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IMPROVED ENERGY MANAGEMENT DURING ANODE SETTING ACTIVITY

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Abstract

In a prebake aluminium reduction cell, the continuous electrochemical and chemical oxidation of the anodes requires regular replacement of anodes in a predetermined sequence. It is important to maintain cell stability and thermal balance during the anode exchange.

The higher amperage operation at Dubal pushed the 'anode current density' towards the anode effect threshold limit. Moreover during anode removal, this threshold limit is challenged causing a higher likelihood of AE. Therefore, the anode setting logic was revamped in order to improve the energy balance whilst operating at an anode current density greater than 1A/cm^2. An optimum utilization of resistance set point combined with an automated down movement of anodes prior to anode removal was introduced. Thereby it improved the thermal balance resulting in a reduction in anode effect frequency by 29% and cell voltage by 9 mV.

This paper describes the methodology of optimising the energy balance during anode setting

Introduction

The most common manual routine operation in a prebake aluminium reduction cell is anode changing. The continuous electrochemical consumption of the anode reduces the height at a typical rate of about 1.6 cm per day. In practice, the anodes in a cell are replaced one at a time in a regular sequence as they approach the minimum acceptable size.

The new anode is adjusted into it position by auto referencing. The top of the anode top is covered with recycled and crushed anode cover material to inhibit carbon oxidation and provide thermal insulation.

As a consequence of the continual increase in potlines' amperage at Dubal, the anode current density has exceeded 1A.cm^{-2}.

The challenge at high current density is to maintain low alumina concentration and low AE frequency. The situation is compounded by the desire to operate on lower energy consumption and better current efficiencies. The energy management

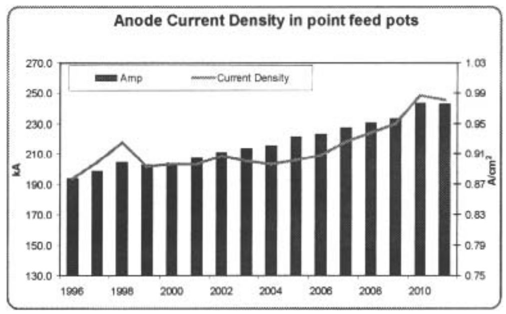

Figure 1: Plant amperage and anode current density in point feed pots at Dubal

during anode setting at higher current density is therefore a challenging task.

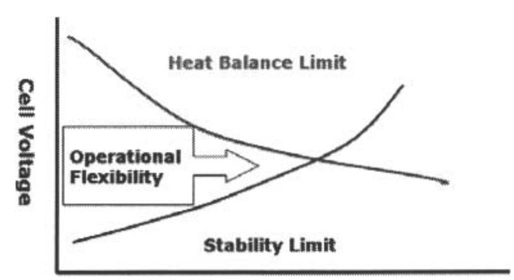

Figure 2: Schematic presentation of the limitation of operational flexibility at higher amperage operation

When exchanging anodes it is important to take into consideration the associated energy change so that process disruption is minimized. Therefore, the setpoint resistance is raised for a fixed period with multiple steps on completion of setting.

Discussion

The thermal effect associated with an anode change has been the topic of many publications. Experimental measurements have shown that immediately after a cold, new anode is positioned in a cell; it quenched a layer of frozen bath on the part of the anode that was inserted in the bath. The frozen layer grows quickly and is reported [1, 2] to have reached to the metal level within 90 to 100 minutes. During this period, the anode draws no current. Remelting of the freeze generally happens within 10-15 hours while it may exceed 24 hours in some cases.

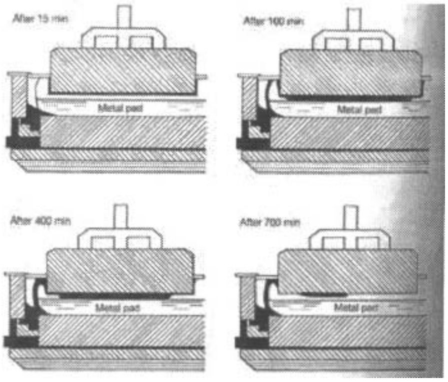

Figure 3: Freeze formation around new anode after anode setting

The amperage increase in potlines outpaced the anode size increase. Consequently, the already high anode current density often exceeded the 'critical current density' during an anode setting operation. This was evident from the unusually high percentage of anode effects occurring during the anode setting operation [3], Figure 4.

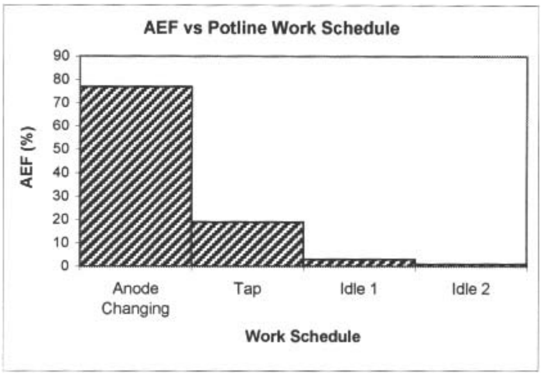

Figure 4: Anode effect frequency distribution in different potroom activity

Energy Management During an Anode Replacement

The calculations of energy loss in an activity in a cell is always approximate because of the uncertainties associated with the dynamic nature of the cell [3]. For example the total heat generated is dependent on the cell voltage, line current and the alumina concentration.

When a potlines amperage is raised the ACD is lowered to satisfy the energy input. As a consequence,

- The electrolyte volume per kA is reduced.
- Rate of depletion of alumina is increased – greater sensitivity to alumina solubility.
- The centre channel width may be compromised.
- Increase in the spatial energy demand for the Anode change.

The heat to preheat and dissolve alumina comes from bath in proximity of feeders in the centre channel.

$Na_3AlF_6(l) + 2Al_2O_3(s) + Heat \leftrightarrow 3Na_2\ AlO_2F_4$

The reaction is endothermic ($\Delta H \approx 450$ kJ)
Therefore, when the energy generation is below the designed value for the steady state heat losses, the cell can have shrinkage in bath volume, excessive anode effects and formation of hard crust which make the operation difficult.

Hitherto, at the end of an anode setting activity, the set point resistance adder would compensate for the disturbance to the cell heat balance due to the introduction of a cold anode. The resistance adder is reduced in three steps. Energy provided per anode is 70 kWh, Figure 5.

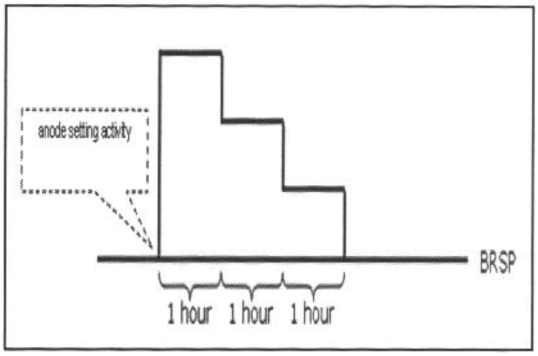

Figure 5: Existing set point resistance adder during an anode replacement

Revised Resistance Adders

The fixed energy supplied during an anode setting activity was found to be inadequate at larger anode dimensions; it met only 38% of the energy demand. This was largely due to longer carbon blocks which drain more heat. The smaller anode-to-cathode distance resulted in slower melt-back of the freeze.

The energy balance during an anode replacement was revisited. The energy requirement for an anode replacement was reviewed using the standard equation:

$$Q = m \times Cp \times \Delta T$$

Where:
Q is the heat energy in kJ
m is the mass of the substance in kg
Cp is the heat capacity in J/mol. K
ΔT is the temperature differential between the final temperature attained and the initial temperature of the substance.

For the size of the anodes in use, the energy required during an anode change operation at 240 kA operation is computed to be 183 kWh, Table I. Any further increase in the value of the resistance adders to meet the energy demand would have also increased the chances of anodes being pulled out of

Table I: Energy demand during an anode setting

Material	Mass (kg)	Energy (kWh)
New anode	1100	212
Anode Cover	400	35
Cover Spillage	50	10
Hot butt removed	250	-52
Hot Anode Cover	250	-22

the bath. Therefore, a different approach was adopted. The resistance curves were carefully analysed. The revised logic was developed on two factors:

a) Resistance adders were developed to satisfy approximately 80% of the energy demand during an anode setting operation.

Resistance set point ramp off over a longer time and shorter amplitude was considered. A small, dynamic resistance adder was developed. The adder would be active for 0.5 to 4.0 hours prior to the start of an anode setting activity and diminished in steps to zero during a preset, variable period of 0.5 to 3.5 hours following an anode setting, Figure 6.

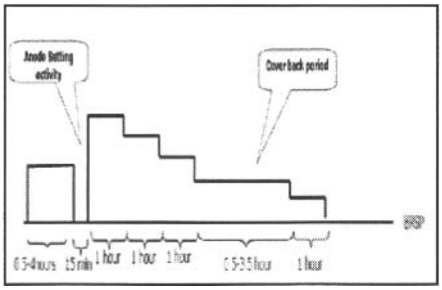

Figure 6: Revised set point resistance adders

b) With longer anodes, Figure 7, the available bath volume was less. Consequently, as soon as a hot butt is pulled out, the dip in the electrolyte level is greater. Effectively, the anode current density on the balance of anodes increases which further accentuates the anode current density increase.

Figure 7: Longer hot butt

A step reduction in the cell voltage was introduced just prior to a hot butt being pulled out of the cell. It lowers the energy demand and nearly satisfies the balance 20% of the energy requirement, Figure 8.

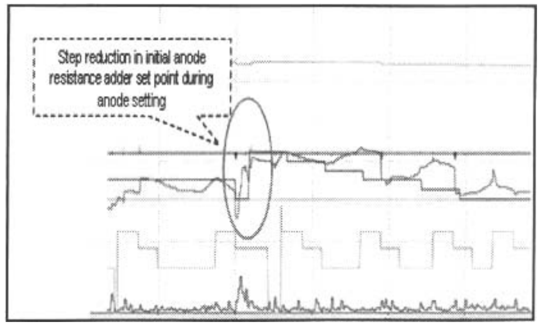

Figure 8: analytical trace data of set point resistance adder during anode setting

The smaller resistance adders improved the anode immersion in the electrolyte [4] and helped in maintaining the anode current density at an acceptable level without provoking an anode effect.

Benefits

The improved energy management during an anode setting activity improved the net voltage and was an aid in reducing anode effect frequency, Figure 9.

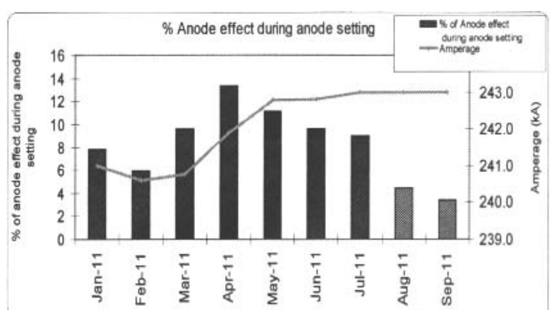

Figure 9: Reduction in anode effect occurrence during anode setting activity

A step reduction in the cell voltage in the anode replacement logic and better cell stability permitted a marginal reduction in the cells' set point resistance, Table II.

Table II: Cell parameters in the anode setting shift before and after implementing the revised adders

Parameter	Unit	Before	After
Cell Volts	V per cell	4.581	4.572
AE Frequency	No per pot-day	0.119	0.024

Conclusions

Both, material and voltage balance should be satisfied during an anode changing operation. Heat to preheat and dissolve alumina comes from bath in proximity of feeder in centre channel. In the absence of an adequate energy compensation for the cold anode, the cell is likely to go through 'turbulence'.

Reduction in cell voltage of 9mV and anode effect frequency by 29% was achieved when the energy demand and energy supplied for an anode replacement was balanced.

Acknowledgement

Dubal management nourishes the culture of continues improvement to upgrade the standard and achieve excellence. Their blessings, guidance, support and encouragement in carrying out the project is gratefully acknowledged.

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