, in Mercês (MG), uses jigs to separate the coarse silica;
- CVRD is starting-up a new project at Paragominas (PA) using autogenous grinding and desliming in cyclones.

There is very little published literature about this matter. No preparation plants descriptions were found except Sampaio & Neves, 2005 and Reis, 2004. About bauxite beneficiation via froth flotation, only the following publications were found: Xu, Plitt and Liu, 2004; Bittencourt, 1989 and Bittencourt et al., 1990. Shaffer, 1985, literally writes that *"the intricate milling and mineral dressing techniques common in the base metal industry are not used on bauxite"*.

The Chinese work is about flotation of diasporic ores, not found in Brazil. The Brazilian publications describe research done at the Utah University under Dr. Miller's supervision by Dr. L.R.M. Bittencourt, from Magnesita S.A., Contagem, MG.

In Brazil, there are different bauxite types according to their origin. All of them are the result of the weathering of the mother rock during the ages. Very basically, making no distinction among mother-rocks or weathering processes, we can find "plateau" bauxites and "mountain" bauxites. The first type is the one found at Mineração Rio do Norte, Oriximiná, PA, or at Paragominas, PA. Extense plateau areas provide continuous thick layers of ore.

Mountain ore bodies, like those at the Zona da Mata region, occur at the top of high mountains. There are not extended continuous ore bodies as in the previous case. The properties of the ore change from ore body to ore body as a result of the nature of the mother rock. But also, in each of the ore bodies, there is huge variation from point to point: the intensity of the laterization process also varies with the position inside the ore body. So, in the same body, it varies too, as a consequence of its point position inside it, in the vertical as well as in the horizontal directions.

The variability of the characteristics of the ore is significant and, what is worst, erratic. The knowledge of this fact demands some attitudes from the plant designer:

a - a blending yard to store and homogenize the feed of the plant is necessary. During the formation of the stock for, e.g., 1 week, incremental samples of the incoming feed will be suystematically taken and the metallurgist will be able to know in detail the main characteristics of the feed the plant will receive during the following week.

b - the extreme variations of the feed characteristics must be evaluated, and the plant must be designed to accept all of them. That means the circuit must be designed robust enough to deal as well with the coarsest or the finest, the richest or the poorest feed. The same applies to the changing grades of quartz or of the contaminants.

c - geological evaluation must be as accurate as possible and try to quantify all these variables. Conventional geology is not enough. To do this, a geostatistical treatment of the available geological information, via cluster analysis, is recommended. This method evaluates each one of the core logs in terms of size distribution, available alumina, reactive silica, insoluble silica and iron grades, washing recovery, overburden thickness, bauxite thickness and mining ratio. It compares core log to core log in terms of similarity, considering all the above parameters. The most similar cores are grouped together and a mathematical virtual distance is established among the cores, in a way that the more similar they are, the closer they stay, and the more dissimilar they are, the farther they stay. A system of clusters is established, defining which cores are similar and which ones are different. A quantification of this difference (the distance in the virtual space) is also established leading to the definition of the ore types.

The clusters are characterized and lead the mine planning in order to assure the desired quality of the feed to the plant and to identify the extremes in the ore population.

2. MINERALOGY

Mineralogy varies very widely. In the Zona da Mata ores, which are our main focus, the ore is gibbsite (in Brazil this is the only ore mineral). It brings associated quartz, clay minerals with emphasis to kaolinite, ilmenite and rutile as titanium bearing minerals. Iron is associated to magnetite, hematite and goethite. There are also manganese oxides. The iron oxides are intimately associated to the gibbsite.

3. MINERAL PROCESSING

Metallurgy of aluminium consists of two steps: in the "refinery", a very pure alumina ("Bayer alumina") is prepared and then sent to the "smelter", where it is reduced to metallic aluminium.

The bauxite to be sent to the refinery must fit significant restrictions:

- alumina grade – there must be a minimum grade for economical processing;
- reactive silica grade – the silica contained in clay minerals reacts with sodium hidroxide during refining, increasing its consumption, and forms a complex with alumina, extracting part of it. Therefore, its content must be strictly controlled. The amount of alumina contained in the non clay minerals, that is, in the aluminium ore minerals, is designated as "available alumina";
- zinc and phosphorus are contaminants;
- iron grade - either maximum or minimum are undesirable;
- insoluble silica grade – there must be a minimum grade, under which desilicification becomes problematic; if the grade is too high, the silica dilutes the available alumina, decreasing its grade;
- size distribution – it must not be so coarse as to make chemical reaction difficult, nor must it be so fine as to hinder settling;
- organic carbon content, due to humic acids.

So, the targets of bauxite preparation can be summarized as crushing it to a proper size to liberate clay minerals (and eventually the other gangue minerals), to attrition the surface of the particles to remove clay and limonite particles adhered to it, to screen or classify the particles according to the size segregation of gibbsite or of the gangue minerals, to deslime to take out the finer clay minerals and limonite particles. If necessary, to remove iron, iron and titanium minerals, quartz and other gangue minerals.

We will examine each one of these steps and the unit operations suited to do it.

4. UNIT OPERATIONS

4.1. crushing

Bauxite ores are very sticky and usually bring a high humidity. In the aluminium industry, contrary to current mineral practice, flows are measured in a humid basis. The main problem is to handle such a difficult material.

Wobbler feeders are used to feed the R.O.M. ore to the crushers. In recent days, apron feeders are displacing them.

Impact crushers are the classical equipment for bauxite as well as for coal. They are designed with special features to avoid stalling: movable jaws, reversible motion of the rotor, heated crushing chamber etc. In recent days "sizers" – the name given to the roll crusher derived from the underground mines feeder-breakers – are taking place.

In this equipment, the rolls are built as rings and force the bauxite downwards. There are cleaning bars to remove the ore stuck to the rolls. Reduction relation is about 3:1 so that at least two stages of crushing are necessary.

CVRD, in Paragominas, PA, has innovated in this aspect too. As the ore will be transported by pipelines, it must be under 65# (0.208 mm). As the main gangue minerals are clays, the project decided to comminute all the ore to -65# and to deslime it. This is done by a semi-autogenous mill followed by a ball mill in closed circuit with cyclones and desliming cyclones.

4.2. scrubbing

The crushed ore must be washed to remove the clay adhered to the gibbsite particles. This is done in big drums, with a special system of lever bars, named scrubbers. A classical routine is to do it in a slurry with about 50% solids in weight for periods of no more than 3 minutes.

4.3. size classification

The scrubber may have attached to it a trommel screen where coarser particles are separated as an oversize product from finer particles, as an undersize. As processing engineers, we do not consider such solution a good one, as the rotation speed suited for good scrubbing is not the same suited for good screening. We think that separating the unit operations of scrubbing and screening and doing them in scrubbers and vibratory screens is a better choice.

Depending on the classification size, vibratory circular screens, vibratory rectilinear screens, high frequency screens or cyclones must be used.

For desliming cyclones are the first choice. Due to their inherent lower classification efficiency, a sequence of cyclone classification operations is often needed.

4.4. dewatering

Concentrates dewatering is done via mechanical dewatering when the washed bauxite is coarse (dewatering screens, cyclones) or in thickeners followed by vacuum filters when it is fine. MRN uses table and belt filters successfully.

Clariant (previously Hoechst) and Escola Politécnica da USP have demonstrated the suitability of the use of filter aids to improve filtration rate and to decrease cake moisture.

4.5. tailings disposal

Tailings disposal is problematic, as tails are mainly extremely fine clay minerals with very difficult settling conditions.

MRN, the pioneer mining company, settles the tailing slurries in ponds and pumps the thickened underflow to the mined strip. It is covered with the next strip overburden, thus minimizing environmental impact.

CBA uses tailing ponds to dispose of these tailings. It is a very expensive item, as full stability must be ensured. A special problem is that in the high mountains where their facilities are localized, sudden temperature variations can cool the lake's surface, generating convection streams which lift the settled particles, generating turbidity. In these conditions, the dam's overflow must be stopped till the water becomes clear again. In its new Miraí project, all of the dam's overflow will be recycled into the preparation plant. The only water to be delivered downstream the dam is that one percolated through the massif's filter.

In this project, to avoid thermal inversion turbidization, tailings will be thickened in a thickener with the assistance of coagulants and flocculants. The idea is to turn them into flocks that are resistant enough to become stable in the bottom of the lake.

Paste thickeners and dry stacking have been tested during process development. A confirmation pilot plant is scheduled for next May.

4.6. gibbsite concentration

The increase of the available alumina grade, or correspondingly, the decrease of the gangue minerals grade, can be achieved by different unit operations. Gibbsite has a specific weight of about 2.7. But in fact, bauxite particles are porous due to the leaching of internal points during weathering. This leads to a smaller actual specific weight and makes it suitable for gravity separation from quartz.

Mineração Rio Pomba took advantage of this fact and used jigs to separate coarse silica (81 % between 6 and 35# Tyler = 3.4 and 0.42 mm).

Iron and titanium bearing minerals are heavier and thus easier to separate. Additionally, they have weak magnetic properties. CBA used Reichert spirals to separate them from bauxite in its Itamarati de Minas plant when treating amphybolitic ores (particles -14# = 1.2 mm + 10 μm). When treating gnaissic ores, spirals showed suitable to separate quartz too, but this size fraction is very poor in alumina so the operation is not economical.

Bittencourt, L.R.M. (1989), aiming to obtain a gibbsite concentrate to be used as raw material for the production of alumina refractories, tried the direct flotation of the bauxite minerals from a Rio Pomba bauxite ore sample, composed basically of gibbsite (50%), kaolinite (15%) and quartz (35%). This flotation had two steps: the first step was the flotation of gibbsite/kaolinite from quartz at pH 2 using alkyl sulfates as promoters, and the second one was the flotation of kaolinite from gibbsite using amines at pH 8.

To treat CBA's ores, CBA/Epusp team tried both routes, the direct flotation of gibbsite and the reverse flotation, floating the contained quartz. The initial studies were done by Freitas, T. G. (2004) in an end-of-course research monograph. His work was followed by Kurusu, R.S. (2005) in another end-of-course research monograph, and by Massola in an ongoing MSc research work. These works were developed under Prof. Chaves' supervision and with strong support, both material and participative, from CBA's Itamarati de Minas Department team.

Part of the iron and titanium fine minerals follow bauxite in spirals concentration and most of them follow bauxite in froth flotation. So, a magnetic separation on the concentrates is useful to further increase available alumina grades.

When the iron minerals are mainly hematite and siderite-goethite, both magnetic and density separation are suitable to reduce the iron content and so increase the available alumina grade.

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