Experience with particle breakdown in gas suspension calciners

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Abstract

Since calcination in Rotary Kilns was replaced with calcination in Stationary Calciners, following the energy crisis in the 1970'ties, Particle Strength, Size and Breakdown of the Alumina produced has been of major concern in design and operation of the Hydrate Precipitation circuit followed by calcination in Stationary Calciners. This paper outlines the FLSmidth experience with particle breakdown in Gas Suspension Calciners (GSC) over the past 35 years from different hydrate sources in both pilot and full scale Gas Suspension Calciners of various design and capacity. The particle breakdown reported in the GSC units ranges from 100 % upwards of the particle breakdown observed in rotary kilns dependent on Hydrate Quality and GSC design / operation. Some impact on smelter performance reported in the literature will be covered as well.

Keywords: Precipitation; Calcination; Alumina; Particle Size.

1. Introduction

Over the past 40+ years significant technology changes/shifts has taken place in Refineries and Aluminium Smelters, the only customer for SGA. The drivers for these changes were and still are economy of scale, energy efficiency and/or improved environmental performance.

In 1935 the first Rotary Kiln for calcination of Aluminium Hydroxide with a capacity of 110 tpd alumina was installed. Until about 1972 where the largest Ø 4.3 x 122 m Rotary Kiln was contracted with a capacity of 1400 tpd sandy alumina, this technology dominated the industry (Figure 1, left).

Figure 1. 3xØ 3.95 x 107 m rotary kilns 3 x 4500TPD GSC units with bag filters.

In 1952, Alcoa commissioned their first 300 tpd Fluid-Bed Calciner producing sandy alumina [1] and since the oil crisis in 1972 only Stationary Calciners have been installed in new Alumina Refineries for production of Smelter Grade Alumina (SGA) owing to about 25-30 % less fuel consumption per ton alumina produced in Stationary Calciners compared to Rotary Kilns.

Today, almost all rotary kilns have been replaced with Stationary Calciners and many of the latest Gas Suspension Calciner (GSC) units [2, 3] are now equipped with Bag House/Fabric Filters (Figure 1, right) instead of Electrostatic Precipitators (ESP). The major reason being, that ESP units are not absolute filters because a plume of alumina dust is emitted from the ESP in case of a power failure.

2. Particle breakdown, alumina particle strength and hydrate precipitation

Ever since the introduction of Stationary Calciners into alumina refineries, Particle Strength, Size and Breakdown of the Alumina produced has been of major concern in design and operation of the Hydrate Precipitation circuit supplying the Stationary Calciners with production hydrate.

2.1. Definitions of particle breakdown

Particle Breakdown (PB) measures the change in Particle Size Distribution on 45 Micron or 325 Mesh sieve size (Rotap) between Hydrate fed into the calcination plant and Alumina discharged from the calcination plant:

$$PB\ (\%) = (wt\%\ Hydrate > 45\ \mu m) - (wt\%\ Alumina > 45\ \mu m) \qquad (1)$$

Or:

$$PB\ (\%) = (wt\%\ Alumina < 45\ \mu m) - (wt\%\ Hydrate < 45\ \mu m) \qquad (2)$$

In general, maximum 10 wt % < 45 Micron/325 Mesh in shipped SGA is specified by Smelters. But up to 15-20 % may be accepted at the Pot. The reason being that super fines measured as % SGA < 20 Microns (i.e. by Laser) is just as, if not more important, subject to the impact of super fines on the overall PSD and flowability of the alumina. Lindsay has reported [4], that resulting flowability (flow time) of the alumina has a negative impact on current efficiency and Green House gas generation in the Smelters.

2.2. Definition of alumina particle strength (Attrition Index)

There is no generally accepted measurement method of Alumina Particle Strength or "toughness" [4], but the alumina industry has used the Alumina Attrition Index determined by the Forsyth-Hertwig test [5] modified and introduced by Alcoa many years back. The Alumina Attrition Index (AAI) is calculated as follows:

$$AAI\ (\%) = 100\ [1 - (\%\ Alumina > 45\ \mu m)_{AFTER} / (\%\ Alumina > 45\ \mu m)_{BEFORE}\ ] \qquad (3)$$

There is no general requirement by Smelters with respect to the Alumina Attrition Index in SGA. However, Smelters prefer strong or "tough" alumina particles that can withstand handling and passage through their Gas Treatment Centre or Dry Scrubbers prior to feeding the Pots [6]. This is to avoid excessive generation of fines and super fines with the negative impact on pot operation as mentioned above [4].

2.3. Particle breakdown in rotary kilns and alumina Attrition Index of SGA

For comparison and confidentially reasons, % Relative Particle Breakdown will be reported onwards in this paper. It is calculated as a % of the absolute wt% Particle Breakdown on 45 µm sieve (Rotap) observed in the Rotary Kiln or GS C at Eurallumina in Italy [8]. As seen from Table 1, there seems to be a relationship between Particle Breakdown in Rotary Kilns, Alumina Attrition Index and Hydrate Precipitation technology [7, 8, 9].

Kilns (Table 4) by selection of conservative gas velocities in the Calciner:

Table 4. Comparison of relative particle breakdown - Same alumina Attrition Index.

Alumina Attrtion Index (AAI) = 16 – 18%			
Calcination Technology	Hydrate	Relative PB	CU(*)
Rotary Kiln (RK)	Hydrate N	100%	100%
GSC Retrofit of RK	Hydrate N	100%	100%
Gas Suspension Calciner	Hydrate O	150%	100%
Circulating Fluid-Bed	Hydrate O	210%	80-83%
*) CU = 100*Actual Capacity / Design or Name Plate Capacity			

Comparing Particle Breakdown between two calciners in different refineries producing different hydrates is difficult and highly questionable, if not impossible?

Table 5. Comparison of relative particle breakdown - Different alumina Attrition Index.

<table>
<tr><th colspan="5">Rel. Particle Breakdown in Calciner Units 2500 – 4500 tpd</th></tr>
<tr><th>Refinery</th><th>Technology</th><th>AAI</th><th>Relative PB</th><th>CU(*)</th></tr>
<tr><td rowspan="2">Hydrate L</td><td rowspan="4">Gas Suspension Calciner</td><td rowspan="2">14%</td><td>150-200%</td><td>100%</td></tr>
<tr><td>150-200%</td><td>~120%</td></tr>
<tr><td rowspan="2">Hydrate G</td><td rowspan="2">23%</td><td>400%</td><td>100%</td></tr>
<tr><td>200-250%</td><td>~75%</td></tr>
<tr><td colspan="5">*) CU = 100*Actual Capacity / Design or Name Plate Capacity</td></tr>
</table>

Anyway, calciners fed with Hydrate resulting in low Alumina Attrition Index after calcination can be scaled-up without significant impact on Particle Breakdown (Hydrate L). While calciners fed with Hydrate resulting in high Alumina Attrition Index after calcination must be turned down to reduce Particle Breakdown (Hydrate G). The calciner units above (Table 5) are designed with the same design gas velocity at 100 % CU.

3. Conclusion

Following many years of R&D work it has been demonstrated that Particle Breakdown in Gas Suspension Calciners depends on Alumina Attrition Index and gas velocities only. Within certain limits the gas velocities can be controlled by the designer of the Calciner plant.

However, the Alumina Attrition Index is indirectly determined by the Hydrate Precipitation circuit and can only be partly mitigated by the Calciner design by selection of conservative gas velocities in the Calciner. In any case, as pointed out by Chandra at AQW 2005 [24]:

"There is little point in the refinery minimizing 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."

4. References

1. Fish, W. M.; "Alumina Calcination in the Fluid-Flash Calciner", Light Metals 1974 , pp.673-682.

2. Fenger, J; Raahauge, B.E. and Wind, C.B."Experience with 3 x 4500 tpd Gas Suspension Calciners (GSC) for Alumina, Light Metals 2004.

3. Raahauge, B.E., "Smelter Grade Alumina Quality in 40+ Year Perspective - Where to From Here?" Proceedings of the 10th International Alumina Quality Workshop, 2015.
4. Lindsay, S.J., "Key Physical Properties of Smelter Grade Alumina", Light Metals 2014, pp 597-601.
5. Forsyth,W.L. and Hertwig,W.R. "Attrition Characteristics of Fluid Cracking Cayalyst", Ind. Eng. Chem. June 1949, pp. 1200-1206.
6. Lindsay, S.J."Attrition of Alumina in Smelter Handling and Scubbing Systems", Light Metals 2011, pp. 163-168.
7. McIntosh, P. "Alumina Calcination Review", Alumina Technology Workshop, University of Sydney, NSW, 1985,pp.205-219.
8. Raahauge, B. E. et al.,"Experience with Gas Suspension Calciner for Alumina", Light Metals 1991.
9. Bhasin, A.B. and Schenk, H.J."Productivity and Efficiency Improvements at the Gove Alumina Plant", Light Metals 1992, pp. 203-207.
10. Zwicker, J.D. "The Generation of Fines due to Heating of Aluminium Trihydrate", Light Metals 1985, pp 373-395.
11. Wind, S., Jensen-Holm,C. And Raahauge, B.E. "Development of Particle Breakdown and Alumna strength During Calcination" Proceedings of the 9th International Alumina Quality Workshop, 2012.
12. Armstrong, L. et al., "Alumina Attrition - Investigation of Hydrate Structure", Proceedings of the 4th International Alumina Quality Workshop pp.239-249, 1996.
13. Sang, J.V."Factors Affecting the Attrition Strength of Alumina Products", Light Metals 1987, pp 121-127.
14. Lopez, J.E. and Quintero, I. "Evaluation of Agglomeration Stage Conditions to Control Alumina and Hydrate Particle Breakage", Light Metals 1992, pp.199-202.
15. P.Clerin, P. and Laurent, V."Alumina Particle Breakage in Attrition Test", Light Metals 2001, pp 41-47.
16. Howard, S.G. "Operation of the Alusuisse Precipitation Process at Gove, N.T. Australia", Light metals 1988, pp.125-128.
17. Tschamper O., "Improvements by the New Alusuisse Process for Producing Coarse Aluminium Hydrate in the Bayer Process", Light Metals 1981, pp.103-115.
18. Anjier, J.L. and Roberson, M.L."Precipitation Technology", Light Metals 1985, pp. 367-375.
19. Audet, D.R. et al., "Stabilization of Product Quality at Yarwun Alumina Refinery", 9th International Alumina Quality Workshop pp.304-307, 2012.
20. Klett,C. et al.,"Improvement of Product Quality in Circulating Fluidized Bed Calcination", Light Metals 2010, pp.33-38.
21. Williams, F. and Schmidt, HW.,"Flash- and CFB Calciners, History and Difficulties of Development of Two Calcination Technologies", Light Metals 2012.
22. Perander, L. et all.,"Coal Gasification and Impacts on Alumina CFB Design", Proceedings of the 10th International Alumina Quality Workshop pp.243-250, 2015.
23. L.M.Perander, J.B.Metson and C. Klett,"Two Perspectives on the Evolution and Future of Alumina",TMS Light Metals, pp151-155,(2011).
24. Chandraskar, S. et al.,"Alumina Fines' Journey from Cradle to Grave". Proceedings of the 7th International Alumina Quality Workshop, Perth, Australia (2005).