Kaolinite Reduction on Bauxite through Mechanochemical Activation with Lime

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Abstract

Bauxite is the primary ore for metallic aluminium production, consisting of aluminium, iron oxides, and kaolinite, a clay mineral commonly found in Amazonian bauxites, as the main carrier of reactive silica. Kaolinite is especially relevant in this context as it reacts with sodium hydroxide in the Bayer process, increasing reagent consumption. This work aimed to investigate the inertization of this silica through the mechanochemical activation of bauxite with lime. The study was conducted in a bench ball mill with different lime dosages. Hydrogarnet formation was observed in conditions with lime dosages higher than 0.5 %. Reactive silica concentration was reduced from 4.1 % to 3.4 % on the conditions when hydrogarnets were formed. In contrast, when lime dosages were increased, the available alumina concentration was decreased from 47.4 % without mechanochemical activation to 47.2 % and 45.6 % with 0.5 % and 2.0% lime dosage, respectively. Among the evaluated scenarios, the better balance between achieving reactive silica reduction through the formation of grossular, and minimizing the impacts in available alumina grade, with minimum formation of katoite, was obtained with 0.5 % lime dosage.

Keywords: Bauxite, Mechanochemical activation, Reactive silica, Lime, Hydrogarnet.

1. Introduction

Kaolinite, a common impurity in Amazonian bauxite, poses challenges during the Bayer process for alumina extraction due to its high reactivity and tendency to form undesirable by-products. The presence of kaolinite increases the consumption of caustic soda and generates more bauxite residue, complicating waste management and increasing operational costs [1,2].

Several technologies have been developed to reduce the impact of this reactive silica source on the process, primarily based on strategies for reducing the reactive silica content in the bauxite and modifying the process to lower soda consumption [3]. Despite promising results, most have not been implemented, indicating that the hurdles to implementation are mainly due to the specific characteristics of the different ores and plants.

By integrating lime into the mechanochemical activation process, researchers have demonstrated a significant reduction in kaolinite content, and thus reduced caustic consumption on Bayer process. This approach not only enhances the quality of the bauxite but also contributes to more sustainable and cost-effective production processes [3–7].

Mechanochemical activation is a process that enhances the reactivity of minerals through the application of mechanical energy. This technique has gained significant attention for its potential to improve the efficiency of mineral processing and material synthesis [8, 9]. When applied to bauxite, mechanochemical activation can notably alter its mineralogical composition, forming inert hydrogarnet phases in digestion conditions and reducing caustic soda consumption. Recent studies have highlighted the effectiveness of mechanochemical activation in reducing kaolinite content in bauxite by using different additives, with lime being particularly effective due to its chemical properties and availability [4-6].

Smith [3] argues that bauxite mechanochemical activation with lime could not be an economical way of reducing caustic losses due to a) the costs associated with the implementation of the ultra-fine grinding and downstream requirements for solid-liquid separation and b) costs associated with a high lime charge required (essentially based on McCormick et al. [4] data, in which > 9 % CaO on bauxite converted significant quartz into hydrogarnet). However, the context of Hydro's pipeline transported bauxite and low temperature alumina operations in Brazil is a particular case where there would be an opportunity to use this technology.

The bauxite processed in Paragominas must be subjected to grinding to adjust the particle size, ideally for its transport as pulp in the pipeline. The bauxite must be dewatered in hyperbaric filters before being fed to the process at the refinery [10, 11]. Also, the quartz content is minimal in the bauxite and often not detected in X-ray diffraction analysis. In contrast, the kaolinite content tends to increase over the years. An additional benefit would be the eventual pH increase of the bauxite pulp pumped in the pipeline, which is demonstrated to reduce pipeline corrosion and improve dewatering performance [11, 12].
In this context, this work aims to investigate the opportunity to reduce the kaolinite content in the bauxite by mechanochemical activation with lime, considering the actual Paragominas milling operation conditions.

2. Methodology

This study was developed using reagent grade CaO and two different Amazonian bauxite samples from Hydro Paragominas, a mine located northeast of Para state, Brazil. Over two distinct periods, incremental samples from the beneficiation plant grinding mill fresh feed were taken every 4 hours for five days. Each campaign's combined sample was homogenized and quartered in a rotary sample splitter to generate aliquots for further characterization and tests. The chemical composition of the bauxite samples is shown in Table 1.

Table 1. Bauxite samples chemical composition.

Element	Sample #1 (%)	Sample #2 (%)
Al_2O_3 – Total	55.08	52.03
Available Alumina	50.57	47.37
SiO_2 – Total	5.13	4.71
Reactive Silica	4.25	4.14
Fe_2O_3	8.37	13.40
TiO_2	1.56	1.69
Loss on ignition (LOI)	29.13	27.61

Two sets of tests were carried out. Sample #1 was submitted to a screening test covering a broader range of lime dosage, from 0 % to 16%. Sample #2 tests seek a finer tunning on lime dosage. It

The formation of insoluble calcium hydrogarnets in the present work is consistent with studies reported by other authors [4, 13], despite with lower lime dosage. Lime dosage of 0.5 % is one order of magnitude lower than the minimum dosage for hydrogarnet formation of 9 % reported by McCormick et al. [4] and 4 % reported by Santos et al. [13]. Further studies should be developed to understand whether this result is associated to the grinding condition with lower residence time in the present work or to other characteristics intrinsic to the different bauxite mineralogy.

4. Conclusions

On laboratory-scale, bauxite mechanochemical activation with lime and water, reproducing the grinding conditions from Hydro Paragominas industrial plant, resulted in the formation of hydrogarnets, such as grossular and katoite. Katoite, an alumina substituted hydrogarnet was the predominant phase formed in higher lime dosages, resulting in relevant loss of alumina when lime dosages were higher than 0.5 %. Among the tested conditions, 0.5 % was the optimum lime dosage, reducing reactive silica grade by 0.7 percentual points, with only 0.2 percentual points reduction on available alumina grade.

5. References

1. Ostap, S. Effect of bauxite mineralogy on its processing characteristics. In: Jacob Jr., L. (Ed.), Bauxite. *Proceedings of the 1984 Bauxite Symposium*, Los Angeles, California. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, pp. 651–671 cap. 30 (1984)
2. Paz, S.P.A, Angélica, R.S., Kahn, H. Optimization of the reactive silica quantification method applied to Paragominas-type gibbsitic bauxites. *International Journal of Mineral Processing* 162 (2017) 48–57
3. Smith, P. The processing of high silica bauxites – review of existing and potential processes. *Hydrometallurgy* 98, (2009) 162–176
4. McCormick, P.G., Picaro, T., Smith, P.A.I. Mechanochemical treatment of high silica bauxite with lime. *Miner. Eng.* 15, (2002) 211–214
5. Silva, F.A.N.G. et al. Mechanochemical Activation of Bauxite, *Light Metals 2012*, editted by Carlos E. *Suarez*. https://doi.org/10.1007/978-3-319-48179-1_5
6. Kumar, R., et al.. Mechanochemistry and the Bayer Process of Alumina Production, *TMS Light Metals 2004,* 31–34, editted by Alton T. Tabereaux.
7. Fortin, S., Forté, G. Mechano-activated bauxite behaviour. *Light Metals 2007*, Orlando, Florida, 87–92, editted by Morten Sorlie.
8. Tole, I., Habermehl-Cwirzen, K. & Cwirzen, A. Mechanochemical activation of natural clay minerals: an alternative to produce sustainable cementitious binders – review. *Miner Petrol* 113, (2019) 449–462. https://doi.org/10.1007/s00710-019-00666-y
9. Bodyrev, V.V., Tkácová, K. Mechanochemistry of Solids: Past, Present, and Prospects. *Journal of Materials Synthesis and Processing*, Vol. 8, Nos. 3/ 4, (2000) 121–132
10. Mendes, B. et al. Performance Changes in Alunorte Bauxite Dewatering. *TRAVAUX 52, Proceedings of the 41st International ICSOBA Conference,* Dubai, 5 – 9 November 2023, 381–393
11. Souza, C., Lima, P., Miotto, P., Study of Influences on the Productivity of Bauxite Slurry Hyperbaric Filtration through Box Behnken Design. *TRAVAUX 51, Proceedings of the 40th International ICSOBA Conference,* Athens, 10-14 October 2022, 235–244
12. C. Souza et al., Statistical modelling of operating parameters on bauxite slurry hyperbaric filtration, *Light Metals 2023*, 183–190, editted by Stephan Broek.
13. R. Santos et al., Estudo do Tratamento Mecanoquímico da Bauxita do Nordeste do Pará, XVI Jornada de Iniciação Científica – CETEM, 03 – 04 July 2008, 15 - 21