Reduction of Anode Gross Consumption with Anti-Oxidation Coating in 500 kA Cells

Dezan Li[1], Junjiang Pan[2], Fapu Li[3], Yongquan Huang[4] and Yan Li[5]
1. Manager of Production Technology Department, Engineer
2. Operation Assistant of 2nd Potroom, Assistant Engineer
3. Vice Director of 2nd Potroom, Engineer
4. Support Engineer
5. Vice Director of 1st Potroom, Engineer
Guangxi Hualei New Materials, Baise, China
Corresponding author: 1592439940@qq.com
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Abstract

Anode consumption is a key economic indicator in aluminium electrolysis production. Reducing anode consumption can directly lower production costs and bring significant economic returns to smelters. This paper presents the primary mechanisms of anode consumption, along with the influence of anode quality and operational techniques. A technology aimed at reducing anode consumption was developed based on structural optimization, where anode anti-oxidation coatings and increased anode carbon block height are essential measures. After implementation in 500 kA aluminium reduction cells, anode gross consumption was reduced by 12.7 kg C/t Al, giving considerable economic returns and offering a valuable reference for the industry. The anode cycle was extended from 36 to 37 days, providing further advantage of this technology.

Keywords: 500 kA aluminium reduction cell, Anode consumption, Anode coating, Increased anode height, Anode cycle.

1. Introduction

With global economic growth and the continuous rise in aluminium demand across industries, the aluminium sector has expanded significantly, becoming an essential component of modern industrial systems. Electrolytic aluminium production is the only method in the aluminium manufacturing process. High amperage, high productivity 500 kA aluminium reduction cell is widely used in China. It offers advantages such as high production capacity and relatively high energy efficiency, which reduced production cost. In aluminium electrolysis production, the anode carbon block is a key consumable material, accounting for a significant portion of total production costs. Anode consumption refers to the amount of carbon anode consumed per tonne of aluminium produced. Reducing it contributes to lowering production costs, while also supporting resource utilization and environmental protection.

1.1 Current Developments Domestically and Internationally

Although China started aluminium production in advanced aluminium electrolysis technologies, later than Europe and North America, it has made rapid advancements in recent years. Chinese universities and research institutes have made breakthroughs through industry-academia collaboration—such as enhancing anode material performance (e.g., by incorporating additives to improve oxidation resistance) and developing proprietary intelligent control technologies for the cells. Major aluminium producers have increased investment, introduced innovative technologies, and reduced raw material consumption by improving anode assembly and optimizing electrolyte composition. China's push for sustainable development in the aluminium smelting industry continues to drive progress in this field, with expectations of narrowing the gap with other nations or even surpassing them.

Developed countries have a solid foundation: Europe, Canada and the U.S.A. began the development of cell technologies early. They have achieved significant results in developing advanced anode materials (e.g., high-density, high-conductivity carbon blocks), optimizing cell structures (e.g., geometric design and MHD flow improvements), and applying advanced monitoring and control technologies. Japan emphasizes precision management and innovation, optimizing anode manufacturing and use through meticulous control of raw material ratios and baking parameters, while integrating multidisciplinary knowledge into cutting-edge equipment development.

1.2 Significance of Research on Reduction of Anode Consumption

Reducing anode consumption has far-reaching implications for the sustainability of the aluminium smelting industry and society as a whole. It contributes to sustainable use of resources by decreasing the consumption of scarce carbon materials in anode production. Additionally, reducing anode consumption increases energy efficiency and lowers energy costs. Finally, it enhances the industry's ability to respond to emergencies, ensuring stable production and a reliable aluminium supply during energy shortages.

2. Main Mechanisms of Anode Consumption

In aluminium electrolysis, anode consumption primarily occurs through electrochemical reactions, physical loss, oxidation, and electrochemical reactions. The main mechanism of anode consumption is the oxidation reaction between carbon in the anode and the oxygen produced during electrolysis. Adding to it is anode air-oxidation, Boudouard reaction and anode dust generation. Impurities and additives in the electrolyte may also increase consumption. Thermal stress may lead to the loss by anode cracking and breaking.

2.1 Chemical Reactions in Anode Consumption

Chemical consumption refers to carbon anode loss due to aluminium electrolysis, air oxidation and Boudouard reaction.

The primary electrochemical reaction is given in Equation (1).

$$2Al_2O_3 + 3C = 4Al + 3CO_2 \tag{1}$$

The aluminium dissolved in the electrolyte may further react with CO_2 produced at the anode in the so called back reaction:

$$3CO_2(g) + 2Al(diss) \rightarrow 3CO\ (g) + Al_2O_3(diss) \tag{2}$$

Air oxidation of the anode is given in Equations (3) and (4). In prebaked anodes, this occurs above 400 °C at the top and side surfaces exposed to air.

$$C\ (anode) + O_2(g) = CO_2(g) \tag{3}$$

or

$$2C\ (anode) + O_2(g) = 2CO(g) \tag{4}$$

The Boudouard reaction, also known as CO_2 burn of the anodes is given in Equation (5).

6. Conclusions

This paper provides an in-depth analysis and application study of technologies aimed at reducing anode consumption in 500 kA aluminium reduction cells. As a key economic indicator in aluminium electrolysis production, the reduction of anode consumption is directly linked to lowering production costs and improving economic efficiency.

The paper first elaborates on the main mechanisms of anode consumption, clarifying the modes and causes of consumption; it then analyses influencing factors such as anode quality and production operations and their specific impacts. It focuses on the role of anti-oxidation coating technology and of anode height increase. To effectiveness of this antioxidation coating was tested on 500 kA cells. The anode cycle was successfully increased from 36 days to 37 days, and anode consumption decreased by 12.7 kg C/t Al.

7. References

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