A Brief Historical Analysis of Heat Loss in Aluminium Reduction Cells in China

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Abstract

This paper analyses the variation trends of heat loss in prebaked aluminium reduction cells over the past 25 years, dividing the changes of heat loss into four stages. Statistical analysis and data mining were conducted on the energy balance test results of electrolytic cells in each stage, revealing the corresponding variation characteristics of heat loss. In the first stage (2000–2009), the heat loss of electrolytic cells ranged from 1.9–2.1 V. During the second stage (2010–2014), the heat loss of electrolytic cells decreased to a range of 1.8–1.9 V. The third stage (2015–2021) saw a heat loss of 1.7–1.8 V. In the fourth stage (2022–present), the heat loss dropped to 1.5–1.7 V, demonstrating an overall continuous downward trend. This research provides a reference for future energy-saving and energy balance management strategies in prebaked anode aluminium reduction cells.

Keywords: Aluminium reduction cell, Heat loss, Energy balance.

1. Introduction

In the calculation and analysis of the energy balance for prebaked aluminium reduction cells, the electrolysis temperature is used as the reference temperature. The energy input includes electrical energy input and the energy generated by additional consumption of anode carbon blocks. The electrical energy input refers to the product of the system voltage drop and the current in the electrolysis system, while the additional consumption of anode carbon blocks denotes the energy produced by its oxidation and other reactions beyond the electrolytic reaction. The energy output comprises the energy consumed by the electrolytic reaction of alumina, heat loss from the aluminium reduction cells, energy required for heating the anode, and energy consumed for heating alumina and other raw materials. The energy balance design of electrolytic cells serves as the foundation for cell design, and a well-calibrated energy balance is essential for stable cell operation [1, 3].

In practical electrolysis processes, the energy utilization rate typically remains around 50 %, primarily due to energy dissipation through conduction, radiation, and flue gas emissions, collectively referred to as heat losses in this paper. The magnitude of these losses directly impacts the overall energy consumption of the electrolytic cell. To reduce heat loss, the energy balance design of the electrolytic cell should first optimize the heat dissipation distribution and total heat dissipation to ensure stable operation and energy efficiency and achieve the required heat dissipation during normal operation. Secondly, by measuring the heat dissipation distribution and total heat dissipation of a normally operating electrolytic cell, the rationality of the heat dissipation distribution can be analysed, and optimization measures can be proposed. During the development of prebaked anode aluminium electrolysis process over different periods, the heat dissipation distribution and heat dissipation in the aluminium electrolysis process have evolved with changes in electrolytic cell design concepts.

This paper analyses the trends in heat loss by examining the energy consumption of electrolytic cells over the past 25 years and the energy balance test results of aluminium reduction cells during different stages. The heat loss management technologies applied in aluminium electrolysis across four phases are introduced, providing insights for future energy balance control in aluminium reduction cells and offering new perspectives for further energy conservation and consumption reduction.

2. Trend of Energy Consumption in China's Prebaked Anode Aluminium Reduction Cells

As shown in Figure 1, based on the prebaked anode aluminium electrolysis energy consumption data for China compiled by the International Aluminium Institute (IAI) [4], the trend of energy consumption in China's aluminium electrolysis can be broadly divided into three stages before 2022. The first stage (2000–2009) saw a rapid decline in energy consumption. The second stage (2010–2014) witnessed a steady decrease. The third stage (2015–2021) experienced a continued but slower reduction in energy consumption. Since 2022, under the dual control policies of energy consumption in China and T*he Norm of Energy Consumption per Unit Product of Electrolytic Aluminum and Alumina* (GB 21346-2022), coupled with the sustained rise in remelting aluminium ingot prices, the profitability of aluminium smelters has continued to improve. As a result, the smelters have significantly increased R&D investments. In 2023, China's average comprehensive AC power consumption for aluminium ingots reached 13 324 kWh/t Al, with electrolysis energy consumption continuing to decline rapidly. Therefore, the period from 2022 to the present is classified as the phase 4. The following sections describe the variation characteristics of heat loss in prebaked aluminium reduction cells across these four phases.

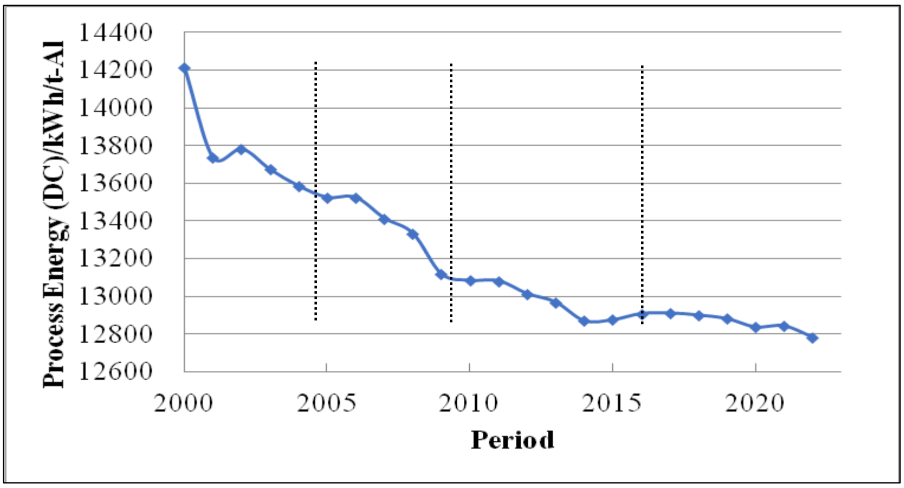

Figure 1. Energy consumption trends in China's aluminium electrolysis industry.

3. Heat Loss Characteristics of Prebaked Anode Aluminium Reduction Cells

In the daily production management of aluminium electrolysis, prebaked aluminium reduction cells are typically divided into zones based on energy balance.

To optimize the energy balance in each zone of the electrolytic cell, energy balance testing and calculations can be conducted to understand the energy distribution characteristics and utilization efficiency in different zones of aluminium reduction cells. This allows for targeted process and production management improvements.

The reduction of energy consumption in all stages of aluminium electrolysis, by decreasing heat loss whether in the upper or lower section, relies on the optimization of the overall energy balance technology of the cell.

In the future, on the premise of achieving overall cell energy balance, the continuous application and refinement of new materials and electrolysis processes, along with technologies for recovering wasted energy, high-conductivity busbars and collector bars, and research on reducing interfacial voltage drop in cast-iron, it is expected to further decrease the relative heat loss in the upper and lower sections of the cell. This will ultimately achieve the goal of reducing energy consumption. The study will provide theoretical support and data references for energy-saving improvements in aluminium reduction cells.

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