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OPTIMISING ANODE PERFORMANCE IN DUBAL REDUCTION CELLS

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Abstract

DUBAL has improved its anode performance in terms of Gross Carbon Consumption (GCC) and anode problems, while sustaining Net Carbon Consumption (NCC) in the potlines despite continuous amperage increase, raw material quality variations and multiple cell technologies. A 5% reduction in GCC was achieved over the past four years through optimisation of anode quality, modification of anode design and adjustment of pot operating parameters and practices. Optimisation was done based on the statistical analysis of key parameters, e.g., anode weight, butt parameters, bath height and line amperage. Anode parameters were monitored using a proprietary Rod and Anode Tracking System (RTS), which reconciles information pertaining to the anode with respect to butt location in the pot and its characteristics, raw materials, green and baked anode quality and the pot operating parameters. Statistical Reports were developed to facilitate faster and better decisions.

Introduction

DUBAL's Jebel Ali plant is one of the world's largest single-site aluminium smelters, having an annual production capacity of more than one million tonnes. DUBAL began its operation in 1979 as a 135 000 tonnes per annum primary aluminium smelter with original Kaiser P69 reduction technology. Over the years, DUBAL has grown from 360 cells in three potlines operated at 150 kA to 1 573 cells in seven potlines operating at amperages ranging from 203 kA to 450 kA. Presently, DUBAL operates potlines with six types of cell technology.

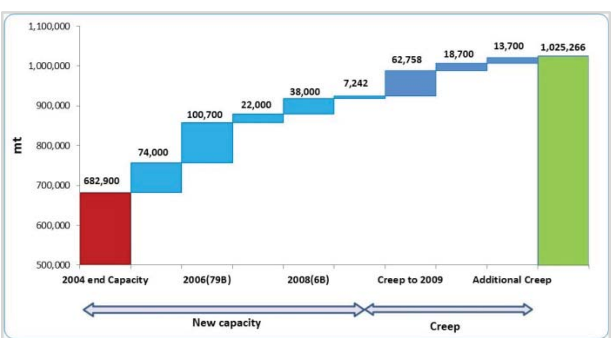

Figure 1. DUBAL's capacity increase through creep.

Figure 1 illustrates how DUBAL has increased its capacity by 95 000 tonnes through amperage increase over the past 8 years. Along with increased metal production, the demand for baked anodes increased from 115 000 to approximately 470 000 anodes per annum. The Carbon Plant's capacity was increased to meet the majority of the total anode demand. The Paste Plant's first production line capacity was increased from 33 tonnes/hour to 36 tonnes/hour and a second line of similar capacity was added. The baking furnaces' capacity was also increased from approximately 50 000 tonnes initially to 480 000 tonnes in 2012.

Figure 2 illustrates the gap between total anode requirement and DUBAL's anode production. This gap was met through the procurement of purchased anodes from international market. Presently, about 12% of the total anode requirement is sourced externally.

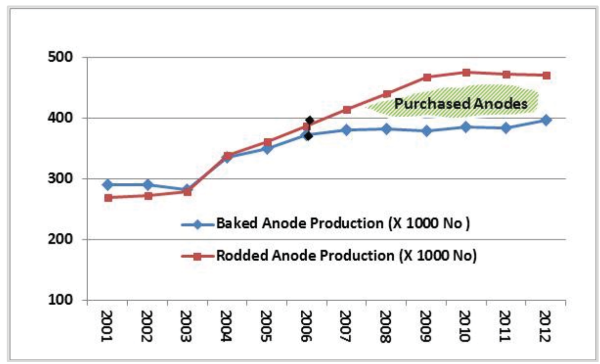

Figure 2. Rodded anode production vs. DUBAL's baked anode production

At DUBAL, the performance of all anodes is monitored on a regular basis using the following parameters:

- Gross Carbon Consumption (GCC),
- Net Carbon Consumption (NCC), and
- Anode problems.

In 2009, the GCC was 581 kg C/t Al; which was high in comparison to the past smelter performance. The traditional practice adopted was to stabilise pot operation with reduction of Anode Shift Life while increasing the amperage. But this operational strategy was not successful in improving the anode performance.

Hence a cross-functional team from Carbon Plant and Potlines was formed primarily to minimize GCC while sustaining pot performance. It was a challenge to maintain and improve the performance of the anodes at the higher amperage because of issues related to thermal balance in the reduction cells. The action was initiated with a statistical analysis of the butt parameters.

Optimising butts parameters

Inspecting anode butts helps to optimise anode shift life and the electrolysis process. As a first step towards optimising anode performance, all the information related to butt parameters was compiled and analysed to identify improvement opportunities.

DUBAL has indigenously developed a RTS, which provides exhaustive information about anode quality parameters during the life cycle of an anode. Each rod assembly has a rod ID and this is linked to the anode stamp. As each rod ID is captured through the system, all the butt parameters along with the raw material information and green anode parameters are linked to potlines information such as cell technology, pot and stall number, and time of anode change.
Therefore, comprehensive butt monitoring data is available and can be used to improve anode quality and pot performance.

At DUBAL's Rodding Shop, approximately 39 000 butts are processed each month. Of these, nearly 15% are closely monitored through manual measurements for top oxidation and anode butt thickness. This data is entered in the mobile device which enables the linkage of the data to RTS. The measurement of both parameters is tricky, as anode butts vary in shape and size. These variations may be because of metal movement and heave, pot design and anodes asymmetry, etc. In case of old technology cells, which do not have good magnetic compensation, greater metal heave results in generating thicker butts in corner stalls than the middle stalls. To address these variations, anode butt height is measured at two locations i.e. at sidewall (T1) and centre channel side (T2) as illustrated in Figure 3.

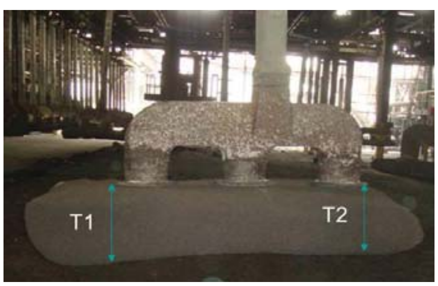

Figure 3. Anode butt thickness measurement

Data is segregated line wise or technology wise through RTS and then processed. Considering the minimum anode butt thickness and air oxidation, Carbon Under Stub (CUS) is calculated and the data is stratified into three categories i.e. Fat, Lean and Thin depending on the scope to enhance anode shift life in the pot. The descriptions associated with these terminologies are as follows:

- Fat - CUS is high and there is a scope to optimise further.
- Lean - CUS is optimal.
- Thin - CUS is low and there is a high risk of iron contamination through stub attack in the reduction cell.

To make the data more meaningful, specification limits for CUS were defined for each type of reduction cell technology. The summarised feedback after the data analysis is provided to the Potlines management team, who utilise the information to determine the appropriate anode shift life. For illustration, CUS data is shown in Figure 4 for a group of cells where operational improvements were done. It is quite evident that the percentage of Fat butts reduced after implementing corrective measures in these cells.

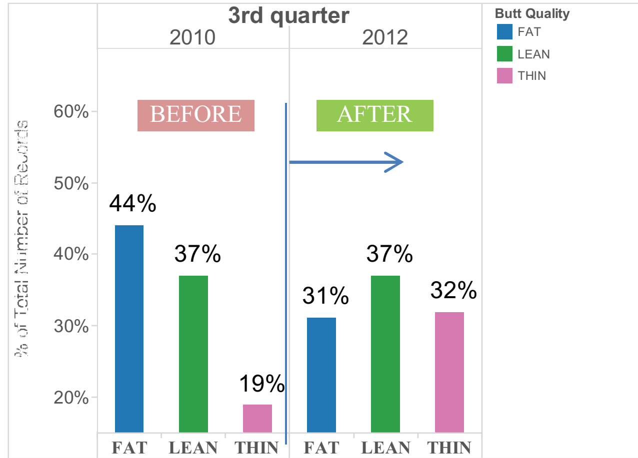

Figure 4. Carbon under stub segregation

Approximately 90% of the butts are weighed using in line scales and the data is available through RTS. Similar to CUS, butt weight data are also statistically analysed through histograms and trends lines, depending on the purpose of investigation.

In sum, data from RTS has helped to develop an anode performance monitoring system. This provided a very good platform to investigate and identify opportunities for process improvements with respect to pot operation and anode quality.
Anode life could be optimised for effective usage of anodes without increasing stub damages and negatively impacting metal purity.

Achieving the optimum anode performance requires addressing a few more challenges in parallel to butt parameter optimisation. These were:

- Improving anode quality, and
- Improving pot operation at higher amperage to sustain metal purity.

Therefore, other key initiatives were also taken in the Carbon Plant and Potlines.

Improved baked anode quality

As stated earlier, DUBAL's total anode requirement is met through internal production and purchased anodes. Actions were initiated in both directions to achieve the best performance.

DUBAL anodes [1]:

DUBAL's Carbon team started the journey in three key areas of Paste Plant operation:

- Paste mixing and forming,
- Coke blending, and
- Dry aggregate recipe modification.

DUBAL's Paste Plant has two production lines. The quality of anodes from one of the production lines was relatively low with respect to green anode density and air permeability. Improvement in density was achieved through vibro-compaction performance enhancement i.e. optimizing motor speed and eccentric angle of counterweight. Investigation into paste quality through petrographic analysis revealed increased coating of pitch around coke grains. The problem was resolved by stopping the spraying of water at the mixer discharged end after modification of the discharge chute.

DUBAL also decided to improve density through coke blending i.e. blending of normal coke with high density coke (higher VBD). The project was initiated by identifying potential coke suppliers and conducting a pilot study. With positive feedback from the pilot study and plant trials, an automated coke blending system was installed in DUBAL's Dock area. Following the successful implementation of this coke blending facility, there was an overall increase of 0.01g/cm³ in anode density and minimal variation in anode reactivity. Anode density increased further by 0.01 g/cm³ with the increase of +4 mesh particles in the recipe.

To summarise, process optimisation in the Paste Plant resulted in an increase in anode density by 0.025 g/cm³ and reduced air permeability from 1.2 to 0.52 nPm.

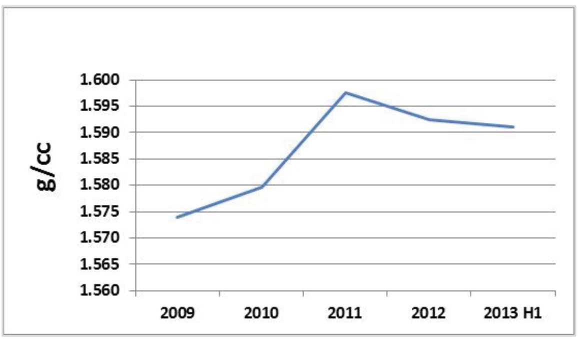

Figure 5. Baked anode density

Purchased anodes:

DUBAL works closely with the suppliers of purchased anodes and shares the performance of these anodes with the aim to improve anode quality with respect to anode density, electrical resistivity and anode reactivity. The following quality control measures were implemented:

- Stringent anode specifications were enforced after understanding the suppliers' process capability with respect to raw materials quality variations, manufacturing process limitations and quality control procedures.
- Process audits are conducted, with regular feedback.
- Clearance to ship the production batch is given only after quality approval is obtained.

Besides this, anode top profile and slot dimensions were modified along with an increase in anode length, to reduce current density and improve GCC.

Improvements in pot operation

Change in anode setting pattern:

To reduce the air burn of anodes, DUBAL tested a few anode setting patterns such as "Single-step anode setting", "Double anodes setting", and so on. These anode setting patterns were initially tested in a few pots in two reduction lines on a trial basis. Following a positive outcome in anode performance through "single-step anode setting", this practice was rolled out across all the potlines at DUBAL. This led to the reduction in exposure of new anodes to air burn by approximately 50%.
The following criteria, as described by Victor Buzunov et al (2008) [3], were applied during the experiments:

- Uniformity of thermal and electrical resistance of the anode carbon during the entire anode shift life,
- Symmetry of horizontal currents in the melt, and
- Even surface of the anode carbon to form reliable coverage.

To visualize the impact of the change, a simulation tool called *ATab* from http://www.peter-entner.com/ [4] was used. Figure 6 illustrates the single-step anode setting simulation using the tool.

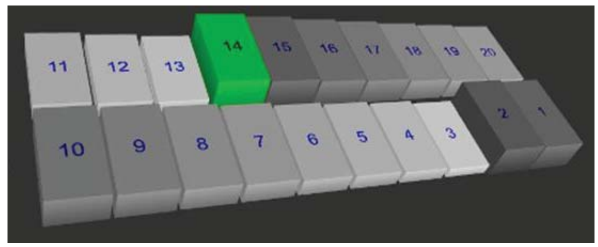

Figure 6. Single-step setting profile, for illustration only

Bath management [2]:

As the reduction of CUS progressed, metal purity in the pots was affected. Also, there was a reduction in bath volume due to the increase in anode size. Therefore, a refinement in the pot feed cycle was initiated to minimise the variation in alumina concentration in bath, as illustrated in Table I.

Table I: Change in alumina concentration in one feed cycle.

	Overfeed Rate	Overfeed Mass (OF)	Superfeed Mass (SF)	Total OF + SF Mass	ΔAlumina Concentration
	%	kg	kg	kg	Wt %
Before	150	50.2	6.8	57.0	1.4
After	125	25.1	3.4	28.5	0.7

Two advantages of the above process change were:

1) Lower anode effect frequency, and
2) The pots were operated with low CUS and lower bath level as shown in Figure 7.

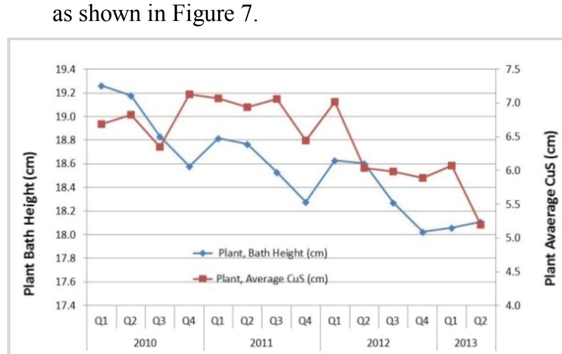

Figure 7. Plant bath height and average CUS.

Consequently, anode shift life could be increased while further improving the metal purity. Metal purity is normally affected by bath attack on stubs. So, as the stub damages arising from the pot operation reduced, a steady increase in the percentage of metal produced with Fe ≤650ppm was noticed, as illustrated in Figure 8.

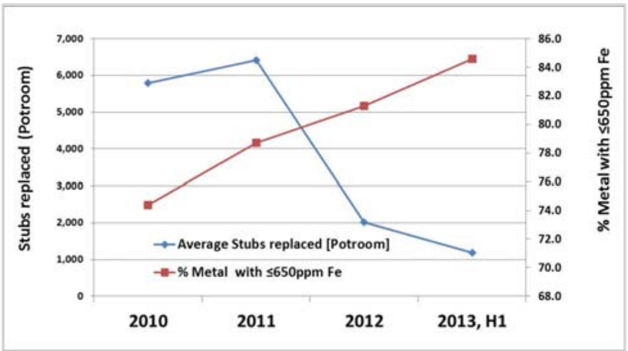

Figure 8. Average stubs replaced and % metal with ≤650ppm Fe.

Results and conclusion

Overall, the following results were achieved over a period of four years through the optimisation process:

- GCC was reduced by 5%.
- Ahead of Schedule was reduced from 0.9% to 0.4 %.
- NCC was sustained.
- Na content in anode was approximately 165 ppm.
- The number of purchased anodes was reduced.

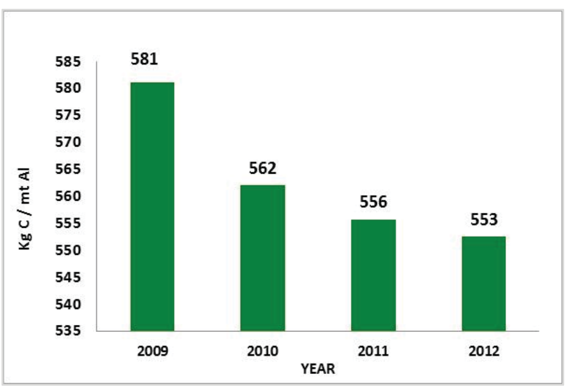

Figure 9. Plant GCC.

These achievements were made possible through a systematic and collaborative approach by both Potroom and Carbon Plant management teams on the following areas of operation:

- Optimisation of anode quality,
- Modification to anode design for purchased anodes,
- Changes in anode setting practices, and
- Changes in bath management.

In conclusion, anode performance is dependent on multiple interdependent process variables, which need to be maintained simultaneously at optimal levels. Thorough process understanding and statistical tools for data analysis are the keys for driving improvements. Last but not the least, Management support coupled with good interaction among the cross-functional teams, helps minimise the risk and improves smelter performance.

Acknowledgements

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