Optimization of Lime Dosage to Digestion at Alunorte Refinery Using Monte Carlo Methods

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Abstract

This paper presents work to establish ideal operational targets for lime to digestion at the Alunorte alumina refinery. To understand the impact of process variability on the required lime demand for both phosphate control and liquor stability, a Monte Carlo study was performed using a mass balanced model of the digestion process. Based on the results of these simulations, a fixed lime demand per tonne of dry bauxite was identified to satisfy greater than 95% of the conditions tested by the Monte Carlo simulation. Further to this, the impact of reduced lime to digestion flows on silica in liquor has been investigated, identifying no substantial risk. Based on this work, a new process controller has been proposed with the aim of reducing lime consumption by approximately 0.2 - 0.3 kg of CaO per tonne of bauxite.

Keywords: Lime; Monte Carlo; digestion; phosphate; control

1. Introduction

Lime is required on the red side of the process to ensure that phosphate does not cause undesirable scaling in the thickener overflow filters, and to guarantee liquor stability in the Clarification area in the form of soluble calcia [1]. In terms of the correct quantity to add, enough lime must be added to satisfy the stoichiometry of the phosphate to hydroxyl apatite reaction as well as the amount required to solubilize say, 20 ppm of CaO. It is important to realize that when more lime than the solubility requirement is added, more soluble calcia is not produced, rather more tricalcium aluminate hexahydrate (TCA6) is created according to:

$$3Ca(OH)_{2(s)} + 2Na[Al(OH)_4]_{(aq)} = 3CaO.Al_2O_3.6H_2O_{(s)} + 2NaOH_{(aq)} \qquad (1)$$

The exact mechanism for this reaction is not well understood and may involve a calcium carbonate or hydrocalumite intermediate species; but it is assumed based on solubility considerations that the final product is TCA6 as shown [2] [3].

This reaction (in this setting):
- Wastes lime
- Adds to the residue load
- Wastes alumina

The concentration of calcia achieved is merely a reflection of the solubility of TCA6. It is not known whether 20 ppm is the exact solubility concentration for Alunorte green liquor, but it is not far from spent liquor literature estimates [4]. Thus, 20 ppm might not necessarily be attainable, but based on the plant’s own historical data and the open literature, it seems a reasonable target to pursue.

Controlling the concentration is not so trivial when adding lime to the bauxite slurry feeding digestion, as the amount of liquor and bauxite slurry required will change, as will the amount of evaporation in the flash train between digester to blow off tank. A control strategy could look at all the relevant inputs and using some assumptions, calculate what the lime flow must be, but the time lag of the process in conjunction with the combination of so many measurement errors make this undertaking problematic.

An alternative approach is to understand just how significant the variation in these controlling parameters are to the required lime dosage. A useful tool for this study is a Monte Carlo simulation [5] whereby the natural variability of the relevant inputs can be simulated and the required lime flow solved. In this way, it can be discovered whether a fixed ratio of lime to the bauxite tonnage can be used to satisfy not just the phosphate demand (which makes sense to be based on the bauxite tonnage, as the phosphate exists in the bauxite), but also the liquor stability. This has been the aim of the present study.

2. Simulation Details

2.1. Model Set-Up

To investigate the impact of the different variables on lime consumption for phosphate and liquor stability, a mass balanced Microsoft ® Excel model was constructed which replicates essentially what process modelling software, (e.g. SysCAD [6]) does, but with a focus only on the digestion area of the process. A schematic of the process model is shown in Figure 1.

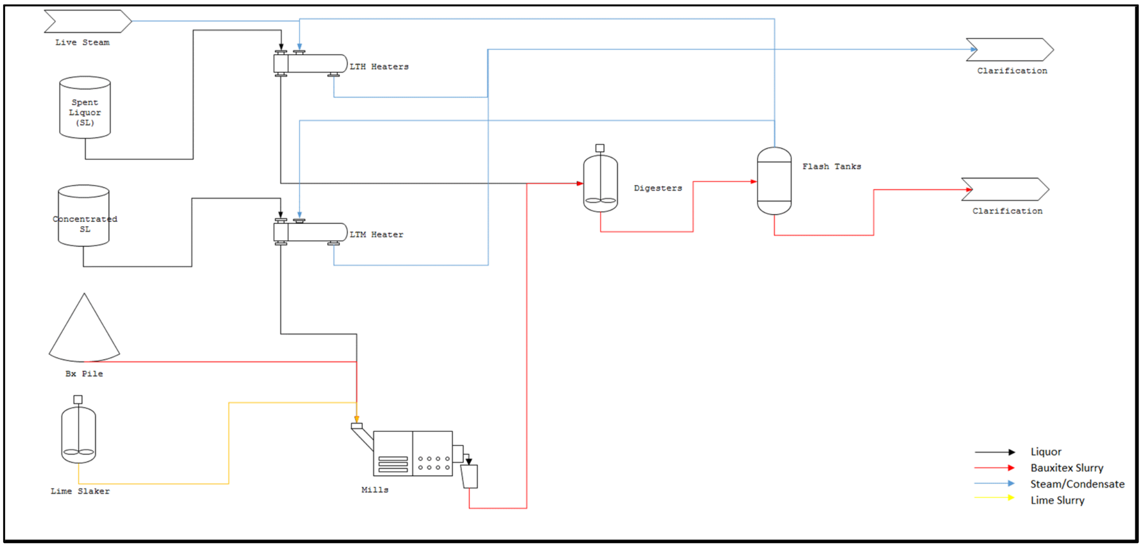

Figure 1. Block Flow Diagram of model under consideration. Note that condensate flows were not modelled but are shown for clarity.

Note that a flaw of this approach versus SysCAD is that the liquor loop is not closed (i.e. just a once through model). In the context of lime consumption investigations, this was not considered too great a sacrifice as the impact on overall liquor properties is not so great.

The process model functions in a very similar way to process modelling software, whereby the user inputs certain fixed variables, and then uses a solver algorithm to determine the values for the free variables. Rather than using a process modelling software's custom solving algorithms, this example depends solely on Excel's Solver ® to tune the freed variables until the output variable achieved the target value. For the simulation set in question, the principal fixed and free variable combinations are:

5. References

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