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Increasing Extraction Efficiency Using a Closed Grinding Circuit

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Abstract

Votorantim Metais – CBA's alumina refinery produces 0.9 Mtpa of SGA. Recently the particle size of the rod-ball mill product has suffered an increase of 35% in the +590 µm fraction. This results from higher grinding charge and variation of bauxite blend, with a rise in proportion of higher Work Index bauxite. Additionally, the top entry design digesters favor low residence time, compromising digestion efficiency even further. This increases residue generation with alumina and caustic loss.

The solution studied was a Closed Grinding Circuit, which aims to control particle size by sieving the mill product at 590 µm, returning the oversize to grinding. This improves digestion efficiency, since smaller particles react faster and suffer less short-circuits.

This work describes the study and estimated gains, along with tests conducted to prove the residence time distribution and analyze the effects of residence time and particle size in digestion efficiency.

Introduction

Companhia Brasileira de Alumínio (CBA), located in Alumínio, 74 km from São Paulo, is the largest integrated aluminium plant in the world. CBA, shown in Figure 1, belongs to the one of the largest industrial conglomerates in Latin America, Votorantim Group. The plant was established in 1955 and includes alumina refinery, smelters, foundry and fabricated products, with a yearly production of 0.475 Mt of primary aluminium.

Figure 1: Companhia Brasileira de Alumínio

CBA Alumina Refinery produces 0.9 Mtpa of smelter grade alumina using a traditional low temperature Bayer Process. Two different types of bauxite feed the plant: Poços de Caldas ore and Zona da Mata ore, the first with 45.5% lower Bond Work Index (WI) than the second.

In the past ten years, the refinery production has increased considerably to feed the smelters demand, as shown in Figure 2.

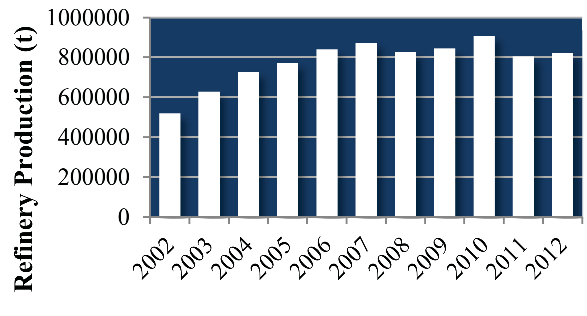

Figure 2: Refinery production over 10 years

The bauxite mix has also changed, with an increase in proportion of Zona da Mata ore (Figure 3), resulting in higher mean WI. In spite of these modifications, the grinding unit has not changed since 2006, when the new rod-ball mill was installed, adding capacity to the three previous ball mills.

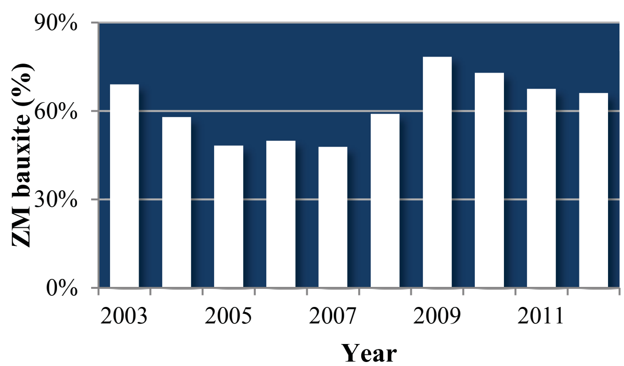

Figure 3: Zona da Mata ore mean blending proportion in a 10-year spam

This scenario caused a substantial increase in grinding product grain size, which resulted in higher alumina loss to Coarse Sand. The Coarse Sand is the coarser residue separated from the liquor in hydroclyones after digestion. Figure 4 shows the deviation of each year average value for available alumina in Coarse Sand in comparison with the mean value of all years combined.

Another aspect which contributes to low digestion efficiency is low residence time. The top-entry digesters employed at CBA, associated with coarser particles, can intensity short-circuits in the vessels. [1]

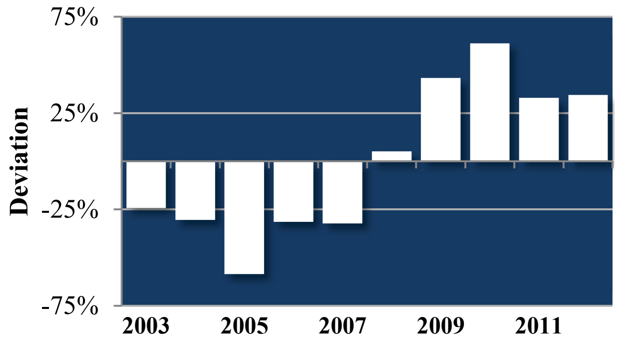

Figure 4: Available Alumina loss in Coarse Sand increase since 2003

Developments

Laboratory Digestion

In order to evaluate the effect of the holding time and particle size in the digestion efficiency, several digestions under different residence time and particle size conditions were conducted in laboratory. Synthetic liquor in the plant caustic and alumina concentration was used in 5 and 10 mL bomb digesters. A representative sample of 10 kg of bauxite slurry sample was collected and separated in 4 size fractions: +1180 µm, -1180+840 µm, -840+590 µm and -590+300 µm.

For each fraction, a reference digestion was conducted by grinding the sample below 300 µm and submitting it to digestion during 30 minutes. This reference was used as reference to compare the results to a practical maximum.

The extent of digestion is calculated by the difference between the alumina to caustic (A/C) ratio of the blow-off slurry and the liquor to digestion. The extraction efficiency can then be calculated comparing the extent of reaction of each sample and the practical maximum for the sample's particle size, according to the equation:

$$\text{Efficiency} = 100 \text{ x } \Delta(A/C)_{pz,t}/\Delta(A/C)_{ref} \qquad (1)$$

$\Delta(A/C)_{pz,t}$ = Alumina to caustic ratio for a particle size and residence time;
$\Delta(A/C)_{ref}$ = Alumina to caustic ratio for the same particle size reference digestion.

The weighted average results are presented in Table 1.

Table 1: Laboratory results of extraction by residence time

Particle Size	Residence Time (min) 20	Residence Time (min) 30
1180 µm	91,6%	98,1%
840 µm	93,2%	98,9%
590 µm	100%	100%
300 µm	100%	100%

It can be perceived that there is no significant difference in extraction efficiency below 590 µm.

Short Circuit

A Residence Time Distribution test was conducted in the digesters by inserting a pulse of inert Barite, $BaSO_4$, in the digester's feed. Samples of the exiting stream were analyzed and the short circuit was confirmed: the first particles left the digester series only seven minutes after their introduction, as shown in Figure 5.

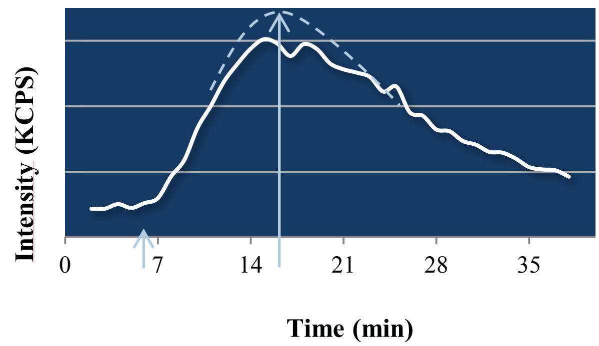

Figure 5: Barite concentration at the exit of the digestion unit

In order to estimate the residence time distribution, the area below the curve was integrated by the rectangle rule and the exit age distribution curve, **E**, plotted:

$$E(t) = I(t)/\int_0^\infty I dt \qquad (2)$$

$$\int_0^\infty E dt = 1$$

E(t) = Exit age distribution
I (t) = Barium intensity

With this curve it was possible to estimate the percentage **P** of particles leaving the reactor before a certain time, t1, by integrating the **E** curve until t1: [2]

$$\int_0^{t1} E(t)dt = P \qquad (3)$$

The average residence time is the time t1 for which P equals 0.5, so that half of the particles have longer residence times and the other half, shorter residence times. The value calculated for this digesters series, 21 minutes, is 37% shorter than previously expected based only on volumetric flow and autoclaves total volume, confirming the short-circuit.

Barite is a fine grain and can be classified as a non-settling slurry which follows the liquid. Larger particles, which are the case for CBA's slurry, settle out of the liquor and exit the digester early. [1] Short-circuit favors higher alumina and caustic loss.

Process Modeling

It was possible to adjust a particle size extraction efficiency model with the laboratory results. A first order Arrhenius-based kinetics model was employed. [3] The model predicts the alumina concentration in the slurry as a function of time, considering the plant's characteristics of temperature, surface area and concentration. The comparison between modeling and laboratory results is exhibited in Figure 6.

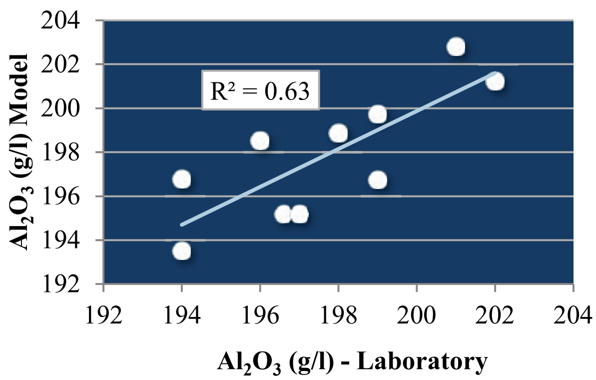

Figure 6: Comparison between modeling and laboratory extraction results

With the model it was possible to confirm that CBA's bauxite slurry particle is coarser than ideality. It takes longer holding periods for larger particles to reach the same efficiency of finer ones.

The model can be used to select the optimum particle size the bauxite slurry to improve efficiency without overgrinding the bauxite. Grinding is an expensive operation which requires high energy expenditures.

Proposed Solution

Improvement of reaction efficiency can be reached, as observed in the tests and in the model, by increasing the residence time and reducing the particle size distribution. The solution studied by CBA is boosting the grinding unit.

Design Trade-Off

Three opportunities, shown in Figure 7, were analyzed:

1. Classifying the bauxite before the grinding mill;
2. Installing a crusher before the grinding mill;
3. Classifying after the mill.

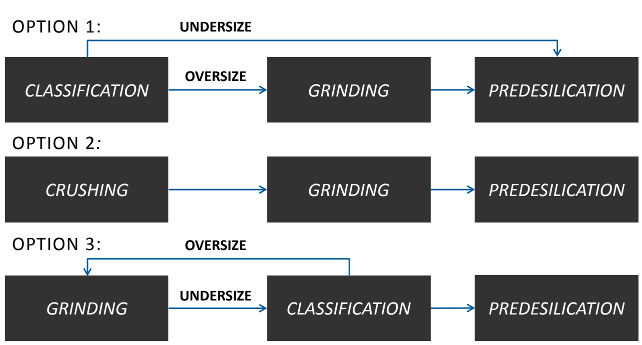

Figure 7: Studied grinding options

The first potential modification was to classify the bauxite before the grinding mill, bypassing the finer particles. This was not possible because there is not enough available space for this operation at CBA's grinding unit. Furthermore, the amount of bypass would be very small considering the current bauxite characteristics and particle size distribution. The lack of space is the same reason why the second option, installing a crusher before the mill, was discarded.

The last option, classifying the bauxite slurry after the mill, was chosen because there is adequate space for installation and it is a common practice amongst refineries. Two types of equipment were studied for the operation: hydrocyclones and sieves. Sieving was selected due to higher classification precision, which avoids high recirculation grinding charge. The final diagram is illustrated in Figure 8.

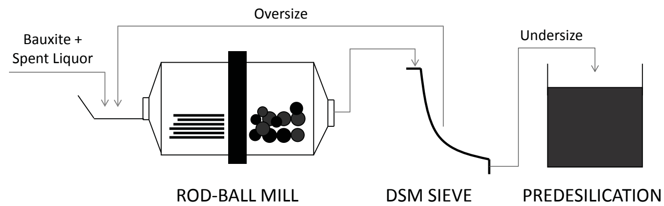

Figure 8: Closed-loop grinding circuit

The smaller particles will have higher extraction efficiency. The bauxite consumption will be reduced and, as a consequence, so will be the caustic loss, generating less residue. Moreover, the refinery energy consumption will decrease in accordance with the reduced slurry flow introduced into the digesters.

Gain Estimation

The consequences of the implementation of the closed-loop will reflect mostly on the Coarse Sand (underflow of the hydrocyclones after last flash).

It was possible to establish a linear correlation, shown in Figure 9, between the percentage of available alumina loss to the Coarse Sand and the +840 µm fraction of the grinding product slurry.

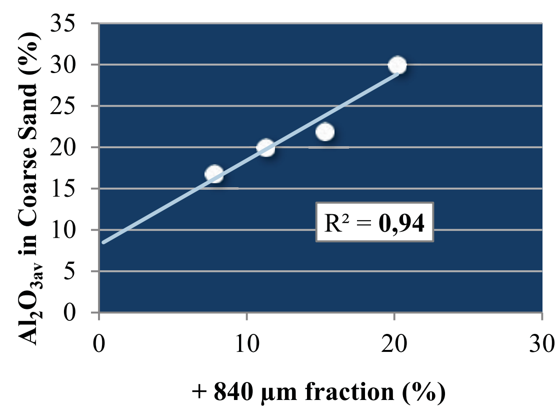

Figure 9: Correspondence between +840 µm oversize and alumina loss to the Coarse Sand

Considering the chosen sieving cut as 590 µm, after the closed circuit a maximum of 5% in the +840 µm fraction is expected. Currently, the average value for the particle size is 15%. According to the correlation, the alumina loss is expected to decrease 50%, resulting in a 0.6% increase on bauxite recovery after the implementation of the project.

Conclusion

The closed grinding circuit is an adequate solution to improve digestion efficiency in the refinery, with direct effect on increasing alumina extraction and also enabling a reduction of short circuits in the digesters.

Static sieves were chosen on account of operation simplicity and precise classification, which will guarantee smaller recycling charge in the mill.

Acknowledgments

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