Reducing Bauxite Residue Production and Storage through Internal and External Recycling of Security Filtration Filter-cake

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Abstract

Reducing the production of bauxite residue (BR) from alumina refineries is a clear industry-wide objective, and recycling this material in the cement industry has been identified as one of the key options for large volumes. For most of the industry, the high soda content found in BR is an impediment to its qualification as an ingredient in the Portland cement clinker. The opportunity of recycling spent filter-cake (SFC) from the security filtration area has been identified as an interesting option to indirectly reduce BR output. This material is typically low in soda, high in calcium and high in alumina content, and mainly originates from the filter-aid, which is tricalcium aluminate (TCA), either in hexahydrate (TCAH) or silicate (TCAS) form, or a combination of both. A cement industry partner has confirmed its interest in this material, which has been extensively sampled at one of Rio Tinto's alumina refineries to verify consistency of composition and particle size distribution. Extracting this process stream would also enable internal recycling as a substitute for lime used in bauxite digestion. To confirm the feasibility of extracting the SFC stream, a series of process impacts were assessed in the laboratory by simulating plant operating conditions, for example mud settling behaviour, slurry rheology and filterability, washer liquor stability, and impurity control in digestion. For most of these, no detrimental impact on the process was identified, and therefore a preliminary design of pilot-scale processing equipment was considered for industrial testing in the refinery.

Keywords: Bauxite residue, Cement, Security filtration, Tricalcium aluminate.

1. Context and Opportunity

Over the last decade, the global alumina industry has increased its R&D effort to find ways to reduce the quantity of bauxite residue (BR) that is being stockpiled on a continuous basis. An average of 150-170 million tonnes per annum (mtpa) is currently produced by the industry, worldwide, and an estimated total of 4 billion tonnes is stockpiled in the various producing countries [1]. Despite decades of research across the industry and academia, a very limited number of successful reuse solutions are in place today. The most successful example is to recycle BR in ordinary Portland cement (OPC) clinker, which has been reported by Mytilineos' Aluminium of Greece (AoG) refinery [2], and Hindalco's refineries in India [3,4,5], and a few others, as reported elsewhere [6,7]. For the Rio Tinto alumina refineries, like in many jurisdictions, the BR soda content is a constraint, preventing or limiting its utilisation in the cement industry.

As part of the International Aluminium Institute (IAI) workgroup on bauxite residue reuse in cement [6], a "cement process crash course" was given by Mr Diego Rosani (consultant for the IAI, formerly holding senior technical roles in major cement companies) in the first week of August 2020. This gave rise to the idea of externally recycling Bayer security filtration spent filter-cake (SFC), based on the fact that OPC clinker contains significant quantities of tricalcium aluminate (TCA). The natural fit comes from the composition of the Bayer security filtration

filter-aid which is typically tricalcium aluminate in its hexahydrate (TCAH, $3CaO{\cdot}Al_2O_3{\cdot}6H_2O$) and silicate (TCAS, $(3CaO{\cdot}Al_2O_3)_nSiO_2$) forms, leading to the combined composition $3CaO{\cdot}Al_2O_3{\cdot}xSiO_2{\cdot}(6\text{-}2x)H_2O$ (where $0.05 < x < 0.25$, typically) [8,9]. The concept would be to extract the SFC stream for the material to be recycled before it is disposed of in the mud washing circuit. SFC represents a few percent of the total residue output from the Vaudreuil alumina refinery and therefore represents an interesting starting point to reduce its BR output.

Two recycling options exist for SFC, which are further described in the next sections. The first option is internal recycling as a source of calcium in the low-temperature digestion. The second is external recycling as an OPC clinker ingredient in a cement plant. Since SFC typically contains much more filter-aid than red mud fines, it is expected that its soda content will be low enough to make it a suitable feed material for cement plants.

It is also worth noting that alumina recovery from SFC has been studied in the recent past [10] but is not one of the options considered in this work. The same applies to the option of recycling SFC as a filter-aid, which had been considered by some plants in the past.

1.1 Preliminary Business Case

A value has been calculated for each tonne of Vaudreuil BR not sent to the disposal area, which includes sustaining CAPEX, OPEX and a part of the closure cost. This number is used internally to evaluate the business case of the various reuse initiatives.

1.2 Internal Recycling to Digestion

Over the years, the concept of recycling SFC into the digestion process as a source of calcium to control phosphate concentration in liquor has been studied and/or piloted in many different refineries (Burntisland, Gove, Jamaican plants, QAL, Vaudreuil, etc.). Various plant constraints or marginal business cases may have been obstacles to a more extensive rollout, but the increasing pressure on the need to reduce BR output makes the concept more attractive and suggests it should be revisited. To perform this type of internal recycling, a simple settler could be used to concentrate the slurry to 40-50 wt %, and use digestion feed liquor to transport it to the normal lime (or milk of lime) dosing point in the digestion circuit. The required CAPEX for installing a small settler should not be prohibitive, and the reduced cost of purchasing lime should justify the investment. A thorough sampling and experimental work campaign was undertaken at ARDC to assess the various process risks described in the next sections and to confirm the validity of our assumptions and a favourable business case.

1.3 External Recycling in Cement Clinker

The concept of recycling SFC to the cement industry is new, and discussions with various experts in this industry suggest that its composition makes it a valuable material to introduce in the raw meal at many cement plants. In addition to using a waste stream instead of mined raw material, SFC could provide additional and unexpected benefits to the cement industry in terms of SO_2 emission reduction or the ability to use cheaper/high-S fuel sources for the clinker kiln. The typical Bayer lime-based filter-aid (TCAH) was effectively considered in the past for flue-gas desulfurisation [11], just like the bauxite residue itself was the subject of a patent in that area [12,13]. It is also worth noting that SO_2 captured by BR in the OPC clinker kiln is one of the benefits mentioned by Hindalco [5]. This could therefore represent a financial incentive for cement producers, along with Scope 1 CO_2 emission reduction of the order of 0.3 tonne of CO_2 per tonne of SFC used in the raw meal, based on the calcium content calculated as limestone equivalents.

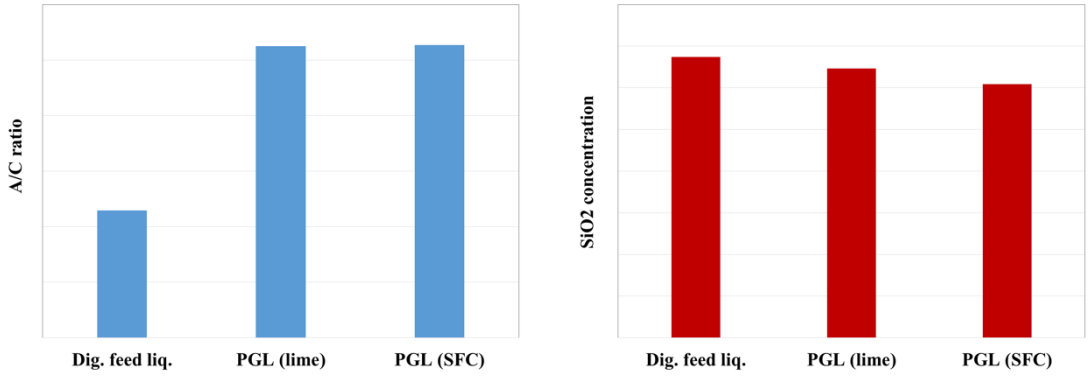

Figure 8. Digestion liquors A/C ratio (left) and silica concentration (right).

4. Conclusions

In view of recycling security filtration spent filter-cake, the material composition was confirmed by an extensive sampling campaign at the Vaudreuil refinery. The tricalcium aluminate component was shown to be a mixture of TCAH and TCAS, corresponding to the approximate formula $3CaO{\cdot}Al_2O_3{\cdot}0.1SiO_2{\cdot}5.8H_2O$. The calcium content, however, suggests the presence of unreacted lime, calcite and other intermediate species in the filter-aid. The sampling also confirmed that SFC contains about 85 % of the tricalcium aluminate species and 15 % of fine red mud solids, and the material soda content is ~1.4 % Na_2O, which is normally acceptable to be considered in North American cement plants' raw meal. Preliminary digestion results suggest that internal recycling is also possible without detrimental effects on liquor phosphorus control, alumina extraction or desilication.

All the settling and filtration tests, as well as slurry rheology measurements, indicate no significant process issue if the SFC slurry stream was to be extracted from the plant before being sent to the mud washing circuit. On the other hand, the first washer liquor stability seems to be impacted in a significant manner when SFC is not part of the feed slurry. While the former was very encouraging, the latter result will require more investigation and evaluation to progress this project to the pilot stage.

Even if the Bayer circuit conditions vary significantly between refineries, the concept of SFC recycling could very well be applicable to other alumina plants, and this article could be used as a guide for similar process impact assessment studies to be undertaken.

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