

## Improving Ball Mill Efficiency through Application of Bauxite Grinding Aid

Santanu Dey<sup>1</sup>, Sagar Pandit<sup>2</sup>, Sandeep Patil<sup>3</sup>, Airong Song<sup>4</sup>, Alpha Barry<sup>5</sup>, Hariharaganesan Natarajan<sup>6</sup> and Gaurav Gite<sup>7</sup>

1. Manager, Alumina Operations

2. General Manager, Bayer Process Development

3. Senior General Manager, Alumina Operations

Hindalco Industries Limited, Belagavi, India

4. Application Technology Scientist, Alumina Process Chemicals

5. Application Technology Group Manager, Alumina Process Chemicals

6. Technical Service Engineer, Alumina Process Chemicals

7. Technical Sales Manager, Alumina Process Chemicals

Solvay, Stamford, CT, USA

Corresponding author: santanu.dey@adityabirla.com

### Abstract

Bauxite grinding is one of the important and critical unit operations in alumina refinery. Ball mill is a power intensive grinding unit where bauxite quality plays a major role in determining the efficiency of operation. However, with the limited flexibility available in terms of sourcing good quality bauxite, it becomes imperative to look out for other viable options for improving the efficiency of grinding, thereby, reducing the specific energy consumption.

In addition to operational improvements in ball mill which have a minor impact on the performance, various chemical grinding aids are tried to improve the grinding efficiency considering the ease of application and minimal CAPEX outlay.

Based on a detailed laboratory evaluation of various bauxite grinding aids, M/s Solvay CYQUEST® GA4400N grinding aid was found to be the most promising chemical aid. Further to the encouraging laboratory results, plant scale evaluation of the chemical was done at one of the refineries of M/s Hindalco which also supported the laboratory claims of increased ball mill throughput, thereby resulting in 8-9% reduction in specific energy consumption.

This paper gives an overview of the successful implementation of CYQUEST® GA4400N grinding aid and the benefits envisaged.

**Keywords:** Ball mill, Bauxite, Grinding aid, Energy.

### 1. Introduction

Generally, alumina refinery is designed based on the bauxite ore reserves at their vicinity. In any alumina refinery, bauxite grinding is one of the key steps where bauxite ore is ground to finer fractions to improve the efficiency of extraction. Bauxite grinding is one of the power-intensive unit operations in alumina refinery where the grinding energy consumption majorly depends on the quality of ore i.e., bauxite hardness. The production capacity of an alumina refinery is thus dependent on the performance of bauxite grinding unit which ensures appropriate fineness of the feed to the digestion process. Over a period, the quality of bauxite starts deteriorating with respect to its extractable alumina content. With the deterioration of quality of bauxite, the grindability of the ore denoted as Bond Work Index (BWI), kWh/t also gets affected adversely. Higher the BWI higher will be the energy required for grinding. Bauxite grinding unit is designed based on the quality of bauxite which is available for the refinery. Also, higher BWI could become a bottleneck

towards maintaining the required alumina production rate due to grinding limitation in bauxite grinding unit.

In ball mills, grinding is done with the help of different sizes of metal balls inside the rotating hollow cylindrical shell. The working principle follows the phenomena of impact and attrition based on which size reduction takes place. The capacity of the equipment is designed based on the bauxite feed requirement to the process of alumina extraction. The process is also called as wet grinding where finely ground bauxite ore gets further ground with caustic liquor to yield a slurry with very fine bauxite particles after further size reduction.

Maintaining steady grinding rate to sustain the refinery production level with control on specific grinding energy is thus the key focus area in grinding section. Hence, it becomes necessary to improve the grinding efficiency. Various chemicals are claimed as grinding aids to overcome these issues and various laboratory experiments are conducted to establish the results. To improve the product slurry quality, a closed-circuit grinding is practiced in many refineries wherein the ground bauxite slurry is screened through a particular size screen and the oversize material is returned to the mill for further grinding to yield the slurry with desired product granulometry suiting the digestion process conditions for maximum alumina extraction. Focus is then given to improve the product granulometry by optimizing the grinding rate with various grinding chemical aids.

A plant scale trial was conducted in two phases with a grinding chemical aid CYQUEST® GA4400N to improve the overall grinding efficiency. The application of chemical aid was successfully established after set of plant trials and thereafter, the application has continued to realize the benefits on a steady basis.

This paper presents the details of the detailed plant scale trial of the chemical aid CYQUEST® GA4400N which got established for the continuous use in the grinding section in order to support the steady refinery operation in one of the alumina refineries of M/s Hindalco.

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## **2. GA4400N Chemical Aid Trial Details**

### **2.1 GA4400N Chemical Aid**

In recent years, bauxite grinding section has emerged as a major bottleneck at one of the alumina refineries of M/s Hindalco. The major reason for the bottleneck is the change in the bauxite quality over the period. There was an increase in the MHA content in bauxite and correspondingly THA content got decreased. This led the plant to process harder bauxites with bond work in the range of 14-15 kWh/t as against 10-11 kWh/t found with softer bauxites. Hence various options were deliberated on improving the grinding efficiency, of which application of bauxite grinding aids emerged as the viable alternative.

Addition of grinding aid improves the grindability by decreasing agglomeration and increasing breakage. Grinding aid facilitates the size reduction so that the energy consumption in ball mills reduces without affecting the product slurry granulometry. Various chemicals were evaluated for grinding efficiency improvement, out of which CYQUEST® GA4400N chemical aid gave ~ 30 % reduction in recirculation. This chemical aid appears to be a low viscosity liquid and the basic properties of this chemical aid are tabulated below in Table 1. Reduction in recirculation in ball mill leads to an increase in bauxite throughput and thereby, reduction in specific grinding energy consumption without affecting the ball mill product fine slurry granulometry.

**Table 1. Properties of Chemical Aid.**

Description of Properties	Details
Product name	CYQUEST® GA4400N
Nature	Mixture
Appearance	Clear Liquid
Odour	Mild
Major component	Hydroxyethylidene-1, 1-diphosphonic acid
Solubility in water	Complete
Specific gravity	1.0 Kg/L
pH	7.0
Storing temperature	0-40 °C
Hazard classification	Corrosive (C)
Flash Point	Pensky–Martens Closed cup–No flash up to boiling point
Conditions to avoid	Avoid excessive heat

CYQUEST® BGA positively impacts the rheological property of bauxite slurry by reducing the viscosity and stickiness during the grinding process. As a result, less energy is required and the specific energy consumption per ton of bauxite ground is reduced. This less viscous slurry is also easier to pump and again requires less energy. The overall reduction in energy consumption ultimately results in reduced carbon emission to the atmosphere.

A family of products have been designed to reduce the viscosity of bauxite slurry during the grinding process. Viscosity reduction results in

- Higher ball mill throughput
  - Eliminates the bottleneck for maintaining refinery production volume with various bauxite blends
  - Increases the availability of ball mill through increase in capacity utilization
- Lower specific energy consumption by reducing the requirement of the number of ball mills
- Increase slurry solids maintaining the product slurry granulometry
  - More efficient use of steam and thereby, optimization of steam consumption
- Reduction in maintenance cost and increase of life of slurry storage tanks

No downstream side impact of this chemical aid.

- The temperature & operating conditions in the Bayer process, are enough to destroy the product after the application in ball mills ensuring no impact on downstream unit operations and product alumina hydrate quality
- The thermal destruction begins at the ball mill, and it completes when the temperature reaches 110 °C

Laboratory scale control tests conducted with bauxites at different feed sizes to assess the reduction in % recirculation with feed size reduction. The % recirculation with feed size of -5 mesh (100 % passing) and -14 mesh (70 % passing) are found to be similar to that obtained in the plant ball mills [1].

Grinding aids of different chemical aid providers evaluated for reduction in recirculation rate and slurry viscosity profile. Slurry viscosity and % recirculation tested against the chemical dosage from 1 % to 0.1 %. Increase in % recirculation and slurry viscosity were observed at a dosage of 1 %. It was also observed that the slurry rheology changes at higher chemical aid dosage where shear-thickening behavior is witnessed mainly caused by ‘Jamming’ effect [1].

Finally, it was concluded that the optimum dosage of grinding aid is 0.1 % both in terms of reduction in recirculation rate and slurry viscosity profile. Hence, it was proposed to take it forward through a plant scale trial [1].

## 2.2 Indicative (First Phase) Trial

In the month of September 2017, first phase plant scale trial initiated in one of the ball mills to assess the performance of the chemical aid. The trial was conducted in presence of the technical engineer of the solution provider.

During the trial, grinding aid CYQUEST® GA4400N was started with minimum dosage and the chemical was dosed in the caustic liquor line which is going to the ball mill for grinding. The dosage later on optimized on step basis based on the oversize generation and product slurry granulometry.

During the trial the following parameters were monitored.

1. Feed size to ball mill (+ 1 inch fraction), %
2. Grinding rate, t/h
3. Caustic liquor flow, cu.m/h
4. Grinding aid flow, both in g/MT and LPH
5. Product slurry granulometry (- 60 mesh i.e., - 0.25 mm fraction), %
6. Physical check of oversize generation

Focus was given to maintain the required product slurry granulometry while optimizing the chemical dosage and ball mill throughput. Almost 70 trial runs were conducted to optimize the overall grinding operation wherein, GA4400N dosage started with 25 g/MT which was optimized to 35 g/MT. The product slurry granulometry and grinding of indicative trial ball mill is given below where the grinding rate had been increased in steps through optimizing the chemical aid dosage maintaining the product slurry granulometry (- 60 mesh fraction) at 63 % as required for the process as given in Figure. 1, 2. The overall slurry solids was maintained at 55-60 % as given in Figure. 3.

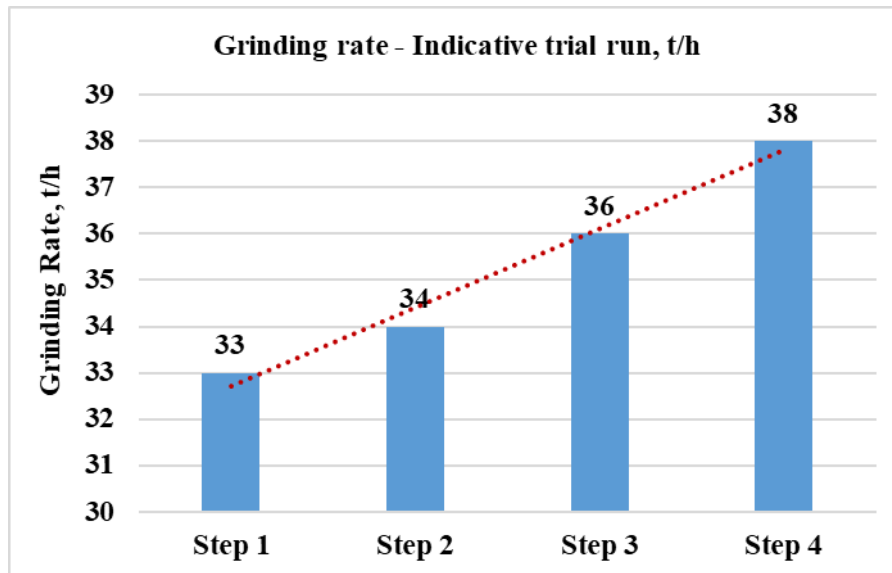


Figure 1. Grinding rate, t/h.

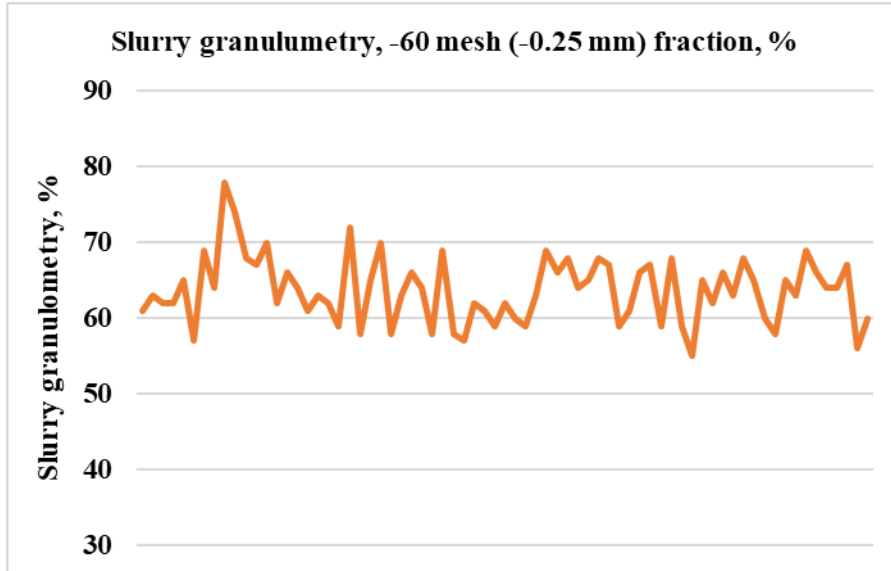


Figure 2. Product slurry granulometry -60 mesh (-0.25 mm) fraction, %.

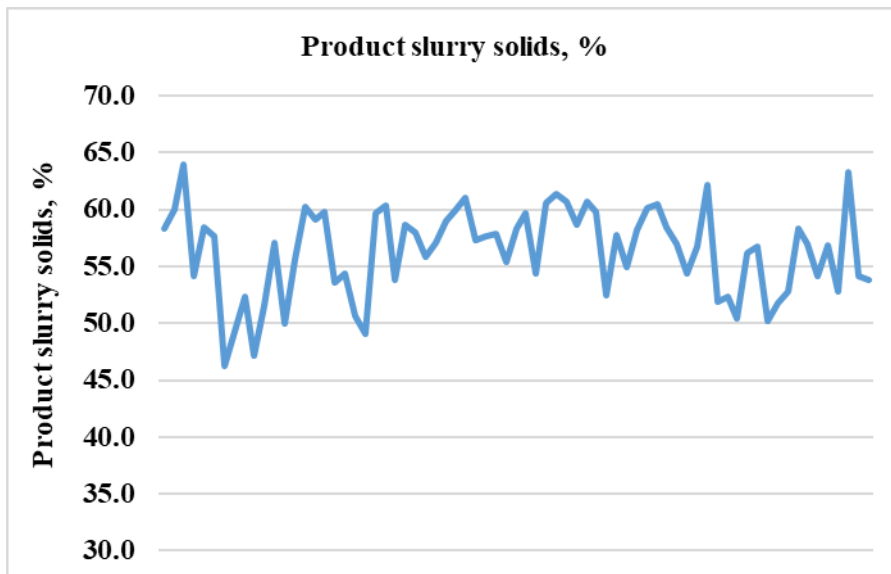


Figure 3. Product slurry solids, %.

In the indicative first phase plant trial, results found encouraging in one ball mill with a throughput increase by 12 % maintaining the product slurry granulometry at 60-68 % (- 60 mesh i.e., - 0.25 mm fraction in slurry) with established GA4400N grinding aid dosage at 35 g/MT. An extended trial was therefore, planned to envisage the benefits across the overall grinding circuit at a larger scale.

### 2.3 Extended (Second Phase) Trial

Extended plant scale trial started with all available ball mills in May 2018 with set baseline established in the earlier indicative trial. The chemical dosage was set at 35 g/MT with all the operational ball mills and the average chemical aid consumption during the extended trial run was in the range of 1.56 MT/month. During this trial run, steady mill operation was monitored with the increased throughput. Slurry granulometry data was also analyzed against the baseline data and the product granulometry was found to have similar trend as in the baseline data - 60 mesh (-

0.25 mm) fraction at 58 %. Specific grinding energy was also monitored during the trial run and compared with the consumption figures prior to the trial.

The trial was started from a baseline at 31.1 t/h (FY 18) and throughput with grinding aid went up to 36.0 t/h in a steady basis. The two months extended trial run was found satisfactory and results were also encouraging in terms of throughput increase maintaining the same granulometry as in the baseline case. The increase in ball mill throughput has been shown in Figure. 4, 5.

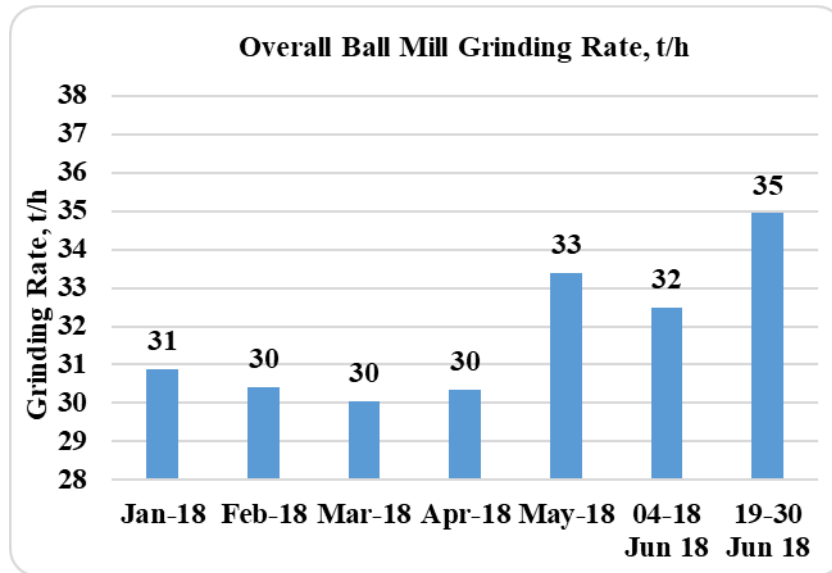


Figure 4. Overall ball mill grinding rate, t/h.

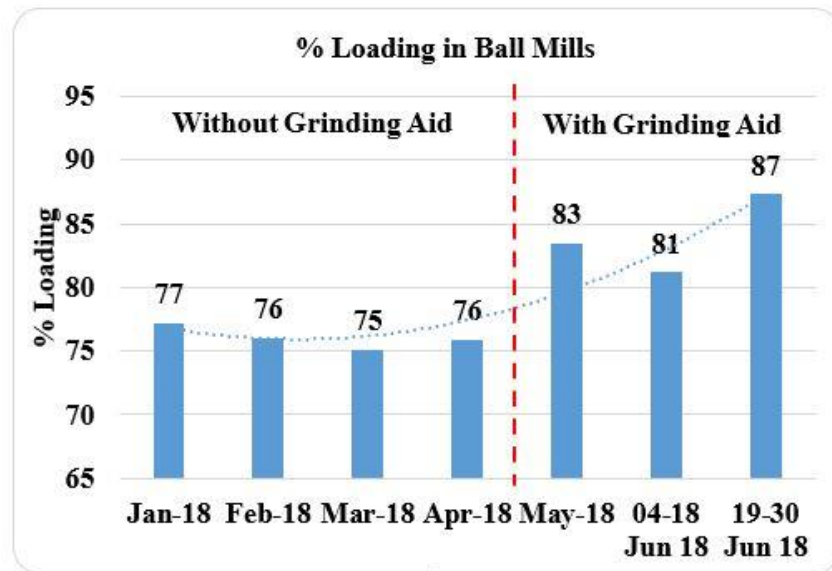


Figure 5. Loading in ball mills, %.

Increased ball mills throughput also helped to maintain the steady plant production level with the higher slurry requirement especially in the month of Jun18 where the average %THA was lower at 35.70 against the plan of 37.38 otherwise it would have been difficult to maintain the steady plant production level. The fine slurry granulometry was also almost maintained during the trial at 57-58 %, however, there was only 1-2 % drop in fine slurry granulometry at increased mill throughput as compared to the indicative trial as shown in Figure. 6. The slurry solids was

maintained at 57-60 % as given in Figure. 7. The extended trial continued for two months that is May and June 2018.

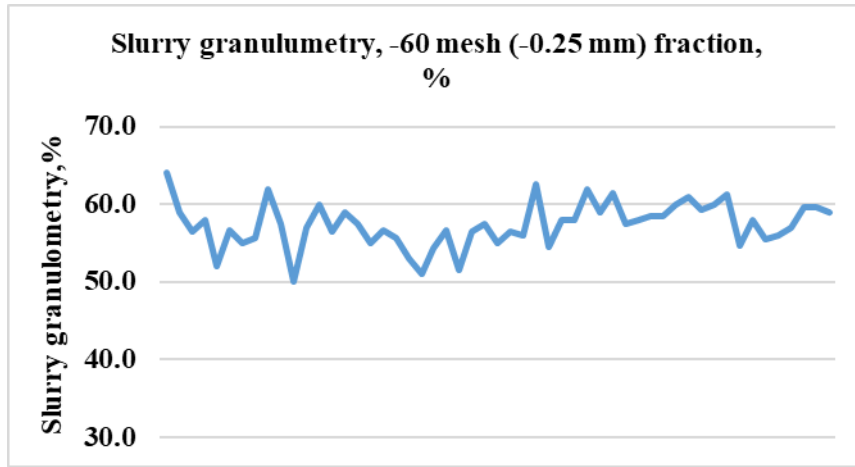


Figure 6. Product slurry granulometry -60 mesh (-0.25 mm) fraction, %.



Figure 7. Product slurry solids, %.

Specific grinding energy for the month of May & Jun'18 also reduced with higher ball mill loading with the grinding aid compared to the earlier months as shown in Figure. 8.

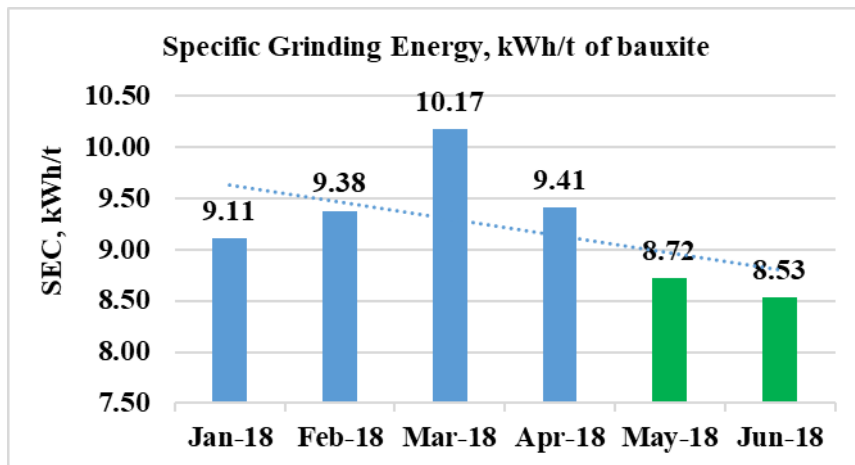


Figure 8. Specific grinding energy, kWh/t of bauxite.

### 3. Summary of Results & Conclusions

After the successful completion of extended trial, it was decided to commercialize CYQUEST® GA4400N chemical aid for continuous application in grinding section to continue the gains. The chemical aid application started on continuous basis in bauxite ball mills immediately after the commercialization. This has helped the refinery to eliminate the bottleneck across grinding circuit to meet the desired refinery production level even with bauxite sources of higher BWI values. The efficiency improvement in ball mills was also significant with the application of grinding aid.

After 2016-17 hardness of the bauxite got increased drastically due to which the ball mill grinding rate had been reduced to maintain the desired product slurry quality in terms of granulometry. Coarse grinding also causes various issues in conventional mud washers due to coarser solid separation leading to higher rake loads, thereby, unsteady mud circuit operation. Therefore, the grinding rate in ball mills had to be restricted at 31 t/h limiting the production rate. After establishment of this grinding aid, grinding rate increased to 33 t/h in 2018-19 and later this was further optimized to 32 t/h in 2019-20 to improve product slurry quality by increasing fineness (-60 mesh) fraction to 64 % from the earlier operating level of 58-60 % as shown in Figure. 9, 10.

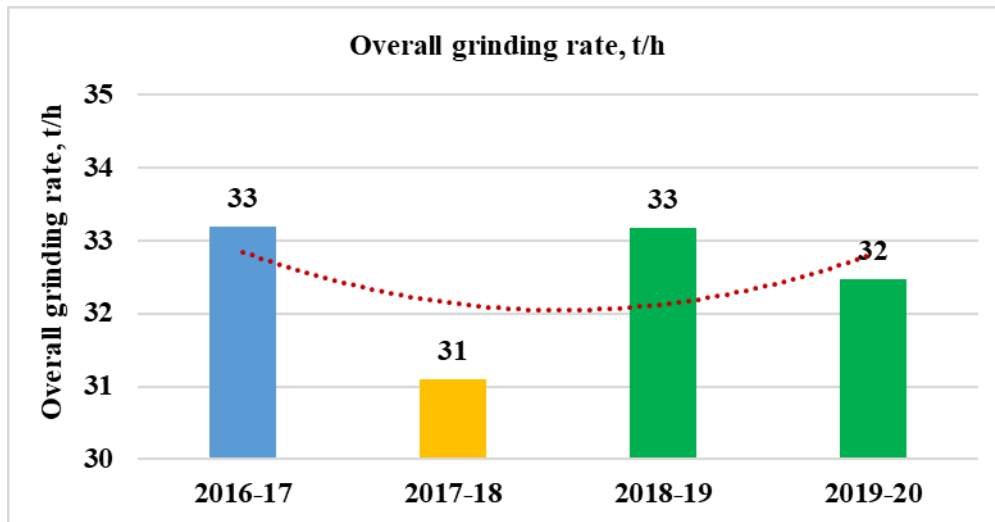


Figure 9. Specific grinding energy, kWh/t of bauxite.

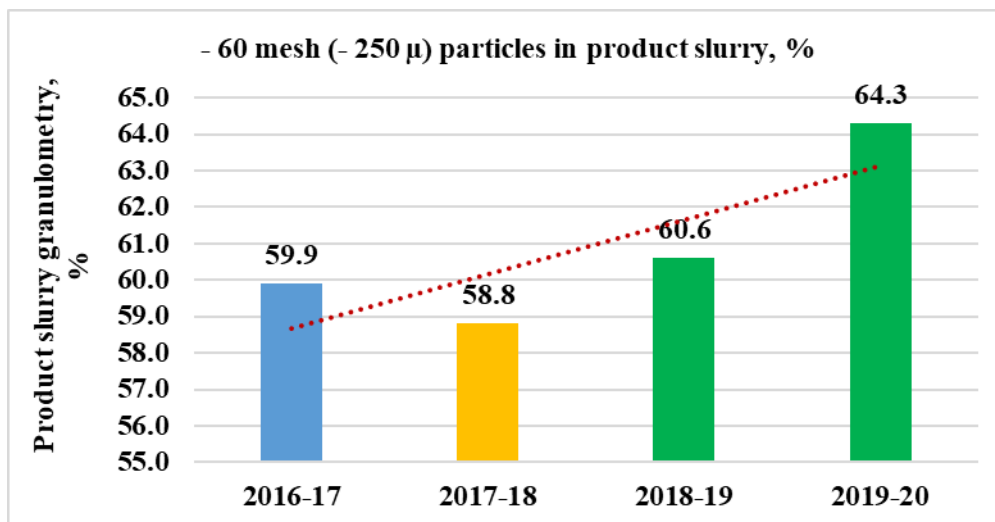


Figure 10. Product slurry granulometry -60 mesh (- 250 μ), %.

With the application of grinding aid CYQUEST® GA4400N at an optimized dosage of 35 g/MT overall grinding rate has got increased by 5-6 % and specific grinding energy consumption has got reduced by 11-12 % in 2018-19 and 2019-20 with respect to the baseline year 2017-18 where the average grinding rate was at 31 t/h and the corresponding specific grinding energy was at 9.4 kWh/t as shown in Figures 11, 12.

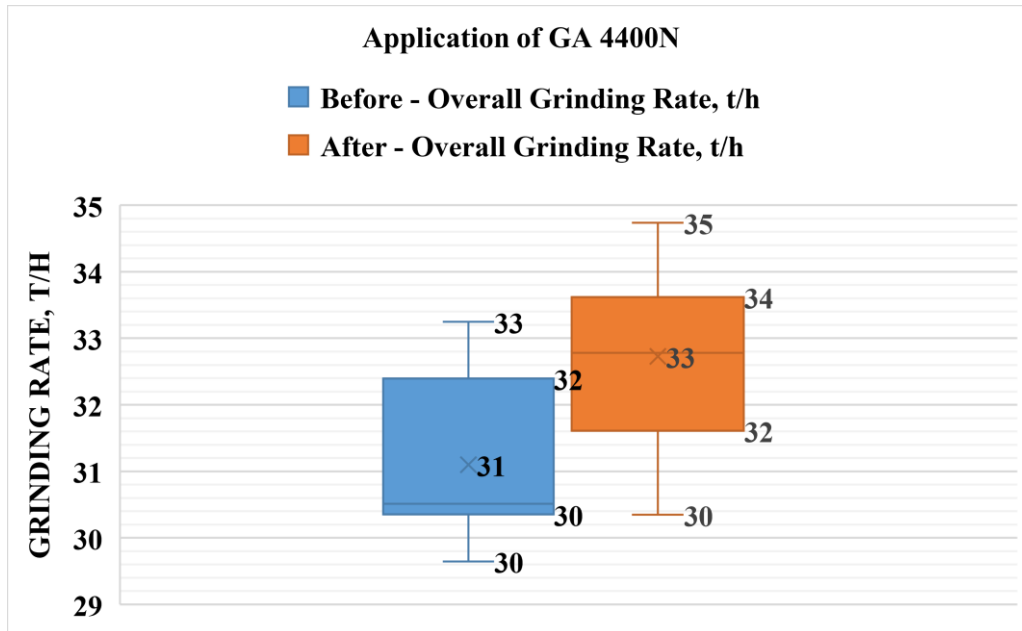


Figure 11. Overall grinding rate, t/h.

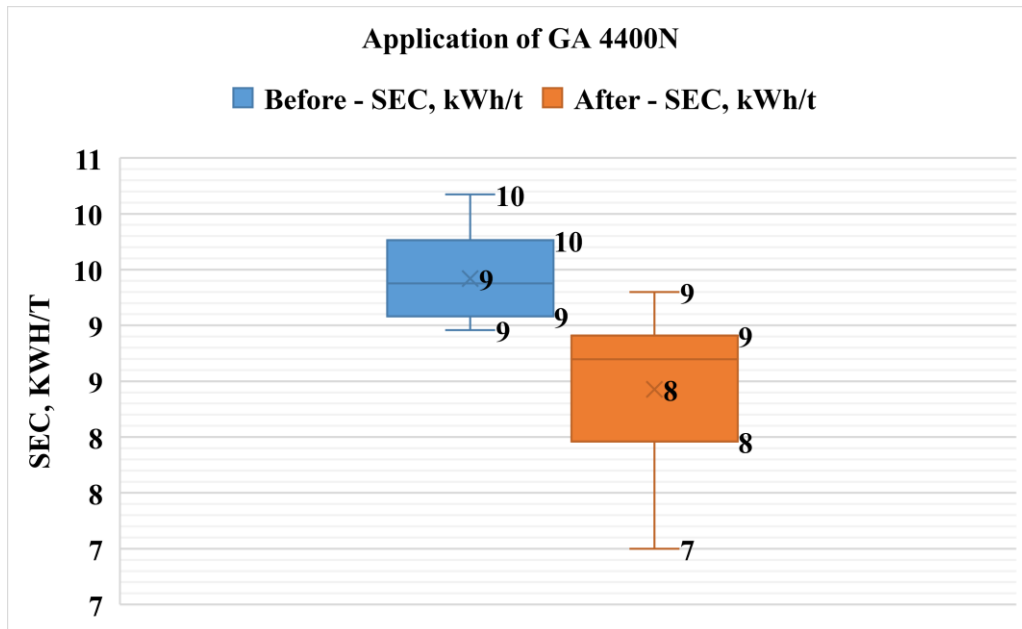


Figure 12. Specific grinding energy consumption (SEC), kWh/t.

It can be concluded that the application of grinding aid CYQUEST® GA4400N in grinding circuit will be helpful for improving the overall performance of ball mills in any alumina refinery especially for the bauxites which are of higher BWI values. The application of this chemical aid is more appropriate for harder bauxite sources and refineries can adopt this chemical based on the bauxite characteristics.

#### **4. References**

1. Sagar S Pandit, S. Sankaranarayanan and V.B. Usulkar, Bauxite Grinding Aids – Development of Test Method and Evaluation of Various Chemicals, *Proceedings of 32<sup>nd</sup> International ICSOBA Conference*, 12–16 October 2014, Zhengzhou, China, 9-10.