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A study on changing regularity of temperature of aluminum reduction cell

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Abstract: *The stability of aluminum reduction cell is the fundamental guarantee for high efficiency and low energy consumption of aluminum electrolytic production. Temperature stability is an essential feature of and basic guarantee for the stability of a cell. In this paper, based on industrial tests on the 300kA industrial cells and a large number of data mining research on it, some regularities of periodic fluctuation of the cell temperature are found along with the feeding circles and the seasons. The relationship among cell temperature, feeding cycles and local air temperature has been studied. In the end, some suggestions for primary aluminum production are provided to improve daily temperature measurement, alumina feeding control strategies and energy balance according to local meteorological data in different region.*

Keywords: *Aluminium Reduction cells, Change Regularity of Temperature, Stability of cells, Feeding circle*

1. Introduction

In the process of aluminum electrolysis production, the stability of aluminum reduction cell is the fundamental guarantee for normal production, which the high current efficiency and low energy consumption are based on. The temperature is often not only a key indicator but also a basic guarantee of the stability of cells. Usually, the temperature is measured once a day during the production of the cells to monitor the status of cells. All of smelters are trying to keep a stable temperature of cells. The questions are if there are some changing regularities of the cell temperature and what is the relationship among the temperature, other factors and production parameters. In the present work, it was studied by means of data analysis and test on 300kA aluminum reduction cells.

2. The cyclical fluctuant temperature of aluminum reduction cells

To research on the detailed characteristics and regularities of the change of the temperature of cells, we monitored the temperatures of the cells continuously on the 300kA aluminum reduction cells, and the variation of the temperatures was recorded continually in real time. Shown in figure 1, the sampling interval of data was 2 minutes, and the blue curve was the real-time data of the temperature, the red curve was the moving-average trend line of the filtered real-time data.

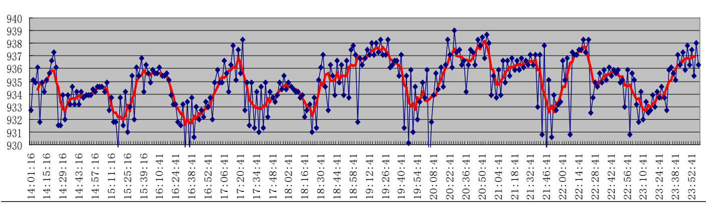

Figure 1: The temperature flunctation of a cell in a day

Fig.1 exhibits that the temperature of cells fluctuates cyclically with the fluctuating range of at least 5℃ or up to 10 ℃. It is an interesting and puzzling phenomenon. In the routine production, the cell temperature is measured once a day at an irregular interval. If so, there will be 5-10℃ errors if it measured at between a peak and a valley of the cell temperature curve. What's at the bottom of it?

We studied instantly the process data and curves recorded by the control system, which are some data of control parameters and some data of cell running status, during the trial time to find some clues. Part of data is shown in Fig. 2. It shows that some curves are waving cyclically, such as feeding cycles, cell resistance, cell voltage and the slope of cell resistance, which are caused by the feeding method to control the concentration of Al2O3. Is that the reason for the temperature fluctuation of a cell in a day?

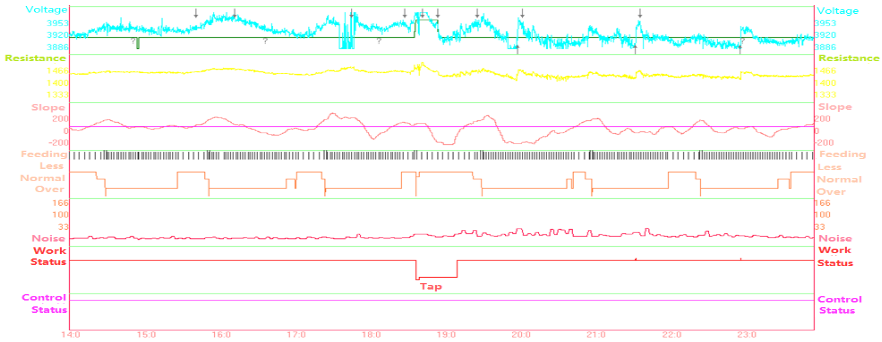

Figure 2: The curves of process data during the trial

3. Feeding model for controlling the concentration of Al2O3

The theory of controlling the concentration of Al2O3 and feeding alumina into cell is shown in Fig.3[1,2]. The goal of feeding is to control the concentration of Al2O3 in the Working Zone. Out of this range, if lower, the Anode Affect will happen frequently, and if higher, the slope will be not change evidently which is essential for Al2O3 concentration control and the slug will be caused.

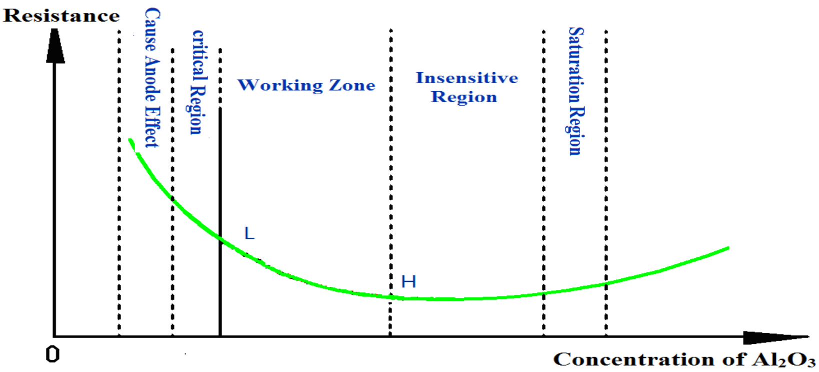

Figure 3: The theory of controlling the concentration of Al2O3 and feeding

In the Working Zone, the concentration of Al2O3 is controlled back and forth between point H and point L by Over Feeding and Less Feeding. This is a dynamic balance process. During these periods, the resistance and the voltage will be changed continuously and cyclically. During Over Feeding process, the concentration of Al2O3 goes up from L to H, and the resistance and cell voltage will be up at the same time. During Less Feeding process, the concentration of Al2O3 goes down from H to L, and the resistance and cell voltage will be down simultaneously。 The control system identifies the concentration of Al2O3 by the change of cell resistance and the slope of it. Therefore, these curves are waving cyclically.

4. The effect of feeding cycle on the fluctuation of temperature

In order to study the fluctuation of temperature, a cell running was controlled for a longer Over-feeding firstly, which input 30% more alumina into the cell than Normal-feeding every time and the concentration of Al2O3 was pushed to Point H gradually, and then run for a longer Less-feeding, to input 30% less into a cell than Normal-feeding, the concentration of Al2O3 was moved to Point L gradually. The temperatures, the cell voltages and the concentration of Al2O3 of cells were traced and recorded during the tests, shown in fig.4. The red point is the shift point between Over-feeding process and Less-feeding process, where the concentration of Al2O3 is a little more than point H in Fig.3 and the cell voltage just begin to rise.

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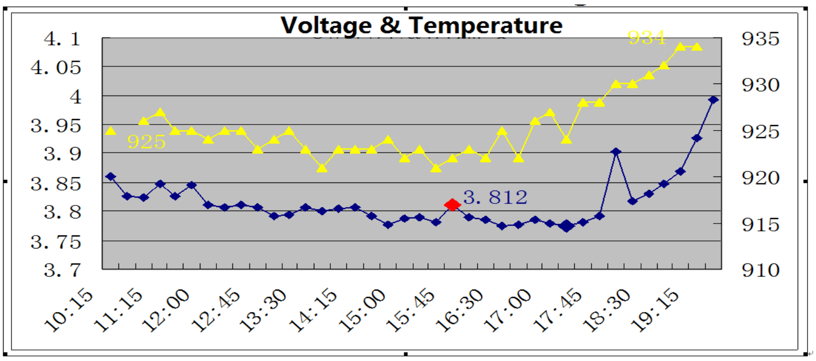

Figure 4: The voltage and temperature during the over feeding and less feeding periods

Shown in the fig.4, during the process of over-feeding, both the voltage and temperature go down, and during the process of Less-feeding, both of them go up. From that test, it is confirmed that the cyclical fluctuant temperature of aluminum reduction cells is caused by the feeding cycles in a short term, such as in a day.

There are two factors, one of which is the variation of voltage causing the variation of energy input into cells, and the other is the variation of Al2O3 quantity fed into cells during over-feeding period and less-feeding period. They result in the variation of the energy needed to heat the Al2O3, and change the temperature cyclically [3-5]

$$Q=0.3356*I*\eta*1.91 \quad (1)$$

where: I=300kA cells, if current efficiency,ηis 0.92, and 30% more or less alumina than normal feeding, that is, 0.88kg more or less fed into cells than normal feeding. Using the following equation, the energy needed can be calculated more or less than normal to heat the Al2O3

$$Q_{bath}*C_{bath}*(T-T_x)=Q_{Al2O3}*C_{Al2O3}(T_x-T_0) \quad (2)$$

Qbath: quantity of bath in cells

Cbath: specific heat of bath

T: original temperature of cells

Tx: temperature after heating the Al2O3

Q Al2O3:quantity of the Al2O3

CAl2O3:specific heat of Al2O3

T0: original temperature of the Al2O3

According Eq. 2, the temperature would change at speed of 0.05℃ per minute during the process of 30% more or less alumina feeding than Normal-feeding.

At the other hand, the input energy varies with voltage variation according Eq.3. During the Over-feeding period, the cell voltage would go down and the input energy would be decreased. During the Less-feeding period, the cell voltage would go up and the input energy would be increased:

$$\Delta U*I= Q_{bath}*C_{bath}*T \quad (3)$$

The variation of Al2O3 concentration causes variation of cell voltage. Basically, it would cause the temperature change of cells at a speed of 0.02-0.05℃ per minute by the calculation based on the test data.

Comprehensively, the cyclical fluctuation of cell temperature is about 3℃-6℃during a feeding cycle due to both the variation of heating Al2O3 and the variation of cell voltage. In a short term, among various factors, the effect of the alumina feeding cycle to change the cell temperature is most apparent.

5. Seasonal fluctuation in the cell temperature

As the effect of the alumina feeding cycle on the cell temperature through the test and data analysis, a new phenomenon was discovered by means of data mining on a lot of measure data on cells. It is that a cell status is cyclically changed along with the local air temperature annually. That is, the effect of the

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environmental temperature on cell temperature cannot be ignored.

Firstly, the temperatures of outside walls and bottom of cells were analyzed in about two years. The temperatures of two cell bottoms measured on different point in the bottom of two cells are shown in Fig.5. It can be seen that the temperatures of different point on one cell are very similar at the same time, but there is difference between two cells.

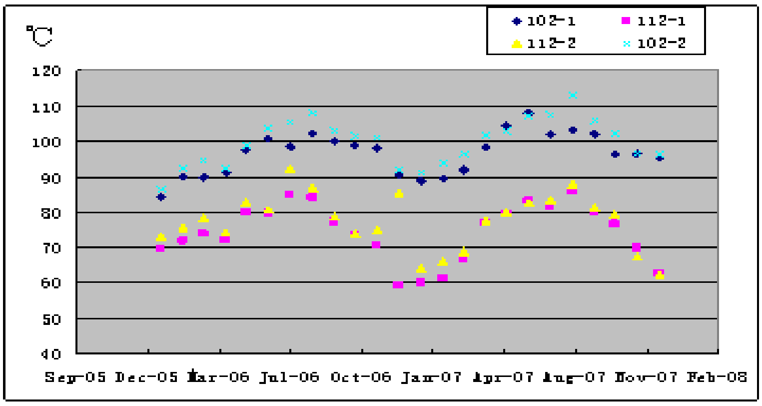

Figure 5: Temperature of a cell during two years

As shown in Fig.5, the temperatures of cell bottom fluctuated periodically in a year while the temperatures of cell inside and cell outside wall did not. What is the reason for it? Usually it is known that the temperature of bottom and the temperature of outside wall for a cell are affected by both the cell temperature and the environmental temperature. And then the collection of local meteorological data and the average environmental temperature is shown in Fig.6.

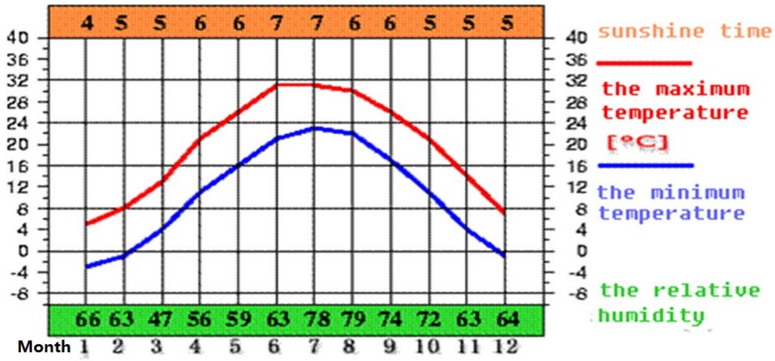

Figure 6: The local annual range of temperature

By comparing Fig.5 and Fig.6, it is found that the trend of the temperature variation of cell bottom is very similar with that of local air temperature in meteorological data. The variant amplitude is about 30℃ and the peaks lean to right. It is a good illustration that the temperature of cell bottom was at the same isotherm of the cell inside temperature, and would move up or down along with the seasonal change of air temperature, but the cell temperature didn’t change along with air temperature directly because of the manual intervention and the self-adjustment on thickness of side-wall of the cells.

A seasonal influence factor of environmental temperature is established affecting cell inside temperature based on the cell voltage by means of data mining, seen in Eq.4.

$$j=F(V_{set},V_{work}) \tag{4}$$

j: a seasonal influence factor

Vset: cell setting Voltage

Vwork: cell working Voltage

F: a function, the number of days Vwork > Vset in a month

A seasonal factor of all measured cells is calculated and shown in Fig.7. It is clear that the trend of the seasonal factor is very similar with that of the local air temperature as well. The data in July and August is a little lower than the tendency because the suction quantity of exhaust gas of cells in those two month is more than that in other months to release heat, which is usually a counter-measures in summer.

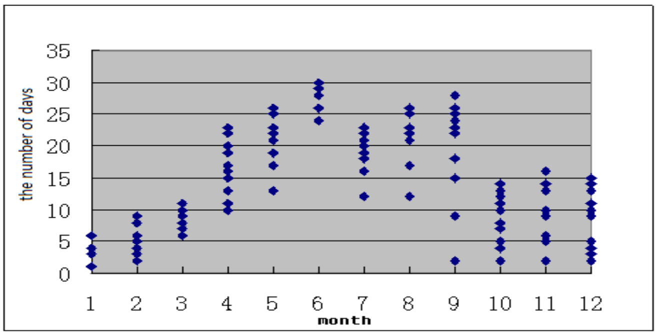

Figure 7: A seasonal influence factor of environmental temperature affects cell temperature

It is useful for operators and the control system to adjust the cell according to the seasonal factor, and helpful for the smelters anywhere to adjust their control strategies according to the local meteorological data and the seasonal influence factor.

6. Conclusions

Based on industrial tests and a large number of data mining research on the 300kA large industrial cells, some results and some improvement advices are reached and provided as follows:

1) The cyclical fluctuation of cell temperature in a day is mainly due to the alumina feeding to control the concentration of Al2O3, which causes cell temperature going down in Over-feeding period and going up in Less-feeding period;

2) The seasonal fluctuation of the cell temperature and the seasonal factor of the local air temperature affect the cell temperature, while the seasonal effect is not reflected directly by the data of cell temperature.

The results gained in the present work would contribute to stability of cell status and energy saving production of prime aluminum through the stability control of alumina concentration, reduction of the cell temperature fluctuation caused by feeding control model, precise measurement of cell temperature, and adoption of seasonal regulation mode according to local climate characteristics.

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