Research on Anode Effect Prediction and Pretreatment in the Industrial Aluminium Electrolysis Cell Based on Zone Anode Current

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Abstract

The increasing length of aluminium electrolysis cells has increased the probability of anode effect occurrence, and traditional anode effect detection methods and killing ways are no longer able to meet the requirements of green production of electrolytic aluminium. At present, there exists a significant delay in the judgment of the anode effect, which leads to the emission of PFC (perfluorocarbons) greenhouse gas for a certain period of time before the anode effect begins to be killed. The precise measurement technology of zone current designed by our team was used to obtain the curves of zone current vs. time in this article. It was found that there would be a certain zone where the anode current first decreased before the anode effect presented in the entire cell (or called high-voltage anode effect, HVAE), providing the possibility for early prediction of the anode effect. Further experiments had revealed that HVAE could be successfully weakened by means of adding alumina manually into the zone where its zone current decreased firstly.

Keywords: Aluminium electrolysis cell, LVAE, HVAE, Zone anode current.

1. Introduction

The anode effect (AE) occurring in aluminium reduction cells disturbs the cell operation and is harmful to the environment, since the perfluorocarbons (PFC, mainly CF_4 and C_2F_6), as extremely potent greenhouse gases, are evolved. When the concentration of locally dissolved alumina in the aluminium reduction cell is insufficient or the local current density of the anode increases to its critical current density, AE begins on several separate anodes locally and finally spreads to the whole cell [1]. AE present in one or two local anodes can be called local anode effect or low-voltage anode effect (LVAE) [2]. When the critical current density is exceeded, AE will occur on other anodes and spread in the electrolytic cell, leading to the global anode effect (or called high-voltage anode effect, HVAE) [3, 4]. With the development of large-scale aluminium reduction cells in China, the problem of uneven distribution of dissolved alumina gradually appears in aluminium reduction cells [5], so an increase in low alumina concentration areas causes an increase in the frequency of the AE coefficient.

Some methods, such as the flow-adapted alumina feeding pattern [6], the LVAE detection model [7], and the electricity-based imaging of the alumina distribution [8], have been developed to improve the uniformity of alumina concentration and to reduce the AE coefficient by controlling the feeders individually. However, it depends to the availability of accurate anode current value which can indicate the local alumina concentration. The main methods to measure the anode current are on the basis of voltage drop at different positions on the conductor [9–11], Hall sensors measurement technology [12–15] and fibre-optic current sensing (FOCS) measurement technology [16, 21]. Since FOCS can eliminate the influence of background magnetic fields totally and obtain accurate current data [17–19], it has now replaced traditional Hall sensors as the primary method for measuring the line current of aluminium reduction cells [20].

Owing to the high cost of FOCS, it was difficult to use the FOCS for online measurement of anode current in aluminium reduction cells before 2023. Luckily, a method to measure zone anode current on-line by using 5 fibre-optic loops was proposed firstly in 2023 [22, 23], and it has become economically acceptable for aluminium electrolytic plant. As a result, it is possible to predict the occurrence of AE according to the characteristics of zone current changing obtained by using this method.

This paper reports the measurement results carried out by our team on a 400 kA electrolytic cell by using a 5 fibre-optic loops measurement scheme. The characteristics of zone current changing before and after the onset of HVAE are discussed. Then both the method of HVAE prediction and the method to weaken HVAE are proposed.

2. Experimental Methods

2.1 Measurement Method of Zone Currents

The measurement experiments were conducted on a 400 kA-electrolytic cell, which had 6 feeding points evenly distributed over the space. So, this cell can be divided into 6 zones according to the feeding point, as shown in Figure 1 (a). Each zone contains four anode rods on the A side and four on the B side. Figure 1 (b) shows 5 fibre optic loops measurement scheme [22, 23]. Six fibre optic loop sensors was installed on the riser buses of the 400 kA electrolytic cell for online measurement of riser bus currents (IR1 – IR6), respectively, and sensors for measuring currents in two feeding zones (Ia1 – Ia5, Ib1 – Ib5) were installed on the anode beams of both the A side and B side simultaneously as shown in Figure 1 (a). Figure 1 (c) presents the online zone current data displayed on the industrial computer.

2.2 Feeding Reduction Experiment for Single-Zone to Produce Artificial HVAE

The feeding method for this 400 kA electrolysis cell is that, Zone 1, Zone 3 and Zone 5 are fed simultaneously, and then Zone 2, Zone 4 and Zone 6 are fed simultaneously as well. So, both the odd number zones and the even number zones are fed by means of the alternate feeding patterns, as shown in Figure 2 (a), in which a vertical line represents one feeding operation for the corresponding zone.

The feeding reduction experiment for designated single-zone was designed to produce artificial HVAE. Taking the feeding reduction experiment of Zone 1 located on tap end shown in Figure 1 (a) as an example, the feeding amount of Zone 1 was set to 0 firstly. Then the feeding mode of Zone 1 can be carried out by following the automatic feeding mode of Zone 3 and Zone 5. It means Zone 1 can be fed manually by using the manual feeding function on the control machine of electrolysis cell once both Zone 3 and Zone 5 are fed automatically. The advantage of this manual feeding method is that, the feeding mode of Zone 1 always keeps pace with the automatic feeding mode of Zones 3 and 5, no matter whether the whole feeding mode of this aluminium electrolysis cell is on the process of under feeding (UF) or over feeding (OF). Finally, if Zone 1 needs to be stopped feeding, it can be carried out by skipping manual feeding mode of Zone 1 after both Zone 3 and Zone 5 are fed automatically. Therefore, the feeding records of different zones during the feeding reduction experiment of Zone 1 were shown in Figure 2 (b), which illustrates the feeding records of Zone 1 by manual feeding mode and those of both even zones (Zone 2, Zone 4 and Zone 6) and remaining odd number zones (Zone 3 and Zone 5) carried out by automatic feeding mode. In order to produce artificial AE, the manual feeding mode of Zone

4. Conclusions

In this paper, the change characteristics of zone currents with time were discussed in detail firstly, and then a feeding reduction experiment for a single zone was carried out to produce artificial HVAE. Finally, HVAE was pretreated by means of adding the alumina to the specific zones according to the characteristics of zone current changing before and after the occurrence of HVAE.

1. There is a certain zone where its zone current decreased firstly before the occurrence of HVAE. This feature makes early prediction of the anode effect possible, which is more efficient than the prediction methods carried out on the basis of the bath voltage.
2. The change of zone current for HVAE which is produced artificially by the feeding reduction experiment for single-zone is similar to that for HVAE occurring normally during production. HVAE can be weakened successfully by feeding alumina to the specific zone manually for several times according to the linear variation characteristics of zone current with time in this zone.

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6. References

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