

## AL02 - Productivity Enhancement at Mahan Aluminium through Amperage Increase

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### Abstract

The design solutions are being developed and tested in a stagewise manner to increase the line current while maintaining low specific energy at Mahan Aluminium. Meanwhile, to utilize the full potential of the potroom, the amperage increase strategy is majorly focused towards keeping a constant internal heat generation in the pots, unless limited by magnetohydrodynamic (MHD) instability. Pot sensitivity analysis was performed to assess the MHD stability limits in the pots of different age and design groups. An operational window was developed while keeping a hybrid approach of constant internal heat and anode-cathode distance. The line current was increased from 367 to 374 kA during 2021-2023 while keeping the pots in the operating window. The necessary corrections in pot resistance, anode cover height, metal height, forced cooling etc. were taken either to keep internal heat generation unchanged or to maintain the isotherms at desired locations with increased heat input. The height of the anode was increased to account for increased carbon consumption. The major challenges were power interruptions and the operation of the first-generation old-age pots, which delayed the increase in potline amperage. The operational issues were identified through stringent monitoring of anode cover temperature, anode cover thickness, side ledge, shell temperature, busbar temperatures etc. The frequencies of carbon dust skimming, pot tending, busbar, and basement cleaning were increased. The forced cooling was modulated, and metal height corrections were done for different age groups and the design of the pot. The technical audit frequency was increased to ensure SOP compliance. The rule-of-thumbs established through simulations were followed to keep the pots in the desired operating window. To facilitate a faster current increase, the old pots were replaced while reducing the pot turnaround time.

**Keywords:** Potroom, Amperage increase, Pot thermal balance, MHD stability, Pot operation.

## 1. Introduction

Mahan Aluminium shifted the focus towards productivity or amperage increase due to rising LME prices during 2021-22. To increase the amperage, it is very important to identify the present state of the pots. The thermal balance [1, 2] and MHD stability [3-9] of the reduction pots are interrelated and are of utmost importance. An increase in electric current passing through the pot would lead to increased heat generation inside the pot. The increased heat generation should be avoided as much as possible by reducing the anode-to-cathode distance (ACD). The ACD is primarily limited by MHD instability. Beyond the stability limit, an increase in the current will require increased ACD, which should be supported by a set of measures to dissipate the increased heat generated in the pot. Therefore, the first step towards amperage increase should be the assessment of the MHD limit. Based on the ACD limit, a strategy can be devised based on keeping a constant (a) internal heat generation in the pots, (b) a constant ACD, (c) a constant voltage, or (d) a hybrid approach combining all three approaches, while assuming that total plant power cannot be exceeded.

Increasing amperage in a potline may lead to a few challenges w.r.t anode and anode current density, possible loss of current efficiency, process, and operational parameters. Increasing anode current density results in a higher rate of anode consumption, due to which either anode size must be increased, anode change cycle time must be reduced, or both. In case of increased anode current density, carbon dust generation may also increase. The increase in carbon dust generation and MHD instability can reduce the current efficiency, therefore, it becomes a tradeoff between productivity gain and efficiency loss which increases specific energy consumption. The operational issues can be identified through stringent monitoring of anode cover temperature, anode cover thickness, side ledge, shell temperature, busbar temperatures etc. The frequencies of carbon dust skimming, pot tending, busbar, and basement cleaning can be increased. If heat generation in the pot increases, operational parameters such as anode cover, metal height, forced cooling etc. need to be modified. The pots of different age groups and designs may make it a bit tedious to handle and track such corrections. The technical audit frequency should also be increased to ensure compliance with standard operating procedures (SOP). The other challenges such as power interruptions and operation of the old age pots, may delay the amperage increase.

The line current at Mahan smelter was increased from 367 to 374 kA during the period of Jul 2021 to February 2023. The strategy to increase the line current, challenges faced and measures to mitigate the same by the operations team are discussed in the paper.

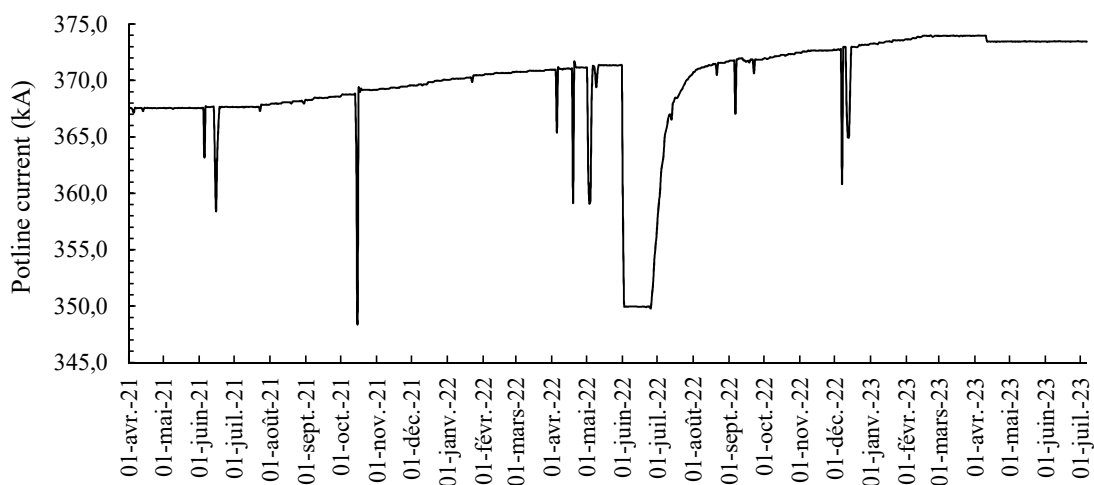


Figure 1. Potline current.

## 2. Approach

The amperage increase strategy is described in Figure 2. Pot sensitivity analysis was performed to assess the MHD stability limits in the pots of different age and design groups. Followed by the computational study to assess the thermal balance of the pots. Pots were categorized into different age groups and analyzed by increasing amperage in steps of 0.5 kA while keeping internal heat generation constant. Based on the simulation study, an operating window was established. The corrective actions were taken to keep internal heat generation unchanged or to maintain the isotherms at desired locations with increased heat input. In old pots without copper inserts, ACD was increased to avoid an increase in instability. Accordingly, metal height was increased in selected pots. The anode cover thickness was reduced throughout by 2 cm. The height of the anode was increased to account for increased carbon consumption. To facilitate a faster line current increase, the old pots were replaced while reducing the pot turnaround time.

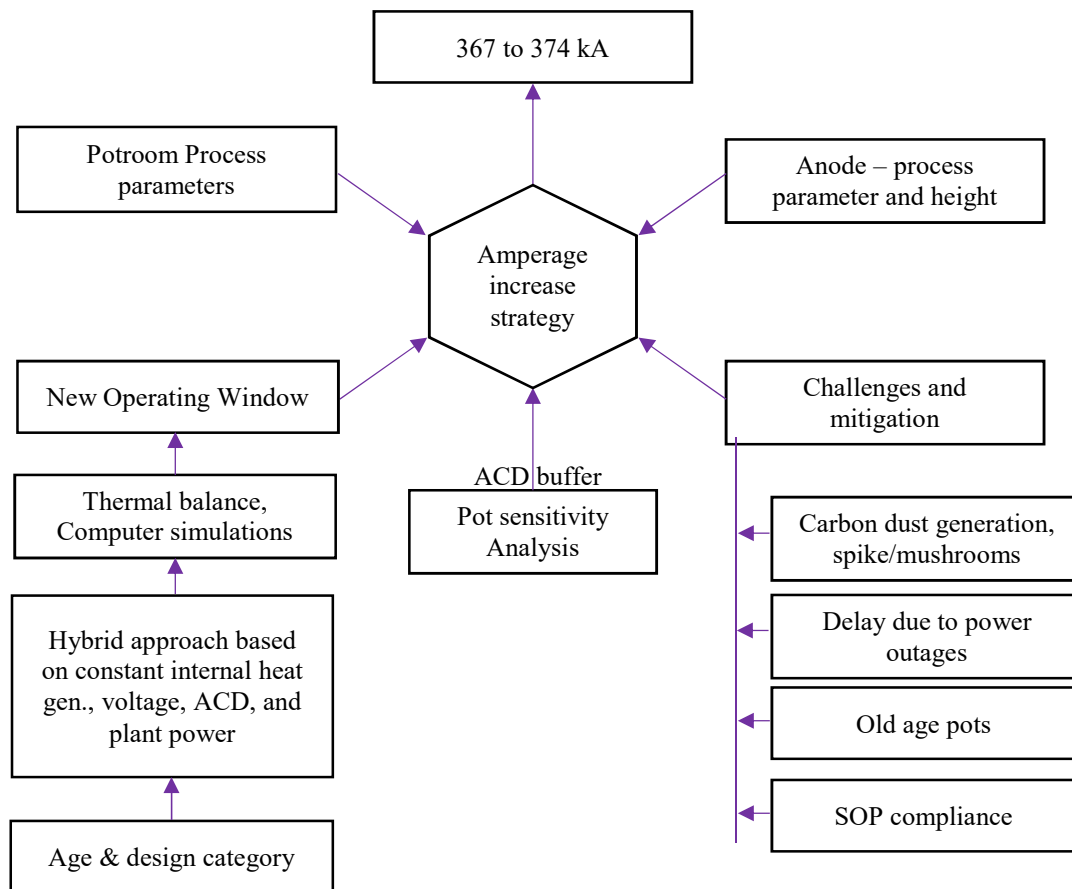
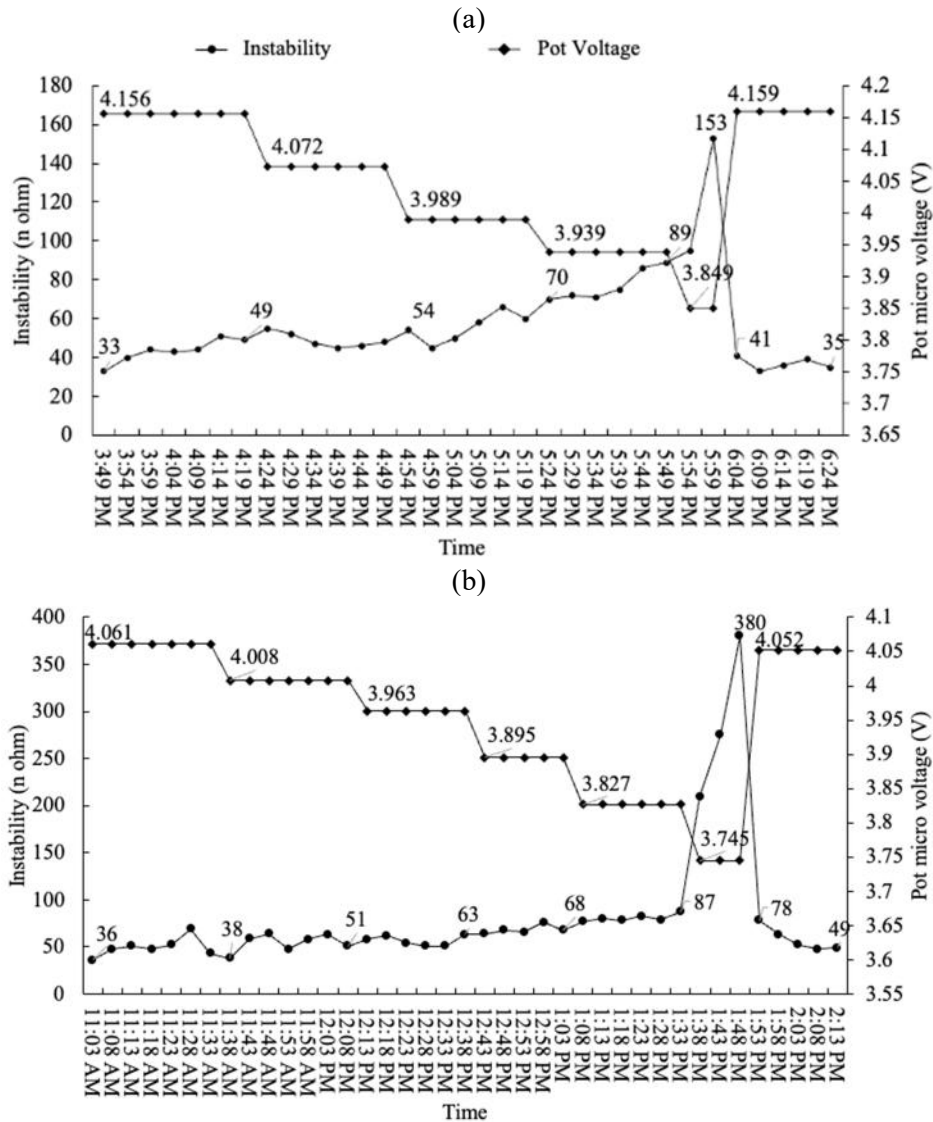


Figure 2. Amperage increase strategy.

## 3. Pot Sensitivity Analysis

To identify the ACD limit, pot sensitivity analysis was performed on pots of different age groups and designs. The anode beam was lowered in steps till the pot instability increases. The sensitivity analysis shown in Figure 3 indicates a voltage buffer between 220-240 mV, implying that ACD may be reduced by 30-40 mV comfortably while amperage increases.



**Figure 3. Pot sensitivity analysis performed on two different pots is shown. (a) Instability increases after >200 mV reduction in pot voltage. (b) Instability increases after >230 mV reduction in pot voltage.**

#### 4. New Operating Window

Pots were categorized into different age groups of 0-100 days, 101-400 days, 401-700 days, 701-1000 days, 1001-1500 days, 1501 days and above. Based on the voltage break-up, bath chemistry, and other parameters, ACD and internal heat generation were calculated. The method to calculate was reported earlier [10, 11]. A thermoelectric model was used [11, 12] to simulate the state of the pots under different age groups and designs. The simulations were performed by increasing amperage in steps of 0.5 kA. The operating windows were formed for the pots with and without copper insert collector bars as shown in Figures 4 and 5, respectively. The correction in operating parameters with an increase in amperage is shown (tested through simulations) in Figures 4(a) and 5(a). In the pots without copper insert collector bar, the internal heat generation was kept constant till 370 kA due to which ACD was reduced by 35-40 mV (equivalent to 1 mm). The operational parameter was not changed till this point. Beyond 370 kA, a constant ACD approach was used to avoid instability. The internal heat generation in the pots increased due to a constant ACD and increased amperage. To establish the thermal balance, the metal height and anode cover

were modified and tested through the computational model. Considering the higher threshold for instability in the copper insert pots, internal heat generation was kept constant till 372 kA, which resulted in an ACD reduction of ~1.5 mm. At a constant ACD and increasing amperage beyond 372 kA, the corrections in metal height and anode cover thickness were tested and established as shown in Figure 5(a). The predicted values (obtained from simulations) of pot voltage, cathode, and bath temperature are shown with increasing amperage in Figures 4(b) and 5(b). During actual pot operation, ACD was increased in a few pots, depending on the increased instability. The anode cover height control was difficult in individual pots, therefore metal correction was done in pots wherever extra ACD was needed. Any deviation from the operating window while amperage increase was again tested through simulations before making any correction.

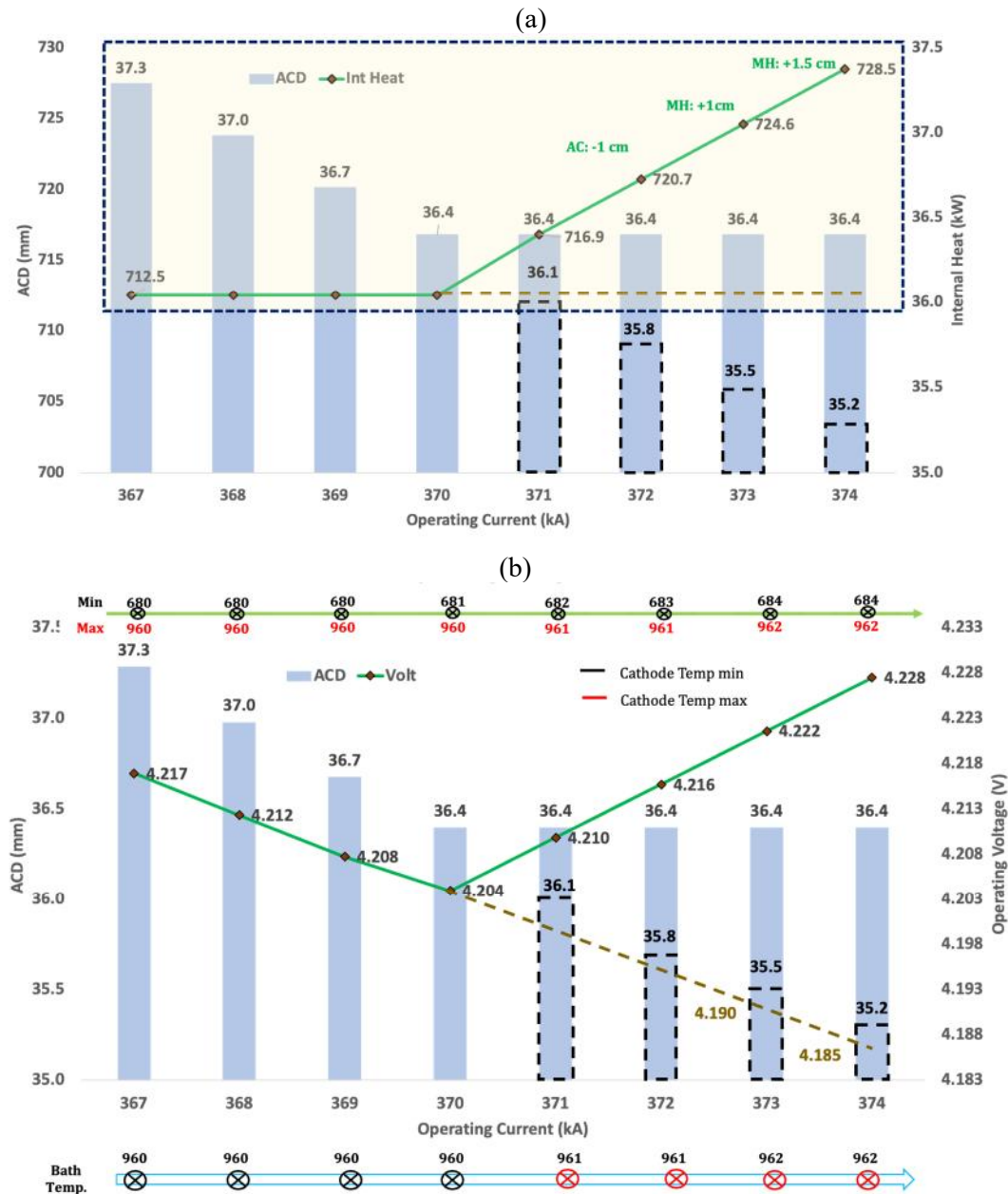


Figure 4. Operating window for pots without copper insert collector bar. (a) Operating parameters with an increase in amperage. (b) Predictions (from simulations) of pot voltage, bath, and cathode temperature.

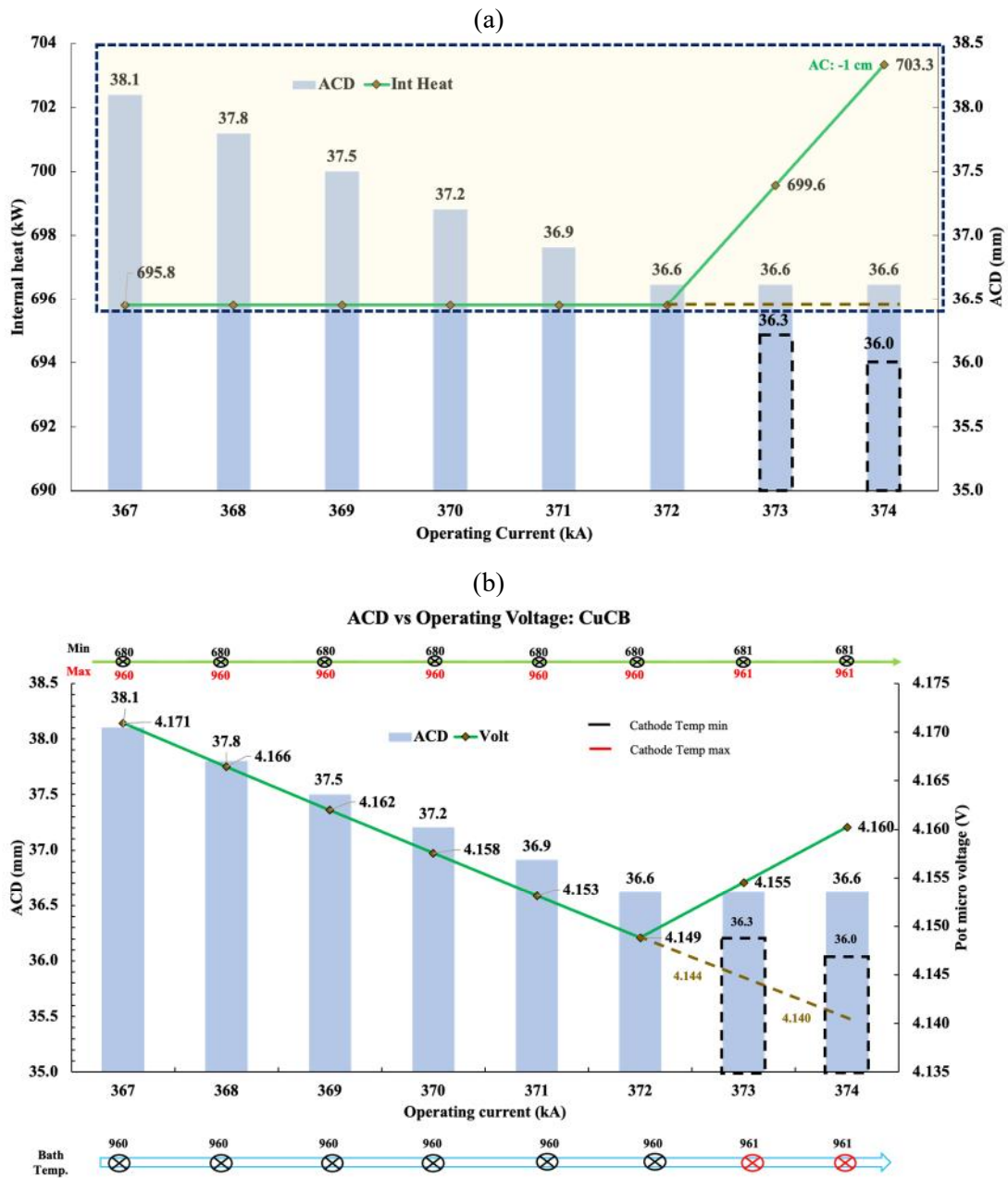


Figure 5. Operating window for pots with copper insert collector bar. (a) Operating parameters with an increase in amperage. (b) Predictions (from simulations) of pot voltage, bath, and cathode temperature.

### 5. Modifications in Process and Operations during Amperage Increase

Beyond 370 kA, the anode cover thickness was reduced gradually by 1-2 cm to facilitate extra heat loss of 9-18 kW from the top [11]. As the cover thickness was decreased, heat loss from the top increased which is indicated by the increased difference between the temperature of the anode cover and ambience as shown in Figure 6. The target metal height was increased by 2 cm in the pots without copper insert collector bars; overall metal height increased by ~1 cm (shown in Figure 7). This helped in dissipating at least 15 kW of extra heat generated inside the pots [11]. The measurements such as ledge thickness, side shell temperature, collector bar temperature, and busbar temperatures were carried out on 10 nos. of selected reference pots after every 15 days.

The trends obtained from the measurements were analyzed and operating parameters were modified accordingly. In the pots without copper insert collector bar, the target excess  $AlF_3$  was increased by 0.2 %, and the target bath temperature was decreased by 2 °C. The amount of bath tapping was increased as per requirement. The forced cooling around the shell was modulated to reduce the cooling around the pots with copper insert. The forced cooling around pots with an age greater than 1500 days was increased.

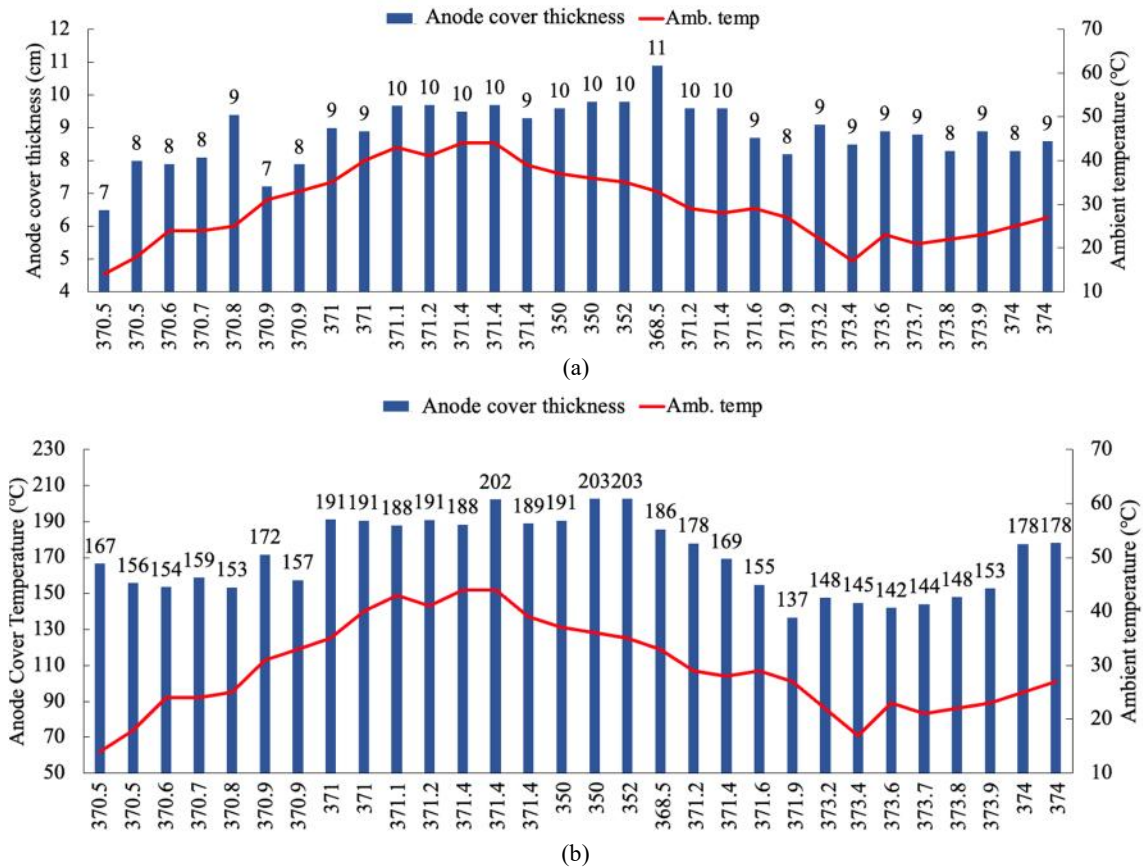


Figure 6. (a) Anode cover thickness and (b) anode cover temperature at different line amperages and ambient temperature.

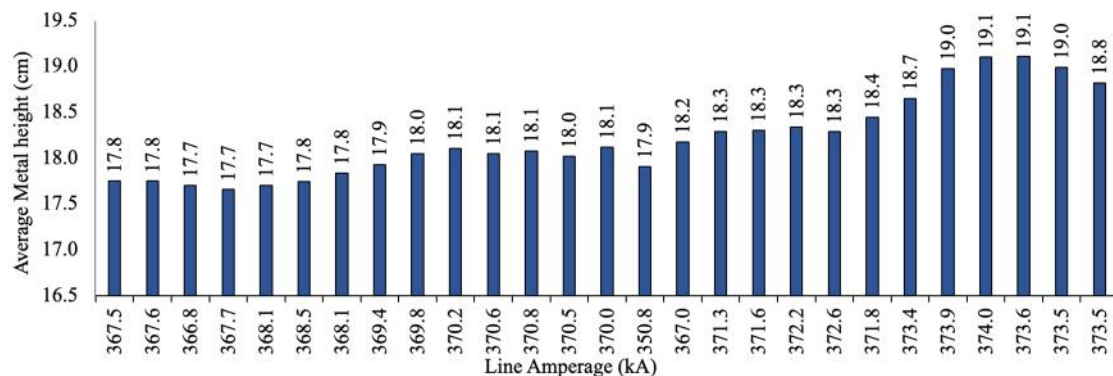


Figure 7. Average metal height with increasing line amperage.

The historical trend of anode butt height, carbon under the pin, and pin wash was studied. Accordingly, the anode height was increased by 2 cm to compensate for the increased carbon consumption. The anode baking temperature was increased by ~20 °C to improve the baked anode

properties. The butt cleaning efficiency was improved to reduce impurities in the green anode process.

## 6. Amperage Increase: Challenges and Mitigation

The major challenge was to operate 53 nos. of the first-generation pots with an age greater than 1800 days. The old pots were prone to fail from the side shell or collector bar. Therefore, a stringent monitoring procedure was adopted to prevent unscheduled stoppages. The first-generation pots were relined faster with a turn-around time of 4.7 days to facilitate the amperage increase plan. To prevent sudden failure, a strict physical monitoring system was put in place to check any red spot on the steel shell, especially in the evening time by switching off the roof lights.

The anode spike or mushroom generation increased during the amperage increase process. Therefore, the operations team focused on increasing the frequency of carbon dust skimming during measurement and tapping shift. The top carbon dust shoveling was made mandatory at specific anode locations of 16-20, 1, 10, and 11 during the anode change.

The audit system was set up for SOP compliance during operational activities such as pot tending, anode change, anode covering, metal tapping, and other critical activities.

## 7. Results

While facing challenges such as first-generation old pots, power outages, carbon dust generation, spikes etc., the line amperage was increased from 367 to 374 kA. The average pot voltage at 374 kA increased by 10 to 20 mV (Figure 8), which includes the net effect of voltage increase in pots without copper inserts and voltage reduction in the pots with copper insert collector bar. The average internal heat generation inside the pots increased by approximately 15 kW. Additionally, the plant operation team was able to maintain the required thermal balance which is reflected in minor changes in values of ledge thickness at the metal-bath interface, as shown in Figure 9. The average instability in the pots decreased as shown in Figure 10. The red shell was monitored regularly but any visible instance was not found. Beyond 370 kA, the bath temperature has reduced by an average of 1 °C and excess  $AlF_3$  in the bath has increased by approximately 0.6 %.

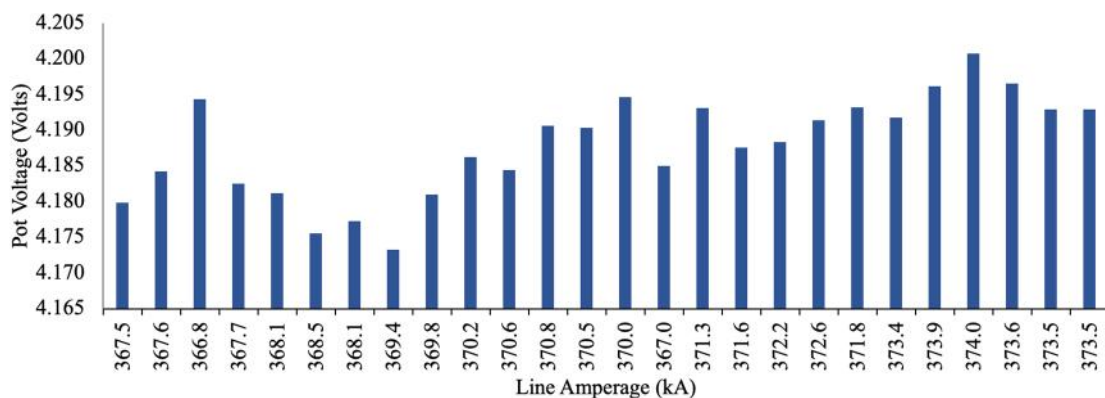


Figure 8. Line amperage and average pot voltage.

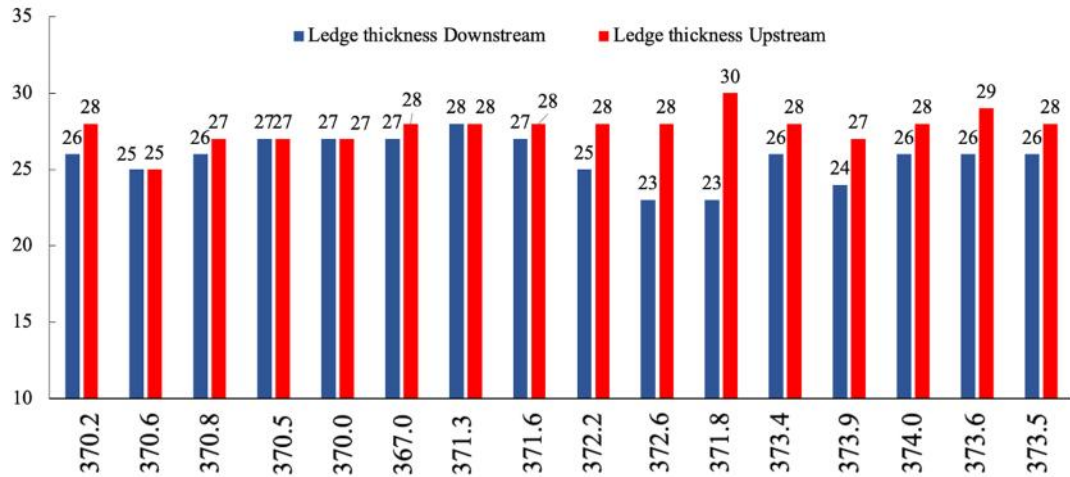


Figure 9. Ledge thickness at metal-bath interface with increasing amperage.

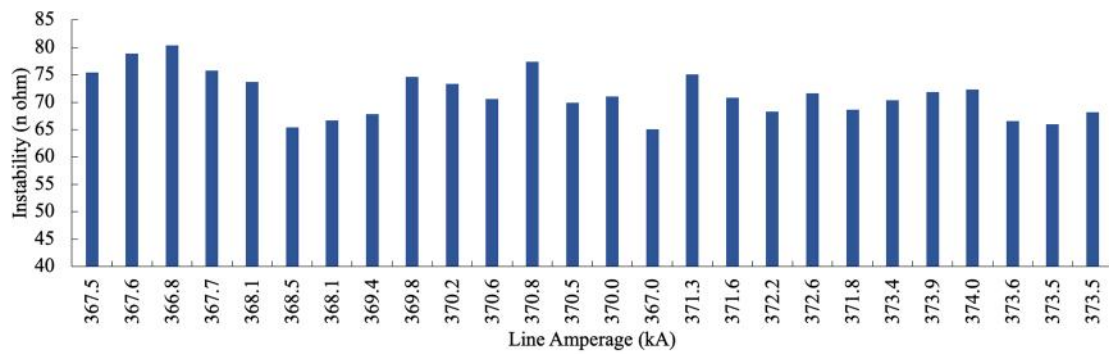


Figure 10. Instability in the pots during amperage increase.

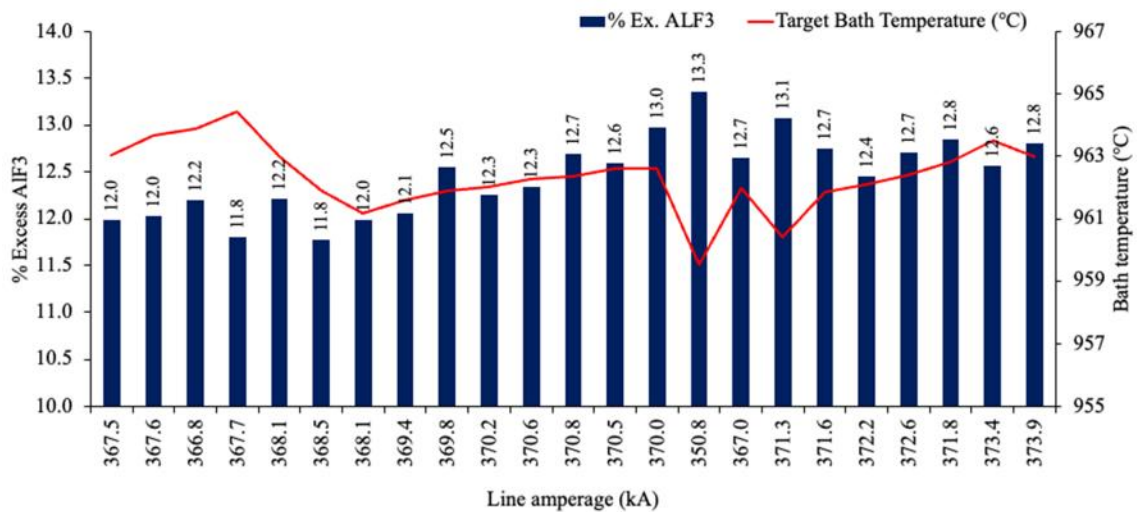


Figure 11. Variation in excess AlF<sub>3</sub> and bath temperature with line amperage.

## 8. Conclusions

The scientific approach to identify the state of the pots, a clear strategy, and potroom execution helped to mitigate the challenges and increase the line amperage by ~7 kA at Mahan smelter without compromising the specific energy consumption. The initial state of the pots was identified through sensitivity analysis and thermal calculations. The computational model was used to predict the thermal balance of the pots at increased amperages and modified parameters. The results from the simulations were used to devise an operating window that acted as a guideline during amperage increase. The internal heat generation was kept constant up to 370 kA and 372 kA in the pots with and without copper inserts, respectively. Beyond 370 kA and 372 kA, a constant ACD approach was used which mainly required corrections in metal height and anode cover thickness.

The forced cooling network (FCN) around the steel shell was modulated smartly to provide extra cooling to the pots without copper insert collector bars. The increased carbon dust skimming frequency and top carbon dust shoveling helped to reduce the mushroom formation. Special measurements were performed which helped to identify and correct the state of the pots while the amperage increased. The ledge thickness only changed slightly with increasing amperage indicating an insignificant deviation in the thermal balance. The major challenges of frequent power interruptions and old-age pots with first-generation design delayed the amperage increase in the potline. However, stringent monitoring prevented unscheduled stoppages of old pots. Additionally, the faster relining with a turnaround time of 4.7 days helped to continue the amperage increase process.

## 9. References

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