ALUMINA FINES' JOURNEY FROM CRADLE TO GRAVE

Chandrashekar, S, Jackson, D, Kisler, J*
Comalco Mining & Refining, Brisbane, Qld, Australia

Abstract

Alumina product quality is a priority for all refineries. Chemical purity of alumina is controlled on the red side whilst physical quality control happens largely within precipitation, with great care taken to meet customer specification. SSA, Alpha alumina and LOI are controlled in calcination.

Particle size is controlled in precipitation. Excessive nucleation, poor size control and particle breakage across calcination result in increased fines in product. Refineries and smelters alike understand size but not strength and the customers insist on certain size numbers. Yet, considerable particle breakage occurs in smelters questioning if the achievement of a spec at the refinery boundary is the best parameter to work to.

This papers looks at alumina quality aspects in a holistic way, from precipitation to smelter reduction cells, with a major emphasis on fines – from 'cradle to grave'. The industry as a whole needs to define, understand and measure particle 'strength'. Although being mentioned for years, has the time come to find ways to eliminate addition of fine alumina and ESP dust to product? Smelters need to consider particle breakage during in-plant transfers in order to reduce dusting, particulate emissions and improve reduction cell efficiency. By working together refineries and smelters can bring about improvements in HSEC issues as well as the bottom line. It is possible that re-defining the quality specification for alumina will improve refinery efficiency whilst better meeting smelter demands.

1 Introduction

Alumina product quality is a priority for all refineries, but who defines quality? "Quality is delighting the customer" and "the customer is always right" are some familiar notions. This is the accepted wisdom in the refinery-smelter business relationship. The contract specification is strictly adhered to, barring the unforeseen. This approach has led to some improvements in alumina quality as the smelters have demanded lower impurities and easier handling alumina. However, is this the best way forward for the future? Our proposition is that we need to look at the refinery-smelter value chain to determine where best to tackle problems. Pushing the responsibility back to the supplier (refinery) is the traditional way but will it achieve the optimal result? Our comments in this paper refer to refineries and smelters in general as we have considered comments from non-Comalco sites as well.

Experience has shown that refineries focus their behaviour on trying to meet contract specifications instead of resolving root causes. While trying to accommodate smelter concerns about product quality are the refineries doing all that is possible or just doing enough to meet specifications without unduly affecting productivity? For example, the refinery focus is often on the –20 µm and –45 µm size fractions of the alumina as these are specified in the contract. Invariably production of coarser product is accompanied by a decrease in precipitation yield (production) and particle strength. In other words, meeting the smelter desire of coarser product comes at a penalty to the supplier, all else being equal. However, recent work has shown that significant amounts of additional fines are generated during alumina handling at the smelters. Are we focusing on particle size when we actually should be looking at particle strength?

Consider the following list of "wants" from a customer (Morrison, 2005):

- Utilisation of the best possible sources located at the best geographical position
- Delivery at a reasonable cost
- Consistency in processability
- Stability in supply
- Minimisation of environmental risk

Interestingly this was written from an alumina refining perspective in terms of the desired bauxite supply. While we might desire high available alumina, low reactive silica and low organics we've learnt to temper our expectations. We've learnt which parameters are best controlled at the mine (for example by bench mining or beneficiation) and which are more effectively controlled at the refinery (by lime dosing, liquor cleaning etc). Have we achieved the same level of understanding with our smelting customers?

The intention of this paper is to question the current refinery-smelter relationship. As a way of illustrating our points we've chosen to trace the path of fines, from their generation in precipitation through to the smelting cell. Our focus on fines is not to say that other chemical or physical properties are not important. Hopefully by drawing attention to some current operating practices and process management philosophies we can highlight the need for change, not just at individual refineries but on an industry-wide basis. It is the express desire of this paper to raise more questions than it answers, but the intention is also to provide some insights into an alternative refinery/smelter working relationship.

2 What Does the Customer Really Want?

In 1999 QAL's owners formed a taskforce to consider product quality and customer's future expectations. A survey of the owner's smelters provided information on the smelter's chief concerns (see Figure 1). It is interesting to note that the highest ranking factor was

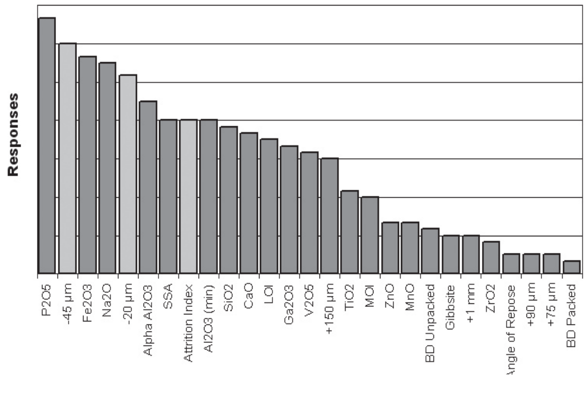

Figure 1 – Alumina Characteristics in Order of Importance from Smelter Perspective

phosphorous, something that can be controlled by increasing lime addition to digestion. Similarly the third most important factor turned out to be iron in product which is surprising given that over 80 % of the iron in aluminium metal comes from sources at the smelter (for example anode rods). On further investigation it turns out that most smelters rely on low iron alumina as controlling iron inputs at the smelter could result in a direct production loss.

The survey data also shows that alumina physical properties were also major concerns for the smelters (for example –45 µm, –20 µm and attrition index). Combining these three categories into one "dustiness" category would have seen it as clearly the highest ranked concern. Alumina fines content has a large impact on a number of smelting sub-processes including bath operation, control of dust, fluoride emissions and greenhouse gases (Lindsay, 2004).

A not surprising message from the smelters was the desire for consistency. The smelters also suggested that refineries should be reporting their process capability with respect to the product specification. Most smelters already measure and report process capability on their own products. Should refineries be held accountable for shipment-to-shipment variation?

Bauxite is sold under contracts with bonuses and penalties calculated according to the bauxite grade. For example, every 1% alumina above a certain level would attract a bonus (higher price) while lower alumina levels would result in a price penalty. Would refineries and smelters be willing to operate under a similar scheme? In the current alumina market it would be interesting to see what product quality trade-offs would be made in order to increase alumina production. Optimisation of benefits and costs rather than a dilution of quality control would be the main reason for a bonus/penalty concept.

3 Refinery/Smelter Collaboration

Most big companies now articulate a 'One Company' philosophy to bring people from different parts of the organisation together under a unified set of systems. Invariably these one company systems and practices include health, safety, environment and community (HSEC), HR, procurement and IT. In some enlightened companies this may even extend to maintenance. In the age of the internet and intranet this is more easily achieved that ever before. However, processing issues are normally kept out of this.

Within a single company, refineries and smelters do not seem to collaborate in their efforts at all, even though their lives are intertwined due to alumina. In other words, even within a company, the refineries and smelters tend to live in different, and often opposing, worlds. This is starkly illustrated in the way we structure our companies. Companies divide themselves into "mining and refining" and "smelting" or "bauxite and alumina" and "primary metal". If this mental divide occurs within single large companies, what hope exists for collaboration between refineries and third party smelters?

Most producers tend to have 'Internal Quality Aims' (IQA), which are tighter than the contract specification. Shipments outside of the internal benchmark require notification to owners and senior management. The value of these internal benchmarks is in imposing discipline on refineries and ensuring that diagnosis of problems and implementation of corrective actions are taken long before the contract specification is threatened. The effectiveness of these internal quality aims in improving alumina quality and consistency was demonstrated at one refinery where a major improvement was achieved in the space of a couple of years. In the year prior to the introduction of the IQA only 30% conformance would have been achieved, which quickly rose to 95% after the IQA was introduced (and has remained there in the subsequent couple of years). The challenge now is to achieve the IQA standard for day-to-day production and not just on shipment averages.

However, IQAs are invariably more difficult with size rather than chemical parameters, as contract specifications on size are tight and there is not much room for movement. Specifications for chemical impurities tend to be ultra conservative, for example a contract specification could be 0.5% for Na_2O whilst the "typical" supply number may be close to 0.35%. However, physical parameters, especially size, tend to be tighter with smelters successfully demanding and obtaining commitments at 12% or even 10% –45 µm (and 1.5% or 1% –20 µm). In some cases the –45 µm limit could be 10% for both the IQA and contract specification. This example highlights the vulnerability of a refinery to breach the size specification.

We started a weekly communication (teleconference) between a refinery and its major smelting customers. This provides an opportunity for the refinery to forewarn the customers of product quality issues in future shipments, even if these issues are not of sufficient seriousness that the contract specification will be breached. Items like maintenance and alumina silo levels are also discussed with the advantage that the smelters are able to provide regular informal feedback. There is also a tendency at tolling facilities for the owners to do the talking rather than the refinery operations team. With third party customers the feedback is often on the basis of 'no news is good news'.

4 Precipitation

While chemical purity of alumina is often controlled on the red-side (e.g. P_2O_5), or even by virtue of the bauxite source (e.g. Ga_2O_3), the alumina physical quality control happens largely within precipitation. However, within precipitation there is a connection between productivity and quality. For example, the parameters which favour high yield in agglomeration (low temperature and high caustic strength) also encourage nucleation.

In a recent survey of industry R&D needs conducted as part of the Alumina Industry Roadmap exercise (now the Alumina and Bauxite Committee of the International Aluminium Institute) untying the knot between productivity and quality was the project which gained the most positive industry support from a short-list of 18 projects. While the interest in this topic is understandable, identifying a route forward will be difficult. Our willingness to pursue this field of study in the coming years will probably be a good indicator of our commitment to radically changing future product quality and circuit productivity. After the change from floury to sandy alumina in the 1970s and the move to hydrocyclone classification, have there been any major advances in precipitation technology in the last ten years?

The strength of the agglomerates is currently not measured, probably because this is so difficult to quantify. In fact, we don't even have a good working definition of hydrate strength. Work has been conducted to develop a test for hydrate strength (Illievski, 2000) but the test is significantly more time consuming and complex to conduct and interpret than the traditional attrition index measurement. The challenge for researchers is to develop an easy to use strength test that can be employed on a routine basis by the refineries. Despite some recent advances in our knowledge we still need to better understand how hydrate strength relates to the strength of the calcined alumina product.

While the effect of oxalate on fines generation is well known, some refineries continue to return unwashed fine seed to agglomeration. This may be as a result of capacity creep outgrowing the existing seed wash system. Workarounds have been found where the unwashed seed is flushed with steam to dissolve solid phase oxalate. The detrimental effect on hydrate strength takes a backseat to the push for higher productivity. Are the alumina fines problems experienced at smelters at least partly a direct result of not creating strong enough agglomerates early in precipitation?

Hydrate classification is also an important consideration. If classification is poor (with more fines reporting to product) then the circuit may be coarsened, losing production as a result. At a large refinery it is estimated that coarsening the precipitation circuit by 1% (i.e. a 1% decrease in the amount of –45 µm in product) may cost A$30 million in NPV terms. Refineries operating conventional hydrate thickeners would never be able to justify the economics of conversion to cyclones on the basis of process stability benefits alone. Does this mean that refineries operating thickeners are forever consigned to living with the operational and downstream product quality problems they create?

5 Calcination

Calcination is controlled to achieve the desired specific surface area, alpha alumina and LOI. For a given calciner the inter-relations between these variables are well known by the operators. Particle breakage in calcination is a more difficult matter with the breakdown influenced both by the calcination conditions and the precipitation conditions which produced the hydrate. While the attrition index measurement gives a guide to particle attrition resistance, it is not accepted (particularly on the refinery side) as being anything other than a relative measure and is certainly not a substitute for a proper alumina strength test.

The move away from energy inefficient rotary kilns to newer technology fluid bed and flash calciners has had an impact on product quality as well as the precipitation circuit. With the replacement of their kilns most Australian refineries have responded to the higher breakage in the new calciners by coarsening their circuits, at the expense of productivity. Merely coarsening the circuit with all else being the same generally leads to a weaker product (i.e. hydrate and hence alumina more prone to breakage during subsequent handling). Therefore in an effort to stick to the size spec refineries could be producing a weaker product that breaks down more easily in the smelters.

An accepted industry practice is the inclusion of baghouse and ESP dust with the product. Smelters question this practice, in particular asking why they should be paying for a material that is often lost to the environment somewhere in the transfer process from the refinery to the cells. If so little of the dust contributes to aluminium production, is the effort put into capture and blending of the dust at the refinery in vain?

Refineries recycling ESP dust back through calcination are limiting their calcination capacity. Removal of the dust stream would allow additional hydrate to be processed. The issue is what to do with the dust? Alternative uses for the dust have been investigated, ranging from pelletisation, recycle to digestion and use as agglomeration seed. While the dust can be redissolved in digestion it is not a very efficient solution to send material back to the start of the process. We have conducted some work with ESP dust as an agglomeration seed which showed that ESP dust blended with fine seed has an insignificant effect on yield (Rodda, 2003). By tracking the alpha alumina content of different size fractions it was shown that the dust grew into product sized particles (see Figure 2). The work also showed that the dust contains some very reactive alumina phases which dissolve when added to liquor, meaning that the dust must be added early in precipitation. Grinding the dust prior to addition with seed had a small positive impact on yield. What other process options are available for making constructive use of this dust?

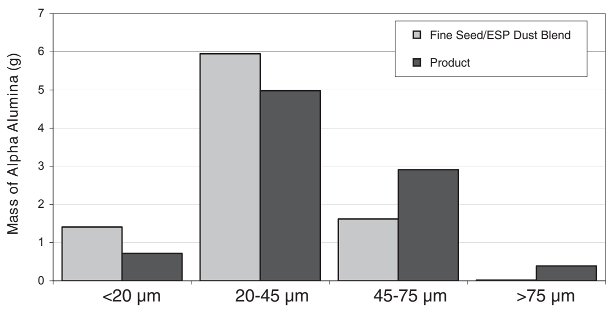

Figure 2 – Growth of ESP Dust in Precipitation as Traced by Alpha Alumina Content

We also question the focus on just three size fractions (–20, –45 and +150 µm) to categorise the product. These three parameters may be sufficient for contract purposes but are they sufficient for a technical understanding of the process? Focusing on a limited number of size fractions made sense in the past, but with the spreadsheet tools now available there is no reason to continue to limit the information available. Considering that at most 10% of the alumina will be +150 µm and another 10% will be –45 µm, this leaves us with no information about the intermediate 80%. Is there value in also monitoring the d_{50}?

It has been reported that the presence of even small amounts of gibbsite in smelter grade alumina provides a route for the unwanted generation of HF (Metson, Hyland and Groutso, 2004). Is all alumina LOI similarly responsible for HF generation, and if so what changes to calcination could be justified to reduce HF generation? Closer control of LOI is a much better proposition for a refinery.

6 Alumina Storage at Refineries

Problems due to segregation are well known and there is considerable evidence indicating size segregation within alumina storage facilities at the refineries (Taylor, 2004). These problems can be caused by operating practices (e.g. gravity fall from discharge chutes), design of storage facilities (e.g. A-frame shed, silo with flat base) or the lack of anti-segregation devices. For example, alumina stored in A-frame sheds has a propensity to segregate as the individual stockpiles within the shed are built-up under the various feed chute locations. Fines tend to accumulate at certain spots around the stockpiles and towards the far ends of the sheds away from the primary air slides. Secondary air slides must be kept in good working order to minimise dead storage space in between air slides and the reclaimed fines need to be continuously blended with coarser alumina from adjacent sections. In practice however this is not a simple matter and often slugs of fines are conveyed to the smelters, especially in times of low inventory when the remaining alumina tends to be finer.

Several innovative designs have been proposed for countering these problems (e.g. Wolf and Barron, 2004). However, the authors are aware of at least one alumina silo constructed recently that was designed with no segregation control devices at all.

Consider the effort that goes into controlling the precipitation circuit: liquor and solids samples are analysed every 4–6 hours from first agglomeration, first growth and last tank as well as a suite of additional samples around classification and seed wash (including analysing the solids for both chemical composition and particle size distribution). These results are fed back to the control room and discussed at daily parameter setting meetings. Now consider the effort that goes into silo management when the alumina is discharged for shipment to a customer. Do operators and supervisors have similar amounts of data and feedback available during silo discharge operations?

7 Alumina Transfer to Smelters

By the time the alumina reaches the smelter a certificate of analysis has been issued by the refinery stating the amount of fines, amongst other quality parameters, for the entire consignment. While the fines content is often within the contract and IQA specifications, the numbers give no indication of the internal consistency of the shipment.

Figure 3 illustrates the fines (–45 µm) content of alumina transferred from an A-frame storage facility to a smelter on a daily basis. The results show that on average the alumina is slightly finer (by 1–2 %) by the time it reaches the smelter but the variability in fines content can be substantial at both the refinery and the smelter. Fines segregation rather than particle breakage is the predominant feature.

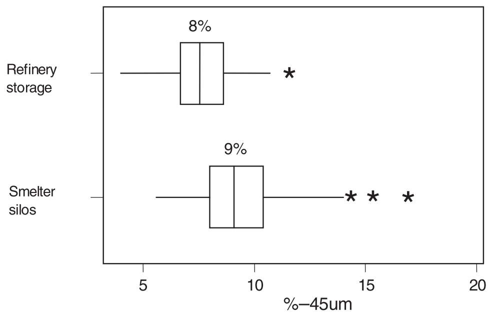

Figure 3 – Fines Content in Storage Silos at Refinery and Smelter

Although it is desirable to keep the average fines content of a consignment to a minimum (less than 10% or even 8%), the consistency of the fines content within and between deliveries is equally important from the customer point of view. Short term variations in fines content can cause excessive dusting and spillages during alumina transfers. For one smelter receiving alumina via a belt conveyor, the response to high fines is to slow the speed of the conveyor to minimise spillage problems and losses. The cost of alumina fines is therefore felt in terms of not just health and environmental impact but also in terms of maintenance, alumina waste and operating costs.

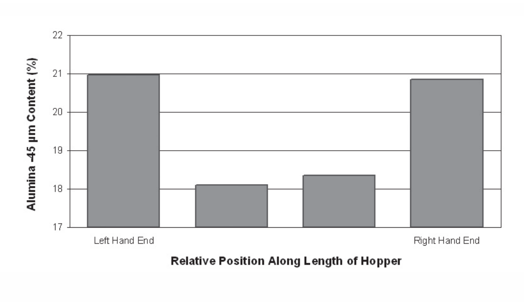

Figure 4 – Fines Segregation in the Reduction Cell Hoppers

8 Alumina Storage at Smelters

Apart from the fines segregation observed in the alumina delivered from the refinery, there is also segregation of alumina in the various silos, bins and hoppers at the smelter. These problems are similar to those experienced in refinery silos. One smelter has implemented a silo management program focusing on reclaiming techniques, such as maintaining a level of at least one third capacity to minimise accumulation of fines in their main alumina silos.

Avalanche phenomena experienced when the bins are nearly empty are a significant contributor to fines variation at the reduction cells. Also, segregation within a reduction cell hopper can be substantial with fines accumulating at both ends of the hopper (Figure 4). Is enough attention paid to design and reclaim techniques for all bins and hoppers throughout the alumina's journey from calcination to reduction cells?

9 Alumina Transfers within Smelters

In 2003, a baseline alumina study was carried out at Comalco smelters to identify the changes in environmental and process performance due to the introduction of gas suspension calciners (GSC) at the QAL refinery. Fines in alumina were measured over a weekly period at different locations between the main silos, the gas treatment centres (GTC) and the reduction cell lines. Figure 5 shows the fines content at various locations at one of the smelters. Although alumina and non-alumina fines sources are recycled from the pot to the GTC outlet and into the reduction cells, the data still suggests that significant particle breakage occurs within the smelter. Of course the amount of breakage will be a function of the particular transfer systems and scrubber technology used at the smelter.

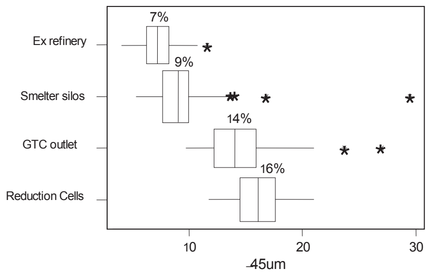

Figure 5 – Particle Breakdown and Fines Variation Within a Smelter

The study revealed that the majority of particle breakdown occurs in the conveying system (i.e. lean and dense phase systems) and/or in the gas treatment centres. For an alumina originally specified as having <10% –45 µm at the refinery, it is not unusual that it would reach the cells with up to 20% –45 µm. Considering the particle breakage which occurs in the smelters, is the achievement of a fines specification at the refinery boundary the best parameter to work to?

At one of the smelters, a program is currently underway aimed at reducing by half particle breakdown in one of the reduction lines by improving control of the dense phase conveying system. Prior to this review the system was experiencing short pipe lifetimes and very high maintenance costs due to the operation of the system under conditions not conducive to dense phase conveying. Anecdotal evidence also suggests that parts of the system had been replaced with non-standard parts due to a lack of understanding about how the system was intended to be operated.

Alumina losses within a smelter can amount to thousands of tonnes per year via spillages, dusting and emissions. At a smelter, a "dust awareness" multimedia campaign (which included posters, stickers, videos and presentations to crews) was launched a few years ago to address the dust issue. The message was straightforward: 'there are simple things that individuals can do to reduce the dust problem'. As a result of the campaign, simple changes in alumina dust control practices contributed to a significant improvement in dust emissions from the site. Aren't changing work practices to reduce operator exposure to dusty environments equally as important as programs aimed at reducing fines in alumina?

Often there may not be any obvious correlation between the size of the alumina particles entering the cell and smelter performance. However, data collected recently at a smelter clearly demonstrates the impact of fines on particulate and fluoride emissions (see Figure 6).

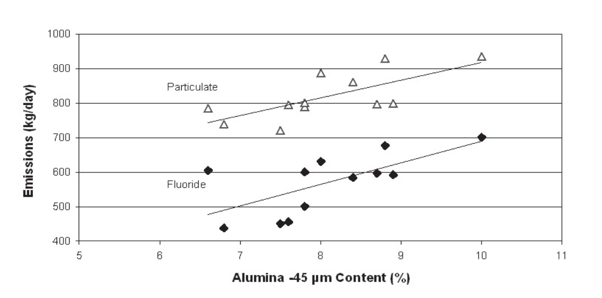

Figure 6 – Impact of Fines in Primary Alumina on Particulate and Fluoride Emissions

Data collected at a smelter also shows a good correlation between fines in secondary alumina from the GTC and unscheduled anode changes over a seven month period (see Figure 7). It is fairly well known that at an increase in anode effect frequency is experienced as dusty alumina shipments are processed, probably due to the very high dust losses during cell feeding.

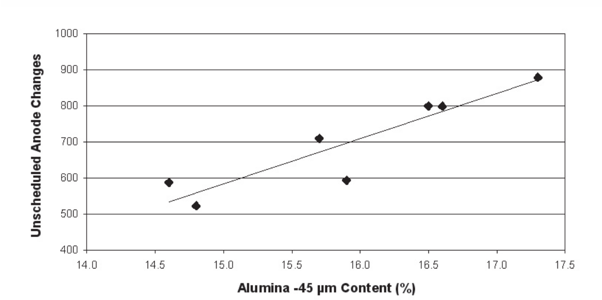

Figure 7 – Impact of Fines in Secondary Alumina on Unscheduled Anode Changes

The current AMIRA project proposal (P791A) regarding potroom dust is a step in the right direction. The project aims to not only quantify dust emissions but also to develop an understanding of dust generation mechanisms and the sensitivity of dust release to alumina properties and variability. Refineries and smelters alike will benefit from this understanding.

10 Conclusion

We are proposing a value chain approach to alumina product quality where the solution to issues like fines and dust is considered from a unified view of the refinery and smelter. We would like to encourage closer collaboration between the two parties in an effort to better understand each others needs and constraints. By working together, refineries and smelters can bring about improvements in health and environment issues. Maybe by redefining alumina quality specifications we can improve refinery efficiency whilst better meeting smelter needs.

Of particular importance is the need to shift our focus to alumina strength rather than size. There is little point in the refinery minimising the –45 µm content of the alumina shipped to the smelter, only for the smelter to attrite the alumina during internal transfers. The challenge for researchers is to improve our understanding of strength and to develop a test which can be used for routine analyses.

Also worthy of attention is the elimination of ESP and baghouse dust inclusion in product. We've successfully tested dust as a seed for agglomeration in the laboratory but there may be better alternatives.

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