# Process and Design Optimization for Producing Low Soda Alumina

**Kiran Bhor[1], Kumaresan Thangaraj[2]. Kaushal Gupta[3], Sandeep Patil[4], Sudhir Kutre[5], Sagar Pandit[6] and Gopalan Shankar[7]**
1. Senior Scientist
2. Lead Scientist
Aditya Birla Science and Technology Co. Pvt. Ltd. Taloja MIDC Tal. Panvel, Maharashtra India.
3. Manager Process Control
4. Sr. General Manager Production
5. General Manager
6. General Manager Process Development
7. General Manager
Hindalco Industries Ltd. Belagavi works Belagavi, Karnataka, India
Corresponding author: kiran.bhor@adityabirla.com

## Abstract



Hindalco alumina refineries operate on conventional Bayer process to produce alumina mainly for aluminum production and part of it is sold as a specialty alumina. Generally, specialty alumina requires $Na_2O$ less than 0.25% for use in touchscreen panels for mobiles, tablets, televisions, etc. In Bayer process the control of the product quality is majorly dependent on the process parameters such as seeding strategy, precipitation temperatures, and time. In the present study in-depth analysis of the precipitation process was carried out with focus on the optimization of the process parameters and streamline SOP to achieve the desired product quality. Alumina precipitation was studied at lab scale by varying the different parameters viz: temperature profile, precipitation time, seeding, etc. Detailed product characterization was carried out to understand the partitioning and form of sodium in with aluminum hydrate precipitate. The best operating conditions were identified which could result in reduction in $Na_2O$ impurity in final product. The CFD simulations of agglomerator tanks were also carried out to study the swirling flow pattern generated as well as possible bypass of the pregnant liquor due to inlet and outlet design configuration. In order to quantify & minimize this bypassing, residence-time distribution (RTD) analysis was performed on the existing design and compared with different inlet outlet design modifications. The lab study helped in optimizing the process parameters like precipitation temperature profiles, seeding strategy and precipitation time to achieve the % $Na_2O$ less than 0.25%, while CFD study provided solutions to reduce the extent of bypassing from 14% to 5% for pregnant liquor. The results are discussed in detailed with in this paper.

**Keywords:** Low soda alumina, Precipitation experiments, Agglomeration and growth, CFD modelling, RTD study.

## 1. Introduction

The Bayer's process produces hydrate and alumina, which is refined from raw bauxite ore in an energy intensive process that uses substantial amounts of caustic soda as the dissolving agent. The basic refining process has remained unchanged, where the productivity and the product quality heavily depend upon the quality of the raw material, process stability and control. In order to use alumina at various non-metallurgical applications, product specifications vary in terms of impurities present in alumina, the particle size distribution (PSD) and hardness, etc. Soda is one of the major impurities which affects the final product quality, hence it has limitation factor for various product specifications. Soda in hydrate exists in two forms: lattice soda and soda adsorbed on the surface of hydrates, which can be controlled by an efficient hot water washing method. While the control of soda in lattice requires special efforts during the crystal formation stage to prevent impurities from being trapped in the crystal lattice. Diluting the solution, raising the temperature, controlling the seeding strategy by varying particle size of seeds, as well as seed loadings can slightly reduce the soda content [1]. The process of producing saturated liquor remains the same for metallurgical as well as non-metallurgical applications. The method of achieving super saturation and the use of seeding with various PSD decides the level of impurities and PSD of the final alumina tri-hydrate. Consistently producing lower soda impurities of less than 0.25 % in alumina is a challenge for the plant's operating team. In general, a trade-off exists between the soda content, the particle size distribution and the productivity. It is important to optimize and balance various variables in the agglomeration and growth of alumina hydrate to achieve lower soda levels. Hence, current study was carried out with objective to find out process parameters for achieving the desired % $Na_2O$ in alumina. This study utilizes experiment and modeling approach to attain the process parameters for desired alumina quality.

## 2. Technical Approach

The precipitation experiments were designed and carried out in lab scale precipitator by varying pregnant liquor (PGL) temperature, PSD, fine and coarse seed loading. The retention time and the precipitated hydrate products were analyzed using X-ray Fluorescence (XRF) and Malvern particle size analyzer for % $Na_2O$ and PSD, respectively. The design of the first plant agglomerator and the turbulence generated due to its inlet and outlet configuration resulted in probable short circuiting of fluid to the next agglomerator. The design analysis was performed using the CFD modelling approach and ANSYS Fluent 16.0 as a tool to converge the solution in steady state. Fluid bypass was quantified using a residence time distribution approach in transient simulation employing inert tracer.

### 2.1 Precipitation Experiments

The experimental setup consists of a water bath for indirectly heating/cooling the slurry with a precise temperature and time controller in order to maintain the desired temperature gradient during the precipitation time. This installation facilitates the adjustment of a start and end temperature as well as a cooling rate to carry out precipitation of alumina tri-hydrate using the pregnant liquor and the seedings. The setup consists of 12 tanks which ensure the proper mixing of the pregnant liquor and the seeds in all the tanks. The pregnant liquor (PGL) required for the precipitation was arranged from Bayer processing plant and the caustic concentration was adjusted to remove any effects for all of the DOE experiments. The seedings used for the experiments were collected in a single lot from Bayer processing plant to maintain the same seed morphology and the impurities. All 12 tanks can be simulated with different seeding inputs as well as different retention times, This facility also ensures the easy discharge of the slurry volume after the desired time for the individual tanks. Input seeds were analyzed for particle size distribution, impurities and SEM analysis for morphology of the seed structure. Experiments (DOE) were designed as shown in Table 1 in order to study the effect of different input variables like retention time, PGL temperature, seed charge and seed ratio on productivity of alumina and the % of $Na_2O$ impurity addition in alumina hydrate. In addition to the DOE experiments, a few sets of experiments with total time duration of 6 hours and sampling at the frequency of 30 minutes were carried out to study the process of agglomeration and soda occlusion in details during the agglomeration step. Samples collected during all experiments were washed with hot water and filtered multiple times to ensure removal of surface soda as well as oven dried for removal of surface moisture. Further, these samples were analyzed for % $Na_2O$ and particle size distribution. For the caustic measurement in liquor standard titration methods were used. The samples collected during agglomeration steps were analyzed using a scanning electron microscope (SEM) for the particles size distribution of impurities, as well as structure and morphology. The results of all experiments will be discussed.

**Table 3. RTD results and mean residence time for all simulated cases**

| No | Design | Mean Retention time (sec) | Dispersion No | % bypassing of PGL at different time | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 10 min | 20 min | 30 min | 40 min | 50 min | 60 min |
| 1 | Existing Design | 6276 | 0.316 | 4.5 $e^{-5}$ | 0.09 | 1.21 | 4.2 | 8.74 | 14.06 |
| 2 | Design 1 | 6250 | 0.317 | 9.1 $e^{-4}$ | 0.34 | 2.45 | 6.44 | 11.37 | 16.44 |
| 3 | Design 2 | 7100 | 0.167 | 1.2 $e^{-10}$ | 3.6 $e^{-4}$ | 0.05 | 0.56 | 2.36 | 5.96 |

Table 3 clearly indicates the better mixing in Design 2 than that of other simulated cases. The inlet and outlet configuration of existing design results in bypassing of 14 % PGL liquor (before 60 min) to next agglomerator, which is maintained at lower temperature. When this PGL enters the next tank at lower temperature, the super saturation increases drastically. Hence, the rate of precipitation increases and results in increased soda in hydrate. While Design 2inlet - outlet configuration of Design 2 results in ~ 5% bypass of PGL, the existing design will result in a higher soda content in hydrate than that of Design 2. The top region of the agglomerator includes all the PGL inlets, fine seed and re-circulatory flow and it needs to be mixed intensively, i.e. higher values of the dispersion number.

## 4. Conclusions

The initial period of higher precipitation rate determines the major proportion of the % $Na_2O$ content association with alumina tri-hydrate. This is due to the increased level of local super-saturation and resulting in a higher precipitation rate in the initial time. The precipitation kinetic experiments clearly show the importance of higher PGL temperature, higher seed load and higher fine seed fraction as well as higher retention time to achieve lower % $Na_2O$ values in alumina. The optimum conditions are supersaturation of 60.8 g/l, total seed surface area of 13.50 $m^2$ and ratio (N) of 0.37. CFD simulations of all designs attempted revealed that t Design 2 performed well in terms of minimizing the percentage short circuiting of both supersaturated liquid and seed slurry. The bypassing of inlet feed is reduced to 5 % (Design 2) from 14% (existing design). The product quality in terms of lower soda (<0.25 %) in alumina can be achieved by maintaining the above-mentioned process key ratio/ supersaturation.

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