Optimum Baking Level of Carbon Anodes for Aluminum Production

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Abstract

Carbon anodes are consumed in electrolysis cells during primary aluminum production. Carbon consumption in pre-bake anode cells is at the rate of 400 kg C/t to 450 kg C/t Al and is affected by the carbon dioxide (CO_2) reactivity and air reactivity of anodes. The anode reactivities are affected by the properties of raw materials and by the parameters of the manufacturing processes. Carbon anode reactivities data over the last three years at Emirates Aluminum ("EMAL", also known as Al Taweelah Operations) were analyzed, with a particular focus on anode baking levels. This study indicates relationships between anode reactivities and the levels of anode baking, measured through the anode real density values. Low and high levels of baking result in higher anode reactivities, while optimum baking level gives the lowest anode reactivities. A real density value of 2.08 g/cm^3 is found to be optimum, as at this baking level both the CO_2 reactivity and air reactivity are lowest. Low chemical reactivities give low net carbon consumption during aluminum production. The understanding gained through this study helps to reduce anode reactivities by adjusting the anode baking level, thereby achieving low net carbon consumption.

Keywords: Carbon anode; CO_2 reactivity; air reactivity; anode baking; real density; net carbon consumption.

1. Introduction

Carbon anodes are consumed in Hall-Héroult electrolysis cells during primary aluminum production. The carbon anode consumption rate is expressed as "net carbon consumption" ("NCC") and is frequently used as a parameter for evaluating anode performance in reduction cells. The NCC in pre-bake anode cells is in the range of 400 kg C/t Al to 450 kg C/t Al. This includes consumption during the basic electro-chemical reaction as well as additional consumption due to current efficiency loss, secondary reactions with air, anode gases and other processes. In every smelter carbon plant, efforts are made to adjust anode manufacturing processes to sustain anode quality despite changing raw material quality. The quality of calcined petroleum coke, in particular, is changing. For example, sulphur content and metallic impurities are increasing. Use of different quality cokes impacts anode quality, which in turn affects anode performance and consumption in reduction cells.

Several papers have been published on how anode manufacturing processes influence anode reactivities and their impact on anode performance in the pots [1, 2]. In this paper, an analysis of three years' data is presented on baked anode reactivities at EMAL – an operating subsidiary of Emirates Global Aluminium ("EGA"). The analysis focuses on the baking process and on how the level of baking influences anode reactivities.

2. Plant Parameters

The EMAL smelter, located at Al Taweelah in Abu Dhabi, United Arab Emirates, has an installed capacity of 1.38 million tonnes of aluminium per year. The smelter has 1 200 electrolytic cells, of which 756 DX Technology cells operate at 405 kA and 444 DX+ Technology cells operate at 462.5 kA. The electrolytic cells use pre-bake carbon anodes, manufactured in two captive carbon plants. The paste plants, baking kilns and rodding plants operate the latest state-of-the-art technologies for green anode manufacturing, baking green anodes, rodding baked anodes and processing butts. The characteristics of the cokes used for manufacturing anodes are given in Table 1.

This paper presents correlations between anode baking level, as measured through real density parameter and baked anode chemical reactivities. Anode reactivities affect the carbon consumption in the pots during the electrolysis of alumina.

The study is based on the EMAL smelter data over a period of three years' operations (2014 to 2016). Process data from the baking kilns was used, along with laboratory analysis of raw materials and baked anode core samples.

Table 1. Typical characteristics of calcined petroleum cokes.

Analysis	Unit	Values
		Range
Vibrated bulk density ("VBD")	g/cm^3	0.85-0.95
Real density	g/cm^3	2.07-2.08
Lc	nm	2.9-3.1
Volatile matter ("VM")	%	0.40-0.45
Moisture	%	0.1-0.5
Ash	%	0.05-0.2
Sulphur	%	1.0-3.0
CO_2 reactivity	%	3-12
Air reactivity	%/min	0.1-0.3
Hard grove index ("HGI")	no	32 - 42
Electrical resistivity	μΩ.m	440-500

3. Finding

3.1. CO_2 Reactivity

As the baking level of anodes increases (indicated by the increase in real density), the study shows that:

- Baked anode CO_2 reactivity residue ("CRR") increases and then decreases after reaching a peak (Figure 1).
- Baked anode CO_2 reactivity loss ("CRL") decreases initially and then increases after reaching a minimum value with increasing real density (Figure 2).

5. Conclusions

- CO_2 reactivity and air reactivity residues of baked anodes increase as the baking level is increased to the level corresponding to anode real density of 2.08 g/cm^3. These parameters are at maximum values at this baking level.
- Above the level of baking corresponding to anode real density of 2.08 g/cm^3, there is deterioration in anode reactivities because of desulphurization and increased reactive surface area.
- A baking level corresponding to anode real density of 2.08 g/cm^3 may be considered as optimum for baking carbon anodes. Anodes baked to this level have maximum reactivity residues and minimum NCC.
- When cokes of real densities higher than 2.08 g/cm^3 are used, there is no gain in anode reactivity residues; therefore no drop in net carbon consumption is expected.
- There is gain in anode reactivities if cokes of real densities lower than 2.08 g/cm^3 are used. However, to obtain best reactivity residues, these anodes must be baked till the anode real densities reach 2.08 g/cm^3.

6. References

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