Development of Ultra–Low Energy Consumption Technology in 500 kA Cells

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Abstract

Aluminium production is an energy-intensive process. On one hand, the country has imposed increasingly stringent requirements on the green and low-carbon development of the industry. On the other hand, energy conservation and consumption reduction are of critical importance to the sustainable development of smelters. Therefore, achieving ultra-low energy consumption in electrolytic cells has become a pressing priority. The solution proposed in this paper optimizes the lining and cathode collector bar structures of a 500 kA high amperage cell, reducing the cathode voltage drop by more than 100 mV, thereby enabling low-voltage, high-efficiency operation. Additionally, the solution integrates auxiliary energy-saving technologies, including energy-saving stubs, online busbar upgrades, anode block slotting, anti-oxidation coatings for anodes, and laser cleaning of anode rods. By employing these advanced technologies, the voltage drop across each conductor component can be further minimized. Complementary process management strategies have also been developed, forming a comprehensive ultra-low energy consumption technology framework for 500 kA cells, and achieving a reduction of energy consumption of 500 kWh/t Al. This approach not only facilitates technological upgrading and energy efficiency improvements but also supports the green and low-carbon transformation of the aluminium industry.

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Keywords: Aluminium electrolysis, Lining design, Energy-saving technology, Ultra-low energy consumption, Cathode structure.

1. Introduction

As increasingly stricter regulatory control is imposed on the energy consumption and carbon emissions of the cells, China's aluminium electrolysis industry is facing huge challenges in saving energy and reducing consumption. Recent years have seen rapid advances in aluminium electrolysis technology in the country. According to statistics [1], China has reached the advanced level of aluminium electrolysis in the world, but it still lags behind in terms of energy cost, mainly due to high electricity price, as well as high electricity consumption in aluminium electrolysis, which accounts for 55–60 % of the total carbon emissions generated in the entire process [2]. Therefore, reducing the energy consumption associated with aluminium electrolysis, particularly electricity usage, has become a widely accepted objective within the industry. This paper examines the voltage components of the cell and investigates low-energy consumption technologies for its operation. Additionally, corresponding process technology management strategies are developed, leading to the establishment of a replicable and scalable low-energy consumption control framework for the cell.

2. Analysis of Energy Conservation and Reduction of Energy Consumption in Aluminium Electrolysis

To reduce the cell energy consumption, the first step is to lower the average voltage and improve current efficiency. In recent years, experts and scholars at home and abroad have undertaken extensive research and industrial trials to reduce cell operating voltage. Shuhong Song et al. [3] compared the applications of the graphitized cathode carbon block and the 50 % graphitic cathode carbon block, and the results showed that the voltage drop in the graphitized cathode blocks is, on average, 45.5 mV lower than in the 50 % graphitic cathode. In the study of the magnetic fluid stability characteristics of graphitized cathodes, Wei Tang et al. [4] confirmed that current efficiency of the graphitized cathode is 1.5 % higher than that of the graphitic cathode. It can be seen that the application of graphitized cathodes has become a hot topic of research, and graphitized cathodes are now widely used in the industry.

We have conducted measurements on the voltage distribution of various parts of the cells in a Chinese smelter, and the results are shown in Table 1.

Table 1. Summary of cell voltage balance in a Chinese smelter.

Item		Voltage Drop (mV)	Percentage
Riser busbar	Vertical riser busbar	30.8	0.77 %
	Diagonal riser busbar	19.1	0.48 %
	Riser flexibles	38.6	0.97 %
	Junction surface	8.5	0.21 %
	Total anode riser voltage drop	97.1	2.43 %
Rim busbar	Busbar voltage drop around the cell	142.1	3.56 %
Anode busbar	Balance busbar	21.4	0.54 %
Anode assembly	Clamp voltage drop	13.7	0.34 %
	Aluminium conductor rod voltage drop	21.2	0.53 %
	Explosion weld voltage drop	8.3	0.21 %
	Anode voltage drop	339.8	8.50 %
	Sub-total	383.0	9.58 %
Cathode voltage drop		226.7	5.67 %
Anode-to-cathode voltage drop		3 126.8	78.23 %
Total		3 997.0	100 %

As shown in Table 1, in the cell voltage distribution, the total anode riser voltage drop accounts for 2.43 %, the voltage drop of the cathode ring busbar accounts for 3.56 %, the voltage drop of the anode busbar accounts for 0.54 %, the voltage drop of the anode assembly accounts for 8.50 %, the voltage drop of the cathode accounts for 5.67 %, and the anode-to-cathode voltage drop accounts for 78.23 %. Since the potline has been put into operation, the anode riser busbar and the cathode ring busbar no longer offer potential for improvement under the current production conditions. However, the voltage drop in the anode assembly, cathode and between anode and cathode can be further reduced through improvements in electrolysis cell lining design and the development of advanced process management technologies.

7. References

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