AL17 - Minimizing SPL Generation via Redesigning Pot and Life Enhancement

Mahesh Sahoo[1], Amit Gupta[2] and S. K. Badajena[3]
1. General Manager
Hindalco Industries Ltd, Hirakud, Sambalpur, Odisha, India
2. Lead Scientist
Aditya Birla Science & Technology Company Pvt. Ltd, MIDC Taloja, Maharashtra, India
3. Associate Professor
Veer Surendra Sai University of Technology, University of Burla, Odisha, India
Corresponding author: sahoo.mahesh@adityabirla.com

Abstract

Primary aluminium production process poses a threat to the environment due to generation of hazardous waste like the spent pot lining (SPL). This has led the researchers to focus on 4R (Reduce, Recycle, Recover, Reuse) approaches to minimize the impact of SPL on the environment. Worldwide aluminium smelters have been looking into ways to reduce the SPL generation per tonne of Al produced, such as enhancing pot operational life, as well as by reusing and recovering value from SPL by its utilization in both cement and ferrous industries as well as coal-fired power plants. Hindalco's Hirakud smelter has also been utilizing the 4R approaches with a goal to minimize the SPL impact on the environment. This paper highlights the redesign approach adopted by Hirakud smelter, which has led to reduce the SPL generation significantly. The paper describes the modification in the cell lining design and materials to enhance pot performance and pot life, thereby reduce the SPL generation from 20.41 kg/t Al to about 15.55 kg/t Al. To enhance the energy efficiency of pot, copper-insert collector bars have also been utilized, which are reported to enhance the pot life, thereby further potential of reducing the SPL generation to the level of 14.14 kg/t Al. Apart from the redesign, other approaches such as recycle, recover and reuse have also been looked upon for effective SPL management.

Keywords: 4R approach, pot life, cell lining, spent pot lining (SPL), aluminium smelter.

1. Introduction

Primary aluminium is produced using an electrolytic process, also known as Hall-Héroult process, from the alumina dissolved in to the molten cryolitic bath. The electrolytic process occurs in a steel pot, which is lined with refractories, to offers mechanical and chemical stability. The lining refractory is typically made of two layers, an insulating refractory, which house a carbon cathode along with collector bar to allow the current flow. The cell usually operates for about 4 to 8 years before it fails. The life of the cell usually varies from plant to plant based on the cell technology & operational amperage. There are various factors, which affect cell operational life, e.g., cell design, quality of lining materials, preheating, start-up procedures and thermal disturbance during cell operational life. Precise start-up procedures and efficient operation play key role in attaining a satisfactory life of a cell. The thermal, mechanical and chemical properties of cathode and lining materials may also lead to failure, if the cell is not designed correctly to ensure isotherms in proper locations. Figure 1 shows a typical cross-section of a Hall-Héroult cell, highlighting cell-lining materials such as carbon cathode, refectory and insulation materials. The cell lining design should ensure that the electrolyte freezing isotherm in the lining (~780 °C) should be just below the cathode blocks into the high dense refractory brick, made of silica and alumina. Due to capillary action, bath impregnation takes place after the sodium front has moved through the carbon and only through the porous network formed by the volatilization & shrinkage of the binder during baking [1]. A freezing isotherm inside the carbon blocks may result in frost heave damage and a freezing isotherm too far down into the insulation refractory layer results in damage of the insulation layer, which is usually less dense and less salt resistant then the upper refractory layer. The thermal conductance of the sidewalls should result in a proper ledge shape and thickness.

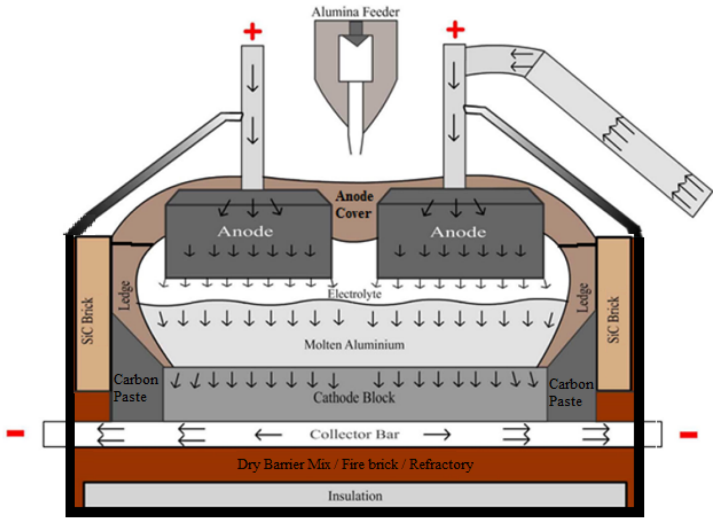

Figure 1. Cross-sectional view of Hall-Héroult cell.

2.1. Role of Cathode in Pot Failure

The pot life depends on various factors, like cell design, lining material, preheating & startup as well as the operational variations encountered during the entire pot life. Regarding materials, along with refractory and insulation, the cathode plays an important role in deciding pot life. Three types of cathode blocks are presently being used in the aluminium industry, for example, anthracitic / semi-graphitic (with 30 %, 50 % or 70 % graphitic content), 100 % graphitic & fully graphitized. Impregnated, fully graphitized cathode block is the recent development to reduce the open porosity in the cathode block, which has positive impact on enhancing pot life, despite resulting in additional costs. Each type of cathode block has its own pros & cons with respect to their properties, which are mentioned in the following Table 1.

Table 1. Relevant properties of cathode block for pot life [2].

Cathode Block Properties	**Semi Graphitic (30–50–70 %)**	**100 % Graphitic**	**Fully Graphitized**
Apparent density (x10^{-3} kg/m^3)	1.54–1.63	1.59–1.64	1.62–1.63
Open porosity (%)	15–20	18–22	21–23
Total porosity (%)	20–23	24–25	26–28
Electrical resistivity at 1000 °C (μΩ·m)	18–26	16–20	10–12
Thermal conductivity at 1000 °C (W/m·K)	14–13	22–18	50–40
Cold crushing strength (MPa)	27–27	25–26	20–26
Thermal expansion coefficient at 20 – 520 °C (x10^{-6}·K^{-1})	3–3.5	2.9–3.4	2.9–3
Sodium swelling (%)	0.35	0.25	0.1
Wear resistance	High	Medium	Low

emission. Though the results from the trial were deemed satisfactory, further extension of this approach would require consent from regulatory bodies.

1.4. Reuse of SPL as Raw Material

Hindalco smelters are also exploring options with the cement industry to reuse the SPL as raw materials. The SPL can be used in the different stages of cement manufacturing process as a raw material as well as an alternative fuel. This work is in the initial stages of development.

3. Conclusions

Spent pot lining is a hazardous waste and a major threat to the environment. It is being managed by Hirakud smelter by adopting 4R (Reduce, Recycle, Recover & Reuse) approach. This work majorly focuses on the first “R”, i.e., redesign of pot lining to reduce the SPL generation. Pot lining was redesigned to improve the thermal balance, ledge profile and isotherm location in the refractory by modifying the lining design and materials along with Cu-insert collector bar. This has not only improved the pot performance with respect to the energy efficiency, but also improved the pot life. The new design pots are already running for the last 5.5 years and offering an extended pot life of more than 200 days along with reduction in lining material quantity by about 3 tonnes as compared to old design. The new cell lining design reduces the SPL generation from 20.41 kg/t Al to about 15.55 kg/t Al, or 23.8 %. Based on cathode surface measurement, the pot life is expected to exceed 2200 days, which provides further reduction potential in SPL generation to about 14.14 kg/t Al or 30.7 % with respect to the original figure. Apart from the redesign approach, other avenues such as recycling and recover have also been tested while exploring the reuse of SPL with cement industries. These sustainable practices would help in reducing the SPL impact on the environment.

4. References

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