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New Cathodes in Aluminum Reduction Cells

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Abstract

Three aluminum electrolysis cells with a novel uneven cathode bottom are being operated successfully in Chongqing Tiantai Aluminum Industry Co., Ltd., China. More and more aluminum smelters are using this type of cathode. In the past year the three 168 kA cells have produced steadily at low cell voltages of 3.70 V to 3.75 V, and the current efficiency (CE) has been improved by at least 1 % in comparison with 127 traditional model cathode cells in the same potline. The technical characteristics of the cells are described in this paper.

Introduction

In 1997, the American Aluminum Association compiled an "Aluminum Industry Technology Roadmap" [1]. In this plan, improvement of the existing electrolysis technology in the near future was prepared in order to reduce the DC power consumption of reduction cell below 13000 kWh/t-Al. A long-term goal was to reduce the DC power consumption to 11000 kWh/t-Al. According to the best DC power consumption of 13000 kWh/t, if to achieve its long term goal, which means DC power consumption must be reduced by 2000 kWh/t-Al. It is almost impossible to reduce the energy consumption down to this goal with respect to the present reduction cell electrolysis technology. This is because, to lower energy consumption by 2000 kWh/t-Al, the cell voltage must be reduced by 0.6 ~ 0.7 V without affecting the current efficiency, i.e. the cell anode-cathode distance (ACD) must be reduced from 4 ~ 5 cm to 2 ~ 2.5 cm. However the current ACD has been already at a critical point due to various technological advances and implementation of computer-controlled. If the ACD is reduced to 3.5 cm or below, the cell voltage will swing, and the cells will not work normally. The current study suggests that the fluctuation of molten aluminum in the cell is of about 2 cm, which accounts for almost half of the ACD. If there is no molten aluminum fluctuations, ACD can be reduced by 2 cm, and the cell voltage will be reduced by 0.6 ~ 0.7 V. Therefore, from the 1980s, people have paid attention to the development and research of TiB_2/C inert cathode drained reduction cells.

The so-called concept of drained type TiB_2/C cathode reduction cell is that the material of cathode is TiB_2/C; advantages of the material are chemical stability to molten aluminum and good wettability to molten aluminum. Cathode aluminum electrolytic reaction can be carried out directly on the interface, the resulting aluminum will go along the slope of TiB_2/C cathode, and therefore there will be no fluctuations in molten aluminum. Industrial-scale experiments of drained type TiB_2/C cathode cell were first reported in 1998 [2]. This is the 92kA drained type

testing reduction cell of Comalco Aluminum Ltd. The lowest DC energy consumption of one cell was then reported to be 12800 kWh/t-Al, which does not seem to achieve the expected results. From 1998 until now 10 years have passed, there were no follow-up study report, and the drained type TiB_2/C cathode reduction cell also failed to meet expectations and industry adoption.

With the support from National Natural Science Foundation of China, Professor Feng Naixiang from Northeastern University, has done two experiments of drained TiB_2/C type cathode reduction cell with the amperage of 1350 A and 2000 A, respectively [4,5]. Although the baking, start-up and electrolysis process went relatively smooth, the testing results showed that the cathode overvoltage was high. In addition, although there is no fluctuation on the cathode surface, the polarization will accumulate high molar ratio of bath freeze on the cathode surface, leaving Al in the crust surface. Its comprehensive effect did not make a significant reduction in cell voltage and the energy consumption.

Over the past 20 to 30 years, aluminum industry has made significant technological advances, but the energy consumption of aluminum production has been between 13000 and 13900 kWh/t-Al. Its key technical problem is how to eliminate or relieve the action of electromagnetic field strength and the anode gas escaping, which mainly cause the fluctuation of the molten aluminum. Fluctuation of molten aluminum surface is the limiting factor for lowering the ACD and the cell voltage.

On the basis of studying the drained cathode cell, Feng Nai-xiang invented a new model of cathode aluminum reduction cell. Three of these new reduction cells were put into production in 168 kA potline of Chongqing Tiantai aluminum industry. The test cells were started in February 2008. And operation of the three cells has been stable and reached significant energy savings.

Structure and Technical Characteristics of the New Cathode Structure Reduction Cell

Feng Nai-xiang proposed several concepts for an energy-efficient aluminum reduction cell with new cathode structures. Typical new cathode structures of reduction cells are shown in Figure 1.

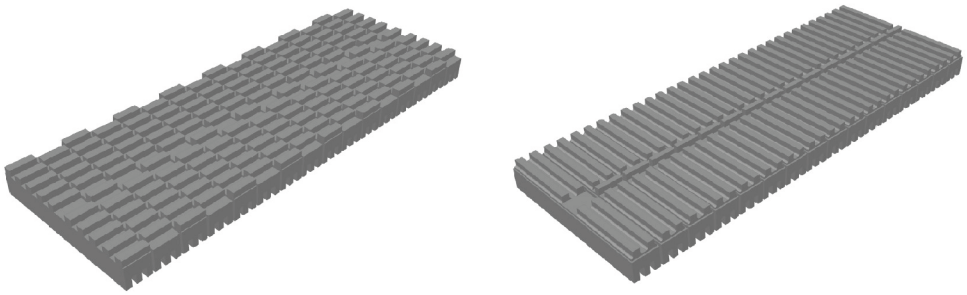

Figure 1. Schematic Diagram of Cathode for the Novel Cell

As can be seen from Figure 1, each new type of cathode carbon block surface is not flat but with ridges. Characteristics of the electrolysis technology and operations for the new cathode structure aluminum reduction cell are as follows.

The effective area for dissolved loss of cathode aluminum will be reduced due to stability improvement of cathode aluminum surface, so it can increase the current efficiency.

Overall height of this kind of cathode carbon block is high, so it has a better resistance to bottom upheaval compared with conventional cathode blocks.

Some tiny aluminum circulations between these ridges on the surface of the cathode can occur. These small circulations can ensure that deposit of alumina will accumulate in the groove above the ramming paste between the cathode carbon blocks, and can ensure that there will be no

deposit on the bottom of the cells. Deposit in the groove prevents molten aluminum from flowing into the cell bottom through the possible cracks formed during baking between carbon cathode block and ramming paste. So it could reduce cathode damage and enhance the service life of reduction cells.

Technology Principles for Wave Reduction and Energy Saving

At present, the cell voltage is usually 4.1 to 4.3 V. The reasons why the current ACD and cell voltage of the reduction cell could not be further reduced are due to the anode gas escaping disturbance and the disturbance of electromagnetic force in molten aluminum, which will cause large fluctuations in cathode molten aluminum.

The anode gas escaping leads to the production of gravity waves of aluminum. On the other hand, great fluctuations in the molten aluminum can also form due to non-uniform velocity field caused by the electromagnetic field in cathode molten aluminum. Therefore, fluctuation in cathode molten aluminum surface is the superposition of gravity waves and electromagnetic force waves. In general, the swirling flow of molten aluminum in the reduction cell is caused by vertical magnetic field and the horizontal current. New cathode structure reduction cells have many raised "walls", which is perpendicular to the fluctuation. These raised "walls" can divide aluminum velocity field of cathode molten aluminum in the reduction cell, and reduce aluminum liquid flow rate. These walls can reduce significantly horizontal current in cathode molten aluminum, and uniform current distribution within the molten aluminum, so the induced source of fluid flow is reduced. And on the raised surface of the cathode, if the raised width is suitable, the horizontal current formed on the raised surface could form aluminum circulation around these raised “walls”. This kind of circulation will not only good for alumina dissolution, but also could reduce the vertical direction wave.

Because these walls can greatly reduce the wave height, the effective ACD is increased. The cell voltage could be reduced by reducing ACD. In addition, the fluctuation reduction of cathode molten aluminum and the increased stability of molten aluminum surface will improve the current efficiency. And therefore energy saving in new cathode structure reduction cells can be realized.

Industrial Test of New Cathode Structure Reduction Cell

New model cathode carbon blocks for Chongqing Tiantai Aluminum Company were manufactured in Shanxi Jinyang Carbon Co., Ltd. The construction of the first cell (108 #) was finished on January 23, 2008, the second (114 #) and the third (115 #) pilot cells were finished on March 9, 2008.

Three test cells adopted flame - molten aluminum two-stage preheating method, 108 # cell was fired and put into test on January 25. 115 # cell and 114 # cell were fired on March 11 and March 13, respectively.

The new cathode reduction cells use the following process technology conditions:

- Cell voltage 3.70 to 3.75 V
- Bath level 18 to 20 cm
- Aluminum level 5 to 6 cm
- Molar ratio 2.3 to 2.5
- Electrolysis temperature 955 to 960 ºC

Test Results of New Type of Cathode Structure Reduction Cell

Three test cells performances for one year are referred to in Table 1. For the convenience of comparison, the average performances of 127 traditional cells are also listed.

Table 1. Comparison in performance between the three test cells and 127 reference cells

	Cell average voltage V	Current efficiency %	DC power consumption kWh/t-Al
108# cell	3.796	92.9	12171
114# cell	3.797	94.0	12039
115# cell	3.759	92.8	12067
Average for test cells	3.784	93.2	12092
Average for ref. cells	4.118	91.8	13352
Comparison	-0.334	+1.4	-1260

From the data in Table 1 it can be seen that (one year) average cell voltage of the new cathode structure is 0.334 V lower than that of the conventional cells, current efficiency is increased from 91.8 % to 93.2 %, which is an increase of 1.4 %. DC power consumption is lowered by 1260 kWh /t-Al, since the average DC power consumption is 12092 kWh /t-Al.

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