High-Efficiency Flue Gas Collection in Aluminium Reduction Cells

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Abstract

With increasingly stringent environmental requirements and the ongoing pursuit of energy conservation and emission reduction, the effective collection of flue gas from aluminium reduction cells has become a critical issue in the aluminium electrolysis industry. This paper conducts an in-depth study on high-efficiency flue gas collection methods for aluminium reduction cells. Through an analysis of existing collection technologies, it is found that equipment renewal plays a significant role in improving flue gas collection efficiency. During the study, the flow mechanisms of flue gas were analysed to gain a deeper understanding of its movement characteristics in the cell, serving as a foundation for optimizing the collection process and ensuring better coordination between new equipment and collection strategies. The application of new equipment not only significantly improves flue gas collection efficiency but also contributes to energy savings. Taking the optimization of a 400 kA cell as an example, after the retrofit, the flue gas suction on the cell was reduced to 3022 m^3/h, only one-fifth of the original value. This significantly lowers the required exhaust fan airflow and drastically reduces flue gas heat dissipation, thereby decreasing the energy input into the cell and improving its energy efficiency. It is estimated that the cell operating voltage will drop by 100–150 mV. Furthermore, after the implementation of this system, the flue gas concentration and temperature will increase substantially, providing a foundation for the development of subsequent technologies.

Keywords: Aluminium electrolysis, Aluminium electrolysis flue gas, Flue gas flow mechanism, Energy saving and consumption reduction.

1. Introduction

Under China's "carbon peak and carbon neutrality" goals, the domestic electrolytic aluminium industry is facing significant pressure to reduce energy consumption and emissions. As a highly energy-intensive and high carbon-emitting sector, aluminium electrolysis consumes enormous amounts of electricity per tonne of aluminium produced, with carbon emissions per tonne several times higher than those of the steel industry, exerting a substantial impact on the nation's overall energy consumption and carbon footprint [1]. Currently, some aluminium electrolysis capacities in China still operate above the benchmark energy efficiency level, with numerous outdated facilities offering considerable potential for energy saving and emission reduction. From a policy perspective, the National Development and Reform Commission (NDRC) and other departments have issued special action plans, stipulating that by the end of 2025, the proportion of production capacity reaching the advanced energy efficiency benchmark must exceed 30 %, while capacity above the baseline efficiency level must undergo technological upgrades or be phased out. Additionally, the industry's renewable energy utilization ratio must reach at least 25 % [2, 3]. Meanwhile, the Ministry of Ecology and Environment (MEE) plans to include the electrolytic aluminium industry in the national carbon emissions trading market, meaning smelters failing to improve energy efficiency and reduce emissions promptly will face substantial carbon compliance costs. With the growing global emphasis on green development, international markets are increasingly imposing stricter carbon emission standards on aluminium products. If China's electrolytic aluminium industry fails to accelerate energy saving and emission reduction, it will be at a competitive disadvantage internationally and missed development opportunities. Substantial energy-saving, emission reduction, and technological advancements are among the primary means to enhance corporate competitiveness, which are critical to the survival and development of smelters [4].

The study on the high-efficiency flue gas collection method for aluminium reduction cells proposed in this paper aims to provide practical solutions and approaches for energy saving and consumption reduction in smelters, while also offering a better platform and space for further studies on waste heat utilization of flue gas [5].

2. Analysis of the Current Status of Flue Gas Collection in Aluminium Reduction Cells

2.1 Structure of Conventional Flue Gas Collection Systems

The flue gas collection system in traditional aluminium reduction cells is a critical component for environmental protection and process control in aluminium production. It is primarily used to capture hazardous emissions, including fluorides and particulate matter generated during the electrolysis process, while ensuring workplace safety and compliance with emission regulations [6].

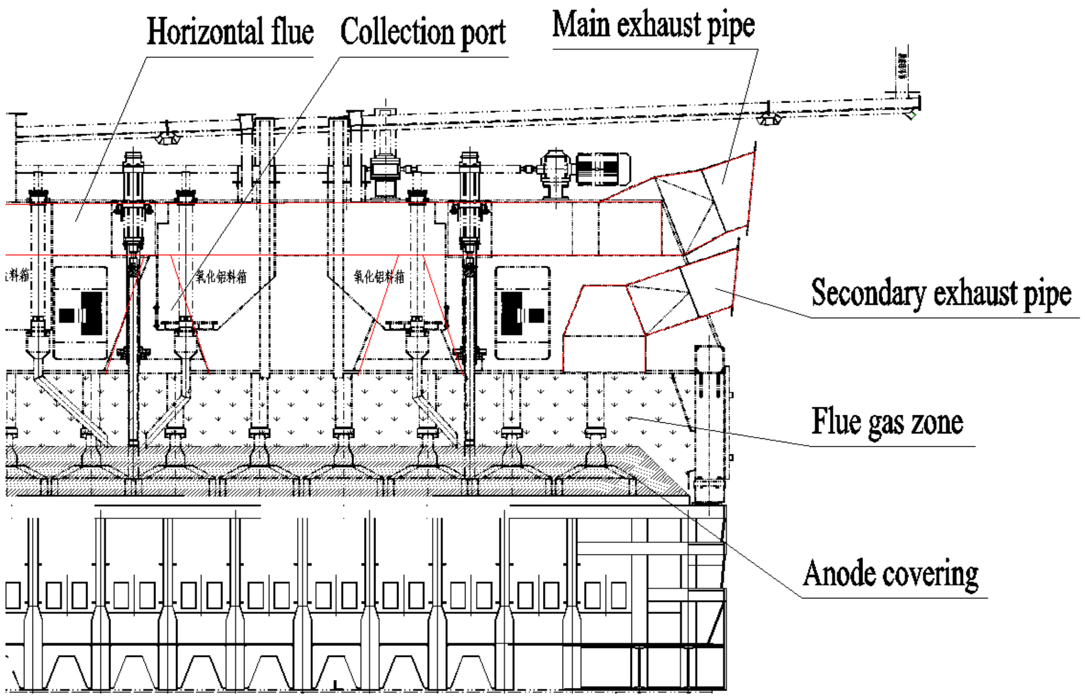

Figure 1. Partial schematic diagram of cell flue gas collection system.

Main components of the flue gas collection system in the cell and related details are as follows (Figure 1):

1) The cell sealing structure comprises the cell doors and hoods, sealing materials, and anode rod seal. The doors and hoods allow openings for tapping, feeding, and anode replacement. Sealing materials, such as asbestos rope or ceramic fibre, are used to fill gaps and edges around openings to prevent flue gas leakage. The anode rod seal employs sealing sleeves or covers around the anode rod to effectively reduce flue gas escape.

5.2 Prospects

The newly designed high-efficiency flue gas collection equipment presented in this study represents a disruptive innovation over the traditional electrolytic flue gas collection system. By capturing and treating flue gas directly at its source, it achieves highly efficient collection of electrolytic flue gas. Centred on energy conservation and equipment renewal, this technology provides smelters with a new development direction, promoting the transformation of the electrolytic aluminium industry toward greater efficiency, intelligence, and sustainability. Moreover, this equipment significantly increases flue gas concentration while reducing heat loss from cells, laying the foundation for further optimization and upgrading of electrolytic processes. This enhances energy utilization efficiency, thereby lowering energy consumption for both smelters and society as a whole. For smelters, reduced energy costs translate to improved economic benefits. For society, reduced energy dependence enhances the security and stability of energy supply while mitigating economic risks caused by energy price fluctuations. This technology has promising industrial implementation prospects.

6. References

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