Industrial Application of Double-Port Energy Saving Technology and HORRS System for Aluminum Electrolysis Cells

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Abstract

This article introduces the basic principle of "Double-port Energy Saving" for aluminum electrolysis cells, as well as the double-port Heat of Output-Side Recovery Regulating System (HORRS) and its industrial application on 400 kA and 500 kA electrolysis cells. By comparing the changes in electrolysis cell voltage, superheat, ledge profile, and current efficiency before and after the operation of the HORRS system, the contribution of HORRS to "input port energy conservation" was analyzed. By regulating the energy flow of the electrolysis cell and effectively accumulating heat, a large amount of recovered heat energy was obtained, and the operational effect and economic benefits of HORRS were evaluated. The results of industrial experiments indicate that the HORRS system has achieved the energy saving targets of both the input and output simultaneously. Due to its significant ability to regulate the thermal characteristics of electrolysis cells, the HORRS system will undoubtedly become an important technology for achieving flexible production in the primary aluminum industry and energy storage and peak regulation of the power grid in the future. It is of great significance for the primary aluminum industry to consume renewable energy electricity and reduce CO_2 emissions.

Keywords: Aluminum electrolysis cell, Double-port energy saving, Thermal characteristics, Industrial application.

1. Introduction

In 2022, China achieved a significant milestone in primary aluminum production, reaching a record high of 40.21 million tonnes, representing a year-on-year increase of 4.4 percent. As a result, China has consolidated its position as the world's leading producer of primary aluminum. Since the inception of the Hall-Héroult process, molten salt electrolysis has remained the sole method for large-scale industrial production of primary aluminum. Over the course of 137 years, the field of aluminum electrolysis has made substantial advancements. However, the production of primary aluminum continues to rely heavily on substantial electricity consumption, with an average DC power consumption as high as 13 kWh/kg Al [1]. This results in approximately half of the energy utilized in aluminum production being lost as waste heat, constituting a significant energy wastage. Consequently, energy efficiency improvements in primary aluminum production have consistently been the primary focus of scientific research in this domain.

Figure 1 illustrates the heat dissipation distribution within the aluminum electrolysis cell. Heat loss in the aluminum reduction cell primarily occurs through three major pathways: heat dissipation from the upper regions, heat dissipation from the shell sides, and the remaining heat loss from the bottom and cathode collector bars. The heat in the upper portion of the electrolysis cell is discharged via the flue gas, accounting for over 50 % of the total heat loss. Although capturing the heat carried away by the flue gas is relatively straightforward, the flue gas temperature is low (120-130 °C), resulting in a low temperature (less than 60 °C) for the medium obtained after heat transfer collection and consequently a low utilization rate. The heat dissipation from the bottom and cathode collector bars is too dispersed to be effectively recovered. On the other hand, convective heat dissipation from the side shells accounts for approximately 35 % of the total heat dissipation and occurs at higher temperatures (240-350 °C), making it the most valuable component for recovery compared to other areas of heat dissipation.

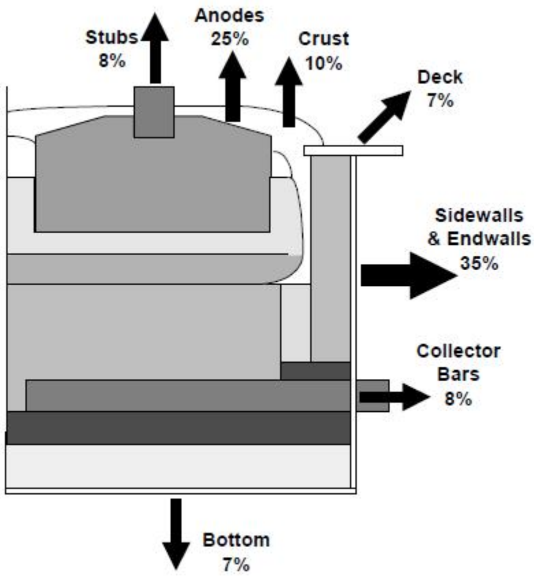

Figure 1. Typical distribution of heat dissipation in aluminum electrolysis cell [2].

The fundamental objective of aluminum electrolysis technology is to minimize energy consumption. The energy consumption required for aluminium production can be calculated using the following formula:

$$W = \frac{298V_{cell}}{\eta} \tag{1}$$

where:

W Energy consumption, kWh/kg Al

V_{cell} Average cell voltage, V

η Current efficiency, %

The primary focus of energy-saving efforts in aluminum electrolysis technology revolves around reducing voltage and improving current efficiency, which falls under the category of "input side energy saving." The core objective of input side energy saving technology is to maintain optimal thermal stability through dynamic optimization of thermal characteristics during operation. However, the progress in the field of input side energy saving is hindered by certain technical challenges:

1) Real time measurements of thermal parameters are impractical due to the corrosive nature of the electrolyte. This makes it difficult to accurately assess the thermal characteristics of the cell in a timely manner.
2) Identifying an adjustment method to achieve the desired thermal characteristics in industrial cells remains elusive. This is primarily due to the theoretical interdependence between the line current control method and the optimal operational objective of electromagnetic stability [3].

400 kA aluminum electrolysis cell. This innovative system combines optimal adjustment of thermal characteristics with heat accumulation recovery and utilization, leading to significant advancements in industrial applications. The HORRS technology effectively reduced the cell voltage in the test cells by optimizing superheat, thereby improving current efficiency, and achieving energy savings on the input side. Next, we plan a large-scale test to demonstrate it. Furthermore, the HORRS system ensures thermal stability even in the face of fluctuating input energy in the electrolysis cell, providing crucial technical support for the flexible production of primary aluminum.

The waste heat recovered from the electrolysis cell through the implementation of the HORRS system is effectively channeled into the heat recovery system and urban heating system of the thermal generator set, marking the successful integration and utilization of thermal energy resources across different industrial systems. This breakthrough achievement establishes a comprehensive "double-port energy saving" technology for aluminum electrolysis and enables the efficient utilization of low-temperature thermal energy resources.

Furthermore, the application of the HORRS system has been extended to a 500 kA electrolysis cell at the Gansu Dongxing Aluminum Industry Co.,Ltd. The system is currently undergoing preparations and is expected to commence operations in September 2023.

6. References

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