KN13 - Smelter Grade Alumina Properties - The Alumina Refinery Challenge

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Abstract

Alumina is the main raw material to produce aluminium. The quality of alumina depends on many factors such as the bauxite, the process design and the process operating conditions. Some quality parameters are more reliant to one or more of the forementioned factors than others. This overview should give a high level overview on the different factors to influence the alumina quality.

Keywords: Alumina quality

1. Introduction

Alumina quality is mainly impacted by:

- Bauxite source
- Process design
- Refinery operations and operational discipline, process parameters

Ideally the required alumina specification should be known before the bauxite is selected and the refinery is designed. Mostly the bauxite is a given, which already determines some of the quality parameters. A refinery is usually designed for a specific bauxite – but over time this bauxite can change as it is a natural material. Other bauxites could also be introduced.

Adjusting the process to influence alumina quality comes with either a big Capex requirement or a higher Opex and / or production impact as there is often a competition between quality requirement and production /costs. Quality also comes down to working out the business case to achieve certain parameters. Therefore, one should be clear, what is the benefit of achieving these desired parameters.

In alumina refineries there are two different categories of quality parameters: Chemical impurities and physical properties. The main chemical impurities/properties are iron (Fe_2O_3), silica (SiO_2), calcium (CaO), soda (Na_2O), Phosphorous (P_2O_5) and traces of many others e. g. gallium (Ga_2O_3) or zinc (ZnO), titanium (TiO_2), alpha alumina/ LOI.

The main physical properties are the particle size (<45micron, <20micron), BET (surface area), Attrition Index, flowability, angle of repose etc.

The quality parameters are influenced in different areas of the process. The table below shows a high level summary of, where the main areas are, in which the quality can be affected. This is meant to be a deeply technical table, but provide an indication, what a refinery can do to control the quality. The number of dots indicate how strong the influence is (three strong dots mean a strong influence).

One example of how design and process condition can impact the quality is shown in Figure 1, which displays the Fe_2O_3 levels of various aluminas coming from different refineries using the same bauxite source.

Table 1. Quality parameters and its origin.

Quality parameter	Mainly influenced by			Where impacted	Process control lever
	Bauxite	Design*	Process		
Fe_2O_3	●●●	●●	●	Digestion, security filtration	Lime addition, digestion conditions temperature, free caustic, holding time..
SiO_2	●	●●	●	Digestion	Pre-desilication
CaO	●	●	●●	Security filtration, liquor chemistry	Operational discipline
Na_2O	●	●●●	●●	Precipitation/ product filtration	Temperature in precipitation; Product wash
P_2O_5, V_2O_5	●	●●●	●●	Digestion	Lime addition
Ga_2O_3	●●	**	●	Digestion/ Precipitation	Temperature in precipitation
Particle size/ Attrition Index		●●●	●●	Precipitation Calcination	Agglomeration/nucleation/ classification
BET/Alpha/LOI			●●●	Calcination	Furnace temperature / bypass

*The bauxite determines the design operating digestion temperature, and hence, some impurities such as Fe_2O_3.
** Unless Gallium plant.

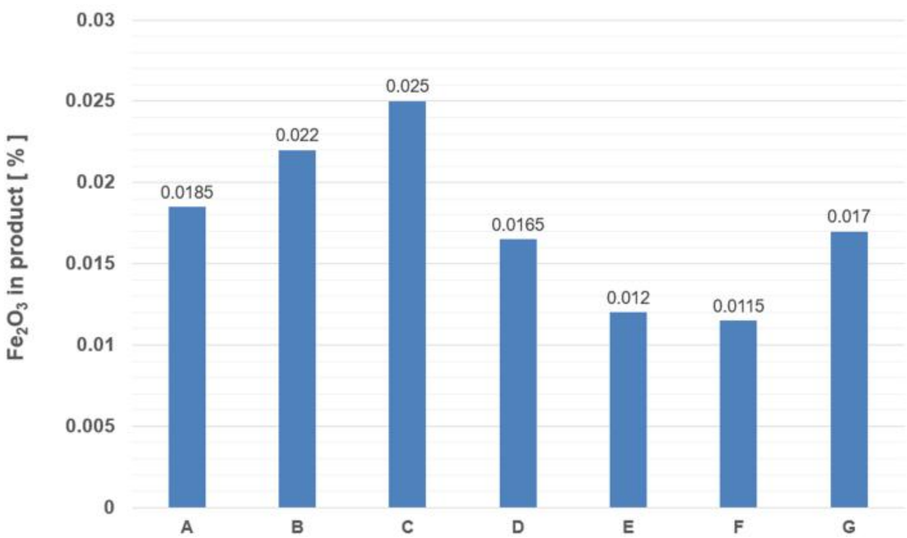

Figure 1. Fe_2O_3 from various refineries using the same bauxite source.

The difference can be quite large. The spread is up to 100 %. Refineries with high temperature digestion, sweetening and high yield produce alumina with low Fe_2O_3 content. Scalping and lime addition support Fe_2O_3 reduction as well. However, these features need to be designed into the plant from the very beginning.

2. Bauxite

Bauxite is a natural raw material and therefore tends to vary over time. The business case of a refinery is usually done by using a representative sample, but this does not reflect the dynamic behaviour over time of the refinery life, when the bauxite is delivered and thus on alumina quality.

Typically, bauxite reserves are estimated for alumina and silica as the key variables and secondly for its boehmite content. Impurities play almost no role at the establishment and commercial evaluation of bauxite mines.

Grade control on mines is usually only done for alumina and silica and sometimes boehmite, the remainder of the bauxite "ingredients" will be just an outcome. Over time the refinery may have a need to use other bauxite reserves with different properties. The reasons maybe for business continuity (having more than just one bauxite source), commercial aspects (other bauxites may be cheaper) or because the refinery has been expanded and as a result, this additional bauxite had to come from somewhere else. Regular bauxite analysis or certificates of analysis do not capture all impacts, that the bauxite can have, as not all different species of all crystalline phase are presented (e. g. goethite/hematite, anatase/rutile etc). Therefore, the refinery will have to manage whatever comes its way.

Organics can have a major impact on precipitation (oxalate), yield, particle strength, if not incorporated in the design. To a degree organics also impact the incorporation of soda and hence, Na_2O in product. This can affect the particle strength significantly. The boehmite content determines whether the refinery has to be designed and operated at low (around 150 °C) or high (250 – 280 °C) digestion temperatures.

3. Process Design

On a high level chemical impurities in alumina is mainly influenced in digestion (except soda and gallium) and physical properties and soda and gallium are mainly influenced in precipitation. One key aspect is whether the refinery is a low or high temperature plant; this is determined by the boehmite content (around >3 % would indicate HT). High Temperature plants typically lead to higher impurity levels in alumina, iron (Fe_2O_3) in particular.

Many aspects of different bauxite properties can be considered in the refinery design to ensure the impact on the alumina quality is limited. Some examples are - but not limited to - digestion layout: single stream vs double stream; sweetening; lime addition → Fe_2O_3, SiO_2, CaO, P_2O_2, pre-desilication (residence time, temperature etc), security filtration selection etc., precipitation circuit design for morphology e.g. classification, agglomeration, oxalate control.

Often impurities in the refinery can be treated in side stream removal systems (i.e. carbonate, TOC (total organic carbon), oxalate, gallium etc.), if they are incorporated into the initial design. The implementation of design features for quality control can be quite expensive if not incorporated in the initial design and may not be economically viable at all.

Since the evolution of alumina refineries has evolved significantly over time, the type of equipment for the different areas of refineries is mostly determined. Hence, for new refineries the equipment selection is usually quite clear. The differences in terms of quality impact is only minor. Retrofitting existing refineries or replacing existing equipment or facilities is usually not economical.

4. Process Operation

Once the bauxite is selected and refinery is designed and built, there are some restrictions, what a refinery can do, in order to achieve certain aspects of the alumina quality. The control levers in a refinery are usually limited; substantial changes would typically require Capex or Opex (e. g. additives). This applies also on the morphology and to some extent the particle strength/attrition index as it depends on the precipitation circuit design.

This leads to the question, whether the attrition index is a good metric to predict the impact on the smelter in the potroom. Because also the morphology of a particle, that has "survived" the mechanical stress in a calciner, can lead to different forms of debris once it leaves the gas treatment centres of the smelter. A particle that consists of many small particles (very mosaic) and has a low attrition index can demonstrate a different (and maybe worse) behaviour in the materials handling system and the subsequent pots of the smelter after it has been smashed up in the gas treatment than a blocky particle with a higher attrition index.

Figure 2 shows different morphologies of particles. The particles stem from different refineries and demonstrate how variable the internal structure of hydrate and alumina can be depending on the precipitation circuit design and its operation.

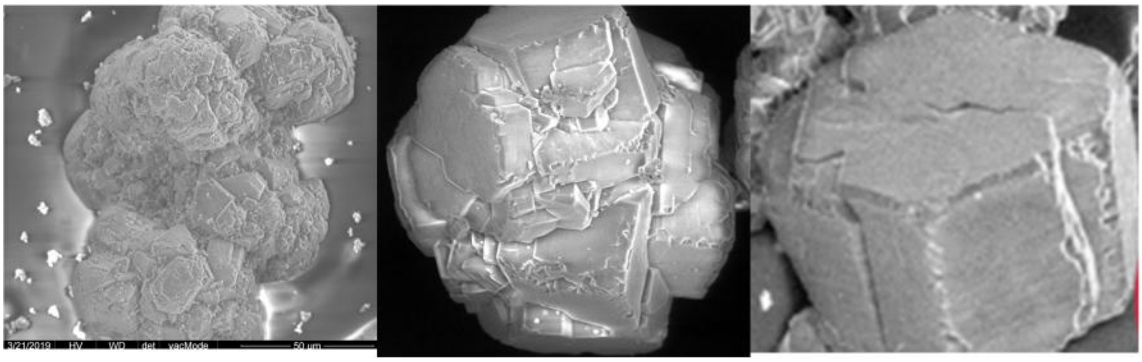

Figure 2. Different morphologies of particles.

The equipment and total percentage of classified material in the circuit as well as the agglomeration set up and interstage cooling is quite determining on how the particle structure can be formed. The presence of oxalate and organics play another role in precipitation levers as they impact on precipitation temperatures and thus yield and supersaturation. This leads to different mechanisms of how a particle can crystallize which result in different particle strength and impurity incorporation such as soda.

Physical properties are managed in the refinery. BET, LOI in the calciner by different furnace temperature. As stated above the bauxite source can play a role here, too, as organics can make the life quite difficult in the precipitation circuit. This is true specifically as particle size is in direct competition with yield/productivity and hence, production.

However, even though it is not possible to undertake big step changes in the quality parameters without major Capex or Opex requirement, the refinery has one good lever to contribute to quality – keep the process and its parameters as constant as possible in order to provide the alumina of as consistent quality as possible.

5. Conclusion

Once the bauxite source is selected and the refinery is designed the alumina quality is fixed. The alumina refinery can adjust alumina quality only in certain boundaries, but this will always come at a cost (either Capex or Opex or both) or loss of productivity. Therefore, a holistic approach should be applied across the entire value chain from bauxite via refinery and smelter to sales and marketing to work out the business case of modifying a quality parameter.