Improving Net Carbon Consumption at EGA with the Support of Anode Tracking and Butt Analyser

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Abstract

Emirates Global Aluminium has a smelting capacity of 2.5 million tonnes of hot metal per year from two production sites - Jebel Ali, which operates 6 different cell technologies, and Al Taweelah, which operates 2 different cell technologies. The original cells at EGA were started in 1979 at Jebel Ali with that plant expanded with more modern cell technologies at regular intervals since then. The Al Taweelah site was started up in 2009 and expanded in 2014. Improving the efficiency of the older cell technologies at EGA has been a constant pursuit which has included various initiatives undertaken over the last 10 years to improve Net Carbon Consumption (NCC). A reduction in overall smelter NCC from 436 kg C/t Al to 420 kg C/t Al has been achieved over this time, with the best performing technology delivering an NCC of 407 kg C/t Al. The requirement to procure raw materials from more than 10 global sources to supply several anode production facilities, and to operate multiple cell technologies, provided EGA with the unique opportunity to assess the impact of these variables on NCC. Changes in anode and cell design, improved anode quality, standardized and improved operational practices, along with optimized raw material usage, were key to delivering the NCC improvement. An integrated anode and rod tracking system and butt analyser were installed at Jebel Ali and this has provided an invaluable platform for integrating anode and cell data and analysis. The tracking system and butt analyser are pivotal in monitoring and fast tracking anode and cell improvements. This paper provides an insight into key factors influencing NCC at EGA and the tools used to evaluate their impact.

Keywords: Net Carbon Consumption (NCC), carbon raw materials, anode tracking, butt analyser, cell operations.

1. Introduction

Due to its regular expansion and capacity creep over the past 37 years, EGA now operates six different cell technologies at or above their design production capacities at Jebel Ali. This imposes stringent demands on cell control and raw material and anode quality.

One of the issues faced in efforts to improve anode performance for each of the cell technologies, was the difficulty of tracking the performance of anodes per technology or by Potroom. This is further complicated by the need to supply 8 different anode types across the smelter, produced from a single Carbon Plant.

Under these circumstances, evaluating the impact of initiatives to reduce NCC proved very challenging. In response to this challenge, a proprietary anode and rod tracking system was developed and installed to provide accurate data on anode production and usage. This was a “game changer” that provided new insights into anode behaviour within individual cells, cell groups, and Potrooms, so the impact of various cell and anode parameters on NCC could be quantified.

This paper describes how the anode and rod tracking system has been used to date as a tool for evaluating and optimizing NCC at EGA Jebel Ali Operations.

2. Anode and Rod Tracking Integrated System (ARTIS)

To handle the complexity of the EGA Jebel Ali site caused by multiple cell technologies using multiple anode types produced in single Carbon Plant, and to provide the data needed for process performance optimization, a strategic decision was taken in 2008 to install an anode and rod tracking system. The various commercial options available at the time were explored, but an ‘off the shelf’ fully integrated system meeting all of the requirements could not be found. Therefore, a decision was taken to develop in-house a modular system that could be expanded as technology continued to evolve. The anode and rod tracking system pilot trials commenced in 2008.

By 2010, EGA Jebel Ali had an operational Anode and Rod Tracking Integrated System (ARTIS) installed to provide extensive information about anode quality, usage, and performance parameters during the anode life cycle. Each rod assembly was uniquely identified, and this was linked to individually identified anodes.

Figure 1 below shows the equipment installed at various stages of the smelter process for rod and anode tracking. Each rod is fitted with a 2D barcode. Barcode readers for the rods and Optical Character Readers (OCR) for the anodes are installed at key locations in the Rodding Plant. Hand held readers are used to manually scan and record the cell/stall location of anodes in the Potlines [1].

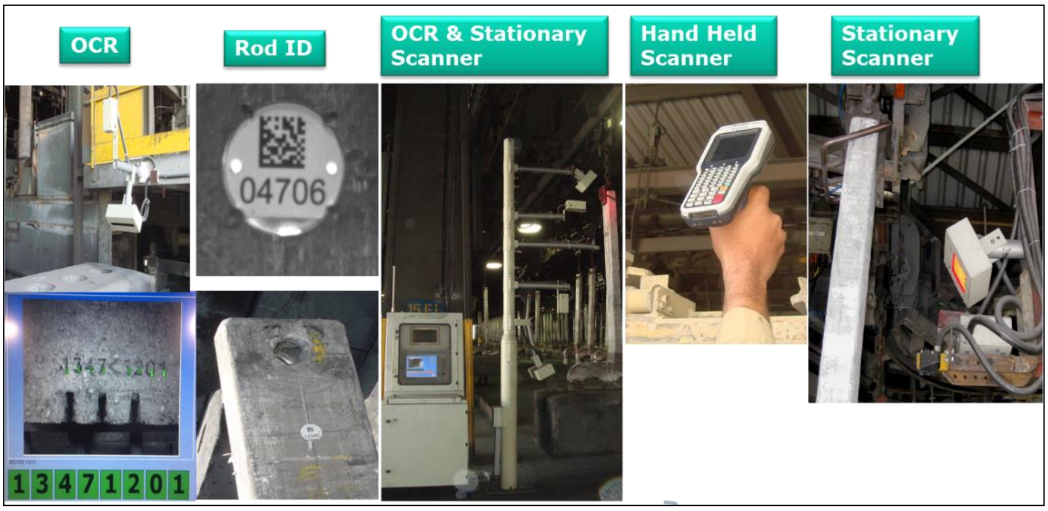


Figure 1. Rod and Anode Tracking Information System hardware.

As each rod ID is captured through the system, all the butt parameters, anode raw material information, and green anode parameters are linked to Potlines information such as: cell technology, cell number, stall number, and time of anode change (Figure 2).

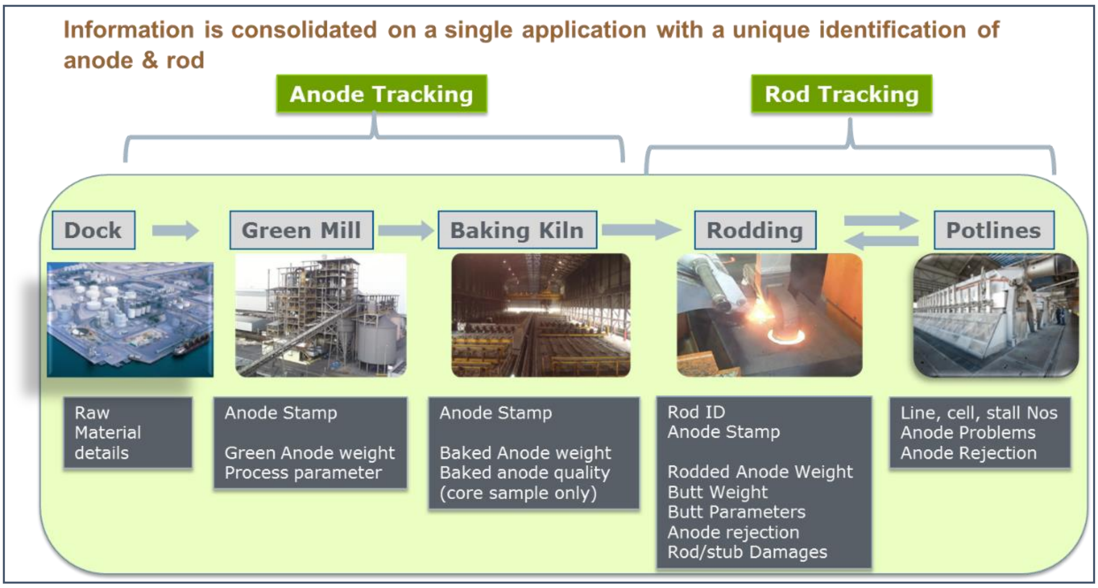
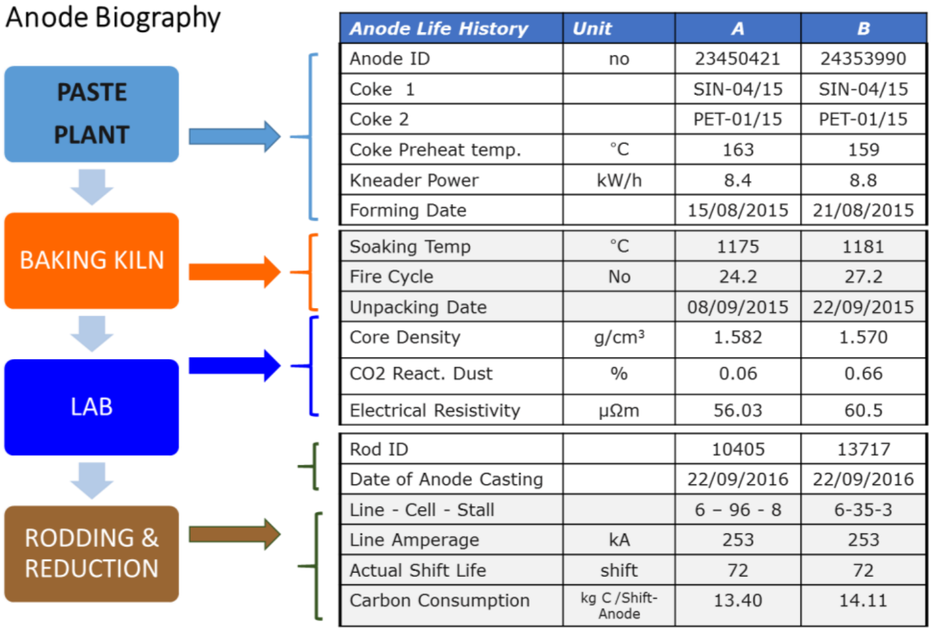


Figure 2. Information available from Rod Tracking System.

In summary, the system provides the biography of an anode as shown in Figure 3. As a result, comprehensive information is available for investigations, troubleshooting, and identification of improvement opportunities for process optimization [2].



Anode Life History	*Unit*	*A*	*B*
Anode ID	no	23450421	24353990
Coke 1		SIN-04/15	SIN-04/15
Coke 2		PET-01/15	PET-01/15
Coke Preheat temp.	°C	163	159
Kneader Power	kW/h	8.4	8.8
Forming Date		15/08/2015	21/08/2015
Soaking Temp	°C	1175	1181
Fire Cycle	No	24.2	27.2
Unpacking Date		08/09/2015	22/09/2015
Core Density	g/cm³	1.582	1.570
CO2 React. Dust	%	0.06	0.66
Electrical Resistivity	µΩm	56.03	60.5
Rod ID		10405	13717
Date of Anode Casting		22/09/2016	22/09/2016
Line - Cell - Stall		6 – 96 – 8	6-35-3
Line Amperage	kA	253	253
Actual Shift Life	shift	72	72
Carbon Consumption	kg C /Shift-Anode	13.40	14.11

Figure 3. Information available for an individual anode (anode biography).

The details shown in Figure 3 are captured for 50-60% of anode production. Information about the precise location where each anode was set in a cell enables in-depth analysis with correlations between anode/cell performance and various anode production parameters. With the ARTIS (Anode and Rod Tracking Integrated System) installed, multiple process improvement projects can be easily tracked without the need to engage additional resources for manual tracking.

3. Installation of Online Butt Analyser Integrated with ARTIS

ARTIS is a modular system which was developed such that any new tracking equipment or enhancement can be easily integrated. Thus, in 2015, EGA Jebel Ali took another strategic decision to install a state of the art online butt analyser. The objective was to develop a system for the precise analysis of butt profiles and dimensions in order to better understand anode and cell behaviour. This system was jointly developed with the supplier and incorporated a unique grid approach to butt parameter measurements as shown in Figure 4. This was the first time that an online analyser utilized a grid system to measure the butt dimensions.

The definition of the grid system can be seen in Figure 4. The butt surface was divided in 21 locations for parameter measurement. Apart from the basic measurements like butt height, length, width, and area covered by bath, other critical measurements such as: Top oxidation, Carbon Under Stub, End burn, Exposed stubs, Butt area, Reduction in butt area, and others are computed. All measurements are available at the grid level. Butt images (Figure 5) are captured from all faces and stored as references, along with grid level parameters, for analysis. A live 'dashboard' is available onsite which indicates the cleanliness of the butt so that immediate action can be taken in the Rodding Room to re-clean any dirty butts.

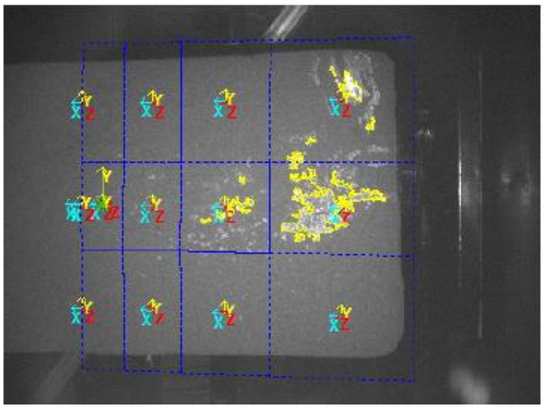


Figure 4. Butt measurement as per grid.

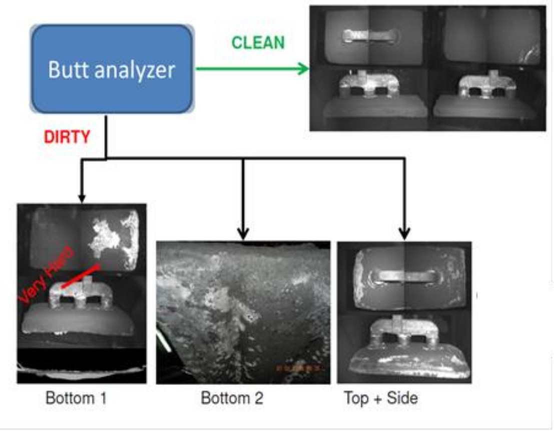


Figure 5. Clean and dirty butt images.

4. Utilization of ARTIS and Butt Analyser Data for End-to-end Process Understanding and Optimization

Overall smelter performance is assessed through the Key Performance Indicators (KPIs) such as NCC and Gross Carbon Consumption (GCC the amount of carbon consumed in Aluminium production without any credit for butts return). At smelter level, NCC is generally computed as a monthly KPI based on a mass balance of total anode tonnes sent to Potlines, total butt tonnes returned from Potlines, and hot metal production. The ARTIS, however, computes anode consumption as the change in weight of a rodded baked anode sent to Potlines minus the weight of that same anode returning from Potlines as a butt. This one to one tracking by ARTIS brings NCC down to daily measured parameter available for each stall of each cell, reported as Carbon Consumption per shift (CC/shift). This parameter (CC/shift), has been the driving parameter for assessing anode performance, and has reduced the assessment frequency from monthly to daily. In this paper, CC/shift (Reported as Kg C/anode/shift) will be used as the key parameter in assessing anode performance.

The following are a number of case studies that demonstrate how ARTIS and Butt Analyser Data have been used to improve anode and cell performance, generating business value for EGA.

4.1. Performance Evaluation and Usage Strategy of Coke

It is well known that the selection of appropriate raw materials has a huge impact on not only the cost of the anodes produced, but also on their quality, and hence the anode consumption rate. As ARTIS provides an integrated information system from the raw material used to the anode performance in the cells, the performance of new raw materials can be assessed in detail, and the routine assessment of approved raw materials that are used regularly is now much more convenient and faster.

4.1.1. Coke Performance Monitoring

The performance of coke from each supplier is monitored periodically to ensure consistency. The case study shown in Figure 6 is an example of where it was observed that a specific coke blend (A+H) resulted in a lower carbon consumption rate when compared to other coke blends across two different Potlines.

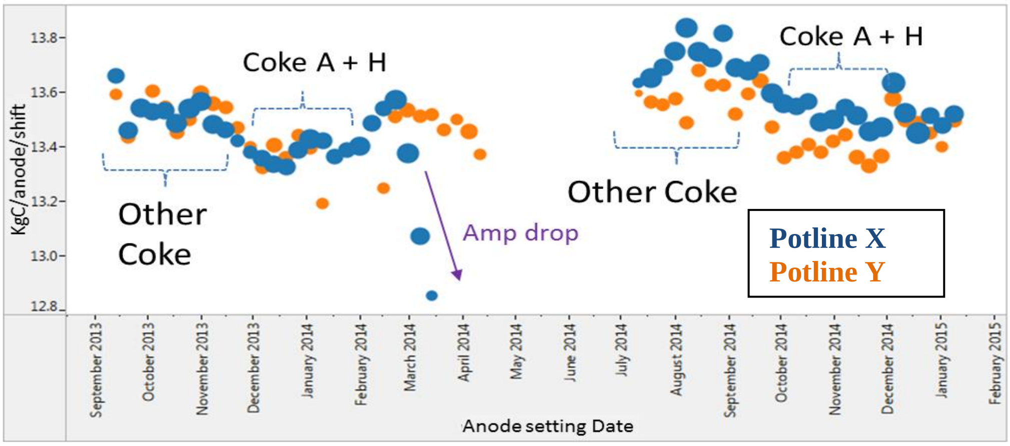


Figure 6. Carbon consumption per shift of different coke blends across two Potlines.

4.1.2. Trial Coke Evaluation

With an aim to generate business value by reducing unit costs, EGA planned to procure coke with higher Vanadium content. A test consignment of higher V coke was procured and a trial batch of anodes produced and supplied to a specific group of cells. The performance of these anodes was evaluated through ARTIS (Figures 7 and 8).

As shown in the Figure 7, vanadium in metal increased in the test cells by 5 ppm during the trial. Prior to the trial, the higher vanadium content of the trial coke was expected to increase anode NCC, however, analysis showed no significant change in carbon consumption of the trial anodes compared to anodes produced with regular coke (Figure 8). This showed that the vanadium specification could be safely revised up to obtain commercial advantage in procurement without affecting the anode performance.

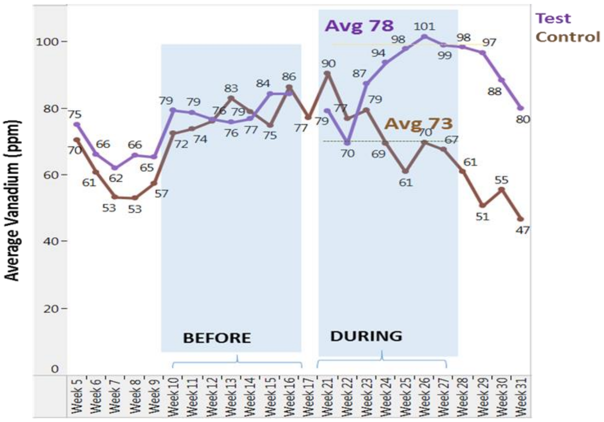


Figure 7. Vanadium in metal (ppm) before and during the higher V coke trial.

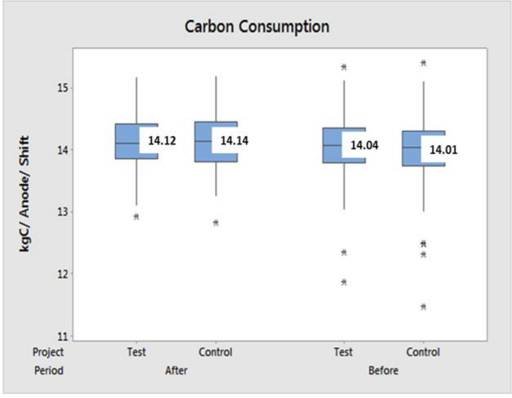


Figure 8. Carbon consumption in trial and control cells, before and after the use of higher V coke.

4.2. Butt Cleanliness as a Function of Butt Source

Integration of the Butt Analyser with ARTIS enables the measurement of the area of a butt covered with bath for each stall location in a cell. If cells are categorised as: new cells, cut out cells, or normal cells, it can be seen from Figure 9 that the contaminated bath area on butts from normal cells is lower than from new or cut out cells. This understanding helps in deciding the strategy for processing butts from cut out and new cells in the Rodding Room.

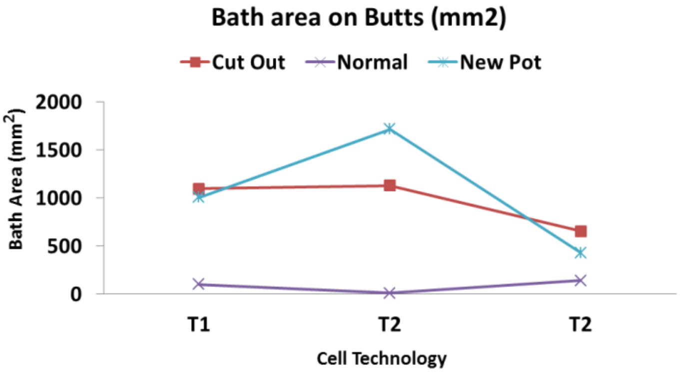


Figure 9. Bath area on butts as per cell condition (Cut out, Normal, New) for different cell technologies.

4.3. Anode Baking Level and Carbon Consumption

One of the well-known critical variables influencing anode consumption rates is the anode baking level. Anode baking level, and the calcination level of the coke used for anode production, can be quantified by measuring graphite crystallite height (Lc) which is the representation of the degree of crystalline ordering. The difference between the Lc of the anode versus the original coke Lc (Delta Lc) was correlated with carbon consumption. When the anode Lc is greater than the coke Lc (i.e. Positive delta Lc), this indicates that the anode has had greater heat treatment (temperature and duration of temperature) than the coke. In order to establish the correlation between coke and anode Lc, three years of data was summarized for all the core sampled anodes as a function of anode stall location in the cell (Figure 10).

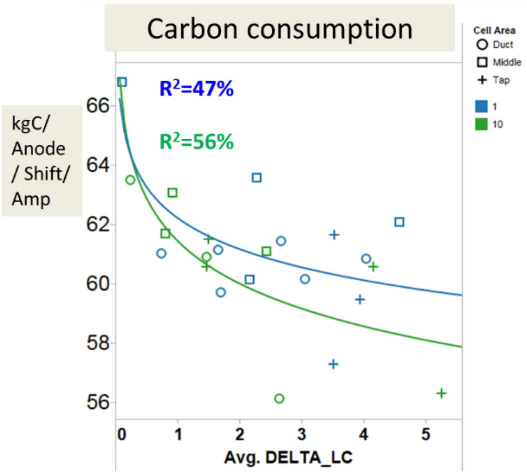


Figure 10a. Normalized carbon consumption per shift versus Delta Lc (Anode Lc – Coke Lc) as a function of anode stall location in the cell (Duct end, Middle of cell, Tap end)

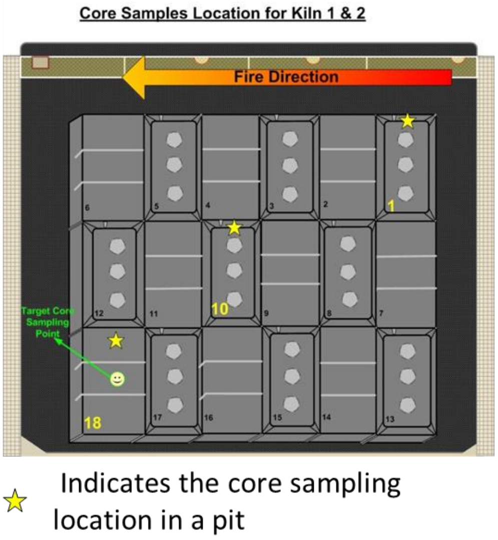


Figure 10b. Anode baking anode location in the kiln (1 or 10).

It was observed that anodes with a higher Delta Lc exhibit lower carbon consumption irrespective of their location in the cell i.e. duct end, tap end and middle location (Figure 10a). Baked anodes are cored from location 1 (Top layer), 10 (Middle layer) and 18 (Bottom layer) of the pit as shown in the figure 10b. It can be seen from Figure 10a that anodes baked in the centre of the middle layer of a pit typically have a lower carbon consumption than the anodes baked at the end of the top layer of a pit. This is associated with the less even heating of the end anodes in a pit, which is a limitation of the baking furnace flue wall design.

4.4. Optimising Butts Parameters to Ensure Metal Purity

The first step in any optimization exercise is to have accurate and reliable measurements. Following this, Butt analyzer data was the key to optimizing anode shift life in the cells without affecting metal purity.

All of the information related to butt parameters is compiled and analyzed periodically to identify improvement opportunities. Approximately 40,000 butts are processed each month in the EGA Jebel Ali Rodding Room. Around 95% of these butts are measured by the online Butt analyser for all dimensions; these data are then integrated with anode quality and key processing parameters through ARTIS. Anode butts vary in shape and size because of the movement and heave of the metal pad in the cells, cell design factors, and anode asymmetry. In older technology cells, which do not have good magnetic compensation, greater metal heave results in thicker butts in corner stalls than the middle stalls. To understand this variation, anode butt height is measured at 16 locations.

Carbon Under Stub (CUS) is calculated considering the minimum anode butt thickness and average top oxidation. It is nominally the amount of carbon remaining on butts below the bottom of the stubs. CUS data is stratified into three categories as follows:

- Thick - CUS is high and there is a scope to optimise further.
- Target - CUS is optimal.
- Thin - CUS is low; going below this limit poses a risk of iron contamination through stub attack in the reduction cell.

To make the data more meaningful, specification limits for CUS are defined for each of the 6 reduction cell technologies. In a similar way to CUS, butt weight data are also statistically analyzed in a way appropriate for the purpose of the investigation. Summarized feedback on the data analysis is provided to Potlines management, who utilize the information to determine the appropriate anode shift life for each technology.

An example of one of the EGA Jebel Ali cell technologies where the CUS had decreased is shown in Figure 11. Around 45% of the butts from this Potline had a CUS less than 2 cm. As a countermeasure to this, anode shift life was decreased and CUS improved to 5.1cm, avoiding any impact on metal purity.

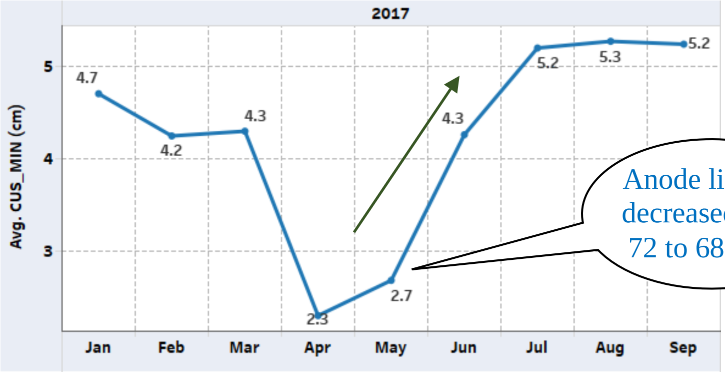


Figure 11. Butt Carbon Under Stub (CUS) improved with a decrease in shift life.

Another example of how metal purity was affected by adverse butt parameters is shown in Figure 12; this graph illustrates butt weight changes along with the reduction in area for one Potline, and the number of inner (Centre of cell) and outer (Cell sidewall) stubs exposed by carbon loss. When anode shift life was reduced in May 2016, % Fe in the hot metal decreased with the reduction in exposed stubs as shown in Figure 13.
To avoid such situations, critical limits for CUS were defined for safe cell operation. Butts parameters from the Butts analyser such as butt area, butt weight, and % exposed stubs were correlated with metal purity of the cells and optimised.

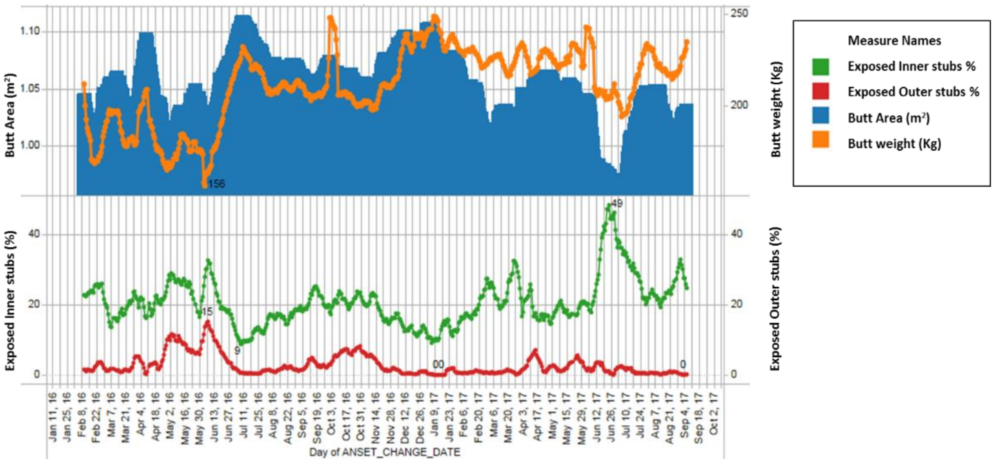


Figure 12. Illustration of butt weight, butt area changes (Top) and their impact on exposed stubs (Bottom).

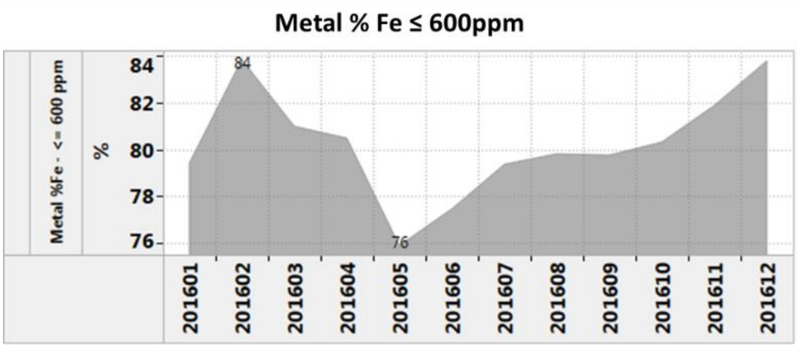


Figure 13. Trend of % of Potline hot metal with Fe ≤ 600 ppm.

As a result of this analysis, butt area reduction up to 13% was set as an acceptable limit with CUS between 3-4 cm. This helps to control metal purity as well as the excess carbon consumption due to thinner butts.

4.5. Stub Damage Affecting Metal Purity

Stub damage is inspected manually and entered to the ARTIS database. This helps to determine the origin of stub damage. Analysis of one year of data shows a strong correlation observed between Fe content in the hot metal versus stub damage caused by Potlines (mainly Ring neck, Burn off and washed stub) (Figure 14). The impact of stub damage for three cell technologies can be seen in this figure. Iron in metal increases as a function of the frequency of stub damage i.e. Ring Neck (RN), Washed Stubs (WS), and Burn Off (BO) (See figure 14, Right). The impact of different alumina feeding technologies on Fe in metal in decreasing order of severity are: Center Break cells (CB), “Poor man” Point Feed (PPF), and Point Feed cells (PF).

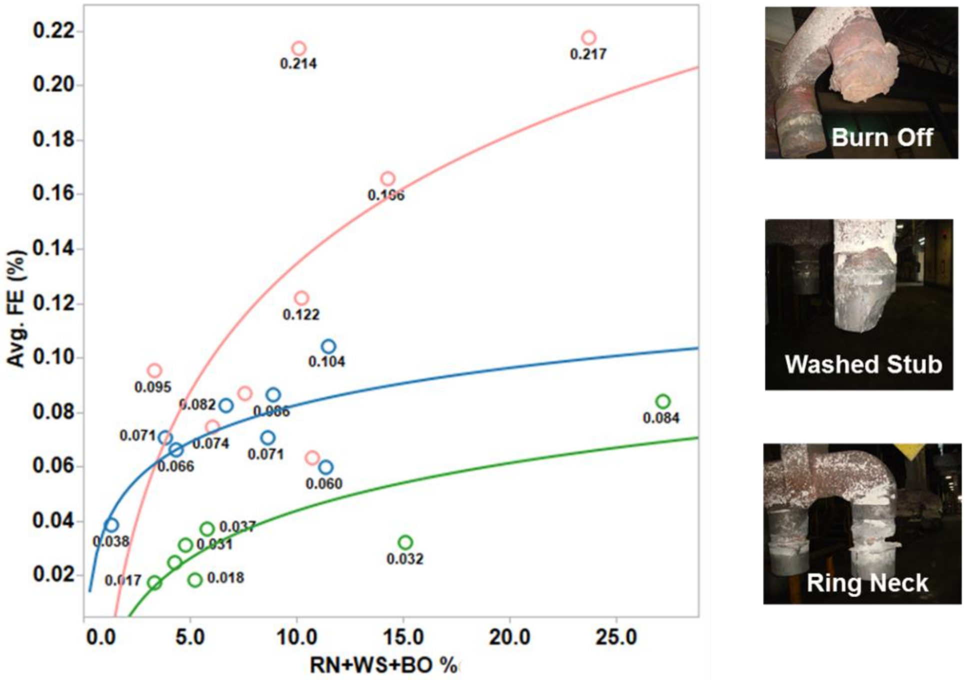


Figure 14. Correlation of %Fe in hot metal vs % Damaged stubs (Sum of Ring Neck + Washed Stubs + Burn Off) for different feeding technologies (Centre Break – top line, “Poor man” Point Feed – middle line, Point Feed – bottom line).

4.6. Feedback on Potline Process Improvement Projects

ARTIS has established an accurate and fast link between carbon and Potline information sources. This has proven to be an excellent platform to investigate and identify opportunities for cross functional process improvements with respect to cell operation and anode quality. Some of the case studies are summarized below for illustration [3].

4.6.1. Type of Cathode Used in the Cell Impacts the Carbon Consumption

As part of continual improvement work, various cathode types are tested in different cell technologies. Analysis of ARTIS data showed that cells lined with type A cathodes exhibited better anode performance than those with cathode type B (Figure 15).

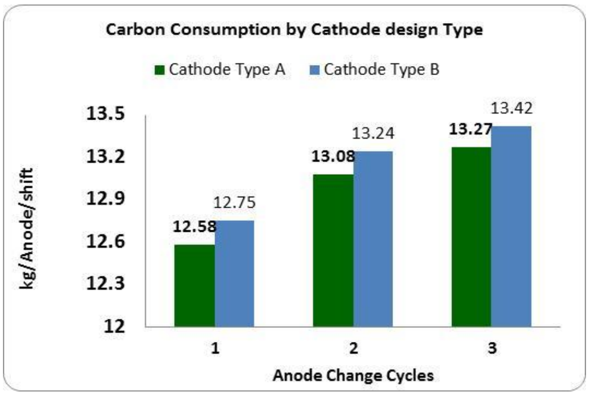


Figure 15. Carbon consumption by cathode design type.

4.6.2. Alumina Feeding Program Impacts Carbon Consumption

The impact of different types of alumina feeding patterns on carbon consumption was analyzed (Figure 16). This showed that the cells using type B alumina feeding pattern gave a lower consumption rate than those using type A feeding program.

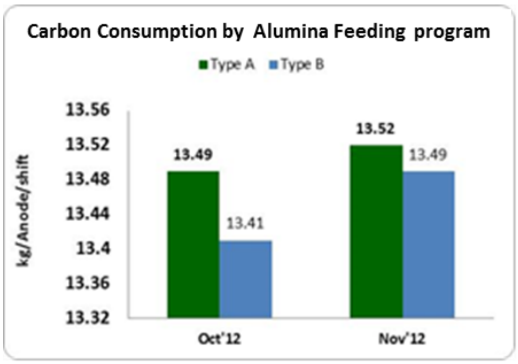


Figure 16. Carbon consumption by alumina feeding program.

Other projects of similar nature were undertaken, for example:

- Evaluating anode covering practices
- Impact of anode mantling with Aluminium spray
- Impact of changes in anode setting patterns
- Anode design modifications (top profile, slot design)

4.6.3. Anode Consumption Pattern for Different Cell Designs

Due to the varying metal pad profiles and metal movements in the cells of different technologies, carbon consumption across the anode working face is not uniform. With ARTIS, the pattern of carbon consumption in a cell was explored. It was observed that the butt thickness is lower at the upstream end for the middle stalls (Figure 17).

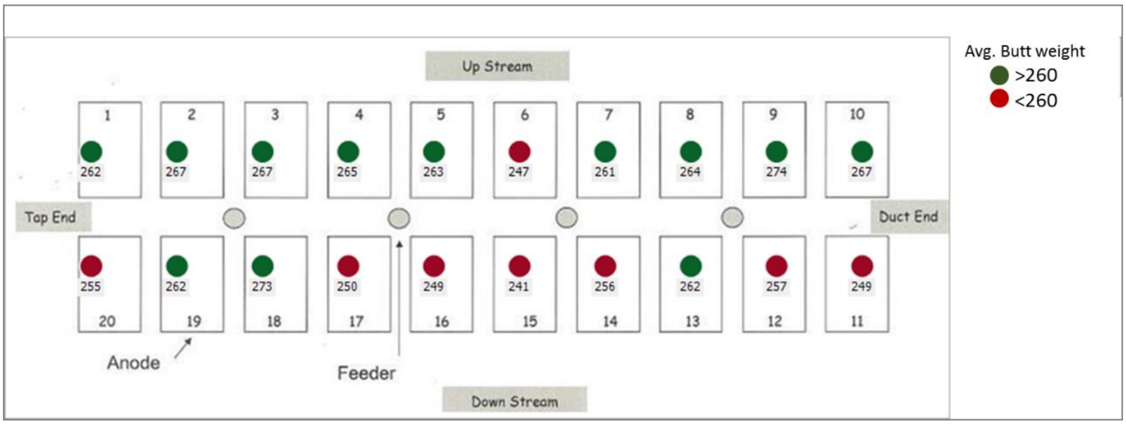


Figure 17. Butt Height as per anode location in the cell.

4.7. Anode Problem Investigation

The integrated database of ARTIS provides an insight to anode performance problems as it combines Potroom and Carbon Plant data on a single platform. For example, three years of anode problem data (e.g. spikes and Transition Joint Weld Failure) were expressed as % of anode problems across the total anode shift life and analyzed (Figures 18 and 19). This provided a pathway to understand process behaviour and establish the probable reasons for the anode performance problem.

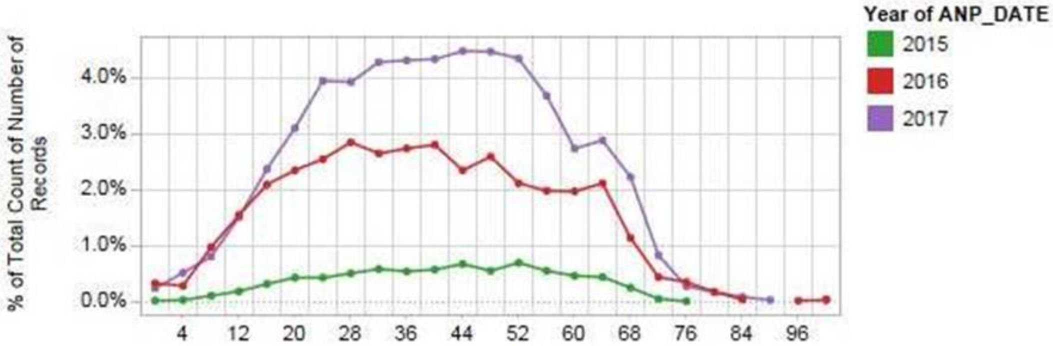


Figure 18. Anode problem (spikes) distribution by shift in anode life.

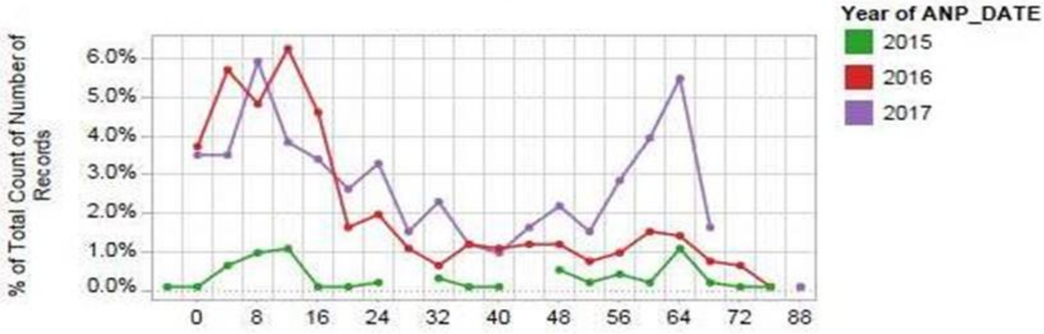


Figure 19. Anode problem (transition joint failure) distribution by shift in anode life.

Anode problem data were also analyzed by Potline section for further insight. As can be seen in Figure 20, anode problem rates varied by section in one of the Potlines: section 3 exhibits the highest anodes problems (19%), followed by section 4 (16.8%), and section 2 (13.5%). Overall, spikes accounted for 68.1% of anode problems. Analysis such as this helps to focus improvement work on the cells where the opportunity is greatest. Adding anode quality data to the above analysis helps to establish the root cause of anode problems and identify corrective measures.

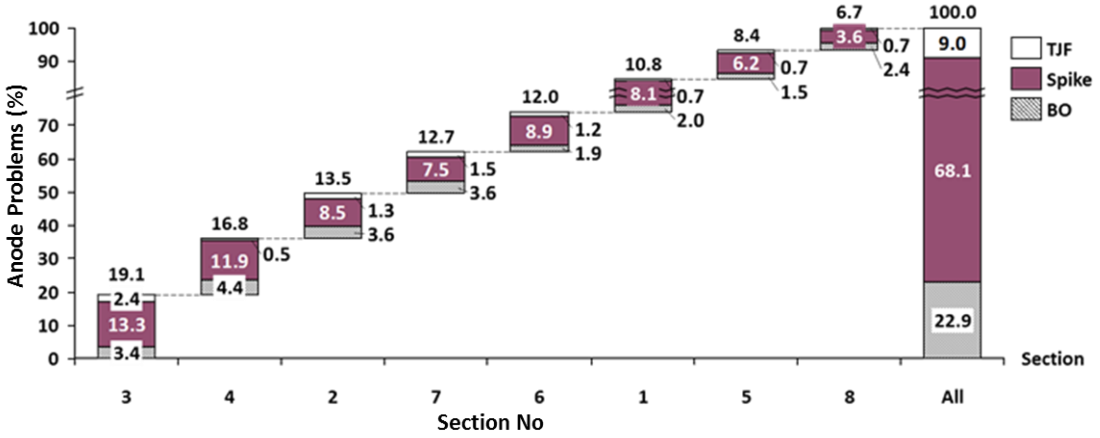


Figure 20. Anode problem distribution as per Potline section.

5. Results - NCC Improvements at EGA Jebel Ali

ARTIS has been successfully utilized in multiple iniatives to improve NCC and GCC and ensure that the most effective operating strategies are implemented. This has enabled EGA Jebel Ali to reduce NCC and GCC over the past seven years despite continuous capacity creep (through amperage increase) over the same period (Figure 21).

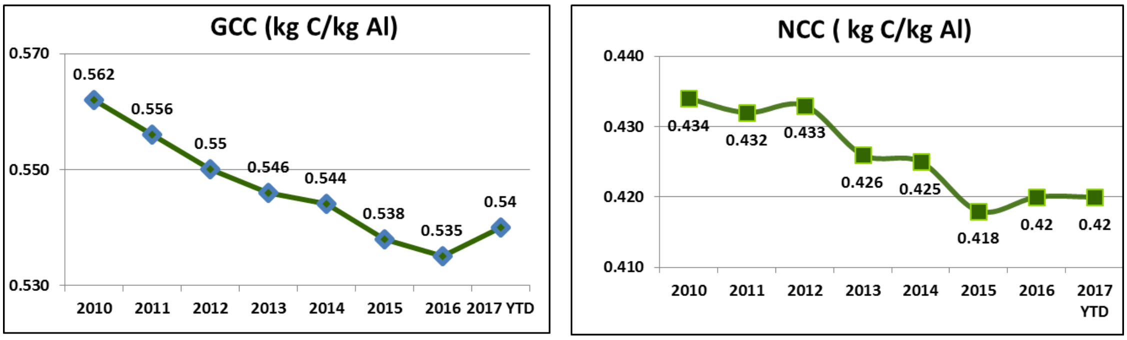


Figure 21. Overall Smelter GCC and NCC trend at EGA Jebel Ali Operations.

6. Conclusion and Way Forward

Anode tracking systems generate vast quantities of data that are often not fully utilised due to absence of integration of anode tracking data with other critical smelter data such as: anode quality, butt geometry and quality, and Potroom operating and quality parameters. EGA has successfully connected these data sets across multiple systems to create a powerful platform for evaluating the impact of changes in cell design, operational practices, and input materials (coke, anodes, alumina, etc.) on net carbon consumption. The collaborative approach of the smelter

and carbon team to utilize ARTIS has enabled EGA to select the most effective means for reducing net carbon consumption within the design limitations of its existing cell technologies.
ARTIS at EGA Jebel Ali has demonstrated its use as a reliable and integrated data system that not only facilitates but accelerates decision making processes. Evaluation of the initiatives to improve Net and Gross Carbon Consumption and diagnose the root cause of anode problems has been a major benefit of ARTIS. The data have also benefitted to minimise the effect of anode quality on metal purity and optimize the smelter process. Effective and faster evaluation of raw material performance and management of rod assembly repair have been other critical advantages.

The current anode and rod tracking information system does an excellent job of cross area information linkage. However, the traceability of baked anodes with regards to baking parameters is limited to the anodes that are sampled for quality verification. EGA is exploring the option to implement the anode tracking within the baking furnace to improve the association of baking parameters with ARTIS. This will provide additional opportunities to understand the performance of anodes that are baked in different locations/situations in the baking furnaces and unlock prospects for furnace efficiency improvements.

Acknowledgements

We would like to express our sincere gratitude for the contributions of those involved in the various initiatives to implement ARTIS and utilize the system to improve anode performance at EGA. Our Special thanks to the Potlines Management Team for their support and close follow up of plant trials in the Potlines.

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