The Votorantim Metais bauxite rod-ball grinding mill

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Abstract

The Votorantim Metais aluminium refinery is located in the municipality of Alumínio, São Paulo State and is fed by the run of mine extracted in three different locations: Zona da Mata, Poços de Caldas and Barro Alto. These differ from the genesis; the first one is the alteration of gneiss and amphibolite that occur in the very top of several weathered hills. This bauxite is washed or beneficiated, removing the finest fraction, before being transported to the refinery. The second, is mined, crushed, then transported. This bauxite has higher grades of reactive silica and fine particles, but is less expensive to mine and is closer to the refinery. The last one has high natural available alumina grades with low natural reactive silica grades, but is a new operation being developed. All bauxites are different; from alumina and reactive silica grades, to natural presence of fines and grindability ease. A study was conducted to better understand the grinding phenomena of this mix in a rod-ball mill. For this evaluation several laboratory tests were executed and a model was calibrated. This model was compared with in field information and process alterations were suggested.

Keywords: Bauxite; ore dressing; rod ball grinding mill; simulation.

1. Introduction

The Votorantim Group started as a textile factory and was commissioned in 1918 in the municipality of Votorantim, São Paulo state. Since then, Votorantim has been diversifying its activities. Industrial operations now include cement, mining and metallurgy (aluminum, zinc and nickel), steel, pulp, orange juice, and electricity generation.

The aluminium business includes four bauxite mines, a refinery, a smelter and plastic transformation units and a mega project, Alumina Rondon. To produce aluminium, the bauxite is mined and transported by railway to the refinery where up to 1 million tons of alumina can be produced, resulting in nearly 500 thousand tons of metal per year.

For the bauxite to be refined, it must be ground. This operation is the first step in the refinery and it is where the bauxite is mixed with spent liquor for further digestion. This size reduction step is carried out in a single body rod-ball grinding mill. The particle size distribution (PSD) resulting from this operation must be controlled as it drives the digestion efficiency and the pulp handling conditions, such as pipes abrasion and sedimentation ease.

This work included sampling and testing bauxites from three different mines: Barro Alto, Poços de Caldas and Miraí. These bauxites vary in PSD, available alumina (AA) and reactive silica (RS) grades, clay content, moisture, among others. These materials are mixed prior being fed to the mill in such a manner that the feed specifications are met. Since the main concern is the mean AA grade, other characteristics are overlooked forcing the equipment to deal with some feed variation. The objective of this work was to better understand the mill operation characterizing its variables; to calibrate a model in order to evaluate quantitatively the consequences of process alterations; and to suggest improvements for the operation.

2. Grinding literature review

Complete theories for particle fracturing must take into account several aspects such as the interaction and propagation of flaws in a particle; secondary breakage; interaction of particles with each other and with the surface of the container; secondary interactions between particles and the grinding media; and physical and chemical interactions between particles and the grinding environment. In addition, the type of transport of the material through the grinding zone and size classification of it will also affect the nature of the product obtained.

This paper does not intend to review all of it and is limited to energetic theories, specifically the Third Theory of Comminution as proposed by Fred C. Bond [1] and with addition of the efficiency factors as proposed by Chester A. Rowland, Jr [2].

These three theories are specific cases of the equation 1 proposed by Charles (1957) [3]:

$$dE = -C\,\frac{dx}{x^n} \tag{1}$$

Where E: Liquid specific energy

C: Material constant

x: Characteristic dimension of the material

n: Power related to the dimension of the material

As proposed by Hukki (1961) [4] n is related to the size range of the evaluated comminution phenomena and might be written as a function of the size resulting in Equation (2):

$$dE = -C\,\frac{dx}{x^{f(x)}} \tag{2}$$

The Third Theory of Comminution, as proposed by Bond (1952) [1], states that "*The total work useful in breakage which has been applied to a stated weight of homogenous broken material is inversely proportional to the square root of the diameter of the product particles.*" In his work, Bond justifies this approach by comparing the results of several applications and concluding that the number of particles of similar shape in a unit volume varies as $\frac{1}{x^3}$, so that the energy input required to break a unit volume or unit weight should be proportional to $\frac{x^{3/2}}{x^3}$ or $\frac{1}{\sqrt{x}}$. Equation 3 is the fundamental statement of the Third Theory.

$$W_t = {}^{K}\!/\!\sqrt{P} \tag{3}$$

Where K : Material proportionality constant

P : Characteristic size of the product

Bond also defined Wi as the calculated specific energy applied in reducing material of infinite particle size to 80 % passing in 100 µm. In his definition, Bond states that this is the relative

Table 7. Experimental and fitted PSD.

Mesh	Product Exp. Acum. Passing	Product Fit Acum. Passing
μm	%	%
6 350	100	100
1 680	97.5	97.5
840	91.0	90.4
420	83.4	80.8
297	78.8	75.8
105	61.1	61.6
53	51.4	53.2
44	50.3	51.1
37	48.7	49.1

6. Discussion

The model calibration PSD is in good agreement with the experimental data, hence the model represents the phenomena with a satisfactory accuracy level. With this model, it is possible to quantitatively estimate, within the vicinity of the calibration data, any alteration of the process. It is known that, by increasing the grinding media charge or the solids content, the product should have a finer PSD.

The value of the model is to have an exact figure of how finer it will be. For instance, altering the rod charge to 30 % (from 23.6 %), the ball charge to 30 % (from 25 %) and the solids content to 60 % (from 57.1 %), the amount of particles retained in 840 μm drops from 9.6 % to 7.7 % (or 20 %) with an increase in power draw by the mill of roughly 200 kW.

7. References

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