Research on Different Characteristics of a Cell and the Implementation of Local Alumina Control

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Abstract

This paper conducted an analysis on different characteristics in a cell operated by an aluminum smelter. There is a gradient in the distribution of bath temperature, superheat, and alumina concentration in the same cell. Aimed at these different characteristics, an industrial test on the local control of alumina concentration was implemented for 6 months. The results showed that the current efficiency of test cells increased by 0.51 % compared to reference cells, the DC energy consumption decreased by 62 kWh/t Al, and the anode effect frequency was decreased by 40 %. The test showed that the local control technology of alumina is promising, and it will be extended to more cells in aluminum smelters.

Keywords: Aluminum electrolysis cell, Local control of alumina, Industrial testing, superheat.

1. Introduction

During the past century, many significant technological advancements have been made since the invention of Hall-Héroult method. It still is the only way to produce primary aluminum at commercial scale. The aluminum electrolytic cell is the heart of metal extracting, which has experienced a gradual increase in capacity from 4 kA to 600 kA. Now the cell size or capacity stills shows an increasing trend, some authors even discussed the possibility of 1 MA cell [1].

The 500 kA cells discussed in this paper were designed by Shenyang Aluminum & Magnesium Design & Research Institute Co., Ltd. (SAMI), and produce about 500 000 tonnes of aluminum per year. The reaction area (also called bath layer) inside the cell is about 20 meters long, 4 meters wide and 0.20 meters high. In such a huge space, the operation is managed by computer control (cell controller):

1) The cell controller manages the cell voltage or the anode-cathode distance (ACD) by monitoring the change of cell resistance with alumina concentration [2, 3];
2) The alumina is fed by several feeding points distributed along cell, to keep the alumina concentration in the bath in a narrow range of 1.5 % to 3.5 % and thus avoid anode effect and sludge [4].

In recent years with the increase of cell size, especially with the use of 500 kA, 600 kA cells, there are some new problems coming to light. The anode effect control, voltage control (operating voltage - set voltage) and alumina control are getting difficult comparing with previous small cells. For instance, the possibilities of high anode effect frequency (especially local anode effects) are higher in larger cells than in small cells. An anode effect is declared when the cell voltage becomes greater than 8 V for more than 15 s, while a local anode effect occurs in less than 15 s. Some local anode effects can be terminated automatically, but some can spread to other anodes and grow up to a full anode effect. In this direction, the sensitivity of cells management became one of the hottest topics in these days.

Focused on different characteristics in the same cell, the first part of this paper describes the measured and analyzed distribution of bath temperature, superheat and alumina concentration. The second part was carried out as an industrial test for 6 months to optimize the spatial gradient of alumina concentration. The third part shows some results after the implementation of local alumina control technology.

2. Research on Different Characteristics in the Same Cell

2.1 Bath Temperature and Superheat

Bath temperature and superheat are two key parameters for the cell control in the production of metal. Most previous papers focused on the distribution in different cells [5, 6], ignoring the variability of temperature and superheat distribution in the same cell.

Only 6 cells were selected (Cell No. 1508 to 1513) for temperature and superheat measurements. In order to get more accurate data, some key rules are listed here:

1) Thermocouple probes, used for bath temperature measurement, needed to be calibrated before the test;
2) The thermocouple probes were inserted into the bath at 10 cm to 15 cm from tap-end hole and duct-end hole for the purpose of measuring in the ACD layer. After the temperature measurement, bath samples were quickly scooped out by spoons.
3) The most important rule was to strictly follow the principle of simultaneous temperature measurement and sample scooping at the tap-end hole and duct-end hole.

After the temperature measurements and sampling, the bath samples were sent to the smelter laboratory for liquidus temperature determination. Then the superheat could be calculated as bath temperature minus liquidus temperature. The solidification of the bath is exothermic, reflecting in the temperature curve as an obvious plateau. The temperature of the plateau is the liquidus temperature. The equipment, bath crucible and temperature curve are shown in Figure 1.

Table 1 lists bath temperature and superheat. In order to get data under different cell conditions, three measurements were carried out for each cell in three days (day 1, day 3 and day 5). The average bath temperature at tap-end is 933.7 °C. The average bath temperature at duct-end is 932.3 °C. Bath temperature at the tap-end is 1.4 °C higher than that of the duct-end. The superheat at the tap-end (9.8 °C) is also higher than the value of 9.1 °C at duct-end. Prof. Naixiang Feng summarized in his book [6] that the superheat is usually between 8 °C and 10 °C. It can be seen in Table 1, that the average superheat in six cells is higher than 9 °C both at the duct-end and tap-end, which indicates that the superheat control is good in this smelter.

Table 2 shows the standard normal distribution of superheat. The mean value is 9.8 °C and the standard deviation (σ) is 3.1 °C at tap-end. The mean value is 9.1 °C and the standard deviation (σ) is 4.0 °C at duct-end. It also can be seen that there are some superheats smaller than 5 °C. Considering that bath temperature decreases by 4.7 °C during anode change [7, 8], the alumina may have dissolution issues in the bath near new anodes. Some optimization methods should be carried out for better control of superheat, which may be the work in the future.

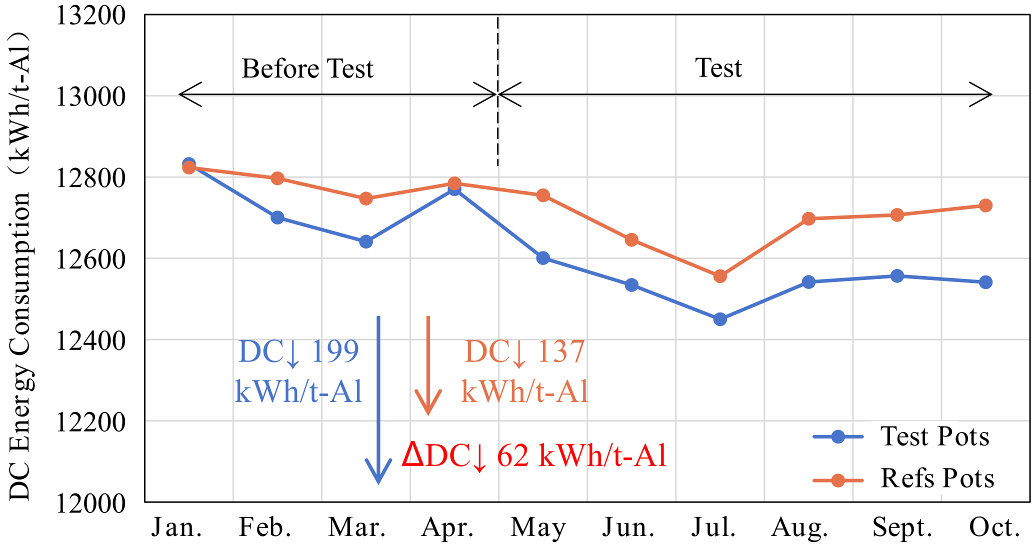

Figure 11. Comparison of DC energy consumption before and after the test.

4.3 Anode Effect Frequency

The average anode effect frequency of reference cells during the test was 0.05 AE/cell·day. The average anode effect frequency of test cells was 0.03 AE/cell·day, which was 40 % lower than the anode effect frequency of reference cells at the same time.

5. Conclusions

(1) Different characteristics of a 500 kA cell were measured in this paper. Bath temperature, superheat and alumina concentration in the half-cell near tap-end are slightly higher than that near the duct-end. A six-month industrial test was carried out to fix this problem.

(2) The local control of alumina concentration was put forward to optimize the spatial gradient. The cell was divided into six sub-regions, and the alumina was monitored and controlled individually in each region according to alumina feeding, transport and consumption. This is an active control for the gradient of alumina concentration.

(3) The individual anode current was used for anode effect detection and termination. The anode effect can be detected 120 s to 300 s before it occurs. The single point feeding technique then is applied for one break or one shot of alumina near the troubled anode. This is a passive control for the gradient of alumina concentration.

(4) Through the implementation of local control in 6 months, the current efficiency of test cells was increased by 0.51 %, the DC energy consumption was reduced by 62 kWh/t Al, and the anode effect frequency was reduced by 40 %. The test showed that the local control is promising, and it will be extended to more cells in the aluminum smelters.

6. References

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