Carbon dust in aluminum electrolysis pots - a vicious circle

Louis Bugnion[1], Jean-Claude Fischer[2]
1. Electrolysis Manager,
2. Director,
R&D Carbon, Sierre, Switzerland
Corresponding author: jeanclaude.fischer@rd-carbon.com

Abstract

Anode dusting in electrolytic bath has been known for years to deteriorate pot performance in aluminum smelters. Suspended carbon particles increase electrical resistivity of the bath, triggering a series of adverse effects for the pot. Under constant pot parameters, carbon dust originates from poor anode quality. In conjunction with faulty pot operation, high dusting level can develop into crisis which will impact production figures for several months. A few examples of crises related to carbon dust are reviewed from root causes to resolution. As a result, a methodology to monitor dusting level and quantify its effect on bath resistivity and pot stability is proposed. Based on plant data analysis and on-site measurements, it allows for comparison between pots and anode populations, making the link between anode quality and pot performance. Eventually it provides a sound basis for the prevention of crises and economical carbon management.

Keywords: Carbon dusting in pots; anode quality; pot performance, electrolyte resistivity.

1. Introduction

Carbon dust is one of the impurities present in electrolytic bath. Carbon particles have a size ranging from micron to centimetre scale with an average size between 1 and 10 µm [1, 2]. Coarse particles float at the bath surface whereas finer ones are suspended in the electrolyte. The average carbon concentration in the bath is of the order of 0.05 % and varies as a function of bath depth [2]. It is larger at the bath-metal interface and close to the bath surface where the coarse particles are found. In dusty pots, the carbon concentration in the bath can reach values as high as 0.4 % [3] with severe consequences for the pot performance.

Carbon dust mainly originates from selective burning of the anodes in contact with CO_2 or air. The binder matrix is burnt preferentially, loosening carbon particles into the bath or within the crust/anode cover. The combustion reactions take place at the anode surface or in the anode bulk where the gases are able to permeate. The reaction rates depend on the temperature, surface structure, permeability and reactivity of the anodes constituents [4].

Other sources of carbon dust are identified such as cathode and ramming paste wear. Carbon fines entrained by the fumes and captured by the dry scrubber system return to the pot through secondary alumina feeding. Likewise, recycled anode cover contains carbon particles which contaminate the bath when falling into it.

The cycle of carbon dust in the electrolytic bath is complex and mechanisms of generation of fine particles, combustion rate and accumulation patterns of suspended particles, impact on bath properties are poorly understood. Carbon excess consumption figures give a hint about the total amount of anode carbon which is not used for the electrochemical reactions but fall short on predicting how much, where and for how long carbon dust remains in the bath.

Over the years, strategies were developed with the objective of 1) Preventing the formation of carbon dust, 2) Monitoring the carbon concentration in the bath and 3) Removing carbon dust from the electrolyte.

1) Major efforts were made in the production of anodes to limit their propensity to dusting [5]. Concurrently, laboratory tests were developed allowing qualifying anodes. CO_2 and air reactivity, air permeability and concentrations of the elements S, V, Na and Ca are the most relevant anode properties with regard to dusting. Routine measurements are mandatory to assess anode quality and to detect issues in the manufacturing process.

   From the pot operation and pot design point of view, bath temperature, anode temperature, anode cover, anode cycle time, current density, anode balance, collar stud protection, butts height play an important role in the accumulation of carbon dust. Monitoring of the parameters and optimization based on cost-benefit ratio shall be realized. However, as discussed below, the cost of carbon dust is always difficult to assess.

2) The carbon concentration in the electrolyte can be measured directly from bath samples or indirectly from samples of secondary alumina, recycled anode cover or skimmed material. Visual observation of anode cover and bath surface and a simple rating system can also be used to monitor dusting level in pots [6]. In the following, a comprehensive method to quantify carbon concentration and its effect on bath resistivity and anode-cathode distance (ACD) is presented.

3) Carbon dust in bath is naturally removed by burning. Skimming at the taphole or cleaning of the anode cavity during anode change are necessary measures to further reduce dusting level.

2. Impact on pot performance

The primary effect of carbon dust is to increase the bath electrical resistivity. Since the cell voltage is prescribed by the process control, a higher dusting level will result in an ACD squeeze. Even though the dependence of bath resistivity on carbon concentration and granulometry is little documented [7], the causal relationship is well known and is the starting point for a chain reaction of adverse effects illustrated in Figure 1. A lower ACD will affect pot stability and current efficiency [8], increasing bath temperature. As a result, the cell performance is reduced and the propensity to dusting is enhanced.

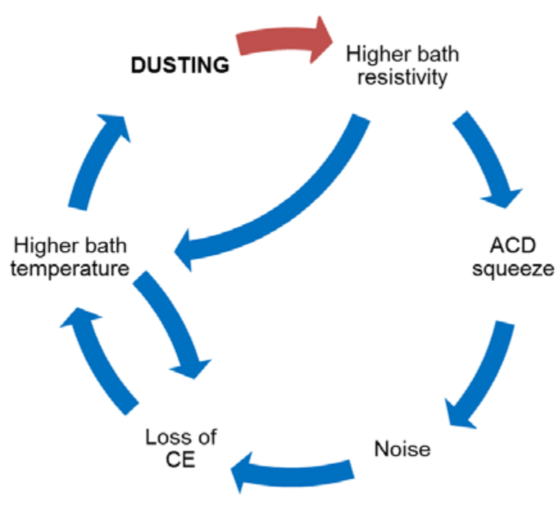

Figure 1. Vicious circle triggered by anode dusting.

In order to assess the impact of carbon dust on bath resistivity and on the resulting ACD squeeze, a simple method is applied. The beam is moved downwards by a few mm and it is kept at that very position during 10 min until it is moved downwards again. The cell voltage and beam position are recorded as a function

Table 4. Economic results.

ECONOMICAL RESULTS	Sp. value	Unit	DESIGN TARGET	CRISIS TRIGGER	CRISIS PARTIAL RECOVER
Al production		tpy	800'000	758'000	783'000
El. energy consumption		GWh	10'040	10'040	10'300
Anode Production		tpy	448'000	436'600	455'700
Butts return		tpy	136'000	103'000	134'600
Coke needed		tpy	267'200	289'900	275'530
Alumina needed		tpy	1'552'000	1'470'000	1'519'000
Loss of Al		tpy	0	42'000	17'000
Loss due to less Al	1'800 USD/t	Mio USD	0	76	31
Extra el. energy		GWh	0	0	260
Loss due to extra el. energy	40'000 USD/GWh	Mio USD	0	0	10
Extra coke needed		tpy	0	22'700	8'330
Loss due to extra coke needed	400 USD/t	Mio USD	0	9	3
Alumina difference needed		tpy	0	-82'000	-33'000
Savings due to alumina needed	250 USD/t	Mio USD	0	-22	-8
Total yearly loss		**Mio USD/y**	**0**	**63**	**36**
Total monthly loss		**Mio USD/m**	**0**	**5**	**3**
Sp. loss on design capacity		**USD/t Al**		**80**	**45**

4. Conclusions

Maintaining a low and steady concentration of carbon dust in the electrolyte bath is a difficult task. It requires careful selection of raw materials and know-how in the manufacturing and rodding of anodes. At operation level, thermally balanced pots, low bath temperatures and uniform anode current distribution reduce the risk of dusting. The optimal cost/benefit ratio in terms of raw materials, process optimization and anode cycle time shall be determined. In this perspective, an objective assessment of the costs generated by anode dusting shall be realized. Under enhanced stress - current creep to increase Al production, ACD squeeze to limit specific energy consumption, change in anode recipe - pots shall react very differently depending on carbon dust concentration and stability margin. As shown by squeezing tests, the actual ACD may vary by 30 % due to higher bath resistivity. A comprehensive monitoring of anode quality, carbon dust concentration, anode butt properties plays an integral part in the prevention of carbon crises.

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