

AL23 - Research and Application of Advanced Energy-Saving Technology for Aluminum Reduction Cells

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Abstract

In the current global carbon footprint reduction efforts, primary aluminum industry has attracted much attention. The annual huge electricity consumption of the Chinese aluminium reduction industry accounts for 6.5 % of the total electricity consumption of the whole society in China. Under the pressure of national policies, China's aluminum reduction industry is accelerating its low-carbon and green transformation. In recent years, NFC/NEUI has successively developed a series of energy-saving technologies for aluminum reduction cells, mainly including new energy-saving anode technology, RuC and copper insert cathode energy-saving technology, magnetic fluid super stability technology, thermal balance optimization design technology, etc. These energy-saving technologies are gradually being promoted and applied in 400 kA, 500 kA, and 600 kA aluminum reduction cells in China. Taking the application of RuC technology in 600 kA as an example, it achieved a DC energy consumption of 12 287 kWh/t Al, which achieved significant energy-saving effects compared to saving 566 kWh/t Al.

Keywords: Aluminum reduction cell technology, Research and application of energy-saving technology, Low energy consumption in aluminum reduction cells.

1. Introduction

China is actively adopting stronger policies and measures, aiming to peak carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060. By 2030, China's carbon dioxide emissions per unit of GDP will decline by more than 65 % compared with 2005, the proportion of non-fossil energy in primary energy consumption will reach about 25 %, the forest stock will increase by 6 billion cubic meters compared with 2005, and the total installed capacity of wind power and solar power generation will reach more than 1200 GW.

On August 27, 2021, the National Development and Reform Commission issued a comprehensive tiered electricity pricing policy for the aluminum reduction industry, encouraging aluminum reduction enterprises to improve the utilization level of non-water renewable energy such as wind power and solar power generation, and reduce fossil fuel consumption. In order to promote energy conservation and emission reduction in the aluminum reduction industry, the National Development and Reform Commission has gradually established a differentiated electricity price policy for the aluminum reduction industry. Starting from 2023, the comprehensive AC energy

consumption of liquid aluminum is lower than 13 450 kWh/t Al (excluding desulfurization energy consumption). Starting from 2025, the comprehensive AC power consumption of liquid aluminum is lower than 13 300 kWh/t Al (excluding desulfurization power consumption). Chinese aluminum companies are actively searching for technologies and ideas to further reduce aluminum reduction energy consumption.

In 2022, China's primary aluminum production reached 40.214 million tonnes, accounting for 6.5 % of the total electricity consumption of 8637.2 TWh in 2022. The peak production capacity of primary aluminum has become one of the key industries for carbon emissions peaking. In recent years, the national supply side reform has achieved results, with limited increase in production capacity on the supply side, increased demand for clean energy aluminum on the demand side, and tight supply and demand leading to a high aluminum per tonne profit market. Opportunities and challenges coexist.

The central task for aluminum smelters is to achieve carbon dioxide emission reduction by reducing the overall AC power consumption to less than 13 300 kWh/t Al (excluding desulfurization energy consumption) in 2025; this is the key to the survival of the smelters.

2. Research and Development of Energy-saving and Low-carbon Technologies in China

Since entering the new century, China has made significant progress in the core technology of primary aluminum, with internationally leading technology for high amperage cells. 600 kA aluminum cell technology has been widely applied, and the average energy consumption per unit product has shown a significant downward trend overall. In 2020, the industry's average comprehensive AC power consumption was 13 543 kWh/t Al, a decrease of 500 kWh/t Al compared to 2013.

In recent years, under the requirements of the national energy consumption “dual carbon” policy, one to peak emissions before 2030, and the other to achieve carbon neutrality before 2060, scientific and technological workers in China's aluminum reduction industry have made continuous efforts to develop energy-saving technologies for the cathode structure of aluminum reduction cells, such as graphitized cathode blocks, graphitized cathode blocks with cast iron assembly, large cross-section high conductivity collector bars, copper insert collector bars, etc., which have achieved varying degrees of energy-saving effects in different application scenarios.

3. RuC Technology Research and Application in China

In order to achieve further energy saving and carbon reduction, Shandong Weiqiao group, NEUI, Tokai COBEX and NFC collaborated to develop the “RuC energy-saving, long life, and high yield aluminum technology” with Tokai COBEX patented ready to use cathode (RuC) technology as the core [1, 2].

The RuC stability in cathode voltage drop (CVD) with low electrical contact resistance is achieved despite the lower contact surface area (- 60 %) compared to conventional cathodes. The low level and stable trend of CVD proves the robustness of the cathodic system [3].

This technology has been undergoing industrial trials on NEUI 400 kA and NEUI 600 kA aluminum reduction cells of Weiqiao Group since December 2016, achieving significant energy-saving, production increase, and pot life extension. In order to better respond to the policy requirements of “dual control” of energy consumption and lead industry technological progress, Weiqiao group has started to accelerate the expanded application of RuC technology in 600 kA potlines.

3.1 Key Role of RuC Technology in Improving MHD Stability

The RuC technology has transformed the cathode assembly method, and by optimizing the cathode structure and upgrading the conductive rod material, the average horizontal current has decreased by 65.3 % compared with traditional cathode structure, significantly reducing the electromagnetic forces in the aluminum pad, slowing down the oscillation of the aluminum pad, widening the effective ACD, greatly improving the MHD stability of the aluminum reduction cell, creating fundamental conditions for stable and efficient operation of aluminum reduction cells at lower cell voltage.

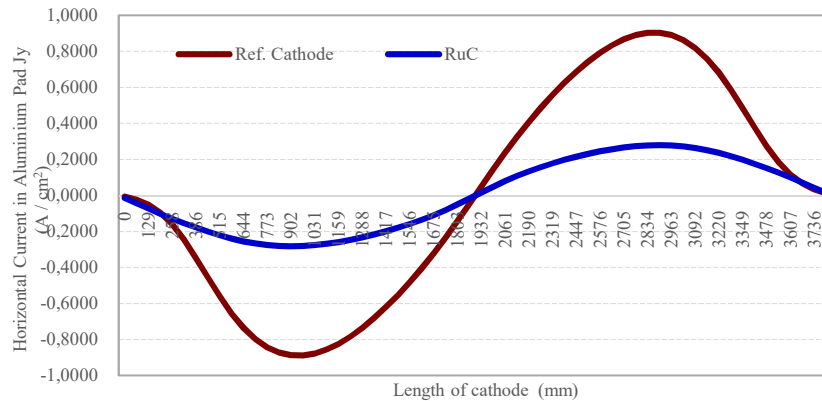


Figure 1. Comparison of simulation of horizontal current distribution in aluminium pad.

Due to the excellent conductivity of RuC, the voltage drop of the 600 kA RuC cell is only about 150 mV, which is 50-100 mV lower than in traditional cathode cells, creating favorable conditions for stable and efficient operation of the reduction cell at low voltage. Figure 2 shows the CVD trend of the 600 kA RuC compared to reference cells over the past 31 months; the CVD of RuC cells is in a relatively stable state for a long time.

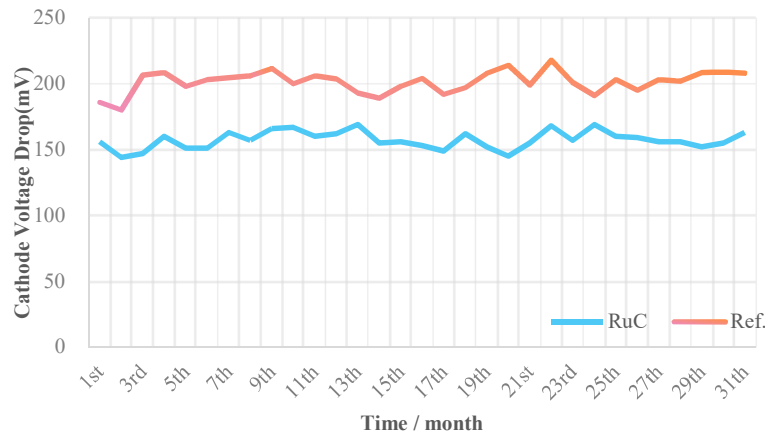


Figure 2. Comparison of CVD trend between RuC and reference cell.

3.2 The Important Contribution of RuC to Extending Pot Life

The RuC technology homogenizes the current distribution on the cathode working surface, significantly improving the uniformity of the current distribution within the cathode carbon block. According to the simulation results, the maximum current density of the cathode working surface has decreased by nearly 30 %. The uniformity of cathode current distribution was significantly improved, which is conducive to reducing the electrochemical corrosion rate.

RuC adopts full copper conductive rods instead of steel rods, reducing the cross-sectional size of the conductive rods by 80 %, which can significantly reduce the thermal stress and deformation of the conductive rod structure, thereby reducing the thermal stress and deformation of the cathode carbon block. The reduced metal volume is replaced by carbon cathode material which increases the distance from the collector bars to the cathode working surface [4].

Due to the structural advantages of RuC itself, under the same height of carbon blocks, the effective life height and overall strength of cathode carbon blocks can be significantly improved, which is beneficial for improving the cell life.

A comparison of cathodic wear testing of two 600 kA RuC cells and two reference 600 kA cells after operating 2 years shows that the maximum annual wear of 600 kA RuC cells is 22.1 mm, while the maximum annual wear of reference 600 kA cells is 31.7 mm. 600 kA RuC cells maximum annual wear is 9.6 mm less than the reference cells, a maximum wear rate reduction of 30.3 %. Based on the testing results, the service life of RuC cells is expected to be significantly extended.

3.3 Lining Configuration and Thermal Balance Design of RuC Cell

The lining configuration of the 600 kA RuC cell comprehensively enhances insulation performance of each area of the cell. The insulation space at the bottom and end of the cathode is improved, the insulation of the bottom and end areas of the cathode is strengthened, and an embedded insulation design on the Si_3N_4 -SiC side blocks is adopted. Figure 3 shows temperature profiles in the 600 kA cell.

Through the optimization of lining configuration and thermal balance design, the RuC cells can maintain an ideal thermal balance state at a low voltage of 3.85-3.90 V, thus giving full play to the core technical advantages of RuC cell with high MHD stability and low cathode voltage drop.

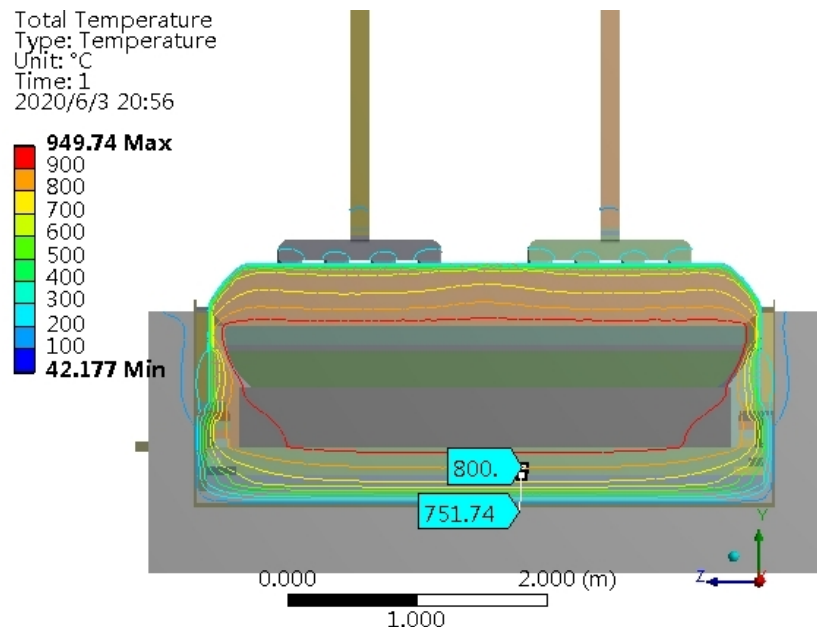


Figure 3. Simulation results of temperature distribution in 600 kA RuC cell.

3.4 Production Process Optimization Technology and Application Effects

In response to the technical characteristics of MHD stability, low cathode voltage drop, and low heat loss of 600 kA RuC, the implementation of this project has formed a complete set of process technical specifications, including lining construction, preheating and start-up and production technical specifications.

As of the end of May 2023, the two 600 kA RuC cells have been operating for 937 and 835 days respectively and achieved excellent main technical and economic indicators. As shown in Figure 4, it can be seen that the operating voltage range of the RuC cells during the normal period is between 3.87 - 3.89 V, while the operating voltage range of the reference cells is between 3.97 - 4.02 V. The average operating voltage of the RuC cells is about 100 mV lower than that of the reference cells.

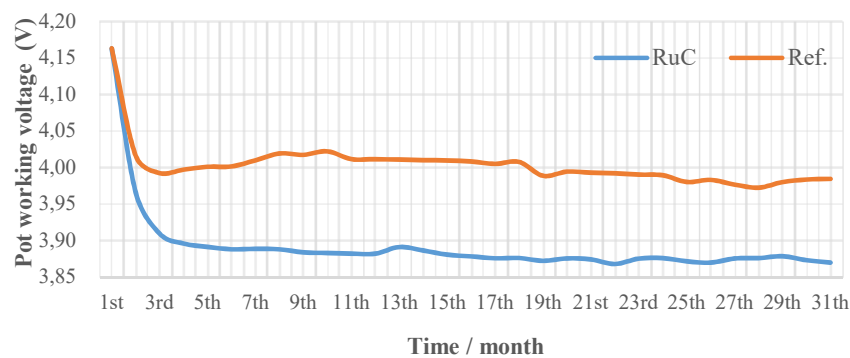


Figure 4. Comparison of working voltage between two 600 kA RuC and reference cells.

As shown in Figure 5, the average current efficiency of two 600 kA RuC cells during the normal period is 94.1 %, while the average current efficiency of the reference cells is 92.0 %. The current efficiency of RuC cells is 2.1 % higher than the reference cells.

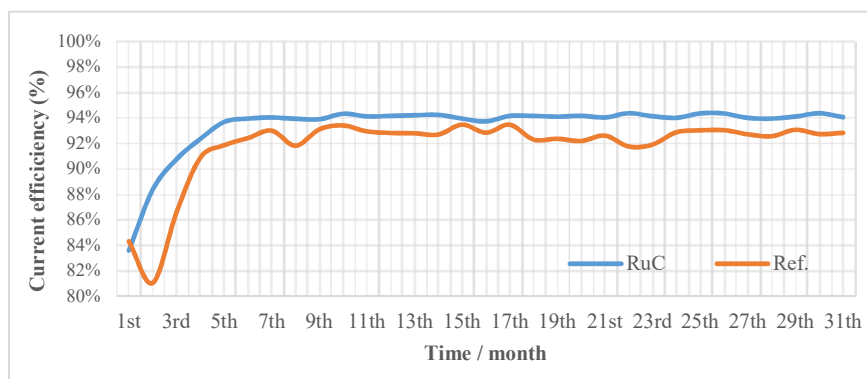


Figure 5. Comparison of current efficiency between 600 kA RuC and reference cells.

As shown in Figure 6, the average DC energy consumption of two 600 kA RuC cells during the normal period is 12 287 kWh/t Al, compared to 12 853 kWh/t Al in the reference cells. The average DC energy consumption of RuC cells is 566 kWh/t Al lower than that of the reference cells.

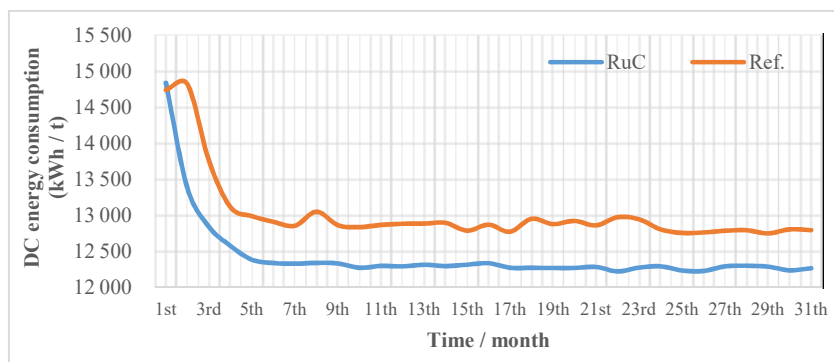


Figure 6. Comparison of DC energy consumption between two 600 kA RuC and reference cells.

4. Conclusions

The new energy-saving and long cell life technology of RuC for aluminum electrolysis developed in this project has achieved industry-leading main technical and economic indicators through application in 600 kA reduction cells.

It is currently the most promising energy-saving technology in the industry, which can achieve significant energy-saving, carbon reduction, and extended cell life. RuC technology plays an important role in promoting technological progress and innovation in the industry, more large-scale applications are underway in China.

5. References

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