AA16 - Iron Removal from Bayer Liquor: The Ma'aden Alumina Refinery Experience

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Abstract

High temperature alumina refineries that treat low-iron bauxite (5 to 10 %) can have elevated concentrations of iron-in-liquor. At Ma'aden an iron concentration in the bauxite above 10.6 % is targeted. Mine grade control and stockpile building and blending is carefully monitored to deliver this iron grade. When bauxite iron is exceptionally high (> 13 %) the Iron concentrations in Ma'aden liquor are at a minimum of 5 mg/L and can deliver a product Iron of 0.010%. Lower bauxite iron concentrations more typically deliver high iron-in-liquor concentrations (12 to 18 mg/L). Dissolution of Iron occurs during digestion, this represents an equilibrium concentration established between the iron-bearing minerals in the bauxite and the liquor. The iron is present as colloidal or nano-sized particles rather than being in solution, and passes through security filtration. Hematite surface area, lime addition, free caustic concentration, temperature, holding time and mineralogy all influence the liquor iron concentration. Elevated SO_4, CO_3 and F concentrations in Pregnant Green Liquor (PGL) would also appear to favour lower iron liquors. As is evident from plant data lime injection into the digesters at 270 °C can bring down iron-in-liquor by up to 7 mg/L, lime addition is an important process operation for iron control and helps dramatically overcome high iron concentrations. To target a lower iron-in-liquor concentration requires an incremental approach, and for this reason a range of small improvements need to be targeted simultaneously. In the precipitation circuit iron is almost completely removed from the liquor and is coprecipitated with gibbsite as it crystallises and grows. An increased precipitation yield lowers the iron-in-product by a simple mass-dilution effect. Targeting an increased Alumina to Caustic (A/C) ratio can improve the precipitation yield, lower free caustic and help increase and maintain bank solids. Holding time and addition of reagents can help with the growth of colloidal iron particles, an increased colloid size will aid its removal during flocculation and filtration.

Keywords: Ma'aden, hematite, seeding, yield, digestion.

1. Introduction

During aluminium smelting the presence of iron in the melt reduces current efficiency, because compounds can be reduced at the cathode and re-oxidised at the anode. Incorporation of trace amounts of iron into aluminium metal also influences its physical properties. Quality considerations require iron concentrations to be controlled and continuously monitored. Iron concentrations as small as 0.015 % in smelter grade alumina (SGA = product) are sufficient to impact on the Cast House product specifications. There are also a limited number of smelters willing to purchase such product, and for these reasons high-Iron product achieves a marginally lower price on the open market.

Mine grade control and bauxite blending are the most critical areas for delivering a consistent bauxite iron grade especially when Iron grades are on average usually low (9 to 11 %). On digestion of bauxite the iron-in-liquor is found to be inversely proportional to the iron content in the bauxite [1]. This is a generic problem for the alumina industry and for this reason high iron-in-bauxite (> 10.6%) needs to be targeted to deliver a low iron-in-liquor composition (Table 1). There is no simple process solution to reduce Iron-in-liquor other than using the sweetening process but this is cost prohibitive. The other more realistic option for the reduction in iron is through an incremental mine and refinery improvement approach.

Table 1. Bauxite iron concentration and its effect on soluble iron, and product iron.

Bauxite Fe_2O_3 (%)	*Liquor Fe_2O_3 (mg/L)	*Product Fe_2O_3 (%)
> 10.6**	6 to 17	0.010 to 0.022
< 10.6	17 to 26	0.022 to 0.030

*Also partially dependent on precipitation yield.

An iron equilibrium concentration will be established between the iron minerals in the bauxite and the hot caustic Bayer liquor. The actual concentration is dependent on Iron mineralogy and iron content, mineral surface area, FC (Free Caustic), precipitation yield, temperature of digestion and the holding time (Table 1 and Figure 1). These factors have been identified from operational data and from experimental work on bauxites containing variable iron concentrations [1, 2]. It is the hematite surface area that is the most important factor for the removal of iron from liquor. A high surface area of hematite is capable of seeding iron from liquor with the precipitation and removal of the colloidal iron (Table 2).

Between 95 to 100 % of the soluble iron entering the precipitation tanks is removed during gibbsite precipitation. This fact allows a set of simple graphs to be drawn. As indicated in Figure 2, the product Fe_2O_3 can be calculated if the liquor iron concentration and precipitation yield are known. The target product quality region is the shaded area for achievable precipitation yields of between 80 to 90 g/L. Elements which also behave in an identical way to Iron-in-liquor include: Ca, Ti, Zn, Cu, Zr, Mn, Mg, Be, Nb, REEs [3]. These are found in significantly lower concentrations in liquor and are also coprecipitated with gibbsite.

After operating the Ma'aden refinery for over 4 years, the relationship between iron-in-bauxite and its impact on liquor and product is now well established. A maximum acceptable iron-in-product is targeted at 0.015 %. Total iron-in-bauxite needs to be above 10.6 % to maintain an iron-in-liquor concentration of below 17 mg/L. However, even when lime injection into liquor at 270 °C is practiced it has been observed that elevated iron concentrations can still occur. The lime addition into digestion must be ~ 25 kg per tonne of bauxite, otherwise high iron concentrations will result (> 20 mg/L). Only after prolonged periods (3 to 4 days) of using low-iron bauxite stockpiles does it starts to make a clear impact on product quality.

any downtime and to help deliver a consistent lime slurry flow to digestion with minimal variability.

The iron-in-liquor composition needs to be reduced where ever possible and requires a multi-step incremental approach rather than the hope of finding a single step solution. Achieving a 10 to 20 % reduction in the liquor iron concentration should be considered a success. In laboratory test work a 5 to 8 % reduction in the iron concentration appears to be possible through improved settling and filtration. The reductions may simply be through removal of the coarser sized colloidal iron particles from the liquor stream.

As Data Scientist W. Edwards Deming has suggested for quality control "Understanding the variation is the key to success in improving the quality". From plant experience at Ma'aden a 14-step plan of action could be followed, for the delivery of an iron reduction improvement. The list details the involvement of personnel from several individual unit operations, all of which can contribute to the overall iron reduction. Success is seen where there is a clear and consistent reduction in product iron over a prolonged period. Suggested steps include:

1. Road map development + communication with mine and refinery personnel,
2. Mine grade control improvements,
3. Stockpile / blending – Target a constant bauxite Iron grade and reduce daily iron variance,
4. Lime addition - Target improved lime pumping, maintenance and operation,
5. Maximise addition of lime to digestion,
6. Ensure that purity and particle size of lime is maintained,
7. Flocculation - Improve particulate settling with improved reagent usage,
8. Minimize settler O/F solids,
9. Security filtration - Improve operation to minimize and remove particulates,
10. Precipitation yield improvements through increased bank solids and reduced impurities,
11. Reduce variance and maximise precipitation yield through increased A/C ratio targets,
12. Reduce FC in post digestion liquor through improved digestion extraction,
13. Magnetic particle removal – install permanent magnets on launders to remove metallic particles,
14. Ensure acid wash liquors from descaling of JPU's are efficiently discarded.

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