Response Characteristics of Zone Resistance in Aluminium Reduction Cell

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Abstract

The aluminium reduction cells can be segmented into several relatively individual zones surrounding the feeders, but the current alumina feeding system still mostly has multiple feeding points to perform simultaneous operations or two groups of feeding points to perform alternately operations, which often results in high or low alumina concentration in certain zones of the cell, leading to faults such as low-voltage anode effects and cell bottom sludge, reducing the current efficiency. The optical fibre current sensor can accurately measure the zone current and individual anode current online, providing conditions for localized independent feeding control method. Zone currents in a 400 kA cell were continuously monitored in this study. The varying characteristics of the resistance in each zone and the cell resistance were analysed. The results indicate that the zone resistance exhibits greater sensitivity to changes in alumina concentration than the cell resistance. Therefore, this paper presents a preliminary method that can either optimize the existing simultaneous feeding control or achieve localized independent feeding control based on the zone resistances obtained from the accurate measurements of zone currents and individual anode currents.

Keywords: Aluminum electrolysis, Optical fiber current sensor, Zone resistance, Localized independent feeding control.

1. Introduction

Prebaked anode aluminum reduction cells contain dozens of anodes. For example, 400 kA and 500 kA electrolytic cells have 48 anodes, while 600 kA electrolytic cells have as many as 56 anodes. These anodes are connected in parallel and collectively carry the electrolysis potline current flowing through the electrolytic cell. Although the potline current has been accurately measured nowadays, the precise value of the current carried by each individual anode remains a great challenge.

The online measurement of individual anode currents was first conducted in the 1970s by Reynolds Metals Company, aiming to detect anode spikes and instabilities. Subsequently, Alcoa also performed measurements of single anode currents and utilized them for independent control experiments during the production process [1]. They adopted the voltage drop method, which involves estimating current by measuring the voltage drop generated by the current flowing through a conductor. This method, known for its simplicity, ease of implementation, and cost-effectiveness, remains widely used in production site research even today. Over time, the measurement positions have shifted from the initial anode rods to the side [2] and top [3] of the anode beam, while the underlying measurement principle remained unchanged. Evans et al. [4] introduced the "many sensors method", employing a sufficient number of Hall sensors to deconvolute the anode current on the anode beam by minimizing interference from the electrolytic cell's background magnetic field. They conducted extensive industrial application tests over several years to monitor changes in anode current [5-7].

The fiber-optic current sensing measurement technology, based on the Faraday magneto-optic effect and Ampere's circuital law, can theoretically eliminate the influence of background magnetic fields and offers high precision. It has now replaced traditional Hall sensors as the primary method for measuring electrolysis potline currents [8]. Our team has taken the lead in conducting experiments using optic fiber current sensors to measure anode currents in aluminum electrolytic cells, verifying the accuracy of measurements of anode currents, pillar busbar currents, and cathode currents [9]. Potocnik et al. [10] subsequently reported similar measurements and compared the high precision characteristics of optic fiber current sensors with other measurement methods. However, due to the inherently high cost of optic fiber current sensors, they have not been used for online measurement of anode currents in electrolytic cells.

Considering the fact of uneven alumina concentration distribution in large aluminum electrolytic cells, independent feeding control for each zone has the potential to significantly improve the uniformity of alumina concentration in the electrolytic cell and greatly enhance electrolysis efficiency [11]. Based on our scheme for measuring individual anode currents using optical fiber sensors [12], we propose a method using 5 or 3 optical fiber loops to measure zone anode currents [13]. Furthermore, we introduce a method utilizing a saddle-shaped optical fiber loop to measure zone anode currents with just one optical fiber loop [14, 15]. Taking an electrolytic cell with 48 anodes and 6 feeding zones as an example, the number of sensors required for measuring zone anode currents is reduced from 48 to 16, 11, or 6, depending on whether 5, 3, or 1 optical fiber loop(s) measurement schemes are used, respectively. Based on an assessment of the benefits achieved, this approach has become economically acceptable for electrolytic workshops.

This paper reports the measurement results conducted by our team on a 400 kA electrolytic cell using a “5 optical fiber loops measurement scheme”. The characteristics of zone current changes and the feasibility of localized independent feeding control based on zone current have been discussed. In addition, the response characteristics of zone currents to anode effects have also been monitored in this study.

2. Experimental Measurement of Zone Currents

The measurement experiments were conducted on a 400 kA electrolytic cell at a specific enterprise. This electrolytic cell underwent major repairs in 2023 and uses a graphitized cathode. It also served as a test cell for low-voltage electrolysis at this enterprise. The electrolytic cell featured 48 anodes and 6 feeders, with each feeder supplying alumina to the surrounding 8 anodes. The alumina feeding control strategy is to alternate underfeed and overfeed, and the feeding speed is equal in 6 zones. The cell voltage is approximately 3.81 V.

In late September 2023, our team installed 6 sensing optical fiber loops on the pillar busbars of the electrolytic cell for online measurement of pillar busbar currents. Simultaneously, sensors for measuring currents in two feeding zones were installed on the horizontal busbars, with a sampling interval of 1 second, to verify the feasibility of optical fiber current sensors. By the end of April 2024, based on the preliminary work, all 16 sensing optical fiber loops were installed on the horizontal busbars, enabling online measurement of zone anode currents throughout the entire cell. And the cell voltage information was collected synchronously. Figure 1(a) illustrates the measurement scheme, while Figures 1(b) and (c) show physical photos of the sensors installed on the pillar busbars and horizontal busbars, respectively. Figure 1(d) presents the real-time zone current data displayed on the industrial control computer used for measurement.

zone resistance in practical processes, a large number of examples are still needed to establish the comprehensive patterns of variation for specific applications.

Finally, it's worth noting that in Figure 6(a), we observed negative currents of up to nearly 30 kA (indicated by the red dashed line) during the occurrence of the effect. Whether this is an artifact of the measurement method itself or indeed caused by local reverse currents induced by effect oscillations in the electrolytic cell is worth further investigation.

4. Conclusions

In this paper, for the first time, we have achieved online measurement of zone anode currents in a 400 kA electrolytic cell using optical fiber current sensors. The difference between the sum of zone currents and the potline current is no more than 2000 A, with a relative deviation of less than 0.5 %. Through the analysis of zone currents and resistances, the following conclusions can be drawn.

1. The anode currents of different zones in the electrolytic cell vary dynamically, with the maximum and minimum currents deviating from the average by up to 20 %. This indicates that the existing feeding control method of adding alumina at a constant rate is unsuitable and leads to uneven alumina concentration distribution and lower current efficiency in the electrolytic cell. Localized independent feeding of alumina based on zone demand is necessary to address the uniformity of alumina concentration.

2. The response trend of zone resistances to alumina feeding is similar to that of cell resistance, suggesting that independent control of alumina feeding for each zone can be achieved by referencing the existing feeding control strategy based on cell resistance. Alternatively, the existing simultaneous feeding control strategy for the entire cell can be further optimized by monitoring zone resistances.

3. The anodic effect first occurs in some individual zones and then spreads to other zones and finally the entire cell. Changes in zone currents and resistances can be used to predict the high-voltage anodic effects.

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6. References

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