Kinetics of Silica Dissolution from Post Differential Extraction Slurry

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Abstract

Differential Extraction is a process that aims to reduce the caustic consumption of refineries when using high-silica bauxite. The process maximizes the extraction of alumina in a fast digestion and reduces the dissolution of silica in the liquor. Subsequently, the residue slurry undergoes a rapid process of solid/liquid separation (S/L) to stop the silica reaction. The objective of this work was to evaluate the extent of silica dissolution post-S/L separation under plant wash conditions. Shrinking Core Model (SCM) heterogeneous kinetics model was chosen for the kinetics evaluation. For this, temperature (71–95 ºC), solids concentration (50 g/L to 150 g/L), and residence time (0–30 min) were study. Factorial design of experiment was applied to evaluate the statistical influence of the factors on the response variable. The results showed that the limiting step of the dissolution process was the surface chemical reaction, and statistical analysis indicated that temperature and residence time mostly affect the silica reaction of the solids post-S/L.

Keywords: Silica dissolution, Slurry, Digestion, Differential extraction.

1. Introduction

Kaolinite content in bauxite, namely reactive silica, represents the main factor related to the loss of caustic soda in the Bayer process. This silica mineral dissolves in the caustic solution and will re-precipitate as a variety of sodium aluminum silicates (known as dessilication products – DSP) which are then discarded in the bauxite residue, implying significant cost increases, or even becoming uneconomical to process high silica content bauxites [1,2]. To reduce this loss, several technological strategies have been studied and implemented [2]. Differential Extraction is one of these technologies. The process takes advantage of the different kinetics of alumina and silica reactions, aiming to maximize the alumina extraction in a fast digestion step reducing the silica dissolution. After the digestion process, the slurry undergoes a rapid solid-liquid separation process to completely interrupt the silica reaction. The separated solids are washed to recover soluble soda before dewatering in press filters to be disposed. The process is claimed to reduce caustic soda consumption by approximately 50 % compared to a conventional Bayer process. [3,4].

Once the solids are separated from the green liquor and mixed with wash water is expected that negligible silica dissolution occurs. In this context, this work aims to evaluate the extent of dissolution of silica after solid-liquid separation considering the refinery conditions to ensure no dissolved silica impact on the product and scaling in downstream equipment in the Bayer loop. The silica dissolution kinetics was evaluated using the overflow liquor from a refinery washer under the following conditions: temperature (71 – 95 ºC), solids concentration (50 g/L to 150 g/L), and residence time (0–30 min). A statistical study was also carried out using a Design of Experiment (DOE) Factorial to evaluate the influence of the control variables on the dissolution of silica.

2. Experimental

2.1 Materials

The experiments were carried out using a representative sample of bauxite from Mineração Paragominas. To perform the digestion a plant spent liquor was used. For the solids washing tests it was collected the overflow from the last washer of the plant clarification circuit. These materials were characterized and kept stored in conditions to avoid changing their characteristics.

2.2 Design Of Experiments

The dissolution test consisted of two main steps: the first was fast digestion (differential digestion and fast S/L separation), and the second step was the solids washing in which the dissolution tests of the silica were performed. Figure 1 presents a schematic of the test scope.

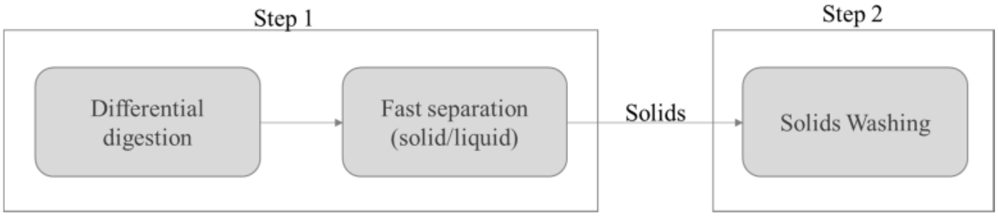

Figure 1. Test diagram.

A factorial design of the experiments (DOE) with analysis of variance (ANOVA) was considered with a significance level of $\alpha = 0.05$, post-dissolution SiO_2 concentration as the main response variable, and the following control variables and levels:

- solids concentration (g/L): 50; 100; 150
- retention time in washing (min): 4; 17; 30
- temperature (°C): 71; 83; 95

In total, 33 runs were performed, 24 referring to the 2^k factorial points with 3 replicates and 9 referring to the repetitions in central point.

2.3 Kinetics Analysis

The dissolution kinetics analysis considered that during the silica reaction on the solid-liquid interface no solid species were produced. Thus, the Shrinking Core Model (SCM) heterogeneous kinetics model was selected for the kinetics evaluation.

The SCM model consists of three main steps: The first step is the diffusion of liquid reactants towards the liquid-solid reaction surface by external diffusion; the second step is the reactions at the interface; the last step is the diffusion of products from the interface to the liquid by internal diffusion between intermediate layers. As the reaction takes place, the solid particle is consumed, reducing its size (Figure 2).

Figure 9 presents the contour plot for the percentage of silica dissolution as a function of Time and Temperature with Solids concentration set at the upper level (150 g/L), as in this condition the effect of solids concentration on silica dissolution is minimized (effects table). Note that lower dissolution values are obtained in less time and lower temperatures.

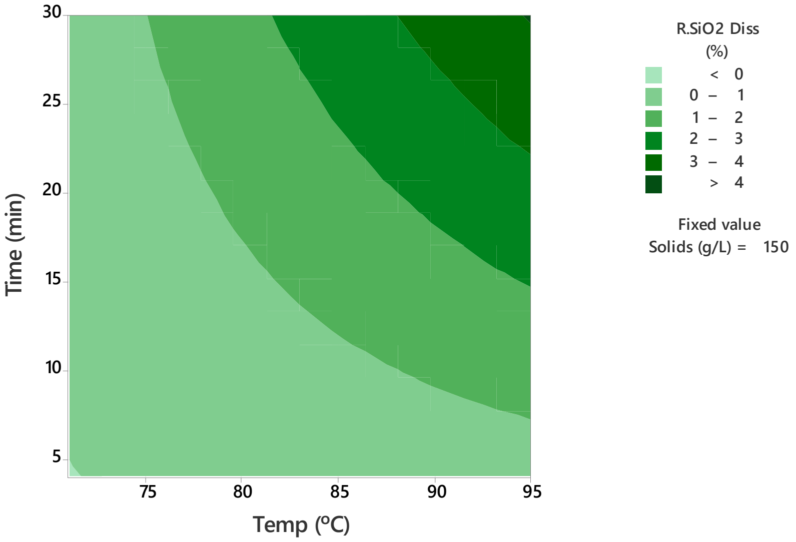

Figure 9. Contour graph % silica dissolution as a function of time and temperature; control variable solids concentration fixed at its upper level.

4. Conclusion

Heterogeneous kinetics was analyzed according to the SCM and demonstrated that the limiting step of the silica dissolution reaction in the post-S/L solids washing step is the surface reaction. Thus, the temperature has a significant effect on the reaction. The test showed that silica dissolution has positive effects when the process temperature and residence time during solids washing are higher. The solids concentration showed a negative influence on the dissolution therefore, the increase in the charge had a lower influence on the dissolution. Statistical analysis indicated positive effects of temperature and residence time, thus corroborating the kinetic analysis performed.

This work collaborates to the overall evaluation of the differential extraction technology, demonstrating that it is possible to restrict the silica dissolution during the fast digestion and from the solids after the solid-liquid separation. The tested confirmed a negligible dissolution extent for the conditions set for this application.

5. References

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