STABILISATION OF PRODUCT QUALITY AT YARWUN ALUMINA REFINERY

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Abstract

The Yarwun Alumina refinery was commissioned in 2004 by Rio Tinto in Gladstone with an innovative design that significantly reduced the capital cost and allowed above 86g/L productivity. Since start-up, maintaining acceptable product quality had been a major challenge. A collaborative project between the refinery and Rio Tinto Alcan's Technology organisation was initiated in early 2008 to address this challenge. After a detailed analysis of the circuit dynamics was completed a number of strategies were found. Some of these strategies were trialed and implemented. The result was acceptable and considerably more consistent product, while a large capital cost solution was avoided. The outcome was largely attributable to Rio Tinto Alcan's long history and expertise in precipitation control circuit design and control philosophy. Once a final control strategy was put in place, product quality dramatically improved, from 50% size compliance to 100% output on specification.

Keywords: Product quality, alumina size, Yarwun alumina refinery, particle size distribution

1. Introduction

Rio Tinto Alcan Yarwun refinery situated in Yarwun, 10 kilometres north-west of Gladstone in Central Queensland, Australia. It commenced producing smelter grade alumina in September 2004, with a current annual capacity of 1.4 million tonnes per annum. An expansion is currently in its final stages to increase capacity to 3.4 million tonnes per annum from 2012.

The refinery processes bauxite is supplied from the Weipa mine (100% Rio Tinto Alcan owned) in northern Queensland. Yarwun was designed and constructed with leading edge technology and environmental design features. Digestion of the bauxite is achieved at high temperatures using an energy efficient jacketed tube design. The design intent was to construct a plant with low capital intensity.

Since start-up, the refinery was not able to achieve a product that was consistently of smelter grade specification with respect to alumina size. As production of the refinery increased, the conformance to specification worsened. In 2008, a collaborative effort between the refinery and Rio Tinto Alcan's technology group was established to resolve the product quality issue. This paper reports the outcomes of this effort and the resultant improvement to the product quality consistency.

2. The Refinery

The philosophy in designing the refinery was to use leading-edge and proven technology in a simple and low capital cost design. The main design features are an energy efficient high temperature digestion and high productivity precipitation.

The precipitation design delivers greater than 86g/L yield of low-impurity alumina but presents a unique challenge in terms of the size of the alumina crystals. This section details the key design features of the refinery's precipitation circuit.

2.1 Row Flow

Digestion is comprised of six jacketed pipe unit (JPU) trains. These require relatively regular cleaning to maintain the heat transfer surfaces. Therefore, the precipitation row typically experiences two modes of flow: five-train flow and six-train flow. That is, the digestion operation provides some inherent instability of flow.

2.2 Seed Charge

The precipitation circuit is an American-type design with separate agglomeration and cementing (growth) stages. 100 per cent of the seed charge is filtered and reslurried for addition to the precipitation row. The growth tanks agitate a high in-tank seed charge of greater than 650g/L. The high seed surface area results in high productivity, and also leads to a high recirculating load of alumina trihydrate inventory.

2.3 Temperature Profile

The precipitation row utilises a gradual temperature profile that closely resembles the optimum temperature profile for maximising productivity. Of the seventeen growth tanks thirteen have slurry coolers. The gradual temperature profile minimises soda occlusion into the product compared to one or two larger inter-stage coolers.

2.4 Classification

The classification of the seed is done with a single stage of hydro-cyclones. The classification stage is designed to process only what is required for 'product' and 'fine seed'. The remainder of the seed is classed as 'coarse seed', filtered with disk filters and recycled to the growth row. Therefore, only 25-30 per cent of the slurry exiting precipitation is classified with the remainder returning to precipitation with an unchanged particle size distribution (PSD). Typically, most plants would use two or three stage classification to ensure an acceptable product size distribution and maximise capture of fines to the agglomeration stage for destruction. There are, however, oxalate-free precipitation circuits that have 'weak' or no classification and acceptable product size.

2.5 Oxalate Co-Precipitation

The precipitation row co-precipitates sodium oxalate; which is a primary by-product from the carbon content in the Weipa bauxite feed. Prior to its addition to the agglomeration tanks, the 'fine seed' is washed to remove solid phase oxalate, thus preventing oxalate precipitation in the agglomeration tanks. The 'coarse seed', however, is unwashed, inducing oxalate precipitation from the growth phase. With the high seed inventory, there is also a high recirculation of solid phase oxalate, predominantly with low activity. Typically, an oxalate co-precipitation circuit would be equipped with 'significant' classification for control of the fines balance but this refinery has achieved a capital optimisation solution.

3. Anatomy of the Particle Size Distribution Cycling

To analyse the cycling of the particle size distribution (PSD) the key indicator, the amount of fines (%-45um), was observed in several sample locations over time. Figure 1 below shows the %-45um in the Fine Seed, Pump-Off and Product hydrate. Cycling of the PSD has been previously observed in several plants and solutions were found to alleviate the variation. Oscillations shown in Figure 1, however, are thought to be significantly more regular than those previously observed in a Bayer precipitation circuit. The most dramatic variation observed was in the fine seed and the least variation was in the hydrate product, thanks to the classification system.

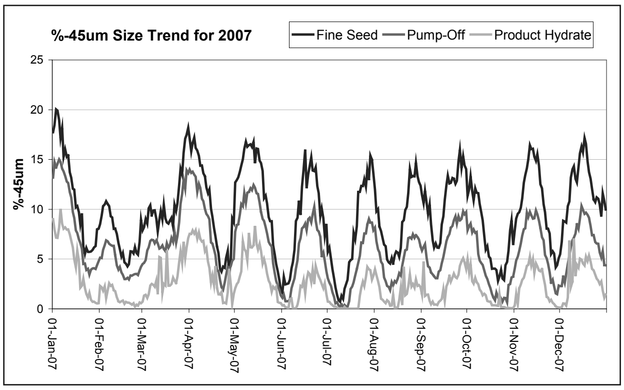

Figure 1: PSD Cycling as a function of time

The variation of the fines in the alumina product was related to these oscillations as the fines in the hydrate product inevitably translates to more fines once calcined due to particle shrinkage.

The variations of the alumina product were increase by some additional fines coming from the breakdown of particles which fortunately was lower during the peaks.

Figure 2 helps to explain how the small particles grow in size, and how the cycle is repeated. The periodicity of the cycle is also clearly illustrated. (1) The nucleation event: the trend upwards of the ultra-fines, %-5um, signals the initiation of the next cycle. (2) The ultra-fines grow and agglomerate and translate through the size fractions. The population balance is unbalanced, depleting the circuit fines. (3) The circuit is coarse and low in available specific surface area, leading to the next nucleation event.

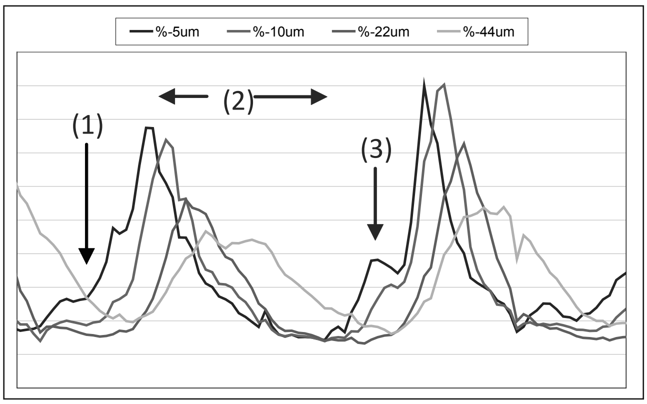

Figure 2: Translation of Nucleation Event through Size Fractions (NB: scale adjusted)

The comparison of weight (or volume) density curves at several times through the cycle also illustrates that the real fluctuations are at the finer sizes, and that coarse particles are not fluctuating significantly (refer to Figure 3).

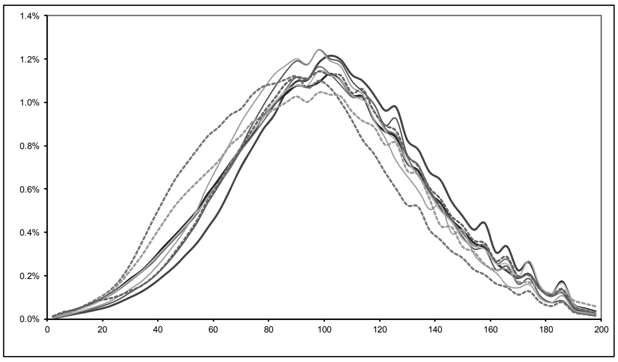

Figure 3: PSD Curves by Weight (or Volume) Density

Expressing the PSD for the same selected times in number density distribution rather than weight density gives greater resolution (Figure 4). The particles varying the most are between 10 and 90 um while the curves for coarser particles are almost overlapping.

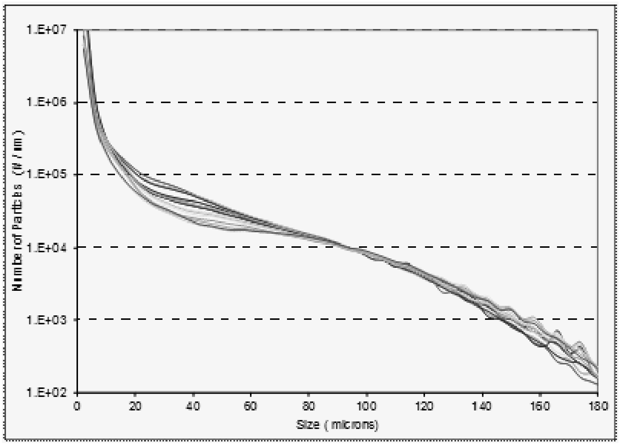

Figure 4: PSD Curves by Number Density

In Figure 5, the number of particles between 20 and 30 um is compared to the number of particles in the size bin above (30 to 44 um), with a delay of three days. A clear correlation can be found. These observations formed the basis of a simplistic model able to predict the amount of fines in the product almost 2 weeks in advance.

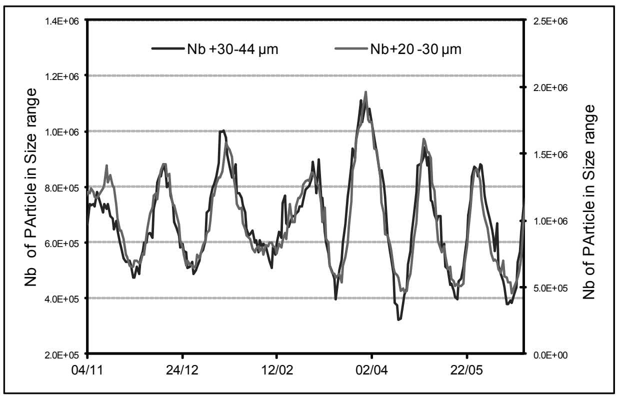

Figure 5: 20-30um Number Density with a 3-day lag, and 30-44um Number Density

Representing the same size ranges on a X-Y graph confirms the good correlation between them as indicated by the R^2.

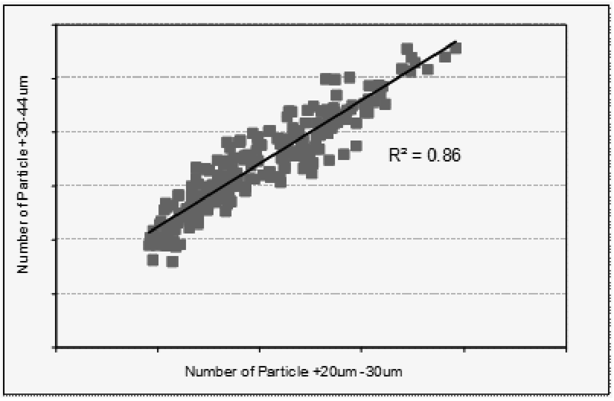

Figure 6: Correlation of +20-30 um and +30-44 um Number Density

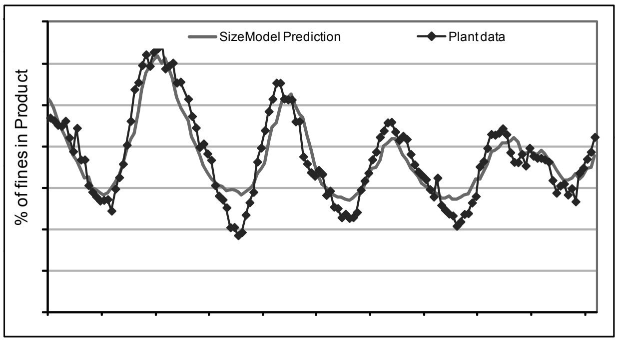

Figure 7: Size Model vs. Actual Plant Data

It was critical to the recovery of the site's product quality to have a comprehensive understanding of the population balance and the refinery's significant drivers for birth and death of crystals. The precipitation control philosophy was formed on this understanding.

4. Product Morphology

In addition to PSD fluctuation, the morphology of the product was seen to vary significantly throughout the cycle. The morphology was analysed using an image analysis technique developed by M.N. Pons from University of Nancy[1].

The technique provides a detailed analysis of the morphology using a series of descriptors, such as sphericity, elongation and average crystallite size. A combination of these descriptors is the best representation of what an experienced observer from the Bayer crystallization field would commonly call indices of mosaicity or blockiness.

Figure 8 shows the output from this analysis. From left to right is an index of mosaicity which showed that Yarwun product was undergoing large swings in the proportion of highly mosaic and highly blocky particles, with not many particles that were of intermediate morphology. This difference is particularly large when comparing the distribution of morphology at the beginning and the middle (sixteenth day) of the cycle. While at the beginning of the cycle there is a big spread of morphology (even bimodal), in the middle of the cycle the particle are clearly predominantly mosaic.

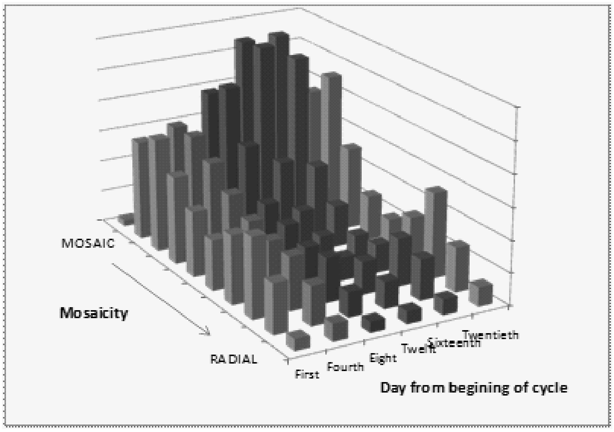

Figure 8: Visual Representation of Variation in Morphology throughout the Sizing Cycle

These observations are supported with SEM analysis of the section used to do the image analysis data capture. The section is made from an epoxy mould in which the particles have been imbedded and cut and polished.

Figure 9, shows particles taken from beginning of the cycle. Two types of particle morphology can be seen: large particles that are round and blocky in shape (radial), and the smaller particles that are irregular and are composed of small crystallites (mosaic).

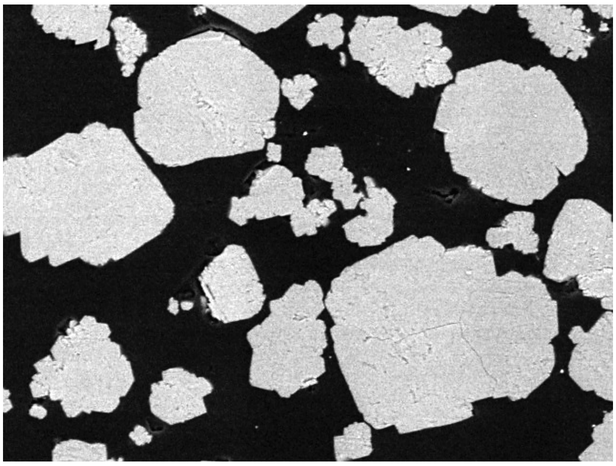

Figure 9 Example of particles from the first day of the cycle

Particles in the middle of the circuit are more homogenous (figure 10), displaying primarily mosaic morphology and irregular in their shape. There is an absence of large blocky particles, seen at the beginning of the cycle, and majority of middle size particles

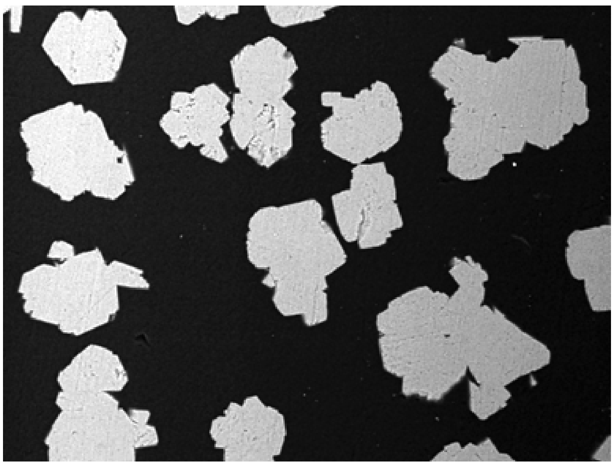

Figure 10 Example of particles from the sixteenth day of the cycle

5. Proposed Solutions

Various solutions to the cycling behaviour of the PSD were proposed and tested to varying degrees over the course of 2008. Due to the economic climate at the time, the priorities were on a low capital cost solution and rapid progression to implementation.

5.1 Two to Three Stage Classification

Installation of additional stages of classification was assessed in a feasibility study. Increasing the strength of classification would concentrate the fines in the 'fine seed', maximizing the ability of the circuit to consume fines when needed. Additional stages of classification would also result in an improved capacity to 'buffer' the product alumina from swings in precipitation PSD.

The advantages of this solution are that it would produce an acceptable quality product with low variability, an improved attrition index and would be more robust to process disturbances. The disadvantages of this solution are the high capital cost and long lead-time to implementation.

5.2 Variable Temperature Profile

In lieu of a strong capacity for destruction of fines, control of PSD can be achieved by controlling the generation of fines. As discussed, the circuit has a comparatively small capacity to destroy fines due to the classification design. However, the gradual, staged cooling design allows for a high degree of control of fines generation. Coupled with this is a requirement for understanding the drivers for nucleation and monitoring the PSD throughout the circuit.

The advantages of this solution are that it would produce an acceptable quality of product with low variability at a very low capital cost. The disadvantages of this solution are the ability to recover after a significant process disturbance and the requirement for frequent process monitoring and understanding of the circuit behaviour and tools for predicting nucleation.

5.3 Reduced Seed Charge

The proportion of the circuit classified can be increased by installing additional stages of classification, or reducing the in-tank seed charge. Reducing the inventory of hydrate in the growth row, increases the proportion of fines inventory destroyed in agglomeration.

The advantages of this solution are that it would produce an acceptable quality of product with low variability, reduce attrition index, with no capital investment required. The disadvantage of this solution is the significant impact on productivity; essentially downgrading the refinery's production capacity.

6. Product Quality After Implementation

A combination of these solutions was implemented at the beginning of 2009 after various trials and modeling of proposed improvements. Since the implementation, shipping conformance has been 100 per cent. At the time of article submission, Yarwun had achieved 34 months of consecutive on-specification product (Figure 11).

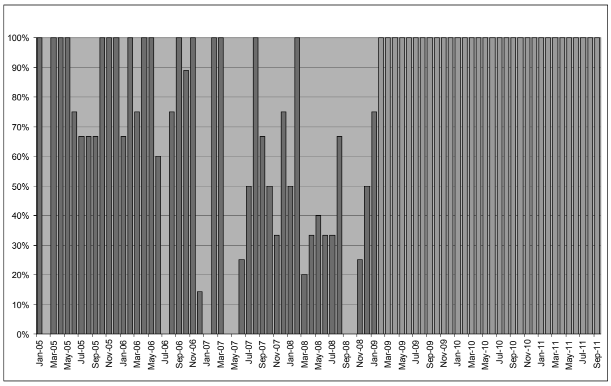

Figure 11: Historical Shipping Conformance at RTA Yarwun

Variability of the daily alumina size and shipped alumina size is significantly reduced, as shown in Figure 12.

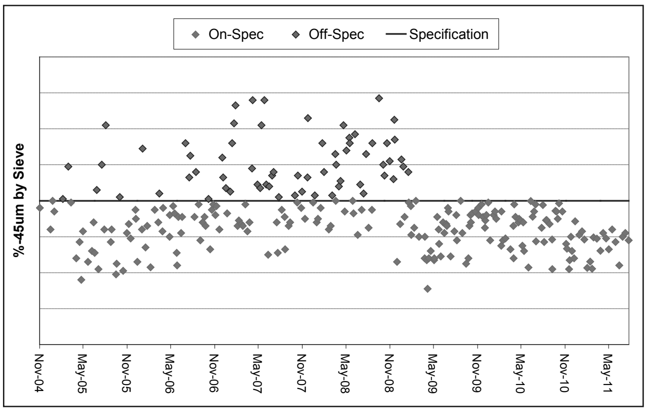

Figure 12: Historical Shipment <45um v/v%

This step change in product quality was achieved without negatively impacting the plant's productivity and with minimal

7. Conclusion

The refinery has been operating at design production capacity with acceptable product size since February 2009. This period of operation is a demonstration of the ability to process Weipa bauxite with a low capital intensity design to produce smelter grade alumina.

8. Acknowledgement

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Reference

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