Managing Pot Operation of 340 kA Prebake Potline at Reduced Amperage of 280 kA

G.G. Pal[1], Janmejaya Dalai[2], Bhabani Acharya[3], Sandip Gore[4], Hitesh Bamrah[5], Rajesh Kumar[6], P. Prateesh[7] and B.K. Kakkar[8]
1. Vice President, Plant 2
2. Smelter Head,Plant 2
3. Smelter Head,Plant 1
4. Associate General Manager
5. Associate General Manager
6. Associate General Manager
7. Associate General Manager
8. Consultant
Vedanta Limited, Jharsuguda, India
Corresponding Author: GG.Pal@vedanta.co.in

Abstract

It is extremely challenging when a Potline is to be operated on lower amperage than the design capacity for an extended period of time. One such case occurred on 12th April, 2017 in Vedanta Limited at Jharsuguda Smelter. Out of six rectifiers (N+1 configuration) to supply current to Potline 4, two developed serious fault and the current was dropped to 280 kA from 340 kA. It was told that it might take more than four weeks to get the fifth rectifier in service. To run the line at 280 kA for over four weeks was a huge challenge. Emergency meeting was held and a strategy was formed to manage the operation at 280 kA. Pot voltage was raised by 200 mV. Some of the actions, immediately enforced, were: tap metal, suspend anode changing activity and ask the other lines to supply liquid bath. About 1000 tons of metal was tapped in 24 hours and more than 100 tones liquid bath was generated. All these measures have given us confidence that we were on the right track. Potline 4 was running at reduced amperage in a healthy way until it was ramped back up to 340 kA smoothly.

Keywords: Operating potline at reduced amperage; Vedanta Jharsuguda; cell energy balance; liquid bath generation.

1. Introduction

Vedanta is the largest Aluminium producer in India with a capacity of 2.3 million ton per annum and a 48 % market share in India's Aluminium industry. Vedanta Limited is renowned for its superior metallurgical alumina and high quality aluminium products and operates a world class international standard smelter in Jharsuguda, Odisha and BALCO - Korba, Chhattisgarh. Potlines are run with GP 320 GAMI Cell Technology from China. Vedanta Ltd, Aluminium & Power, Jharsuguda has set up a greenfield aluminium smelter in Odisha with a capacity of 1.75 Mtpa (0.5 Mtpa + 1.25 Mtpa) and 3615 MW Power Plant, one of the single location largest smelter in the world. The company has built high quality modern infrastructure at Jharsuguda with full-fledged township having all the modern amenities for the staff. At Vedanta Limited, we are committed to providing our employees with a supportive, rewarding and safe work environment with a high degree of engagement and empowerment, enabling them to realize their full potential.

Vedanta Limited, Jharsuguda has 2 smelters consisting six potlines. Smelter 1 consists of two potlines and each potline is supported by a rectifier station with a facility of 5 rectifier transformers of 85 kA capacity each. Also, a separate carbon plant to supply anodes and independent cast house to take metal from both potlines. Smelter 2 potlines are supported by a rectifier station with a facility of 6 rectifier transformers of 76 kA capacity each. All six are in operation except the PM, these are based on n-1 configuration and five rectiformers are always in operation. Like Smelter 1, Smelter 2 also has a separate carbon plant and also separate cast house. The potlines in Smelter 1 were commissioned in 2008 with the design current of 325 kA. Potlines in Smelter 2 were started in Sep 2014 with design current of 340 kA. In Smelter 2, two lines are fully commissioned and the other two are under commissioning. With continuous process improvements, operational excellence along with technical innovations, the amperage in Smelter 1 Potline has been increased up to 328 kA. Smelter 2 amperage has been increased as well up to 343 kA.

2. Rectifier Incident :

On 12 April 2017, Pot line 4 which was operating at 340 kA had a failure of potential transformer. Because of this, two rectifier units had to be taken off and we were left with only four rectifiers, bringing down the amperage to 280 kA from 340 kA. Unfortunately there was no provision to get the supply from other rectifiers of other lines. We did not have any alternative except to manage the line at 280 kA for indefinite period. Running the line at lower amperage was a huge challenge. The biggest issue was to find an equilibrium of thermal balance, running the line cold which could be disastrous for the line and it was very likely that the line could be shut down if the corrective action was delayed.

3. Impact of the Reduced Load & Corrective Actions Taken to Maintain Potline at 280 kA

The Potline in smelter 2 Vedanta has been designed to run at 340 kA and all parameters like liquid levels, bath temperatures, noise etc. were optimized to operate the line smoothly. But due to unforeseen breakdown in line 4 rectifier unit amperage came down to 280 kA. This had a large impact on the parameters of prebaked cell and we faced a dozen of obstacles. The main challenge was to maintain heat balance at reduced load and keep all pots running. Next 24 hrs. were very crucial & critical as line can go either way if urgent actions are not taken immediately. This aim needed utmost care, complete focus and greater co-operation from all the teams. So immediately after the failure of rectifier, emergency control room was set up, brainstorming sessions were conducted to make the strategy to handle the situation. Finally the team came up with an emergency action plan and developed guidelines for operating a Potline at reduced load. Same incident was experienced year back in the smelter 1 which also helped a lot to set up the SOP and control parameters even faster than previous incident. Primarily team focused on maintaining the heat balance which was badly disrupted due to sudden power reduction.

4. The Following Actions Were Taken to Manage the Impact of 280KA and Save the Line.

4.1. The maintenance of high bath temperature was the primary step taken to maintain heat balance in the pot. For doing that the set voltage of pots were increased from 4.18 V to 4.5 V. The ratio between the metal height and bath height was disturbed leading to a greater metal height in comparison to the bath height. Extra tapping was planned to hold the temperature in the pot constant by reducing the metal height from 27 cm to 24 cm, but without resources and immediate extra metal handling capacity in cast house it was not possible to execute it. It was one of the most challenging jobs to take the extra metal out in order to maintain heat balance in the pots. As a way out we have decided to skip one cycle tapping in Potline 3 which was running with normal amperage and moved all resources to Potline 4. For fast tapping we have taken help of Hencon (tapping vehicle) from Smelter 1. It helped us evacuate the metal with speed from Line 4 without much overloading the cast house. Proper planning resulted in evacuation of approximately 1050 Mt extra metal from pot, i.e., 550 t in 24 h and another 500 t in 48 h.

4.2. To speed up the tapping sections, the floor must be free from all other activities like anode change so we decided to skip 4 anode change cycles immediately to speed up the metal tapping and beam raising activity.

4.3. The sudden drop in amperage resulted in sudden decrease in bath temperature which could have been a major cause of bath freezing in the pot. This largely impacts the stability of the pot. With low energy it was a big challenge to maintain the bath levels in the pots. Bath level dropped down from 16 cm to 8 cm on average. We were fortunate to have lines 3 and 5 with normal amperage. Immediately we made donor pots in both lines and started generating bath. With great team effort we were able to produce more than 100 tonnes liquid bath per day, which really helped us save very critical pots from the low amperage impact. For everyday tapping of such a huge quantity of 100 tonnes of liquid bath, a dedicated team was assigned by stopping ramp up (new pot addition) in the other lines until the line came under control.

4.4. To see the trend of critical potline parameters as well as to find the abnormal pots, the frequency of measurements increased from the normal 32 h to 4 h for critical parameters like metal height, bath height and bath temperature.

4.5. Maintaining bath temperature was a great challenge during low amperage operation. Many pots reached the range of 900 °C and even 880 °C in some pots. Handling of such critical low temperature pots was really a great experience and big learning for the whole team.

5. Stabilizing the Line at 280 kA

5.1. Safe Operating Procedure (SOP) was revised from time to time according to the situation. As sudden reduction of amperage from 340 kA to 280 kA itself was a great risk for the potline which could have resulted in potline stoppage. This was prevented by a great team effort, proper action plan, a dedicated rescue team and a defined SOP in place which kept Smelter 2 Potline operating at 280 kA for more than a month.

5.2. In such adverse condition of low amperage, we succeeded to stabilize the pots at low amperage without losing any pot in the line.

5.3. Careful observations of all the pots, analysis of all the parameters of a pot, planning of modifications in pot activities such as anode change, anode covering, beam raising, bath correction, tapping, killing anode effects (AE) when required, etc. was eaasential to determine all the changes required for maintaining the Potline at reduced current of 280 kA.

5.4. With keen observations of all the pot parameters, trends were prepared in order to have a clear picture of the status of the pots in Line 4. The state of the pots in running condition in a potline can be reviewed by observing these parameters. Fluctuations in these parameters directly indicate the state of the pot and corrective maintenance activities to stabilize the pot can be put in place.

5.5. Total 4 anode cycles were skipped in the first cycle of anode change to manage the tapping activity smoothly. Later on two skips per anode change cycle were included systematically according to the lower consumption rate of anode due to low amperage.

6. Parameter Trends

Bath temperature, excess AlF_3, set voltage, average voltage, bath height, metal height, noise, anode effect frequency (AEF) and amperage can be studied through the following trend graphs.

6.1. The sudden drop in current also shows an increase in Excess AlF_3. This resulted in the greater fluctuation in bath ratio. AlF_3 feeding was completely stopped until the pot parameters were stabilized. The impact was clearly visible through the bath analysis report of bath samples from Line 4.

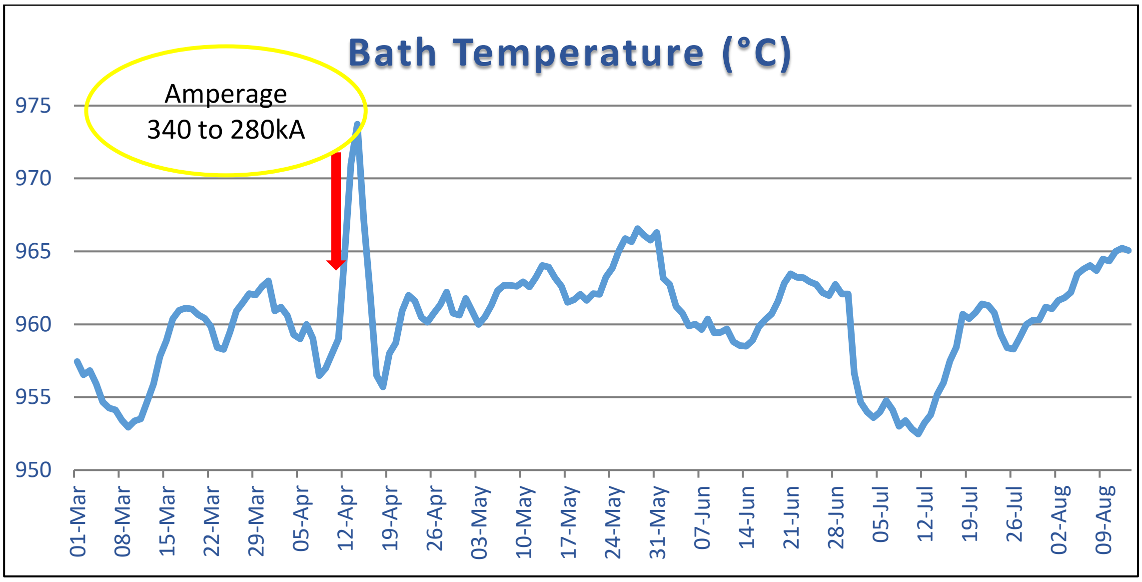

Figure 1. Bath temperature trend.

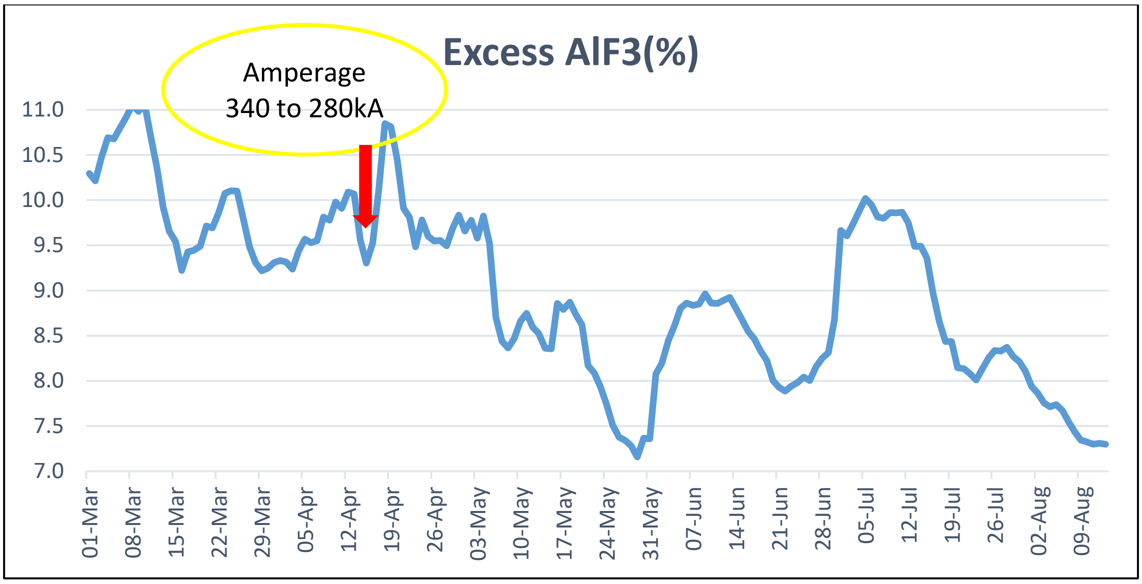

Figure 2. Excess AlF_3 trend.

6.2. The anode-to-metal distance (AMD) (set voltage) of the pot of Line 4 was balanced depends on the availability of the total Mega Watt from rectifier to maintain the bath temperature and bath level. The higher Set voltage was maintained to keep all other parameters under control for the reduced load scenario.

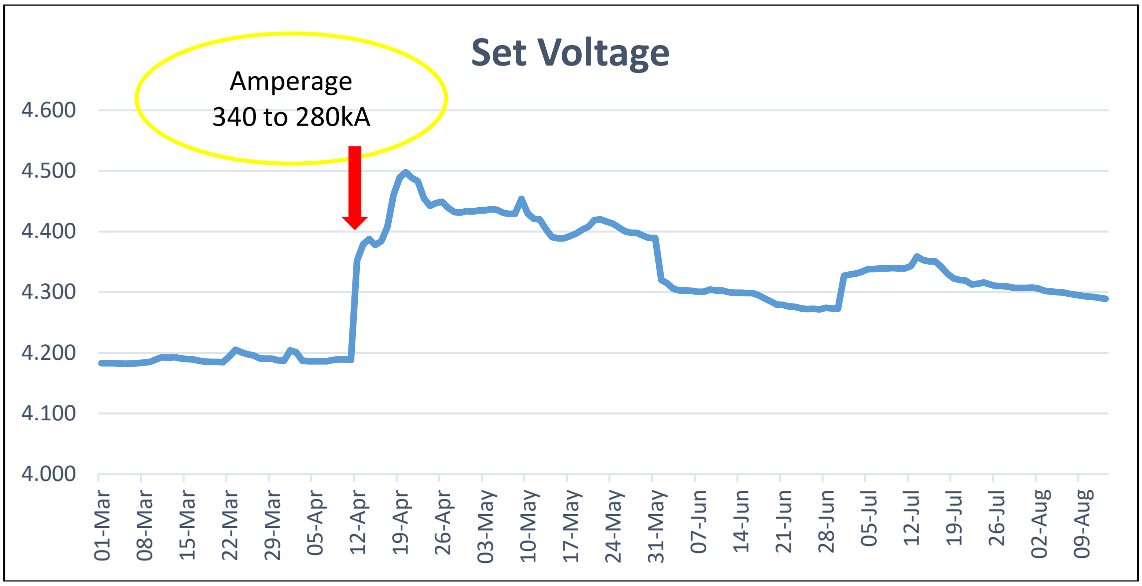

Figure 3. Set voltage trend.

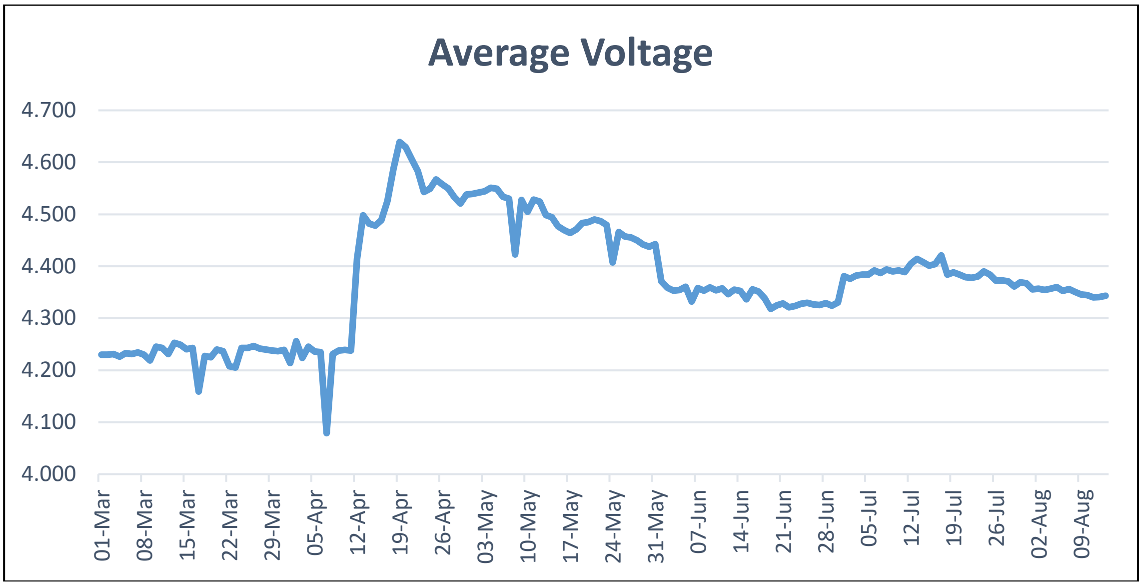

Figure 4. Average voltage trend.

6.3. The reduced current directly impacted on the bath level which showed a steep decline in the bath height. To maintain the balance of parameters, liquid metal was evacuated from the pots by tapping higher amounts of metal.

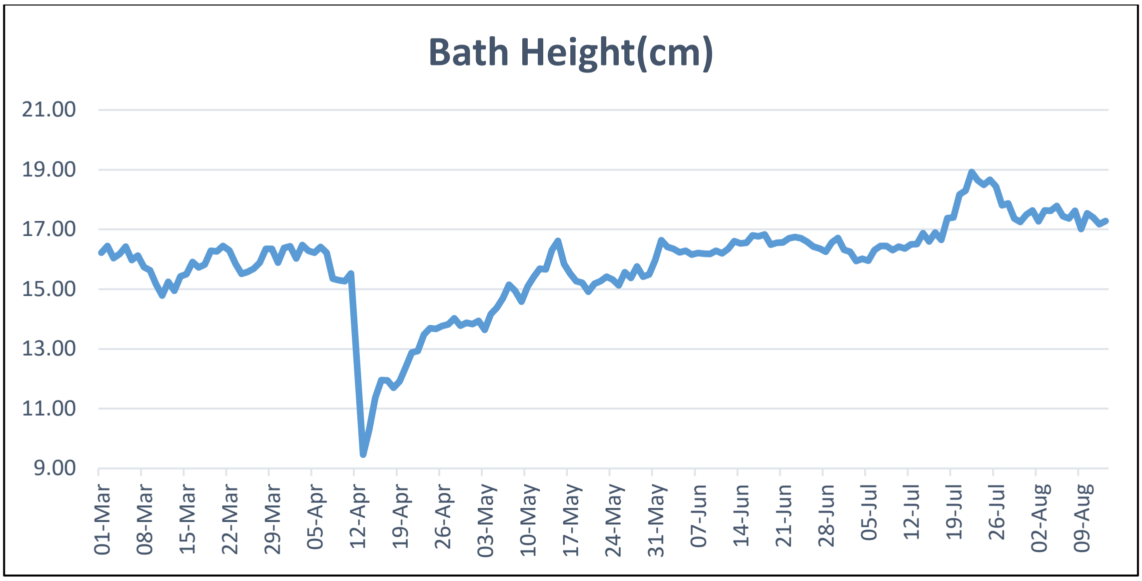

Figure 5. Bath height trend.

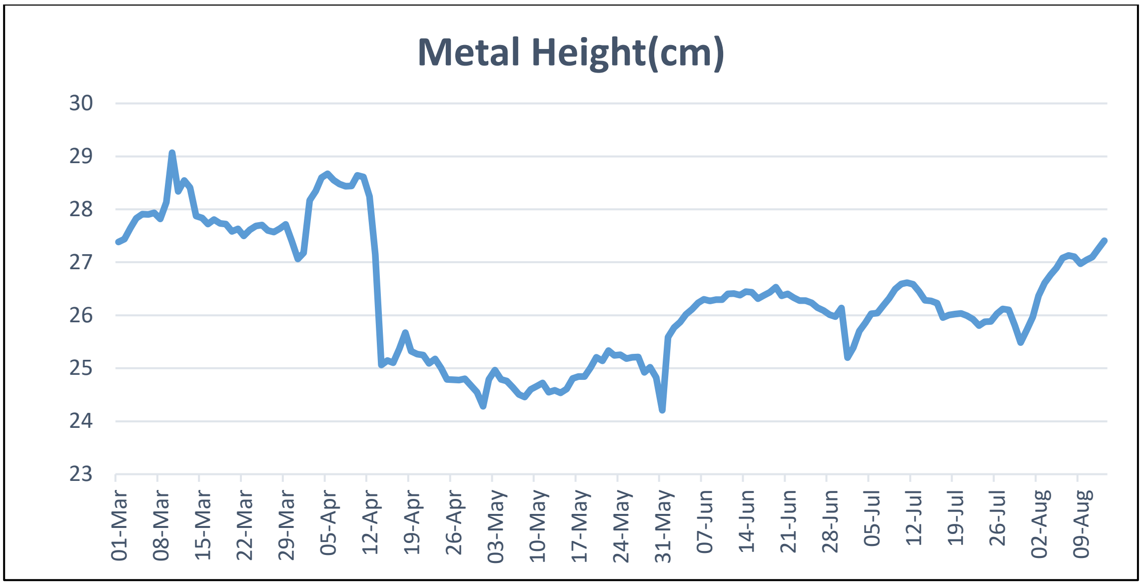

Figure 6. Metal height trend.

6.4. The higher set voltage and low amperage has also resulted in the sudden decrease in noise in the pots. But due to all sorts of deviations from the normal settings of pot parameters, such as low bath height, cold pot, the pots had high number of anode effects (AE). Their frequency can be seen rising prominently. The high number of AE was also due to manually induced AE to maintain high bath temperature.

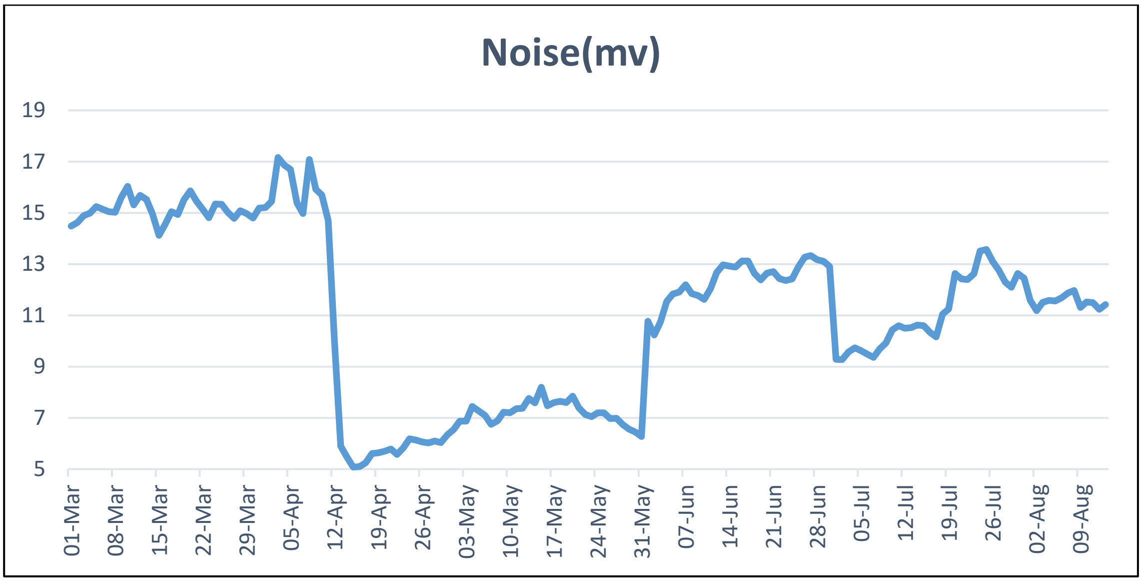

Figure 7. Noise trend.

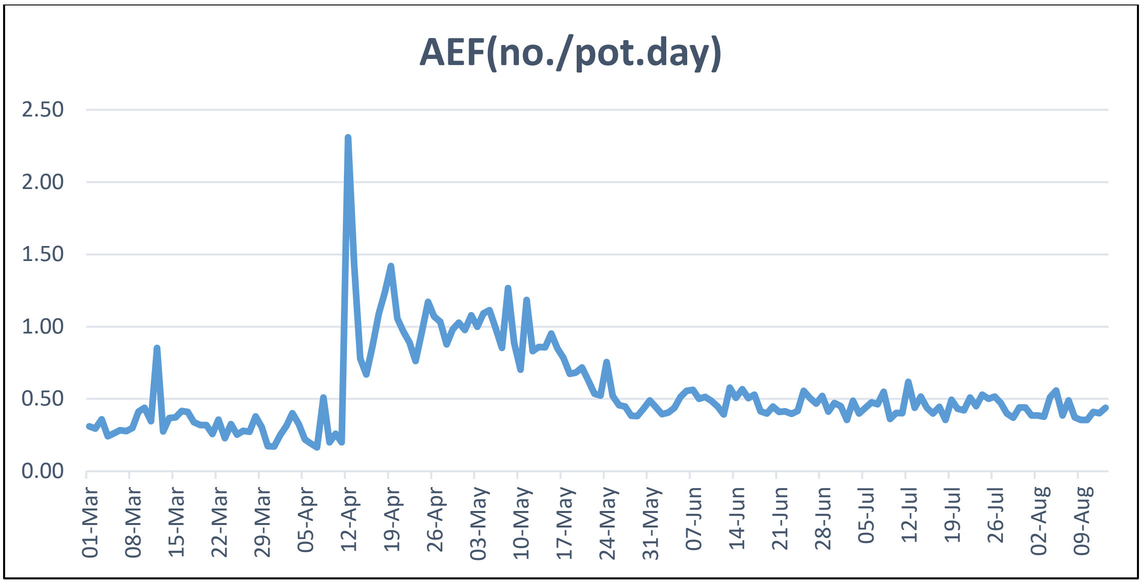

Figure 8. AE frequency trend.

6.5. Rectifier team worked day and night to make defective transformers ready and accordingly we started increasing the current from 2 June. Smelter 2 potline team also kept ready the parameters suitable for current increase with proper SOP, defined action plans along with clear roles and responsibilities to face the challenging phase smoothly without affecting the pot stability.

7. Challenges During Operation at 280 kA and During Current Increase

7.1. Low Temperature and Extended Side Freeze

7.1.1. After power outage and low amperage operation at 280 kA for a long time, we faced many issues with pots running at low bath temperatures. Low energy input caused shrinkage of liquid bath.

7.1.2. Extension of side freeze at low bath temperatures started causing bending of anode stems, clad cracks at the corner anodes and caused great difficulty in replacing anodes at the corners in some pots, as breaking of hard corner freeze got very difficult in low bath temperature pots.

7.1.3. We had issue of extended freeze at the tap end in some of the pots that posed great threat in metal tapping, as ladle siphon was not inserted properly in the pot which resulted in the bath tapping along with the metal. Tapping of bath along with the metal causing the chocking of furnace launders at cast house and it further increased the delay in tapping due to additional launder cleaning job in the cast house.

7.1.4. To come out from extended side freeze issue we took some actions like holding high voltage (energy), pouring liquid bath, soda addition, etc., in low temperature pots. Pots were running in starve feed to cause heat generation in the bath volume as well as to prevent sludge formation due to accumulation of undissolved alumina in the pots.

7.1.5. Well before current increse, we had come out of above mentioned problems by dedicated team work and focus on bath chemistry. We had different category of pots like low AlF_3 - high temperature and high AlF_3 - low temperature whose bath exchange was done by tapping from high AlF_3 % pots and pouring in low AlF_3 % pots, and vice versa.

7.1.6. Following are a few examples of increased side freeze (ledge) which was one of the greatest challenges during low amperage as well during current increase.

Ledge thickness before power reduction at A side – 11.4 cm and at B side – 12.4 cm

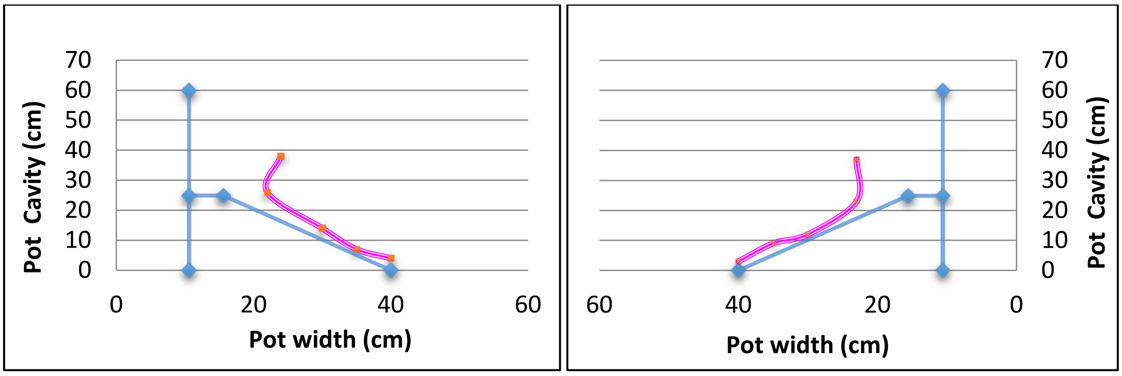

Fig 8. Ledge thickness before power reduction.

Ledge thickness after power reduction at A side – 13.4 cm and at B side – 13.5 cm

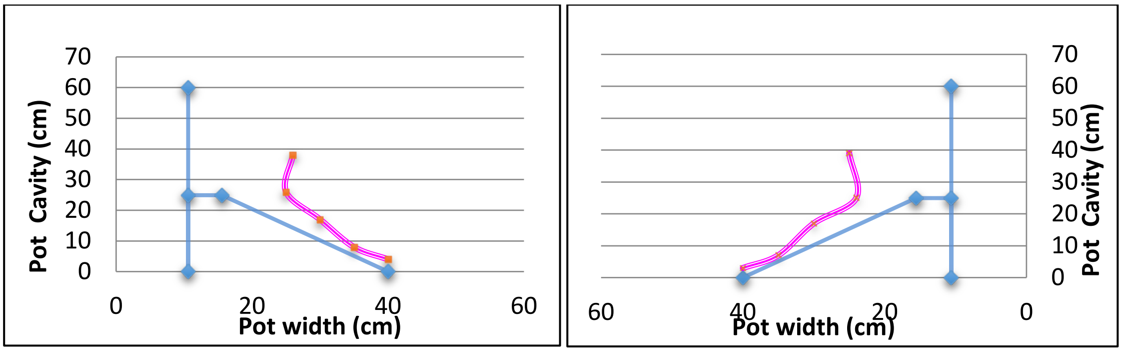

Fig 9. Ledge thickness after power reduction.

7.2. Continuous dropping of bath level in pots

Low bath level and low temperature in the beginning was a hurdle for anode changing as it led to high disturbance and instability in pots. Due to which we reduced no. of cavity scooping to maintain bath level in the pots. Bath generation and pouring was given a top priority.

7.3. Maintaining thermal equilibrium and heat balance at 280 kA

During 280 kA every pot room activity especially anode changing and metal tapping was a challange as finding the exact thermal equilibirium and heat balance took some time and till that time extra metal tapping was continued on selected pots where bath temperature was low and metal was high.

7.4. Metal tapping ladle trips

At 280 kA metal production was smaller in pots than in normal condition but according to the metal blending plan and ladle capacity we could not add total metal from the fourth pot in a single ladle though there was space available in the ladle but not enough. So, the number. of ladles tapped and trips to the cast house was the same even though the metal quantity was less.

7.5. High bath generation

With current ramp up from 280 kA, the frozen bath from the side freeze started melting the liquid volume increased. Moreover, there was calculated reduction in set voltage with each increment in amperage, which resulted in reduction in anode-cathode distance, thereby causing liquid bath height increase, wherein the volume was same, which required to be tapped to maintain pot stability. Major concern while bath generation during current ramp up was the pot stability as high volume of bath resulted in increased horizontal component of current flowing through the anode stubs touching the bath also, the lowermost anodes in the pot started getting attacked at the pins by bath height increase. All these resulted in noise amd pot voltage increase and further bath generation. The quantity of liquid bath tapped from the pots was around 160 to 180 ton per day from one line. There was challenge for meeting the requirement of volume of liquid bath to be tapped in limited time with limited resources pertaining to availability of bath moulds, bath crucibles, mould handling fork lifters, etc. With team effort from services, operation and support from top management; hard work by shift operators and focus in union to stabilize the potline, we could manage timely removal of liquid bath from the pots and the same process in still progressing as we are gradually increasing the amperage.

7.6. High carbon dust

With bath temperature increase during current increase, and unstable heat balance and high heat generation, caused collapse of anode cover and air oxidation of anodesthis altogether resulted in excess carbon dust in the pots. This caused further issue in developing pot noise, high voltage, high bath temperature and a cyclic process of carbon dust formation. To break the cycle and to stabilize the potline and to decrease the chance of mushroom (spike) formation, excess coke was timely skimmed and extra top shoveling also started as we had sufficient bath level in each pot. The process of coke skimming and extra shoveling in high coke pots is still continuing as we are still increasing the amperage.

7.7. High value and high standard deviation of bath temperature and excess AlF3

As we increased the amperage, pots moved from one thermodynamic equilibrium to another and in the process there was high variation in bath chemistry and ledge profile. Although there was reduction in set voltage with increased amperage to compensate the extra energy input and heat balance, there was sudden jump in bath temperature in many pots. Those pots having dynamic equilibrium problem during amperage increase, reacted abruptly when fluoride was added to compensate bath temperature. With abrupt increase in fluoride percentage pots moved from high temperature to very low temperature. On the other hand, there were some other pots with very slow change in fluoride concentration and bath temperature even after constant feed of fluoride. The initial stages of current increase showed high standard deviation of bath temperature and excess aluminum fluoride. The alumina feeding cycle was also unbalanced due to change in liquid volume, which also affected the AlF_3 control by logic. However, pots getting stable with constant monitoring, fluoride control, soda addition in required amounts and voltage compensation, the standard deviation in AlF_3 feed as well as excess AlF_3 % reduced. But the variation of bath temperature is still a challenge as many factors are contributing to it such as amperage increase, carbon dust generation, bath height increase, air oxidation of anodes, etc. The team is focusing on reducing the standard deviation in bath temperature and working on AlF_3 additions table to be stable for achieving desired bath temperature in the range of 960 ± 2 °C.

7.8. Variation in metal level

As we proceeded from 280 kA to higher amperage there was a change in liquid bath level due to melting of side freeze, which resulted in a drop in effective metal level due to pot cavity increase. Even though the set voltage was gradually reduced to compensate the increased energy generation, yet due to the drop in metal level, noise level increased due to disturbance in magnetic balance of some of the pots. Those pots started getting very unstable after operations such as metal tapping and anode change. Anode effect duration was also high in such pots. We poured liquid metal in some unstable pots to meet the desired magnetic stability by increasing metal height. Although we have achieved stable metal height in the pots with revised metal tapping table and effective tapping of excess liquid bath, there were some pots whose metal level was changing due to the presence of undissolved alumina (sludge) which was created during operation at reduced amperage. The team is now focused on removing sludge from such pots by constant raking of cavity and treatment with green pole during anode change.

8. Current Status

We successfully increased amperage to 325 kA until 25 August 2017. We have very concrete plan to further increase it up to 340 kA without affecting the pot stability. Challenges are not yet over as we are moving towards the higher amperage. But the team is very confident and prepared for smooth increase and expecting full amperage in September 2017. Figure 10 shows the amperage.

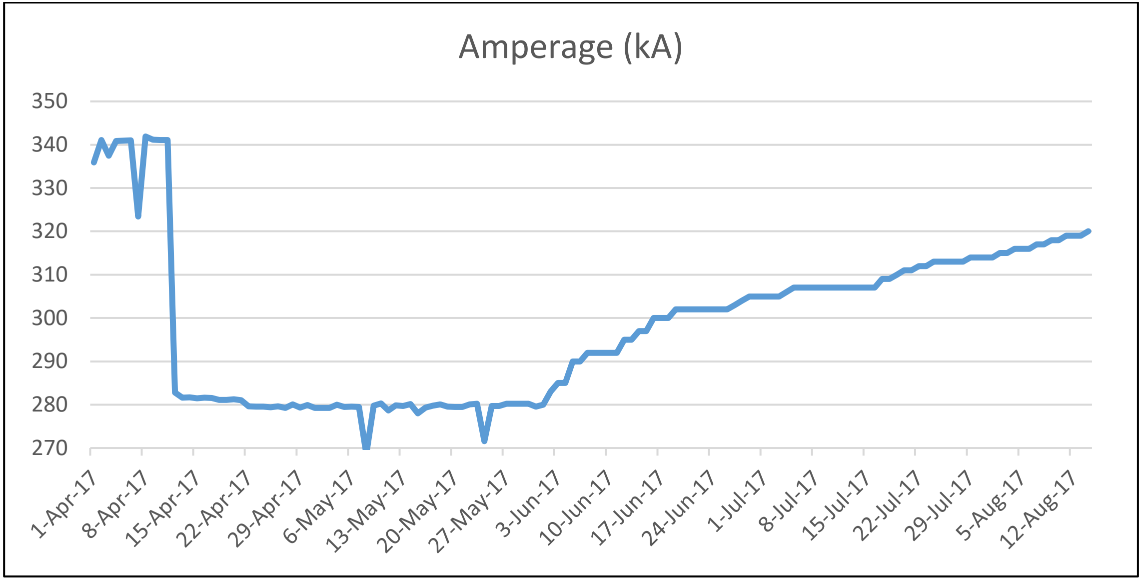

Figure 10. Current ramp trend.

9. Acknowledgement

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Vedanta Limited, Jharsuguda, India