Study of Influences on the Productivity of Bauxite Slurry Hyperbaric Filtration through Box Behnken Design

Clara Souza[1], Paula Lima[2] and Paulo Miotto[3]
1. Process Engineer
2. R&D Laboratory Supervisor
Alunorte Alumina do Norte do Brasil, Barcarena, Brazil
3. Chief Operational Executive, Legasys Industrial Solutions, Campina Grande, Brazil
Corresponding author: clara.de.souza@hydro.com

Abstract

The Hydro Alunorte refinery receives bauxite slurry used in the alumina production from Mineração Paragominas, both sites located in Pará – Brazil. This bauxite slurry is transported via pipeline and dewatered in hyperbaric filters located in Alunorte. This study was carried out to evaluate the influence of the addition of milk of lime in bauxite slurry on the productivity of the hyperbaric filters considering ranges of pH, densities, and particle size (top size) of the bauxite through the application of the statistical technique Box Behnken Design in order to decrease pipeline wearing rates. The simulation of the filtrations was carried out on a laboratory scale, and the cake formation time was the main outcome, which, in turn, enabled the calculation of the filters' productivity. The analysis of variance applied to the laboratory results allowed a regression model to develop a relationship between the control factors and the response variable productivity with R^2(adj) of 80.56 %. The slurry density had a positive quadratic effect on the model equation, being the factor with the most significant impact on filter productivity. The increase in pH with the addition of milk of lime into the bauxite slurry and higher bauxite top sizes also positively impacted the response variable. On the other hand, more basic pH levels enhanced the negative effect of the top size reduction on productivity. The impact of this factor is nearly negligible at pH close to neutrality. This study will support future experiments on an industrial scale for the decision-making of the most economically viable slurry modification alternative and optimized operational parameters that meet both the pipeline and hyperbaric filters needs.

Keywords: Bauxite slurry, Design of Experiment, Milk of lime, Pressure filtration, Top size.

1. Introduction

Most of the bauxite processed at the Alunorte refinery comes from Mineração Paragominas (MPSA), both sites located in Pará - Brazil. Bauxite is pumped from the mine to the refinery in the form of a slurry with 50 % solids content through a 244 km long pipeline. Once at Alunorte, the slurry is filtered in a plant with 13 hyperbaric filters to raise the bauxite solids content to 86 %, and then directed to the Bayer process digestion stage. The hyperbaric filters are composed of a set of twelve rotating discs inside a cylindrical pressure vessel, where the pressure difference through the cloths is produced with compressed air. The bauxite's filtrate is treated to reduce its solids content and recycled to incorporate the refinery's industrial water supply.

Pipeline integrity studies carried out previously showed an accelerated metal thickness loss, mainly due to erosion and internal corrosion problems caused by bauxite slurry transportation. These problems put impact on decreasing useful lifetime and increasing the frequency of pipeline maintenance. For this reason, it became necessary to evaluate the increase in slurry pH through the addition of milk of lime, as well as to change the particle size (top size) and slurry density, with a high probability of impact on the Alunorte's hyperbaric filters performance.

Widely used in industrial applications, milk of lime was one of the options considered for the slurry pH raising test mainly because it is a product with low cost and high alkaline content. In addition, milk of lime is already commonly used in alumina production through the Bayer process, having benefits in the alumina extraction efficiency, controlling impurities formation from ore, aiding in the pregnant liquor filtering process (TCA coating), and caustic soda loss minimization by bauxite residue [1]. Preliminary studies indicated a consumption of approximately 700 to 1.000 g CaO per tonne of bauxite in order to raise slurry pH from 7.0 to 10.5. This prior CaO addition in slurry would probably replace or reduce the 800 g/t milk of lime dosage currently used for bauxite's digestion depending on the quantity of CaO that remains in the solid phase after bauxite slurry filtration. This issue will be approached in parallel studies along with the review of possible impacts that industrial water containing milk of lime may offer to its users, such as cooling tower make up and flocculant preparation.

Bauxite filtration is a relatively rare applied process all around the world. Thus, the approach to this topic is scarce in the literature. MPSA's peculiar logistics to transport the ore to Alunorte via pipeline requires it to be in the form of slurry, meeting a certain range of particle size and density. For this reason, Alunorte develops many studies involving dewatering performance. Alex Pinheiro et al. [2] conducted an industrial-scale test with Alunorte's hyperbaric filters using Design of Experiments (DOE). Results indicated that rotation speed, basin level, and pressure significantly influence the productivity (solids throughput), cake moisture, and solids in the filtrate. This work indicated no significant correlation between the bauxite's particle size and the filtration performance.

Focusing on concept analysis, Selomulya et al. [3] developed hyperbaric filtration studies to investigate the implications of micro-properties (size, structure, and strength) of coal aggregates for coal dewatering. The authors indicate that low cake permeability due to smaller capillaries, related to fine particles, can be overcome by higher filtration pressures. However, high pressure may also have the opposite effect, altering the interconnected pores by collapsing the cake structure, resulting in low filtration rates.

Thus, this work aimed to study the influence of the three control variables (pH, density, and top size) on the filtration process productivity (response variable). It will support the decision-making of the most economically viable slurry modification alternative that meets both the pipeline and hyperbaric filters needs. The study was conducted on a laboratory scale using Box Behnken Design (BBD) statistical technique.

2. Methodology

2.1 Box Behnken Design

A Box Behnken Design (BBD) was developed with three factors and a central point to understand the influence of top size, density, and presence of milk of lime (pH) in bauxite slurry on hyperbaric filter productivity. Currently, up to 12 % in mass of particles exceed 300 µm, and typical values for d90, d50, and d10 are 197, 75, and 4 µm, respectively. Higher pH levels above the current value of 7.0 were tested by adding milk of lime with 176 g/L solids content and d90, d50, and d10 equal to 75, 15, and 5 µm, respectively. The levels for each factor are specified in Table 1.

4. Conclusions

This paper aimed to evaluate the impacts of the top size and density of the bauxite slurry and the addition of milk of lime on the filtration process productivity of Alunorte's hyperbaric filters that dewater the bauxite slurry from MPSA.

Based on a Box Behnken Design with filtration equipment on a laboratory scale, it was possible to satisfactorily obtain the necessary data to evaluate the influence of the input variables (top size, density, and pH) on the output variable (hyperbaric filtration productivity).

It was possible to obtain an adjusted model with R^2(adj) of 80.56 %. For all scenarios evaluated, the increase in density positively impacted productivity. This fact is related to the positive quadratic effect of density in the equation obtained for the model. This factor proved to be the most significant for changing the filter's production capacity.

It was observed that the profile for productivity at pH values close to 7.0 does not show significant influence from the change in top size. On the other hand, it is possible to achieve high productivity by changing the density to values above 1.46 g/cm³.

In addition, pH and top size increase positively impacted productivity. Higher pH levels (around 10.5), make productivity more sensitive to the top size control variable when compared to lower pH values (around 7.0).

This study will be useful to define future experiments on an industrial scale to compose the complete analysis of the best parameters of the bauxite slurry and optimized operational parameters that meet both MPSA pipeline and Alunorte's hyperbaric filters productivity needs. Furthermore, future experiments will be performed to optimize bauxite cake moisture and study the impacts on keeping using the dewatered filtrate with milk of lime as industrial water supply to Bayer process.

5. References

1. B. I. Whittington, The chemistry of CaO and $Ca(OH)_2$ relating to the Bayer process, *Hydrometallurgy 43 (1996)*, 13-35.
2. Alex Pinheiro, Americo Borges and Enio Laubyer, Study of influences on the bauxite moisture and solids in filtrate in the hyperbaric filters through Design of Experiments (DOE) statistic tool, *The Minerals, Metals & Materials Society (2013)*.
3. C. Selomulya et al., Micro-properties of coal aggregates: Implications on hyperbaric filtration performance for coal dewatering, *International Journal of Mineral Processing 80*, 2006, p. 189–197.
4. G. E. P. Box and D. W. Behnken, Some new three level designs for the study of quantitative variables, *Technometrics*, November 1960, 2:4, 455-475.
5. Jurgen Hahn, Reinhard Bott and Thomas Langeloh, Theory and practice of filtration in the alumina industry, *Proceedings of the 9th International Alumina Quality Workshop*, Perth, Australia, 18-22 March 2012, 103-109.
6. Douglas C. Montgomery, *Design and analysis of experiments*, 5th Edition, John Wiley & Sons, INC, 2001, 684 pages.