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METHODS TO IMPROVE FUEL UTILIZATION FOR OPEN TOP ANODE BAKING FURNACES

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Abstract

As a baking furnace ages, cracks and openings develop in the furnace which allow outside air to enter. Unless proper corrective actions are implemented, gas consumption can increase, final baking temperatures can decrease, and baked anode properties can deteriorate. In this paper, methods are presented for improving the efficiency of fuel utilization for aging furnaces, and thereby lowering fuel consumption, while maintaining or improving anode finishing temperatures and anode properties.

Introduction

During the whole production procedures of prebaked carbon anodes used for aluminium electrolytic cells, baking is the last yet one of the most important procedures[1].

Sunstone Development Co., Ltd currently has 4 baking furnaces which numbered as BF#1, BF#2, BF#3 and BF#4. BF#1 was rebuilt in 2010, so BF#2, which commissioned in 2007, is the oldest furnace operating now. BF#2 is an open-top baking furnace with 38 sections (7 pits in each section) and 2 automatic control firing systems. Each system has 3 firing frames, an exhaust manifold, a temperature and pressure measuring frame and a cooling fan. The fire configuration includes 3 preheat sections, 3 firing sections and 8 cooling sections for each system. However, because of the improper maintenance, severe deformations were observed in BF#2 after four (4) years of operation; cracks and openings developed in the furnace which allow outside air to enter. Gas consumption increased, final baking temperatures decreased, and baked anode properties deteriorated.

The Soaking time and anode Electrical Resistivity (ER) in BF#2 in 2008, 2009 and 2010 are shown in Table 1.

Table 1 Soaking time and anode ER of BF#2 from 2008 to 2010

Items	2008	2009	2010
ER (μΩm)	54	55	58
Soaking Time (h)	46	58	64

Heat Balance Analysis

In order to help the operators to efficiently control the operation of BF#2, heat balance theory is used to analyze the status of the furnace. However, due to the huge size of the baking furnace and the measurement complexity of all the heat factors, few anode manufacturers actually do the measurements. Instead, they calculate the heat factors of their own furnaces based on the heat balance analysis data published by other Institutes and Research Centers [2]. And this is what Sunstone did for BF#2 in 2008 and 2010 respectively. The results are shown in Tables 2 &3.

Table 2 Heat Balance Sheet in 2008 (BF#2)

Heat Input		Heat Output	
Items	%	Items	%
Natural Gas Combustion Heat	28.36	Anodes Heating-up	19.82
Packing Coke Combustion Heat	9.84	Packing Coke Heating-up	8.36
Volatile Combustion Heat	32.50	Energy loss in fumes	33.59
Existing Furnace Heat Storage	3.56	Heat Loss from top of furnace	7.12
Preheated Air Heat Storage	25.74	Furnace Heat Storage	29.38
—	—	Cold Air Heating-up	1.73
Total	100	Total	100

Table 3 Heat Balance Sheet in 2010 (BF#2)

Heat Input		Heat Output	
Items	%	Items	%
Natural Gas Combustion Heat	40.24	Anodes Heating-up	16.20
Packing Coke Combustion Heat	10.50	Packing Coke Heating-up	7.53
Volatile Combustion Heat	28.25	Energy loss in fumes	42.6
Existing Furnace Heat Storage	3.61	Heat Loss from top of furnace	6.45
Preheated Air Heat Storage	17.40	Furnace Heat Storage	28.34
—	—	Cold Air Heating-up	3.25
Total	100	Total	100

As we can see from Tables 2 & 3, BF#2 deteriorated in 2010 compared to 2008. More and more outside air entered, heat losses and gas consumption increased, more heat was brought away by the fumes. All these problems resulted in higher gas consumption, lower final baking temperatures, and deteriorated baked anode properties.

Within all the heat input items, assuming the loading rate and volatile content are constant, gas combustion heat is the only factor that varies. Within all the heat output items, energy loss in fumes, cold air heating-up and the heat loss from top of furnace are the more variable factors compared to the others. It is expected that as a baking furnace ages, cracks and deformations would develop without proper maintenance, gas consumption would then increase.

Proper Maintenance, Operations and Sealing

To solve above problems, process engineers were appointed to find out methods to improve fuel utilization in BF#2 by implementing proper maintenance and sealing.

(1) Proper maintenance

First of all, it's very important that the baking furnace is properly maintained. All vertical gaps that are wider than 3mm between bricks and all spaces at joint locations such as the corners around the pits, flue wall and flue caps, flue wall and head wall, etc, should all be stuffed with refractory clay. Also, all flue cap covers in the C1, 1P, 2P, 3P and the 2 green pack sections should be closed tightly and sealed, Plastic sheet of 5mm thick is added on the top of the 1P, 2P and the two green pack sections for better sealing, which is shown in Figure 1.

Figure 1 Green Pack Section that sealed with plastic sheet

The negative pressure in the flues of the 1P section should be reduced to about 90Pa when the zero point set is located at the first firing hole in the C1 section. With all these done, it can prevent the outside cold air from entering the furnace and consume gas, so as to improve fuel utilization and at the same time increase soaking time and final baking temperature.

Secondly, to determine the proper soaking time, which is the time period from when the flue temperature achieves the target final baking temperature till the time the next fire moves. Soaking time can be extended to 70 hours by increasing the heat-up rate during the 850℃-1200℃ heat-up stage.

Volatile consists mainly of tar (fire point: 425℃), methane (fire point: 525℃) and hydrogen (fire point: 625℃). Since the combustion of volatile has close connection to the fume temperature and heat-up rate in the flues, sufficient burning of volatile could happen by speeding up the heat-up rate in 1P section and by increasing the final baking temperatures, so as to ensure the flue temperature get to or above the firing point when the volatile are released

(2) Monitoring and Analysis of the operational parameters of the baking furnaces

Daily operational parameters are monitored so as to take corrective actions to any abnormal situations promptly to prevent equipment failure and the resulting wastes of natural gas. The experimental findings show that the preheat air could be better utilized to improve the utilization of waste heat by setting the cooling fan at the first firing holes of the C4 section, so as to improve gas utilization.

(3) Better sealing of the base for thermocouples and burners, monitoring the length of burners

Outside cold air that enters the flue through the base of the thermocouples could cause the temperatures measured by the thermocouples to be lower than they should be, resulting in excess gas being poured into the flue. The outside cold air entering the flue also requires extra gas to heat it up and causes higher gas consumption. Thus, to seal the base for thermocouples and burners could prevent outside could air from entering, so to reduce gas consumption.

The length of burners could also affect gas consumption. Burners of different length would pour natural gas out to different distances, making the flues to achieve different temperatures at top and bottom. Our experience indicates that the flue can achieve relatively even temperature distribution between the top and bottom when the gas poured out distance reaches 30-50% of the flue depth. Thus, the length of burners should be included as part of the standard management system; burner should be changed when it is burned to an inadequate length.

Refractory Cover added on top of the C1 Section

In order to make full use of the heat in the cooling sections, a refractory cover is added on top of the C1 section.

A huge amount of heat is retained in the cooling sections. If this part of heat could be fully used, gas consumption could be greatly reduced. The temperature of preheat air could easily achieve 1000℃ or above at the 6P section if the cooling fan is properly located somewhere at the C4 or C5 sections. By doing this, gas consumption could have a noticeable decline [4].

Normally, temperatures in C1 section (no more burners in this section) will drop significantly due to heat transfer. In order to slow down the temperature drop, lengthen the anode soaking time at or above 1050℃, and at the same time make full use of the retained heat in C1 section to preheat the air, so as to reduce gas consumption, a refractory cover is added on top of the section to prevent the heat to easily transfer to the top (Figure 2).

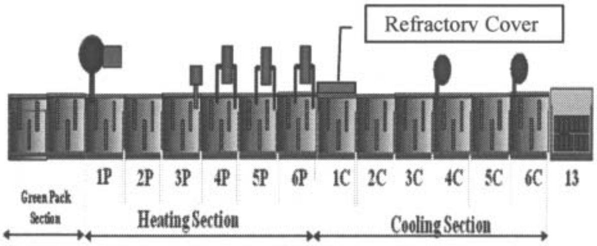

Figure 2 Operational Scheme of BF#2

The refractory cover is mainly made of a steel frame of the same size as a section, thermal insulation felt, and refractory asbestos. There are steel ropes along the diagonal and fixed on the four corners of the cover, and a hook fixed at the intersection of the ropes for easy handling of the cover by cranes when fire moves. Figure 3 shows the top view and sectional view of the refractory cover.

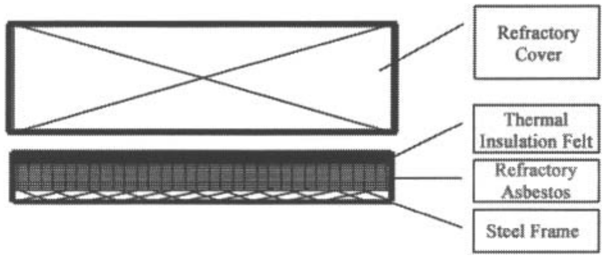

Figure 3 Top view and sectional view of the refractory cover

The refractory covers are used on both fires of BF#2 (Figure 4).

Figure 4 Refractory cover used in BF#2

Experimental Results

With all above mentioned corrective actions implemented, the heat balance of BF#2 is calculated again, results are shown in Table 4 below.

Table 4 Heat Balance Sheet of BF#2 under experiment

Heat Input		Heat Output	
Items	%	Items	%
Natural Gas Combustion Heat	31.02	Anodes Heating-up	21.28
Packing Coke Combustion Heat	9.12	Packing Coke Heating-up	9.89
Volatile Combustion Heat	27.85	Energy loss in fumes	35.30
Existing Furnace Heat Storage	3.61	Heat Loss from top of furnace	6.23
Preheated Air Heat Storage	28.4	Furnace Heat Storage	31.28
—	—	Cold Air Heating-up	1.02
Total	100	Total	100

Comparing the results in Table 4 with those in Tables 2&3, we can see the Natural Gas Combustion Heat is the major heat input and it gets lower in Table 4 because of the refractory cover which enables better use of the retained heat in C1 section. Also, the fume heat loss and the heat loss from top of furnace decrease, which shows less cold air entering the furnace resulting in lower heat consumption.

The anode final baking temperature, electrical resistivity (ER) and gas consumption before and after all the corrective actions implemented are shown in Table 5. The results show that the anode final baking temperature increased by 50℃ to 1100℃ while the anode ER and gas consumption decreased significantly.

Table 5 Anode Final Baking Temperatures and ER

Item	Before	After
Anode Final Baking Temperature(℃)	1050	1100
ER (μΩm)	58	54.5
Gas Consumption (GJ/metric ton of baked anodes)	3.5	2.5

Conclusions

(1) The final baking temperature can be increased by improving maintenance, operation and sealing of baking furnace.

(2) The retained heat in the cooling sections could be fully used to preheat the air and improve fuel utilization by adding a refractory cover on top of the C1 section, so as to improve anode properties.

References

1. Pingfu Wang, "Production Technology and Applications of Prebaked Carbon Anodes Used in the Aluminium Electrolytic Cells (Metallurgical Industry Press, 2004), 149-150.
2. Li Zou, "Methods of Energy-saving for Anode Baking Furnaces" (Non-ferrous Metal Design, 2005), 20-22.
3. Guanghua Yang, Wenzhong Chen, "Thermal Technology Analysis on Anode Baking Furnaces" (Light Metals, 2007), 40-44.