CB08 - Practical Use of Online Chemical Analyser for Spent Anodes Quality Control

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Abstract

This technical paper examines the practical application of an online chemical analyser for spent anodes in the aluminium industry, focusing on improving quality control and addressing challenges related to delayed laboratory analyses. The significance of spent anode quality control is discussed, highlighting the need for real-time monitoring of their chemical composition. Traditional lab-based analysis methods are compared with online analysers, identifying the latter's advantages in enhancing process efficiency and control. Feasibility studies are presented for equipment selection, and the working principle of the online-inline chemical analyser is explained.

This first-time installation of the near-infra-red (NIR) Online Chemical Analyser includes installation, performance testing, and data utilisation for effective control and events analysis. The paper also covers change management, equipment enhancements, and lessons learned. Finally, the value captured through improved anode quality is assessed, and a way forward is proposed, involving the roll-out of the online chemical analyser to other rodding rooms in Emirates Global Aluminium (EGA) to optimise operations further and ensure consistent product quality.

Keywords: Spent anode, Online analyser, Quality control, NIR, Process control

1. Introduction

EGA is a globally recognised aluminium smelting company that has maintained its competitive edge by adopting cutting-edge technologies to preserve its status as the world's largest ‘premium aluminium’ producer. One such initiative by EGA is the implementation of an Online Chemical Analyser, a first-of-its-kind technology in the aluminium industry. This analyser is a key initiative to EGA's vision for the "Smelter of the Future."

The Online Chemical Analyser (OCA) is an intelligent automation system with NIR technology installed on equipment to provide real-time quality data on spent anodes. This data is then stored and analysed, and any deviations from standard patterns are flagged with alerts. This paper will delve into the practical applications of the evolving Online Chemical Analyser for spent anode control, including its benefits, drawbacks, and potential applications.

2. Background on Spent Anodes Quality Control and the Importance of Monitoring

The smelting industry has been working to reduce the carbon consumption involved in the production of aluminium by optimising various factors, including potroom design, efficiency, and anode quality (specifically anode reactivity and conductivity). Anode reactivity, influenced by Na, Ca, V, and Ni, is critical in determining anode performance. Improved Na levels in the butts (Figure 1) reduce anode reactivity. This leads to reduced carbon dusting in pots, lower carbon consumption, improved cell productivity and enhanced customer satisfaction.

As EGA had continuously increased its capacity and operated above design limits, focusing on balancing energy prices and LME, the strenuous requirements of anode quality, including resistivity, reactivity, density, and baking levels. These factors had become increasingly important.

Raw materials typically consisted of 60 % coke, 14 % pitch, and 26 % recycled butts, with butts contributing the highest percentage to sodium contamination. However, there were limitations regarding the capability of dynamically responding to changes in sodium. The past process of adjusting the butts cleaning process relied on delayed sample collection and analysis, sometimes culminating in up to a few 8-hour shifts and the challenge of taking representative samples due to the heterogeneity of the material and its impurities. Such variability in the anode quality became a significant challenge while operating with very low anode-cathode distance (ACD) pots due to ever-increasing amperages in the potrooms. Efforts had to be made at the source of the variability through proper control [1, 2, 3, 6].

Given the feasibility of controlling Na levels in recycled butts by improving internal processes, implementing an Online Chemical Analyser has become a priority for EGA.

Figure 1. Anode butt picture.

3. Challenge Faced without the Analyser

To enhance the performance of anode butts, monitoring their composition, including the Na content level, was crucial. At EGA smelter Phase 1 (potlines 1 and 2), located at Al Taweelah, approximately 340 tonnes of spent anodes are recycled daily through a crushing circuit, and the quality assessment was based on random samples. However, the sample results were released only after 7 days, making it challenging to segregate the crushed butt material already stored in a silo of 4 000 tonnes capacity. The need was to have Na level in butts as live data to control upstream process efficiency.

EGA had begun searching for alternatives to the traditional sampling process control like on-belt sensors. After thoroughly investigating the market for online sensors, SpectraFlow Analytics (SFA) emerged as the top contender, given that SpectraFlow had provided over 10 years of exceptionally robust and accurate sensors to the cement and minerals industries and showed the ability to measure in minimal as well as high concentration levels. Several talks were held to evaluate the testing of spent anodes in the supplier lab to establish their suitability for practical usage.

4. Working Principle of OCA

The Crossbelt analyser (Figure 2) for the real-time analysis of solids on a conveyor belt uses halogen light as an energy source. This safe, non-intrusive energy enables its user to analyse minerals, organics and moisture of the conveyed material in real-time, down to minimal concentration ranges, as the application at EGA shows. It provides sufficient energy to analyse run-of-mine (ROM) materials with variable particle size distributions (PSDs).

The near-infra-red (NIR) energy of the light from the eight halogen bulbs of the Crossbelt setup is partially absorbed by the material passing underneath the analyser. The Fourier Transform Infrared (FTIR) spectrometer records the absorption every 420 milliseconds. It averages the collected spectral information to a minute-by-minute output converted by the calibration logic into chemical or mineralogical minute results.

The NIR online system works independently of belt speed and (variations in) load. In the crush butt location at EGA, both are on the lower side, but the system has already been installed in applications with 12 000 tonnes per hour.

Besides the Crossbelt application, the NIR technology can also be applied on an air slide for fine pulverised materials, e.g., on alumina.

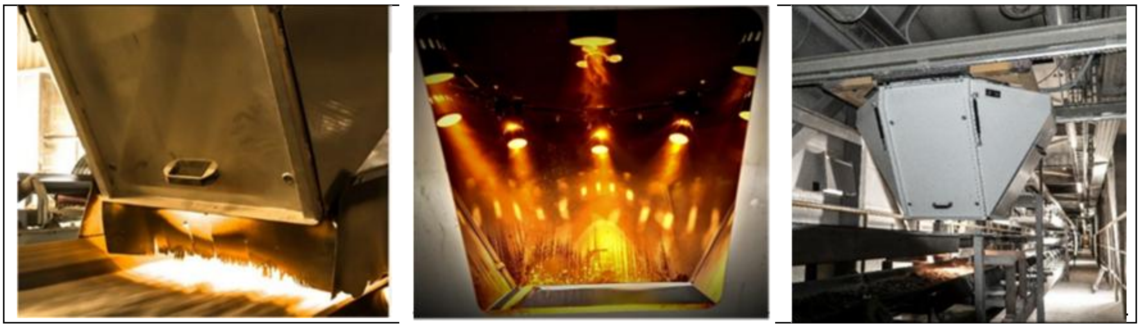

Figure 2. Cross Belt Analyser *(Outer and inner view).*

5. Feasibility Study

Samples of spent anodes with varying degrees of contamination were sent to SFA for a pilot study. Before sending, these samples were analysed at EGA laboratory so the results could be used to develop the calibration model by SFA.

Based on the samples EGA provided and their lab analysis, SFA was able to develop a simple yet robust model to predict the Na concentration of the blind samples provided as part of the test.

This showed that the SFA technology using NIR could safely predict the Na concentration in varying ppm ranges (Figure 3). Besides Na, Ca, Fe, Si (in ppm range) and ash (in %) were also calibrated successfully as part of the study.

With these promising results (Figure 3), EGA concluded that with the help of the SFA online chemical analyser, the spent anodes' recycling process could be optimised, leading to more efficient and cost-effective production.

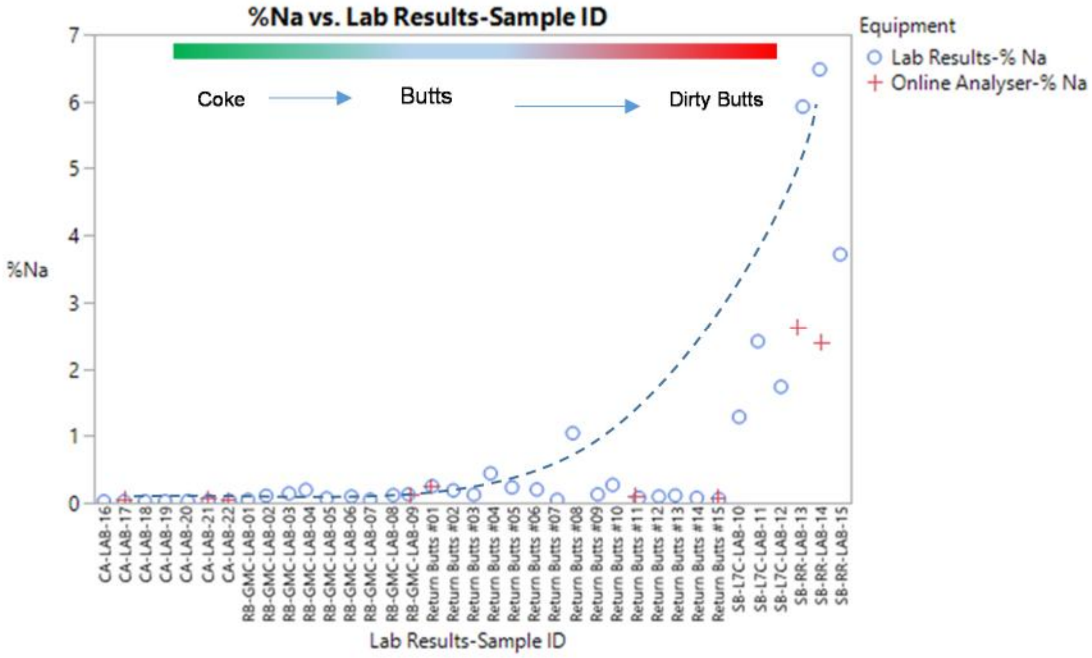

Figure 3. Pilot OCA vs lab.

6. Road Map for the Development of an Online Chemical Analyser

Figure 4 shows the road map for the development of an online chemical analyser with major milestones.

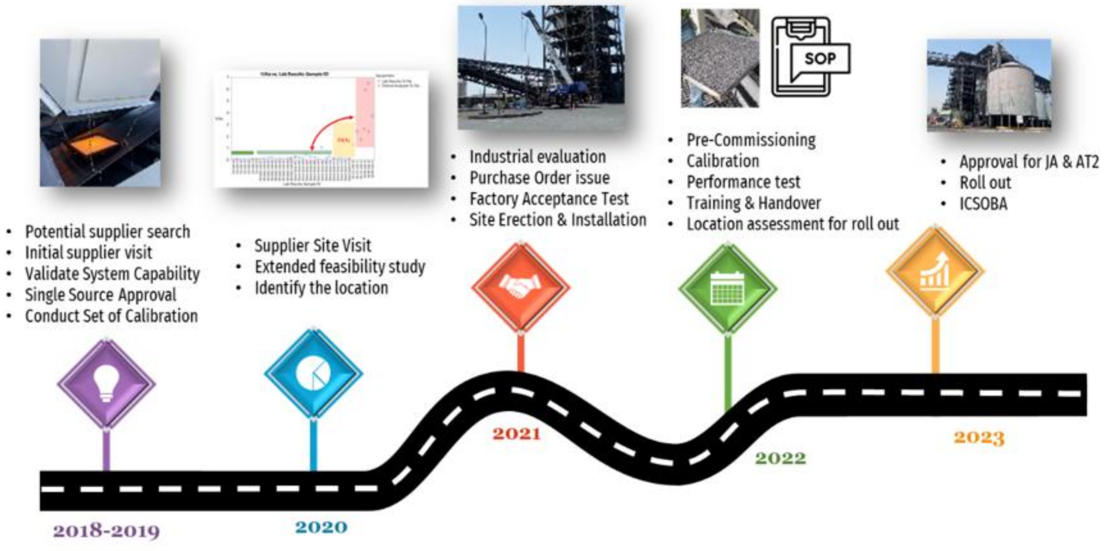

Figure 4. Development journey of the OCA.

7. Installation

The NIR online analyser system is installed over a suitably accessible conveyor belt. The location was chosen to use real-time data for corrective measures, ideally in a closed-loop control system. Any location after a crushing system or a transfer point offers a representative surface for ideal analysis.

An additional platform can be provided, as in the case of the installation at EGA (Figure 5). Besides that, stabilised power (120/230 VAC at 50/60 Hz, 16 A at 230 VAC/ 20 A@120 VAC), clean compressed air (backup vortex cooling) and a fibre optic cable for data transfer to the distributed control system (DCS) needed to be supplied to the installation location to be connected to the control cabinet. The analyser part is mounted on a frame over the conveyor belt and then connected to the nearby control cabinet. The system is set up to withstand vibrations and keep the spectrometer and control cabinet in stable temperature conditions, despite the high summer temperatures, such as in the UAE.

As a last step, a canopy was installed over the analyser to shield it and the measurement point from direct sun and rain. The whole installation process and testing of the hard- and software is supported by an engineer on-site and remotely by the Swiss engineering team.

After the mechanical and electrical commissioning, the prepared calibration models are loaded. The model development is based on client specific (in this case, EGA crushed butt samples) analysed at the SpectraFlow laboratory in Switzerland and by the laboratory at EGA. The spectral information and lab essay for all samples are the basis for the calibration model for any application.

The model is then tested on-site to make the final adjustment to the specific site conditions.

Figure 5. OCA installation.

8. Testing and Performance

One of the main challenges in using the OCA is ensuring accurate performance assessment, given its dynamic nature and the large amount of material (approximately 2 tonnes) scanned every minute. The high heterogeneity of the butts [Figure 6] also contributes to the variability of impurities within the short scan time frame. EGA reviewed lab sampling practices to address these challenges and modified the slicing/splitting procedures to obtain the most representative sample. Once the installation is completed, the Analyser is ready for testing. During the testing process, special attention is given to verifying the system's functionality and obtaining accurate measurements. This involves verifying the comprehensive calibration procedure *(as the calibration work was done beforehand, and the model was then uploaded)*, meticulous adjustment of relevant settings, and the execution of both dynamic and static sampling tests on the recycled spent anode. It provides confidence in the reliability and consistency of the measurements obtained, guaranteeing that the recycled crushed butt falls within the required range for optimal recycling efficiency.

During static testing (Figure 6), the analyser captures measurements when the recycled butt is stationary. Static testing allows for precise analysis of specific properties and characteristics of the butt under controlled conditions. The static test sampling provides valuable insights into the composition, concentration, and quality of the recycled butt.

Dynamic sampling involves capturing measurements while the recycled butt is in motion, reflecting its real-time behaviour and properties during recycling. This dynamic analysis enables the identification of any variations or fluctuations in the butt composition, ensuring optimal process control and monitoring.

Figure 6. Static testing and heterogeneity of samples.

A dynamic sample procedure was developed to collect 8-10 kg samples at 15 s frequency for cross-verification with lab analysis to validate the OCA results. Each collected sample was crushed to 2-3 mm size and passed through a splitter multiple times. Three samples were taken from the splitter and further ground to 200 mesh for XRF measurement. Only the XRF analysis of a sample with less than 100 ppm difference in Na was considered homogenous and fit for evaluation.

Out of the 85 samples collected, 48 were identified as homogeneous. These homogeneous samples were then compared with the readings obtained from the Online Crossbelt Analyser. The results showed that approximately 80 % of the OCA analyses were within ± 100 ppm of the samples' composition.

This performance indicates that the OCA readings were consistent and reliable in assessing the composition of the *validated* samples (identified as homogenous). The OCA's ability to accurately measure and validate most of the samples highlights its effectiveness in providing reliable data for analysis and decision-making.

9. Value Capture

Sodium (Na) in crushed butts is one of the critical quality metrics. It is proportionally linked to sodium in the anode, which is a catalyst and enhances the sensitivity to the reactivity of anodes

(Figure 7). The reactivity of the anodes is measured by carboxy reactivity dust (CRD). If not inhibited by sulfur, a higher Na content in anodes leads to a higher CRD [4, 5].

A higher CRD value also means the anodes will likely generate carbon dust during usage. Excessive dust levels can detrimentally affect pot performance, leading to reduced efficiency. This, in turn, influences the carbon consumption within the anodes [5].

Therefore, the Na content of the anodes is pivotal in determining the performance and efficiency of the pot line, as well as the overall carbon consumption within the anodes. Monitoring and controlling the Na content in the butts (and anodes) to ensure optimal pot performance and maximise efficiency in aluminium production is crucial.

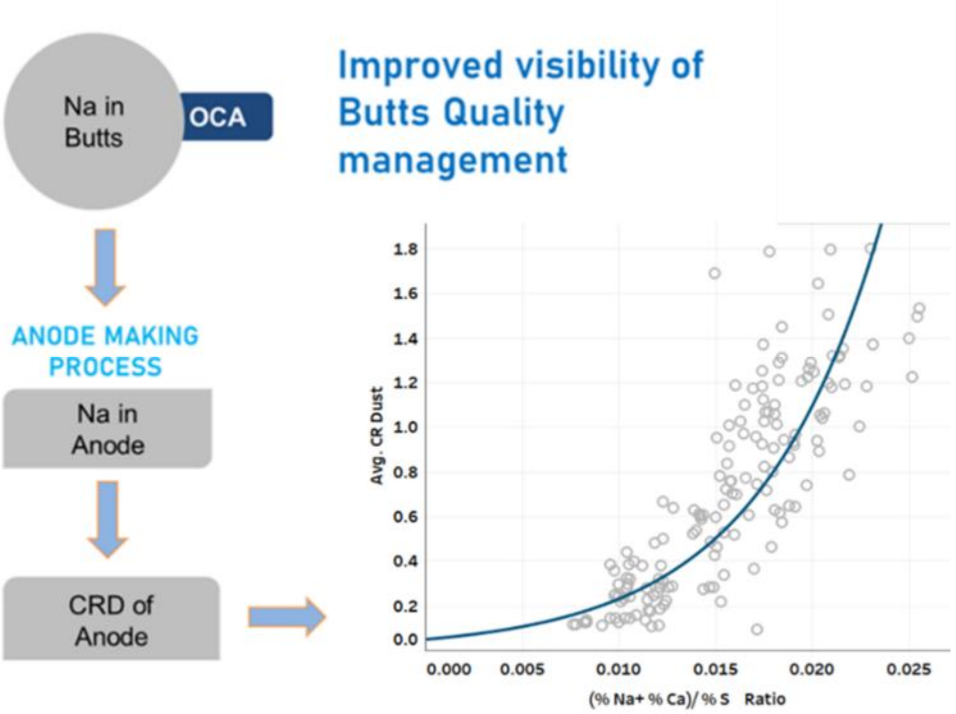

Figure 7. Anode impurities vs CRD.

10. Utilisation of OCA

10.1 Dashboard Alerting

After the OCA's successful installation and performance testing, a dashboard was developed to provide real-time data to the operator in the control room. The dashboard displayed aggregated data (Figure 8) to enable a quick response time, allowing for the identification of patterns in the current trend of spent anode quality and providing warnings when necessary. This implementation resulted in the following benefits:

- Avoidance of delays in visualising the product quality.
- Mapping actions and events upstream (Process) based on the data.
- Reduced dependency on manual sampling.
- Minimisation of sampling errors.

The dashboard facilitated efficient monitoring and control of the spent anode quality, empowering operators to make informed decisions on time while mitigating the risks associated with delays and potential sampling errors.

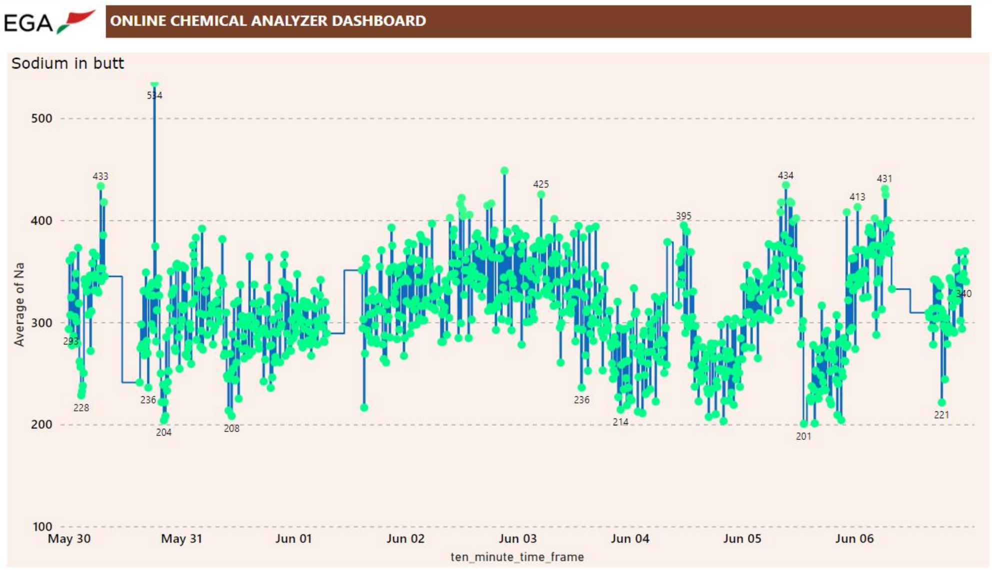

Figure 8. Real-time Na contamination in spent anode.

10.2 Events Analysis to Showcase the Benefits.

Following the integration of OCA into regular operations, an instance of OCA stoppage occurred due to a communication failure (Figure 9). However, butt crushing system continued its operations during this period. Intriguingly, it was observed that in the absence of OCA functionality, there was a noticeable increase in sodium (Na) levels in the butts, ranging approximately from 25 to 100 ppm increase, despite implementing other routine controls. This elevation in Na levels can be attributed to the lack of a feedback loop for the proper control actions during the process.

Several factors may contribute to the rise in Na levels when the OCA system is offline. These factors include manual cleaning practices, the introduction of high-temperature butts into the system, and the efficiency of the blast wheel in the butt shot blast process. Having accurate real-time information about the quality of spent anodes at the right time enables prompt actions in the plant day-to-day operations. This facilitates timely interventions to address issues related to Na levels and ensures optimal process performance.

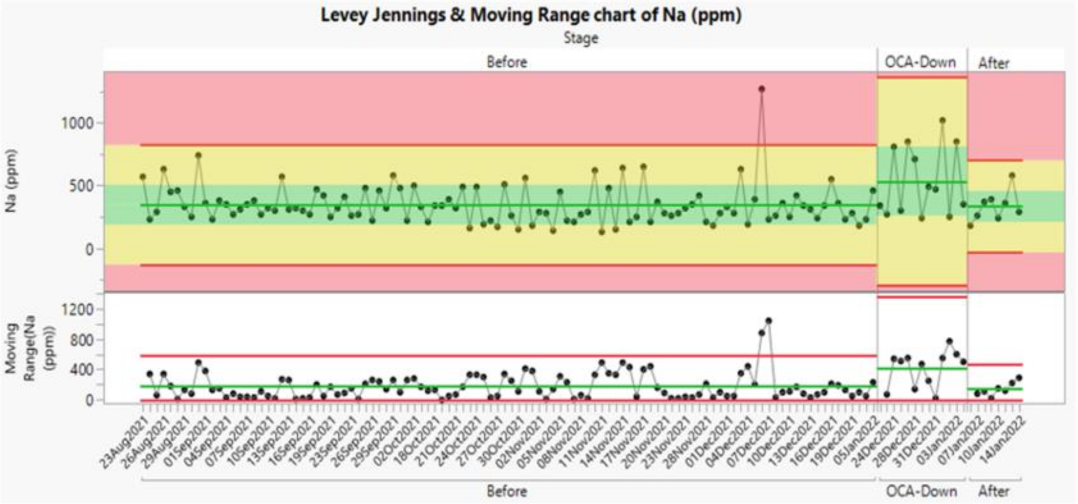

Figure 9. Na in routine butts during OCA operation vs OCA stoppage.

10.3 Utilization of OCA for Street Butts Feeding

One of the crucial aspects of rodding operations is to ensure thorough cleaning of the butts. However, there are instances when uncleaned butts are offloaded from the system and piled up for further cleaning. Managing this inventory pile poses a challenge for routine rodding operations, mainly due to the high variability in the Na content of these street (offloaded) butts which are either stripped outside during or butts which cannot be processed due to high contamination of Na.

Including an OCA system with real-time quality monitoring has significantly eased the challenge associated with 'street' butt re-use. The information provided by the OCA enables the visualization of trends and drifts in Na levels during street butt feeding events. Figure 10 visually illustrates that introducing street butts into the system results in a notable increase in instances where the Na level exceeds 600 ppm, compared to the standard processing of butts.

The real-time data provided by the OCA system plays a pivotal role in decision-making, helping determine whether to continue or halt the feeding process based on the observed Na levels. This assessment of street butts prompts actions to improve the efficiency of both offline and online in-house cleaning practices, ensuring better cleaning outcomes and overall operational effectiveness.

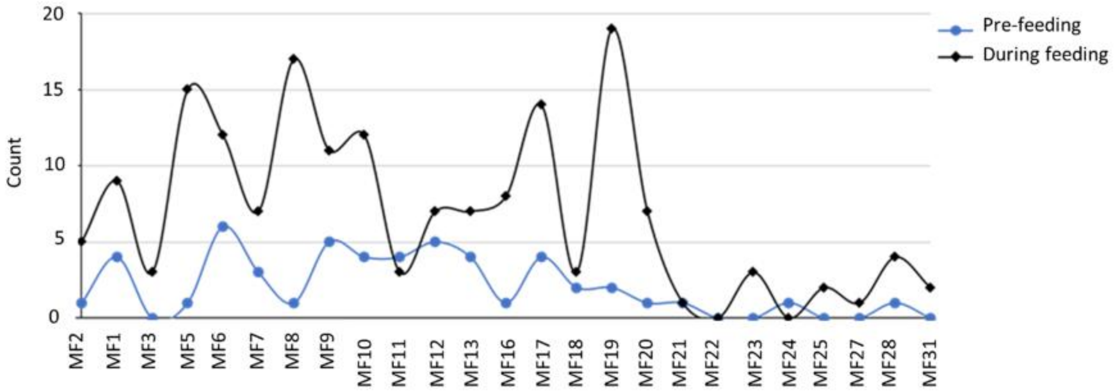

Figure 10. Count of instances Na >600 ppm before and after street butts feeding.

10.4 Equipment Enhancements and Learnings

The utilisation of OCA in day-to-day monitoring is continuously evolving, and several challenges have been identified and addressed for its smooth and innovative operation.

a. The provision of a camera connected to the control room screen for live information,
b. Installing a LED screen in the control room to alert the control room of the rapid change in the Na of butts.
c. The use of a rubber curtain to protect the light for correct scanning,
d. Providing access for top cleaning of the OCA.

10.5 Impact of Na Control in Spent Anodes

The real-time information OCA provided on spent anode quality enables shop floor personnel to take timely corrective action on equipment or process practices (Figures 11 and 12). In addition to the roll-out of OCA, several other initiatives were taken to reduce Na in spent anodes; as a result, Na was decreased in baked anodes by approximately 150 ppm (by 200 %).

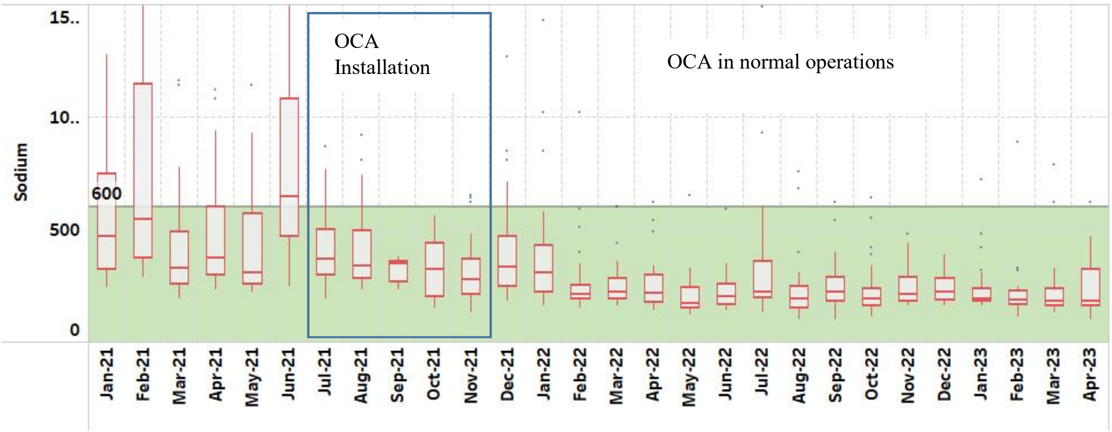

Figure 11. Na ppm trend in routine butts.

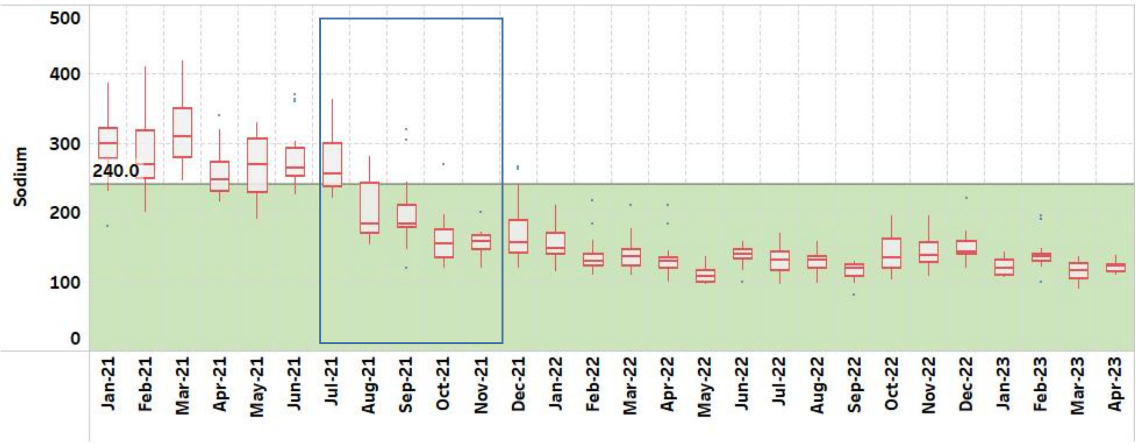

Figure 12. Na ppm in baked anodes.

11. Change Management

Building confidence in the OCA among individuals directly or indirectly involved in carbon quality was challenging. Awareness sessions were conducted, and standard operating procedures (SOP) were modified to explain the working principle of the OCA.

Furthermore, a comprehensive training program was implemented for all personnel involved with the OCA. This program covered the functionality of the OCA and provided guidance on interpreting warning signs from the dashboard. The goal was to ensure timely action on the shop floor to control Na levels in spent anodes based on the information provided by the OCA.

12. Conclusions and Way Forward

After implementing OCA at the Al Taweelah Phase 1 (potlines 1 and 2) site, EGA has decided to roll out the same system across other sites. Additionally, work has been initiated to link the OCA with all the process drivers from the source in the pot line to the point of measurement at OCA. Linking all the critical processes in the cleaning circuit will enable the development of an explanatory model. The model aims to identify the key controlled variables in the process and establish operating ranges for these variables to benchmark the sodium level in the spent anodes and sustain the benchmarked baked anode quality.

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14. References

1. S.M. Hume, Anode Reactivity*, Influence of Raw Material Properties*, 2nd edition, by R&D Carbon*,* 1999.
2. Y.K. Hoang, B. Vitchus, Laboratory studies on the impact of vanadium and sodium on the air reactivity of coke and anodes, *Fifth Australasian Aluminium Smelter Technology Workshop*, October 1995, 430-446.
3. Les Edwards, Quality and process performance of rotary kilns and shaft calciners, *Light Metals* 2011, 895-900.
4. B. Coste and J.P. Schneider, Influence of coke real density on anode reactivity consequence on anode baking, *Light Metals* 1994, 583-592.
5. Werner K. Fischer, Felix Keller and Raymond Perruchoud, Interdependence between anode net consumption and pot design, pot operating parameters and anode properties, *Light Metals* 1991, 681-686.
6. Edouard Mofor, Impact of anode top cover composition on anode butt quality, *The 7th International Conference on Electrodes for Primary Aluminium Smelters*, Reykjavik, Iceland, 25-27 April 2017.
7. K. Fassbender et al., Cleaning of spent anodes of the aluminium process, *Light Metals* 1987, 541-552.