Cost-Effective Transition to Larger Anodes - From Concept to Implementation

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Abstract

The Mahan Aluminium Smelter of Hindalco Industries Limited, located in Madhya Pradesh, India, operates using AP30 technology with a design capacity of 360 ktpa. To meet the growing demand for aluminium, manufacturers are increasingly adopting amperage enhancement as a cost-effective strategy to boost production. Higher amperage operation necessitates several modifications, including process optimization, busbar upgrades, anode area expansion, and cathode lining improvements etc.

Mahan smelter identified anode area expansion as the most viable approach to increasing amperage due to its favourable cost-to-benefit ratio. This paper presents a comprehensive study of the systematic efforts undertaken by the carbon plant to develop and implement larger anodes, from conceptualization to full-scale production, within the constraints of the existing infrastructure. Key process modifications and equipment upgrades in the green anode plant and anode baking furnace are discussed in detail. Additionally, the paper highlights the challenges encountered during the conversion process and the corrective measures taken to ensure a seamless transition. The successful implementation of larger anodes has contributed to increased amperage at the potline, enhancing overall smelter performance. With further potential for amperage growth, the study provides insights into the optimization of carbon operations for improved efficiency in aluminium smelting.

Keywords: Aluminium smelting, Amperage increase, Carbon anode, Design modification

1. Introduction

The Mahan smelter operates with AP36 pot technology. Initially commissioned at an operating amperage of 367 kA in 2013, the line continued to operate at this amperage until the end of 2021. To meet the increased aluminium demand, the potline amperage was successfully ramped up to 376 kA. In the potline, aluminium is produced through the electrolytic reduction of alumina in the presence of cryolite, prebaked carbon anodes, and cathodes. Mahan is an integrated smelter where prebaked carbon anodes are manufactured and supplied from a carbon plant located within the complex. The Carbon Plant is an integrated facility consisting of three units: the Green Anode Plant (GAP), Anode Baking Furnace (ABF), and Anode Rodding Shop (ARS). In the GAP, a dry aggregate mix comprising calcined petroleum coke and recycled anode is mixed with coal tar pitch. The homogenized paste is subjected to vibro-compaction to achieve specific dimensional tolerances, packing density, and mechanical strength necessary for downstream processing. The green anodes are then charged into the ABF. The ABF is a closed ring open-top furnace divided into four fires, each consisting of 3 preheating zones, 3 heating zones, and 4 cooling zones with 1 zone for unpacking of anodes. The furnace has a peak flue-gas temperature of 1130 °C at the burner zone. Energy required for raising the temperature of flue-gas mainly comes from pitch volatile matter combustion in the preheating zone and heavy fuel oil (HFO) combustion in the heating zone. Heat transfers from hot flue gases to refractory walls to packing coke to anode blocks. Thermal evolution during the baking cycle increases the anode temperature to almost 1080 °C, ensuring higher conductivity and compressive strength of anode blocks. Post-baking, anodes are transferred to the ARS. Here, carbon anode blocks are assembled with steel pins through a casted joint created using molten cast iron. This process ensures a low-resistance electrical connection between the carbon anode and the busbar system in electrolytic cells. The final rodded anodes are then subjected to quality inspection before being delivered to the potroom.

With amperage creep in the potline, anode current density rises linearly. To maintain a similar anode replacement schedule and ensure an optimum voltage drop across the carbon anode block, it is necessary to modify the carbon anode block design. Reducing the anode voltage drop can be achieved by increasing the current-carrying cross-sectional area of the anode and increasing slot height [1, 2]. Originally, the standard anode block dimensions are 1550 mm (length) × 650 mm (width) × 680 mm (height). Given the spatial constraints associated with increasing the anode width, the viable approach is to extend the length of the anode. The proposed design involves increasing the anode length by 30 mm, resulting in an additional surface area of approximately 18 360 mm^2 per anode. To facilitate a higher rate of gas dissipation, the anode slot height was increased by ~130 mm. Based on empirical correlations, these geometric changes lead to a reduction of approximately 24 mV in anode voltage drop. Moreover, this change does not necessitate significant alterations in the anode rodding process or pot cell configuration, ensuring compatibility with existing infrastructure. Upgrading the anode plant to produce larger anodes is a familiar approach in the smelting community, with many such efforts reported in the past [2]. Figure 1 shows the overall process flow of the smelter. Equipment modifications necessary for manufacturing larger anodes are presented against each process unit.

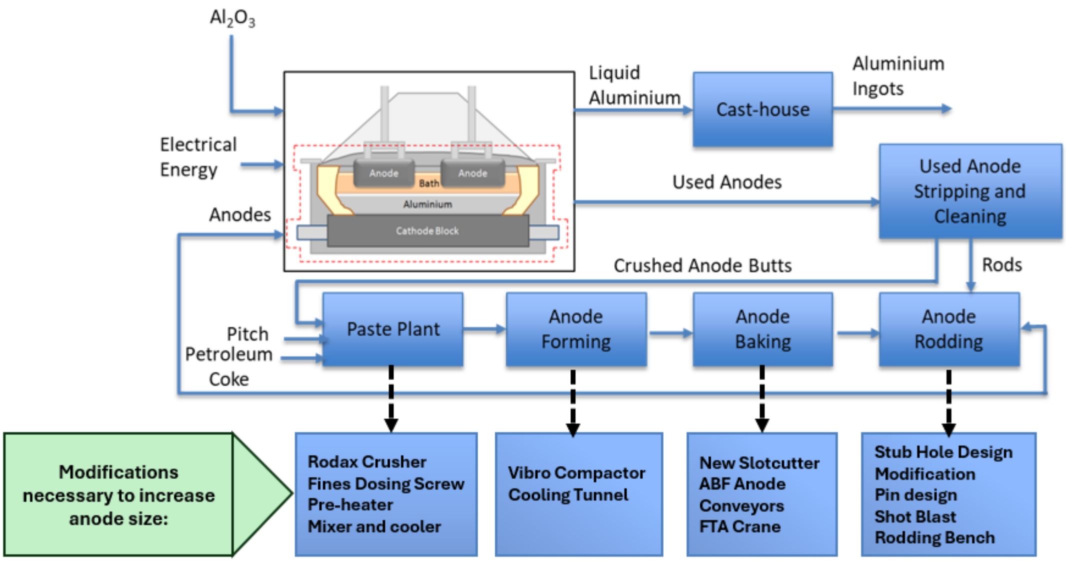

Figure 1: Process flow diagram of smelter and the necessary modifications in carbon plant.

2. Carbon Plant Upgradation

This section covers the process and equipment upgrades done in the carbon anode plant to enable it to produce larger anodes.

3. Way Forward

While the amperage of the pots is being increased to 400 kA, the stem assembly design remains unaltered. The increased flow of current through the same stem and thimbles will result in an increase in voltage drop, due to increased current density. Thimble geometry also plays a crucial role in the volage drop in the block. Thus, the design of the anode block, stub hole, stems, brackets and pins will be modified to avoid increase in anode assembly voltage drop at high amperage operation.

4. Conclusion

To support the amperage increase in the smelter, three major modifications were made in the anode block design: (i) anode length, (ii) anode height, and (iii) slot height. The key process and equipment modifications made to achieve this goal are discussed in the paper. In the Green Anode Plant (GAP), the dimensions of the molds were adjusted to accommodate an extra 30 mm length during compaction. The hydraulic systems were also upgraded to meet the additional load requirements for producing larger anodes.

In the Anode Baking Furnace (ABF), the FTA height was increased to improve the clearance between the central conveyor and the suspended anodes. A feasibility analysis was conducted to determine if the existing fume treatment centre design was sufficient for handling the extra flue gas flow rate resulting from baking larger anodes.

5. References

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