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ALUMINUM REDUCTION TECHNOLOGY

Enviroment- Emissions / Anode Effect II

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On Continuous PFC Emission Unrelated to Anode Effects

Wangxing Li, Qingyun Zhao, Jianhong Yang, Shilin Qiu, Xiping Chen
Zhengzhou Research Institute of CHALCO, Zhengzhou, China, 450041
China National Engineering & Technology Research Center for Aluminum, Zhengzhou, China, 450041
Jerry Marks
J Marks & Associates, LLC, 312 NE Brockton Dr, Lees Summit, MO 64064
Chris Bayliss
International Aluminium Institute, London SW1Y4TE, United Kingdom

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Abstract

An investigation was made into operating parameters that could result in continuous PFC emission unrelated to anode effects in two smelters. Anode current distribution was measured in QY smelter. No obvious correlation was observed between the non-homogenous anode current and continuous PFC emission. Bath temperature and alumina concentration were synchronously measured during continuous PFC monitoring in LX smelter. No continuous PFC emissions were observed when reduction cells are operated at stable bath temperature and alumina concentration. No clear relationship emerged among these factors and further surveys need to be made in other smelters. The effect of feeding mechanism was also investigated. Metal tapping and anode exchange can disturb cells' balance, which result in cell voltage rising, and then may cause continuous PFC emission. It is found that the continuous PFC emission only occur in some particular cells and is different from cell to cell even with the same line current. The continuous PFC emission is only a small portion in total PFC emission.

Introduction

PFC survey was performed in CHINALCO smelters (1) using accepted IAI/USEPA measurement methodology. The survey was done in different running statuses such as normally-operated, power-limit, newly-started and new control-mode. PFC emission of normally-operated smelters is close to that of western ones (2). During this survey non-AE PFC emission, however, also called as continuous PFC emissions were first observed. These continuous PFC emissions occurred when no anode effects were taking place. What caused these continuous PFC emissions? Is it universal for all cells or particular for certain cells? Could it be eliminated? A research plan to study continuous PFC emission from Chinese smelters was made in China National Engineering & Technology Research Center for Aluminum/Zhengzhou Research Institute of Chalco (ZRI). Results from the first phase of the study are discussed in this paper.

Research Plan and Objectives

The existence of continuous PFC emission is like a puzzle. A research plan was developed in ZRI to solve the puzzle. Two smelters were selected to perform studies on continuous PFC emission in the first phase of the plan. One is a pilot plant (code QY), and the other is a common industrial smelter (code LX). QY has two potlines, 320kA cells and 162kA cells respectively. LX has three potlines, all are 176kA cells.

Investigation Objectives in QY smelter

Single-cell studies were performed on two 320 kA cells. Objectives of the study were as follows: (a) Determine the proportion of continuous emissions unrelated to anode effects to the overall PFC emissions. (b) Determine if continuous emissions occur in all cells or in only a few cells. (c)Determine if continuous emissions could take place as a result of non-homogenous current distributions among cell anodes.

Investigation Objectives in LX smelter

Single-cell measurement was performed on two 176 kA cells which belong to different potlines in LX smelter. The purposes are to determine if bath temperature, feeding mechanism and alumina concentration are the factors affecting continuous PFC emissions.

Results and Discussions

Investigation in QY Smelter

Gas sample came from two different single cells. Cell numbers were QY-320-6 and QY-320-7.
Monitoring duration for QY-320-6 was eleven hours. Two AE peaks were collected (see Figure 1a). The maximum CF_4 emission rate is 0.463 g/s. And CF_4 emission is almost zero when there are no anode effects (see Figure 1b).
Results are shown in Figure 2a from QY-320-7 during six-hour measurement, during which one AE peak was monitored. The maximum CF_4 emission rate is 0.848 g/s. During most of measurement period, CF_4 emission is close to zero when no anode effects occur (see Figure 2b).

Anode Current Distribution Measurement Anode current of cells was usually measured with Millivolt Fork. Voltage drop is measured on every anode rod between two probes at fixed distance apart. The current in each rod is:

$$I_i = \frac{\Delta V_i}{R_i} = \frac{\Delta V_i A}{\rho(T_i)L}$$

Where: ΔV_i = mV drop, R_i = resistance of the rod between the fork tines, A = cross-section of the rod, ρ_i = resistivity of the rod (function of rod temperature T_i between the tines), L = distance between fork tines.
In cell control practice it is assumed that all the rods have the same

temperature. Then, the resistance is the same in each rod and will fall out in the calculation. The sum of measured electric currents in individual rods is then easily normalized to the line current. Measured current distribution in anode rods is normalized to line current in the following way:

$$I_{i-norm} = \frac{(\Delta V)_i}{\sum_{1}^{N} (\Delta V)_i} I_{Line}$$

Here, $I_{i\text{-}norm}$ = Normalized current in each anode rod, kA; I_{Line} = Line current, kA; $(\Delta V)_i$ = Individual rod voltage, mV; N = Number of anode rods.

Anode current of two QY-320 cells was measured, calculated and plotted (see Figure 3).

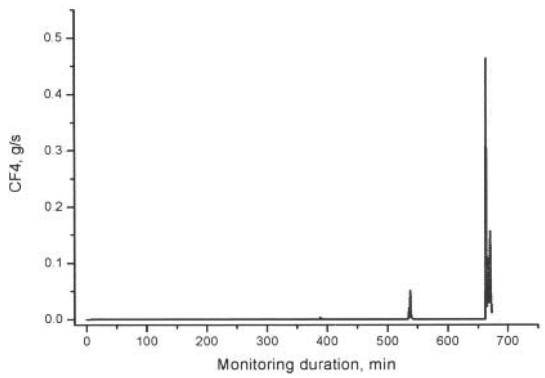

Figure 1a Original CF_4 Emission Trace of QY-320-6

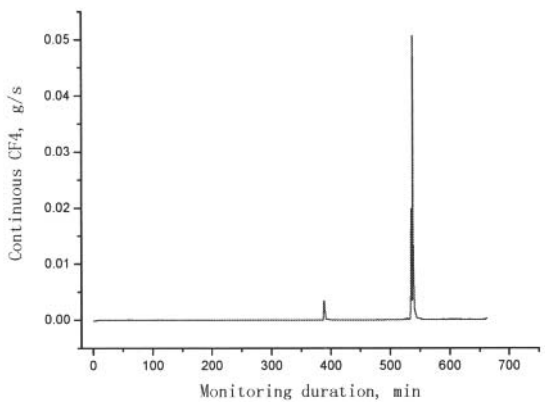

Figure 1b Continuous CF_4 emission of QY-320-6

Graph 1b came from graph 1a by cutting the AE peak which appeared after 660 minutes' monitoring, they took over the same measurement period of QY-320-6. Graph 2b came from graph 2a by cutting the AE peak which came forth after 350 minutes' monitoring, they also described the same measurement period of QY-320-7.

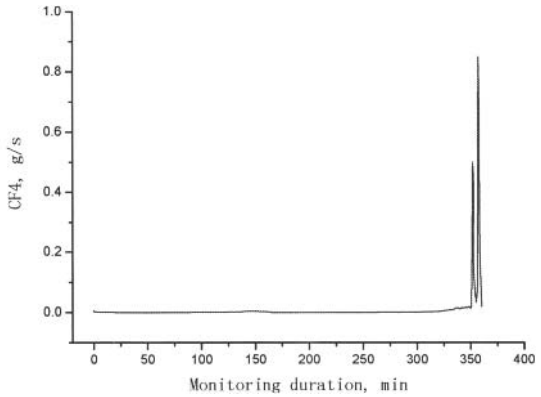

Figure 2a Original CF_4 Emission Trace of QY-320-7

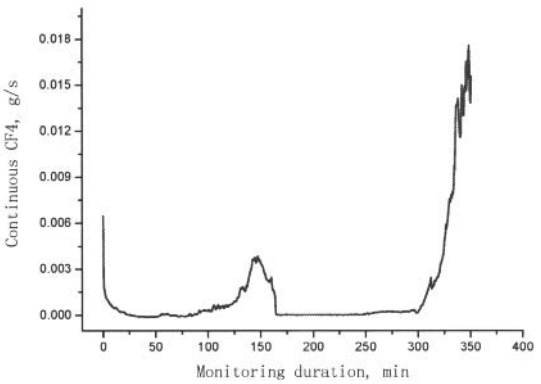

Figure 2b Continuous CF_4 emission of QY-320-7

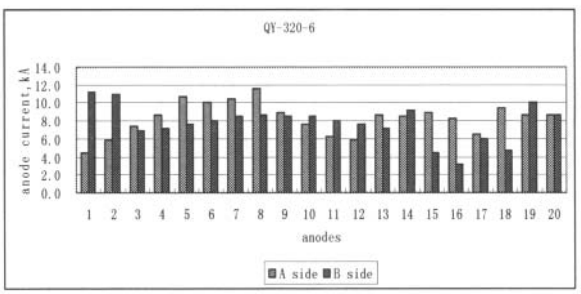

Figure 3a Anode current distribution of QY-320-6

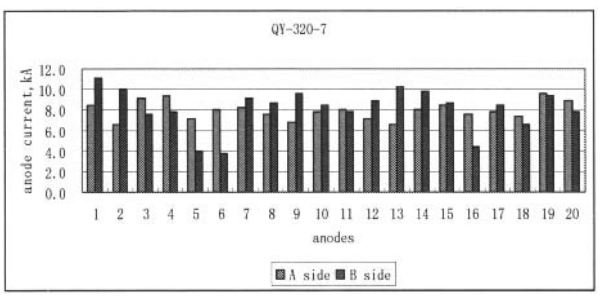

Figure 3b Anode current distribution of QY-320-7

Anode current distributions of QY-320-6 and QY-320-7 were measured once two hours. First current measurement was performed when PFC monitoring had gone on 120 minutes. The mean value of five measurements from QY-320-6 was plotted in Figure 3a. Three measurements were performed on QY-320-7 and the mean value was plotted in Figure 3b.
Anode current distribution in QY smelter is similar to anode current distribution variability measured in Western cells (3). There is no obvious relationship between maximum anode current and continuous PFC emission.

Percentage of Continuous PFC Total CF_4 and non-AE CF_4 from two cells were calculated (see Table I). Continuous PFC emission is only small portion of the measured PFC emissions from 320 kA cells. There are different CF_4 emissions from different cells even with the same line current.

Table I Proportion of Continuous CF_4 Emission

Cell number	Total CF_4	AE CF_4	Non-AE CF_4	Ratio, %
QY-320-6	188.55	183.05	5.5	2.91
QY-320-7	443.74	417.29	26.45	5.96

It can be learned from investigation in QY smelter that continuous CF_4 emissions are only small portion of the total PFC emissions. The amount of continuous PFC varies from cell to cell from near zero to a detectable level. The measured variability of current flow among the anodes is similar to that of Western reduction cells. There was no clear correlation of continuous PFC emission with maximum anode current.

Investigation in LX smelter

Single-cell measurement was performed on two 176 kA cells which belong to different potlines in LX smelter. The purposes of this investigation were to determine if bath temperature, feeding mechanism and alumina concentration affect continuous PFC emission.
Results from LX176-334 cell Exhaust gas from LX176-334 cell was sampled and monitored continuously for 47.54 hours. No AE peaks were observed. Continuous CF_4 emission was almost zero during the whole measurement (see Figure 4).

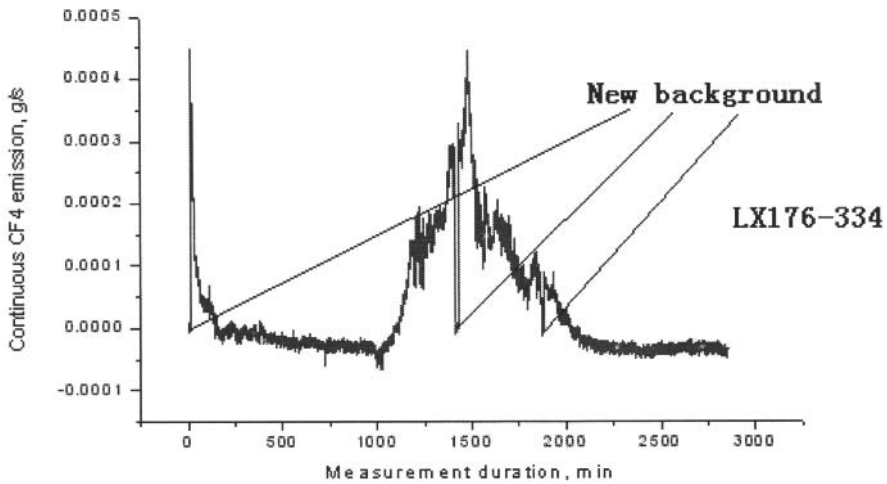

Figure 4 CF_4 emission trace of LX176-334

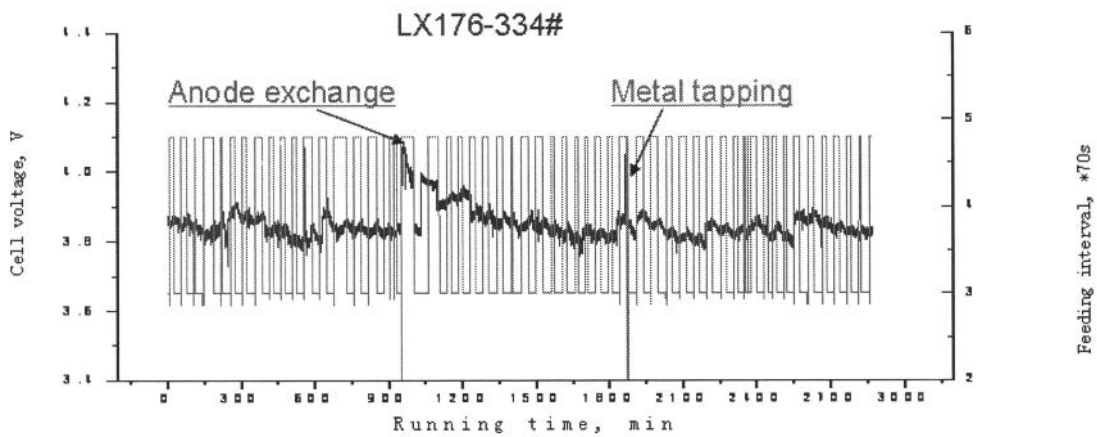

Figure 5 Trends of cell voltage and feeding interval during measurement

During measurement, the change trend of feeding interval is described in Figure 5 together with cell voltage. It is obvious that feeding is under good-control. No clear correlation was found between feeding mechanism and continuous CF_4 emission. As compared Figure 5 with Figure 4, it can be seen that detectable CF_4 emitted soon after setting new anode.

Bath temperature and alumina concentration were measured during PFC monitoring (see Figure 6 and Figure 7). Bath temperature was measured with K-thermo-couple which has auto-reading function. Alumina concentration was measured with LECO-RO500C.

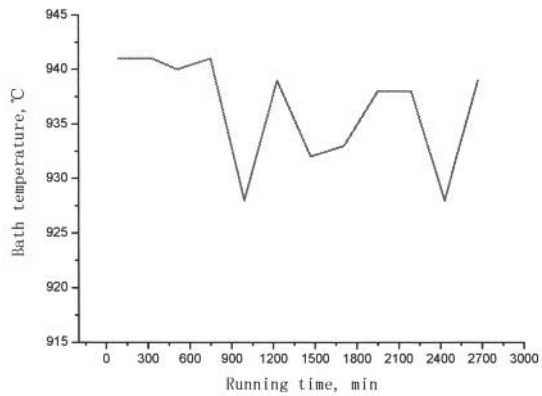

Figure 6 Trace of bath temperature during measurement

The maximum bath temperature difference in LX176-334 cell was 13 ℃. As compared Figure 6 with Figure 4, it seems that continuous CF_4 easily emits at lower bath temperature. The influence of bath temperature on continuous PFC needs further investigation.

Benefit from good feeding mechanism, alumina concentration in the cell showed stable and in good-control (see Figure 7). The percentage of alumina concentration in the range of 2.0%~3.0% was 87%. No clear relationship was found between alumina concentration and continuous PFC emission.

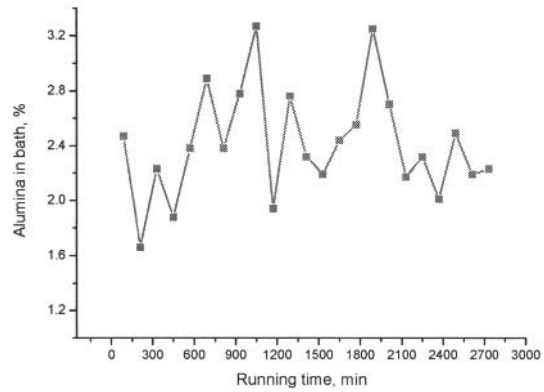

Figure 7 Trend of alumina in bath during measurement

Results from LX176-435 Cell Measurement duration is 45.61 hours for LX176-435 cell. No AE peaks were observed during monitoring as well. Continuous CF_4 emission is near to zero during the whole measurement (see Figure 8). Change trends of cell voltage and feeding interval are plotted (see Figure 9). As compared Figure 9 with Figure 8, no clear correlation was found between feeding mechanism and continuous CF_4 emission. Metal tapping and anode exchange caused rising of cell voltage. It can be seen that metal tapping could cause a little continuous CF_4 emission. Bath temperature of LX176-435 was also measured. Bath temperature changed in a narrow range of 924~933 ℃ during the whole measurement (see Figure 10). There is no clear evidence to show continuous CF_4 emission cause by unstable bath temperature.

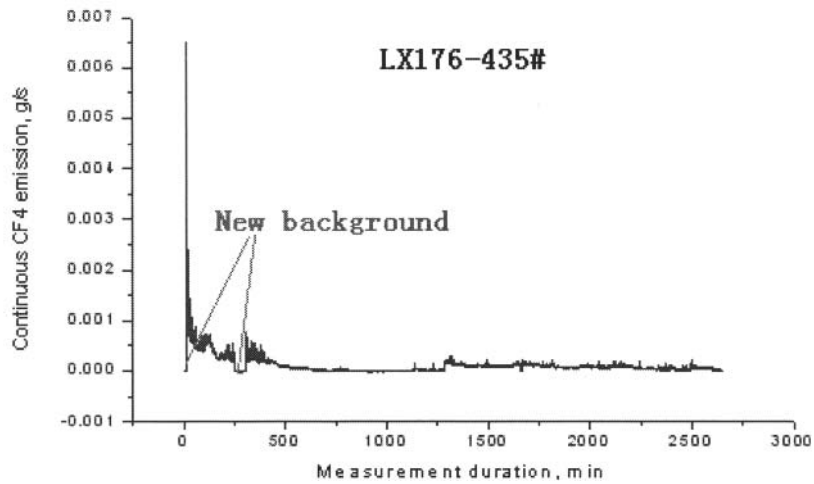

Figure 8 CF_4 emission trace of LX176-435

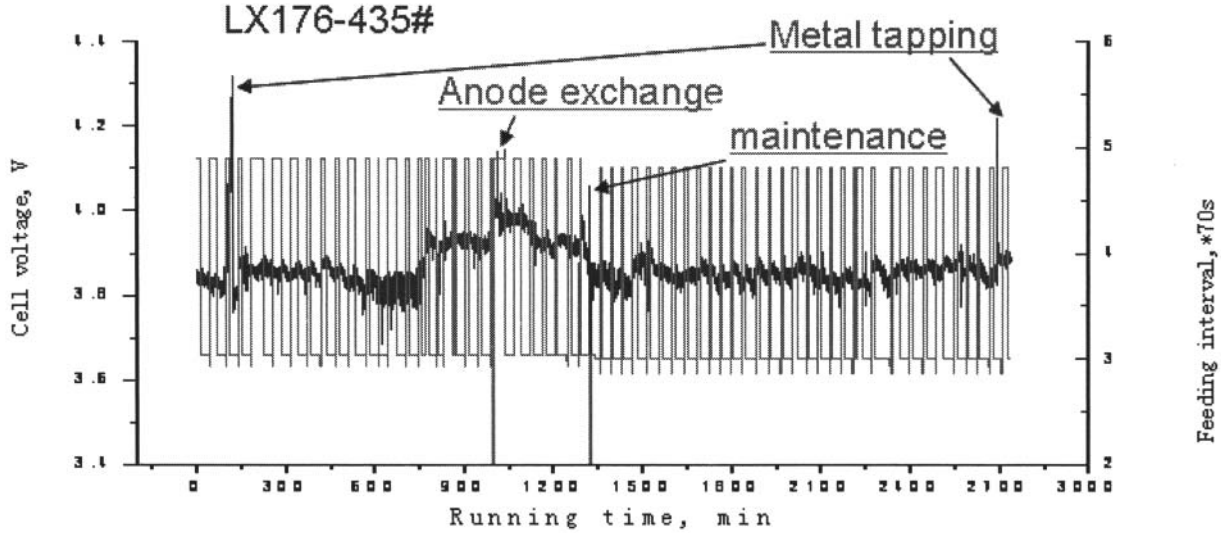

Figure 9 Change curves of cell voltage and feeding interval during measurement

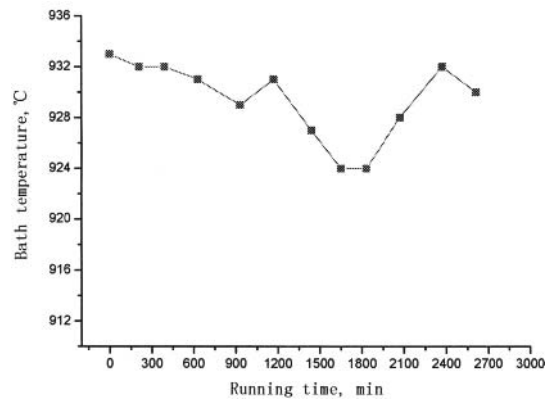

Figure10 Trace of bath temperature during measurement

There was a good feeding mechanism, stable bath temperature, quite homogenous alumina concentration in LX176 potlines. Therefore, very low AEF took place in LX176 potlines and the continuous PFC emissions in the measured cells were almost zero. Because anode exchange and metal tapping disturbed the stability of reduction cells, they would have some effects on continuous PFC emission. Perhaps line current in LX smelter was a bit low so that it had very low continuous PFC. No clear correlation was found among bath temperature, alumina concentration and continuous PFC emission.

Conclusions

Different cells have different CF_4 emission level even with the same line current. Continuous PFC emission from QY smelter is only a small portion of total PFC emissions. The measured variability of current flow among the anodes is similar to that of Western cells. No obvious relationship was found between maximum anode current and continuous PFC emission. Anode exchange and metal tapping disturb the stability of cells, and could cause continuous emissions. Continuous PFC emission from LX176 cells was almost zero. Influences of bath temperature and alumina concentration on continuous PFC emission are not clear in the survey of LX176 cells. Perhaps low line current could play a role in continuous PFC emission. More surveys need to be done on higher amperage cells.

Future Plan

Anode exchange and metal tapping cause instability of cells in the short-term, which may result in continuous PFC emission. More studies should be done to determine further whether anode exchange or metal tapping cause continuous PFC emission. Continuous PFC emission may take place when bath temperature goes down. More investigation should be carried out to determine the further influence of bath temperature. More detailed survey need to be done to find out if local alumina concentration influences PFC emission. More investigation is needed to determine if higher amperage (>300 kA) is easier to cause continuous CF_4 emissions than lower amperage cells like <200 kA. Reduction of PFC emissions requires efforts from smelters all over the world. ZRI would like to strengthen cooperation with IAI in the future. More surveys will be done with the help of a more powerful and flexible equipment donated by Canadian Aluminum Association and Environment Canada as part of the Asia Pacific Partnership on Clean Energy and Climate (4).

Acknowledgement

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