

Mineração

Concentration of bauxite fines via froth flotation

(Concentração de finos de bauxita por
flotação)

Resumo

A Companhia Brasileira de Alumínio (CBA) tem usinas de beneficiamento de bauxita em Poços de Caldas e Itamarati de Minas e uma nova unidade de produção em Mirai (junho de 2008), todas localizadas no Estado de Minas Gerais. As usinas de beneficiamento têm as operações unitárias de britagem, desagregação em escrubers e peneiramento. O oversize das peneiras é o concentrado ou bauxita lavada. Em Itamarati de Minas, os finos são deslamados e concentrados por diferença de peso específico em espirais de Reichert, complementadas por separação magnética de alta intensidade.

Os rejeitos ainda contêm bauxita, que pode ser separada por flotação reversa da sílica e depressão da bauxita. Usam-se amido como depressor e amina como coletor. O pH precisa estar em torno de 10,0. Os minerais portadores de ferro e de titânio acompanham a bauxita, o que exige uma operação adicional de separação magnética para atingir o teor desejado de alumina aproveitável.

Esse trabalho descreve o desenvolvimento de processo para o minério de Itamarati de Minas, em escala de bancada, realizado nos laboratórios da Escola Politécnica da USP.

Palavras-chave: Beneficiamento de bauxita, flotação, flotação reversa.

Abstract

Companhia Brasileira de Alumínio (CBA) has bauxite processing plants at Poços de Caldas and Itamarati de Minas, and a new processing plant at Mirai that has been operating since June, 2008; all of them are in the State of Minas Gerais. The plants have units for the crushing, scrubbing and screening operations. The screened oversize is the concentrate or washed bauxite. At Itamarati de Minas, the fines are de-slimes and concentrated by gravity separation of the iron-titanium minerals in Reichert spirals followed by HIWMS.

The tailings still contain bauxite, which can be separated by reverse froth flotation (flotation of the quartz and depression of the bauxite), using starch as a depressant and amine as a promoter; the pH must be around 10.0. The iron and titanium bearing minerals are depressed with the bauxite and an additional magnetic separation operation is necessary on the depressed bauxite.

This paper describes the work performed on Itamarati de Minas' samples on a bench scale at Escola Politécnica, University of S. Paulo.

Keywords: Bauxite preparation, froth flotation, reverse froth flotation.

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1. Introduction

Aluminium metallurgy consists of two steps: in the “refinery”, where 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 fed to the refinery must meet significant requirements:

- Alumina grade - there must be a minimum grade for economical processing.
- Reactive silica grade - the silica contained in clay minerals reacts with sodium hydroxide during refining, increasing soda consumption, and forms a complex with alumina, stealing part of it. Therefore, its content must be strictly controlled. The amount of alumina contained in the non clay minerals, i.e. in the aluminium ore minerals, is designated as “available alumina”.
- Zinc and phosphorus are contaminants.
- Iron grade - a minimum amount is necessary for proper processing. Excess dilutes available alumina.
- Insoluble silica grade - there must be a minimum grade, under which desilicification becomes problematic; if the grade is too high, the silica also dilutes the available alumina, decreasing its grade.
- Size distribution - it must be not so coarse as to make chemical reaction difficult, nor so fine as to hinder settling.
- Organic carbon content, due to humic acids.

Bauxite processing plants exist only in Brazil. In other aluminium producing countries, it is usual to mine the richest ores and feed them to the refinery. Depending on the silica/available alumina ratio of the ores, poorer ores can be fed to specially designed refineries.

Companhia Brasileira de Alumínio (CBA) has a strong commitment to the environment. Its reserves in the Zona da Mata region, State of Minas Gerais (MG),

are at the moment the greatest bauxite reserves in Brazil. Zona da Mata is a rainforest region – even though it has been degraded to a great extent – and the ore bodies are at the tops and slopes of high mountains.

Mining is done by open pit; the top soil is reserved. After mining, there is an effort to recover the landscape configuration and the top soil is returned, corrected and fertilized. When the land belongs to third parties, the original culture (pasturages, sugarcane, eucalyptus, or coffee) is replanted. When the mining has been carried out in land belonging to CBA, native forest species are planted. As a result, in this region, the rainforest area is actually increasing.

The same care is taken concerning ore dressing. Maximum recovery of available alumina and an effort to transform tailings into by-products has been in course for the last 15 years.

This paper describes the results achieved with the -48# fines processing via froth flotation. Amphibolitic ores from Descoberto, MG, gnaissic ores from Itamarati de Minas and Mirai, and different blends of these ores have been tested on a bench scale and in a pilot plant. Quartz is floated and bauxite is depressed with cornstarch as a depressant and amines as promoters. The iron and titanium minerals present in the ore follow the bauxite. Therefore, the depressed product must be separated by magnetic separation to yield a bauxite concentrate and a magnetic product.

1.1 Literature review and history

In the Zona da Mata region, there are two kinds of bauxite ore, depending on the mother rock: gnaissic and amphibolitic. The minerals assembly is quite similar till the 42# size fractions; below that fraction, gnaissic ore presents high quartz amounts and amphibolitic ore presents a greater amount of titanium and iron bearing minerals, diluting the bauxite.

Both ores are dressed at CBA’s processing plant in Itamarati de Minas. Previous investigation has shown the suitability of the gravity processing in Reichert spirals to remove heavy minerals (Oba, 2000). An industrial circuit has been erected at the plant, complemented by a high intensity wet magnetic separator to remove the magnetic fine particles that remain in the concentrate after densitary separation (Bergerman, 2003; Bergerman and Chaves, 2004).

That process works very well for the amphibolitic ore but poorly for the gnaissic one. Therefore, it was necessary to find an alternative route. Considering the size of this fraction, the solution was froth flotation.

There is very little published literature about this matter. No processing plant descriptions were found. About bauxite processing via froth flotation, only the following publications were found: Bittencourt (1989); Bittencourt et al. (1990); and Xu, Plitt and Liu (2004).

The Chinese work (Xu, Plitt & Liu, 2004) is about flotation of diasporic ores, not found in Brazil. The Brazilian publications describe research done at Utah University, under Dr. Miller’s supervision, by Dr. L.R.M. Bittencourt, from Magnesita S.A., Contagem, MG. Aiming to obtain a gibbsite concentrate to be used as raw material for the production of first class alumina refractories, Bittencourt tried direct flotation of the bauxite minerals from a Rio Pomba bauxite ore sample, composed basically of gibbsite (50%), kaolinite (15%) and quartz (35%). In Bittencourt’s work, flotation was carried out in two steps: the first step was the flotation of gibbsite/kaolinite from quartz at pH 2 using alkyl sulfates as promoters; and the second step was the flotation of kaolinite from gibbsite using amines at pH 8.

Initially, we tried both routes: the direct flotation of gibbsite and the reverse flotation of the contained quartz. We have also tried to reproduce Dr.

Bittencourt's work, with no positive results for the tested ores. Then we went on with the reverse flotation. The initial studies were carried out by Freitas (2004), in an end-of-course research paper. His work was followed by Kurusu (2005), in another end-of-course research paper, and by Massola in an MSc research work (2008).

There is sound experience and knowledge on quartz flotation from itabirites. Technical and scientific aspects are well known and dominated. We used this know-how and transferred it to bauxite.

These works were developed under Prof. Chaves' supervision and with strong support, both material and participative, from CBA's Itamarati de Minas Department team.

2. Materials and methods

2.1 Exploratory tests

Freitas (2004) performed the initial test work using samples of gnaissic ore from Itamarati de Minas and samples of Flotigam EDA amine promoter provided by Clariant (Clariant, 2001). Freitas used samples taken from the underflow of 6" cyclones dressing gnaissic ore. The minerals present in the samples are quartz, gibbsite, silimanite (Al_2SiO_5), rutile, goethite, ilmenite and kaolinite. Chemical analysis of flotation feed indicated: 12.2% available alumina, 48.1% insoluble silica, 1.1% reactive silica and 21.4% Fe_2O_3 .

Exploratory tests tried reverse cationic flotation of quartz using Flotigam EDA and starch as a depressant. Flotigam addition varied in the 200-400 g/t range, and starch in the 250-450 g/t range. Visual inspection of the samples indicated that the best results were obtained using about 300 g/t of each chemical. As iron and titanium minerals follow bauxite to the depressed product, an additional medium intensity magnetic separation improves the quality of the bauxite concentrate. A scavenger flotation step with addition of promoter was tried.

2.2 Systematic testing

Kurusu (2005) carried this study further and made systematic bench tests, rougher-cleaner-scavenger tests and locked cycle tests in order to represent a continuous circuit ('scavenger' is defined here as the flotation of the depressed product of the rougher stage, and 'cleaner' as the flotation of the rougher floated product).

Samples for this campaign were taken at Itamarati de Minas's plant for 5 hours per day during 5 days, taking increments every hour. Samples were decanted and dewatered in situ, sent to S. Paulo where they were dried, homogenized and quartered. Aliquots were taken for size analysis, chemical analysis and mineralogy.

Tests comparing the flotation of deslimed material and material with slimes showed slimes to be noxious to flotation, in the sense that they increase reactive silica and decrease alumina grade and recovery in the concentrate. Consequently, the samples had to be deslimed before flotation; desliming was carried out in 1 1/2" (40 mm) cyclones at a d_{95} of about 10 μm .

In a first set of experiments, Kurusu checked the previous results, varying promoter addition between 200 and 400 g/t, keeping depressant addition at 300 g/t and keeping pH at 10.0. In a second set, Kurusu kept promoter addition at 300 g/t and varied depressant between 0 and 600 g/t at the same pH. Having confirmed 300 g/t as the best promoter and depressant addition, a rougher-cleaner-scavenger test was carried out. It demanded additional 150 g/t of promoter to the scavenger stage. The scavenger depressed went to magnetic separation.

After all those experiments, a locked cycle was tested in order to simulate an actual flotation circuit by recycling products and adding new feed. A locked cycle with 5 rougher steps was tested, recycling cleaner depressed plus scavenger floated to the next rougher stage (Figure 1). Promoter and depressant dosages were at 300 g/t and pH at 10.0.

Magnetic separation of the depressed scavenger was carried out to yield a bauxite concentrate and a magnetic product, as the iron and titanium minerals present in the ore follow the bauxite. The non-magnetic product is the final bauxite concentrate.

3. Results and discussion

3.1 Exploratory tests

The best results of the exploratory tests were a flotation concentrate (scavenger depressed) with 22.9% available alumina, 22.0% insoluble silica, 1.3% reactive silica and 53.8% Fe_2O_3 . After magnetic separation, the non-magnetic product yielded 42.5% available alumina, 16.2% insoluble silica, 1.2% reactive silica, and 9.3% Fe_2O_3 . Final mass recovery was 36% and metallurgical recovery 64%. Rejection of insoluble silica was 81.3%.

3.2 Systematic testing

The size analysis per size fraction is shown in Table 1.

This table shows the existence of misplaced material (+35#) and of coarse particles, too heavy for froth flotation (+65#). These particles had to be separated by screening. It also shows 5.5% of fines (-400#), which, after the extraction of the +65# mass, increased to 8.3%.

For systematic testing, results showed little variation resulting from promoter addition between 200-400 g/t (with 300 g/t of depressant and pH 10.0), for Kurusu was close to the optimal conditions: available alumina in concentrate varied between 22.07 and 24.62%, its recovery varied between 70.4 and 76.2% for masses recovery between 30.5 and 34.9%.

In the second set of experiments, keeping promoter addition at 300 g/t and varying depressant between 0 and

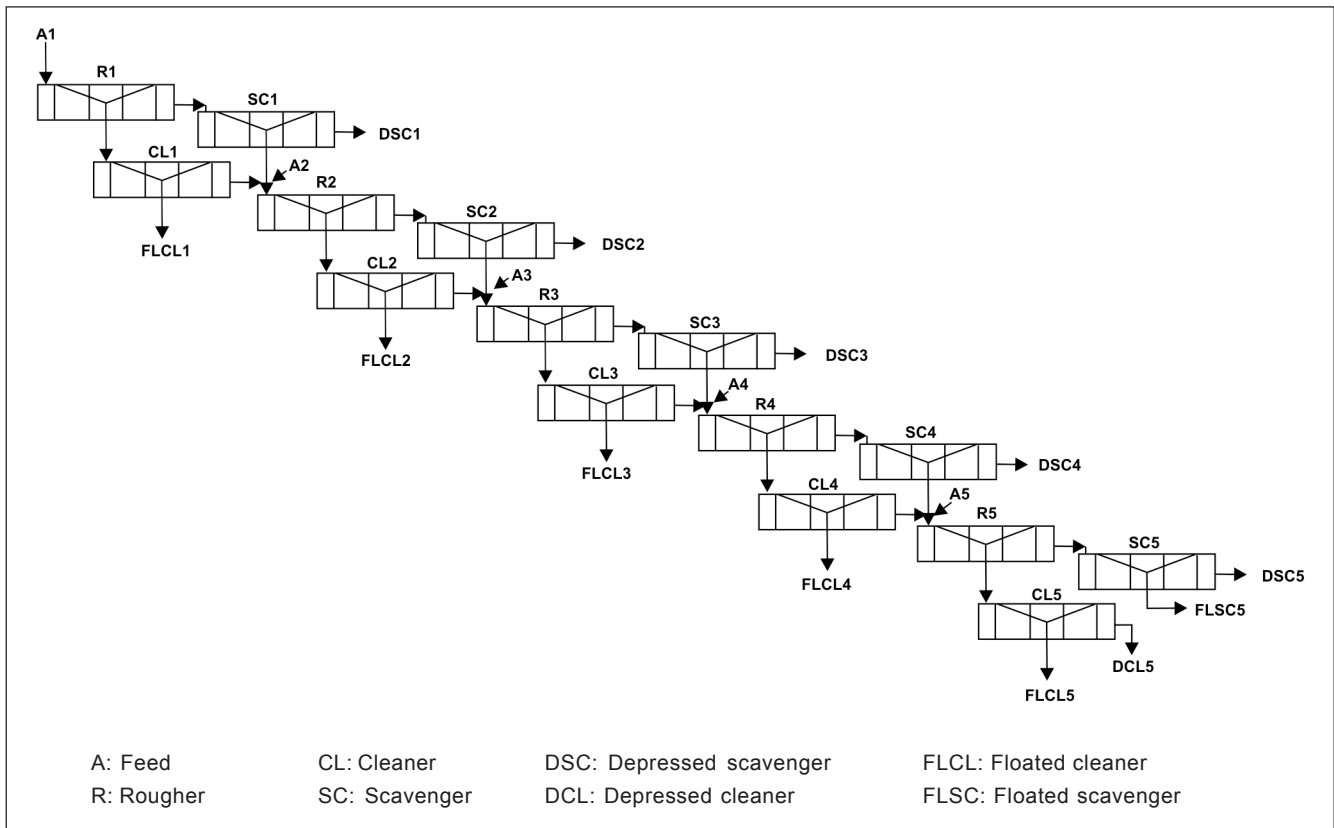


Figure 1 - Locked cycle test.

600 g/t at pH 10.0, once again there was little variation in the results: available alumina in concentrate between 15.58 and 23.52%, recovery between 69.8 and 82.3% for masses recovery between 39.3 to 54.0%.

It was thus determined that the best dosage was 300 g/t for both chemicals, yielding an available alumina recovery of 82.3% for 21.8% available alumina in concentrate and mass recovery of 44.8%.

In the rougher-cleaner-scavenger test, with the addition of stage 150 g/t extra promoter at the scavenger stage, mass recovery in froth flotation increased to 46.3% with available alumina grade of 25.6% (recovery of 92.9%), Fe₂O₃ of 38.9%, insoluble silica of 7.0%. Figure 2 shows the products of this operation. After magnetic separation, these figures changed to 17.8% mass recovery, available alumina 49.3% (recovery of 68.7%), Fe₂O₃ 11.9%, insoluble silica 11.0%.

Table 1 - Size distribution and chemical analysis (%) of 6" cyclone underflow.

# Tyler	Mass	Reac. Silica	Insol. Silica	Fe ₂ O ₃	Available Alumina
35	4.0	7.0	20.0	14.8	30.6
65	29.6	2.5	63.5	11.8	11.9
100	20.7	3.9	59.5	12.4	11.0
150	18.1	3.5	50.7	15.9	12.7
200	10.3	4.6	37.6	21.3	17.8
400	11.8	7.0	18.9	24.9	17.8
-400	5.5	3.5	14.7	25.8	16.1
Calcul.		4.0	48.0	16.1	14.2

The results for the locked cycle with 5 rougher stages were: 27.8% mass recovery, 29.7% available alumina (recovery of 71.2%), 33.5% Fe₂O₃ and 4.1% insoluble silica. After magnetic

separation, the non-magnetic products were: 13.3% mass recovery, available alumina 52.6% (recovery of 60.4%), Fe₂O₃ 9.0%, insoluble silica 2.8%. Figure 3 shows the flotation products of this test;



Figure 2 - Rougher, scavenger and cleaner operations.

Figure 4 shows the products yielded by magnetic separation of the depressed scavenger.

4. Conclusions

The technical viability of the recovery of alumina contained in tailings (6" cyclone underflow) through reverse froth flotation of silica was demonstrated. Starch was used as depressant and amine as promoter with pH around 10.0. Magnetic separation is necessary to separate iron and titanium minerals from the bauxite concentrate.

The overall benefits obtained from this process include an increase in bauxite concentrate production, an important decrease in the emission of effluents and in environmental impact, and an increase in the life-time of the tailings dam. Also the iron and titanium concentrate has potential use as a Portland cement additive and the silica can be used as an aggregate for road maintenance at the mine site.

No grinding is necessary as the feed consists of natural fines, a tailing in the present circuit.

Although froth flotation of silicates is well known and mostly applied for mineral concentration, the use in bauxite is not usual. Therefore, this is a pioneer, innovative process for bauxite concentration.



Figure 3 - Floated and depressed - locked cycle test.

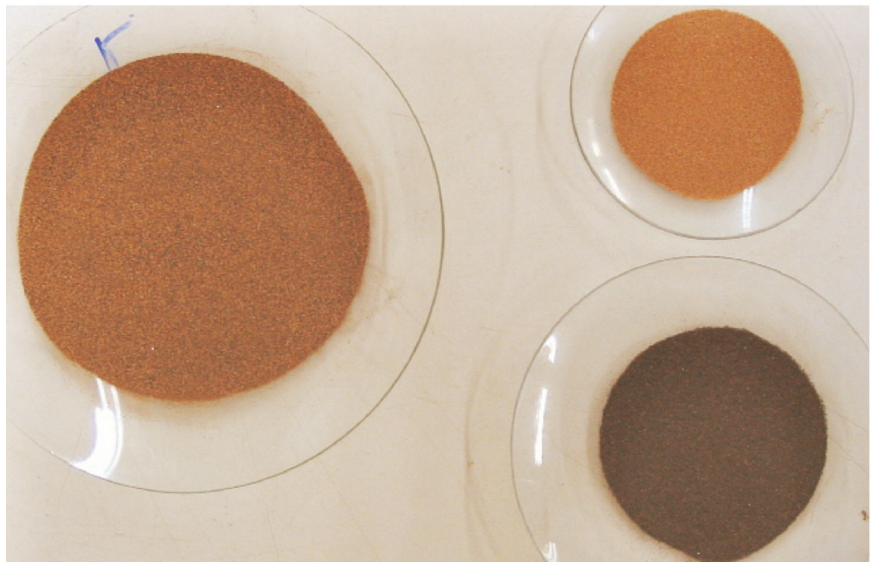


Figure 4 - Products from magnetic separation.

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