Essential Readings in Light Metals: Electrode Technology for Aluminum Production.
Edited by Alan Tomsett and John Johnson.

ANODE DUSTING FROM A POTROOM PERSPECTIVE AT NORDURAL AND CORRELATION WITH ANODE PROPERTIES.

Halldor Gudmundsson
Nordural-Century Aluminum Ltd; Grundartangi; Akranes, IS 301, Iceland

Keywords: Anodes, Dusting, Anode Spikes

Abstract

Anode performance in the cells is ultimately the most important measure of the anode quality and is not always reflected in the quality certificates. Nordural has through the years developed some tools to measure anode performance in the cells to use as feedback to anode suppliers so that they may improve the anode performance. Anode dusting in the cells leading to anode spikes and loss of current efficiency can be the biggest issue in the supplier – customer relationship. This paper shows some examples of anode dusting excursions experienced with three anonymous anode suppliers, how it was measured in the cells and how it was reduced or resolved in cooperation with the suppliers.

Introduction

Smelters need to maximize production per cell day and minimize energy consumption. Minimizing gross carbon consumption is also necessary for smelters that purchase anodes from an outside supplier. From a potroom perspective the anode quality has a direct effect on current efficiency and also dictates how aggressively the operating parameters can be pushed, for example how thin the anode butts can be while still maintaining current efficiency. Quality of workmanship is also an important factor in pot operations and anode performance. Anode dusting in cells leading to anode spikes and loss of current efficiency is therefore a situation that both anode quality and operating conditions can contribute to [1,2,3]. Any attempt to quantify anode quality excursions from a potroom perspective must also take into account the effects of operating parameters. Carbon dust in the bath can be directly related to increased anode spike frequency and loss of current efficiency [1,2]. The carbon dust increases the electrical resistance of the bath leading to an increase in temperature and a reduction of the anode to cathode distance (ACD) [2].

The sources of carbon dust in a cell are [1,2]:

- Dust from anodes due to selective oxidation of the pitch binder matrix releasing the petroleum coke grains into the bath.
- Cathode wear which contributes between 0.5 – 1 kg carbon per tonne of metal produced
- Carbon collar paste to protect anode stubs can add between 0.5 and 6 kg carbon per tonne of metal.
- The recycled anode cover material can contain up to 5wt% carbon.
- Carbon in the secondary alumina between 0.15 and 0.5wt%

The removal of dust from a cell is helped by the following [2]:

- A slight amount removed with tapped bath
- Burning in the cell gas flame
- By manual skimming of the taphole
- By cavity cleaning during anode change.

Modern prebake cells with point feeder with low anode effect frequency and which have well covered anodes with less open flame have a greater tendency to accumulate carbon dust.

Quantifying the amount of carbon dust in cells has been done mainly by weighing the amount of skimmings from cells [1,2,3] but that material is a mixture of bath and carbon. Perruchoud et. al. [3] published formulas for quantifying carbon dust generated by air burn and carboxy burn based on anode properties as measured by R&D Carbon methods.

Measuring the concentration of carbon in the secondary alumina is also a good indicator but not always reflecting the dusting in the cells [3]. Measuring the footprint of anode butts is a good measure of anode dusting as long as airburn due to poor covering practice does not influence the results.

According to Stokka [6], carbon dusting in point feed prebaked pots seems to be more dependent on anode calcination level and the quality of the anode covering, than the laboratory measured air and CO_2 reactivity. This paper attempts to quantify dusting using a quick and simple method of observation and data is shown how it correlates with anode quality information.

Anode performance in cells at Nordural

The Nordural smelter was started in 1998 with an initial production capacity of 60,000 tpy and 120 pots in one potline. Subsequent expansions have been as follows:

- 30,000 tpy expansion of existing potline in 2001
- 130,000 tpy startup of second potline line in 2006
- 40,000 tpy expansion of second potline in 2007

Through capacity creep the current production capacity is roughly 280,000 tpy from 520 cells. The Nordural smelter has always had an emphasis on minimizing Gross Carbon consumption since the anodes are supplied outside Iceland.

Table 1: Physical and chemical properties of three anode types used at Nordural.

Physical Properties		Supplier A	Supplier B	Supplier C
Apparent Density (2 Stdev)	kg/dm³	1.59(0.03)	1.59 (0.02)	1.62 (0.02)
Specific Electr. Resistence (2 stdev)	μΩm	53(4)	54(4)	53.5(2)
Thermal Conductivity (2 stdev)	WmK	3.3(0.6)	3.5(0.9)	3.6(0.2)
Air Permeability (2 stdev)	nPm	0.9(1.4)	1(1)	1.5(3)
CO2 Reactivity Residue (2 stdev)	%	85(8)	91(4.4)	89(1)
CO2 Reactivity Dust (2 stdev)	%	5.1(4.4)	2.9(2.3)	2.5(0.5)
Air Reactivity Residue (2 stdev)	%	80 (14)	82(8)	98(1)
Air Reactivity Dust (2 stdev)	%	4.6(6.4)	4.5(2.3)	0.4(0.2)
Spent butts fraction	%	20	16-20	0
Slots in anode		Moulded slots	Cut slots	Cut slots
Collar paste used on anode pins		Yes	Yes	Yes
S	%	1.1	1.5	1.4
Fe	ppm	350	250	360
Si	ppm	90	77	190
V	ppm	130	150	60
Ni	ppm	137	120	200
Na	ppm	170	135	100
Ca	ppm	93	92	340
Ash	%	0.2	-	0.3
Air dust according to [3]	kg/t Al	3	2.8	0.4
CO2 dust according to [3]	kg/t Al	3.5	2.9	2

For the past 4 years Nordural has been using anodes from 3-4 suppliers at a given time. Table 1 shows the typical values of anodes from three suppliers which are the subject of this study. The table also indicates the fraction used of spent butts, type of slot made in the anode plus the calculated dust emissions from airburn and carboxy burn according to the formulas of Perruchoud et. al. [3]. The anodes are segregated into sections of cells, in numbers of 80 to 260 cells where they are used exclusively. The anode performance in the cells can thus be monitored and sections compared. The anode performance has been measured by observing:

1. The level of dusting in the cells as measured by a simple rating system of the dust visible in the tapping hole. The dusting is assigned an index from 1 to 3 (Figure 1)
2. The frequency of anode spikes
3. The footprint and thickness of anode butts.
4. The carbon concentration of the secondary alumina.

The dusting is evaluated by checking the taphole. If there is dusting it will be visible there due to accumulation in the corners. A rough scale used to evaluate dusting is as follows:

- Dusting index = 1 means there is no carbon dust visible in the taphole.
- Dusting index = 2 means that there is some dust visible but it could easily be skimmed out once.
- Dusting index = 3 means that there is more dust than can be skimmed out once.

Figure 1: The level of dusting evaluated in the tapping hole, in this case a dusting index of 2.

This evaluation is done weekly by looking into 40-60 cells from each section using the same type of anode. This takes not more than 2 hours. An average dusting value is calculated from each such campaign. The more cells that exhibit no dusting, the closer this value gets to 1 so this system is designed to measure low dusting. As the average dust value approaches the value 3 the scale gets effectively saturated but then other parameters such as spike frequency, frequency of soft butts and high carbon in the secondary alumina start to increase or be more common. It is very important to do this evaluation at the same time in the work schedule and the most representative time is to do it just before the pot is tapped for metal.

Anode dusting excursions

Figure 2 shows the number of extra anodes changed per month due to spikes over a period of slightly more than 5 years for the three anode types considered. Anodes from supplier C is in use only part of this period. Figure 3 shows the average monthly dusting index for each anode type.

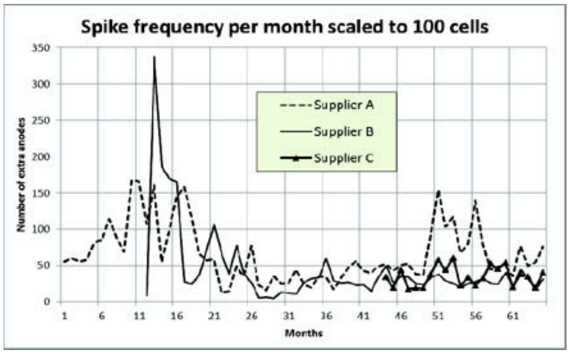


Figure 2: Anode Spike frequency per month scaled to 100 cells shown for three anode suppliers over a period of 64 months.

A level of up to about 50 extra anodes changed due to spikes per 100 cells per month is considered to be acceptable taking into account the effects of operational parameters and the quality of anode covering. A level of more than 100 to 150 is a serious excursion requiring correction of operating conditions and evaluation of anode properties. Such excursions have lead to drops in current efficiency of about 2-5%.

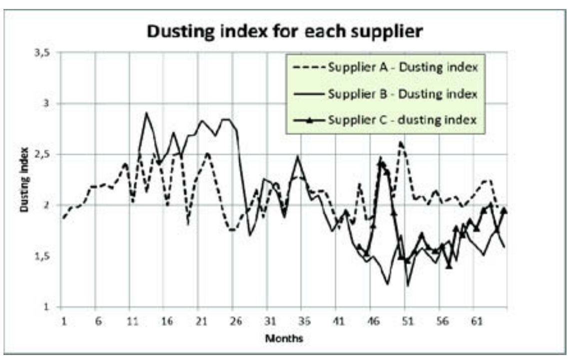


Figure 3: Dusting index for each supplier over a period of 64 months.

Figures 2 and 3 indicate that a dusting index greater than about 2 can lead to difficult periods of high anode spike frequency if the operating conditions are not revised accordingly such as increasing the ACD, shortening the stand time of the anode or even lowering the line current in extreme cases. The level of carbon in the secondary alumina follows the general drop in dusting trend observed. According to Perruchoud et. al. [4] the normal level for carbon in secondary alumina is about 0.3% when there is no dusting issue. For most of the period studied here the carbon level of the alumina sampled is lower, yet as described in the following sections dusting problems can still be actual.

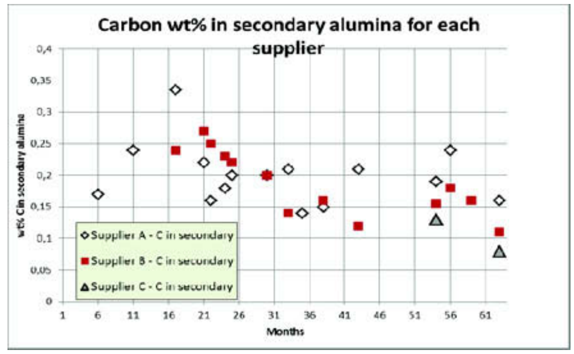


Figure 4: Carbon in secondary alumina of samples taken from Fume Treatment Plants dedicated to pot sections where the supplier anodes are used.

Supplier A, dusting excursions:

Figure 5 shows the number of extra anodes change per month due to anode spikes, the dusting index evolution and the ACD evolution. Also shown is the anode stand time and anode butt thickness. The calculations of ACD are checked against measurements made two times during this period. During this period there are some line current fluctuations but the net trend is an increase in line current.

Anodes from this supplier have shown about four periods of major spike excursions during this period of 64 months.

Between months 7 and 13 the number of spikes increases above the level of 100 and simultaneously the dusting index starts to rise above the level of 2. Increasing ACD starting in month 11 does not effectively drop the number of spikes until month 18 when the ACD is increased dramatically. The level of dusting fluctuates but still remains high until month 24. After that the dusting index fluctuates around the level of two until month 47 when the next spike excursion starts. Between the months of 21 and 46 the level of spikes is acceptable due to the lift in ACD although the level of dusting is on the high side. The next spike excursion starting in month 51 is at the same level of ACD during the previous 10-12 months. The level of ACD is lifted and the anode standtime is reduced to respond to the increase in spikes.

Looking at the specific electrical resistance (SER) values, the reactive elements, the reactivity dust values (CRD and ARD) for the anodes the possible reasons for increased dusting around month 11 is perhaps a combination of poor baking and an increase of reactive elements. The second dusting and spiking excursion at month 51 looks to be mainly due to an increase in reactive elements since the level of baking had improved.

Figure 7 shows that the air and carboxy dusting are typically on the high side which fits well with the elevated level of dusting and spike frequency.

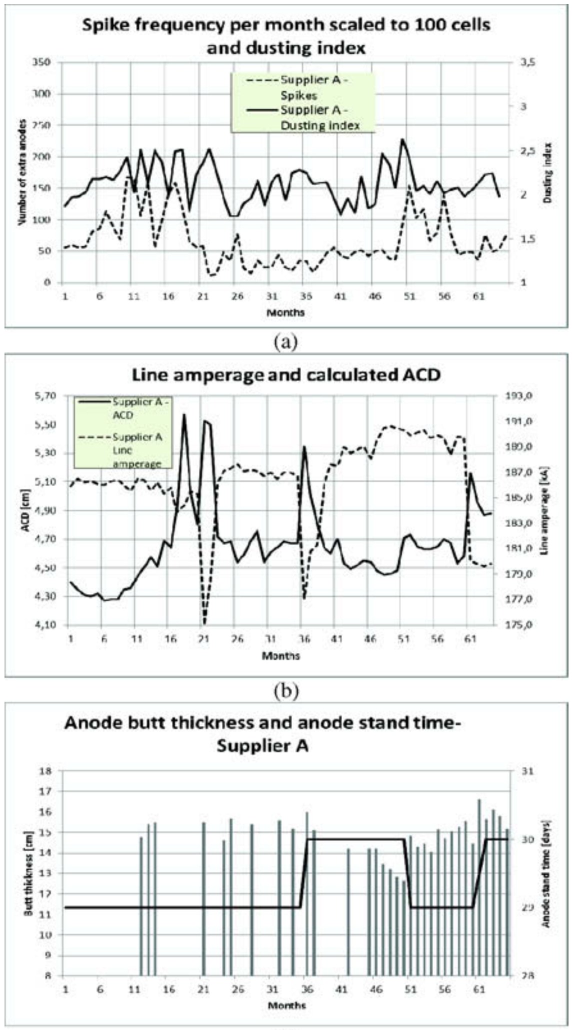


Figure 5: (a) Dusting index and spike frequency. (b) Line amperage and calculated ACD. (c) Anode butt thickness and stand time.

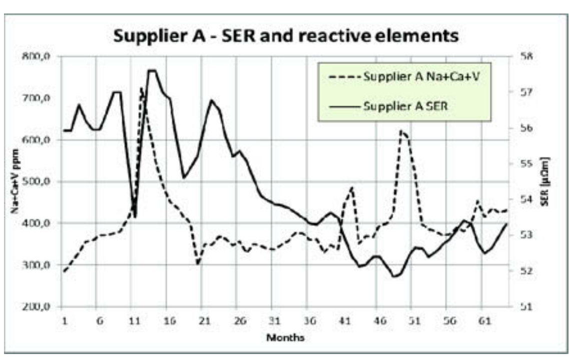


Figure 6: Specific Electrical Resistance (SER) and sum of reactive elements over the same period for supplier A.

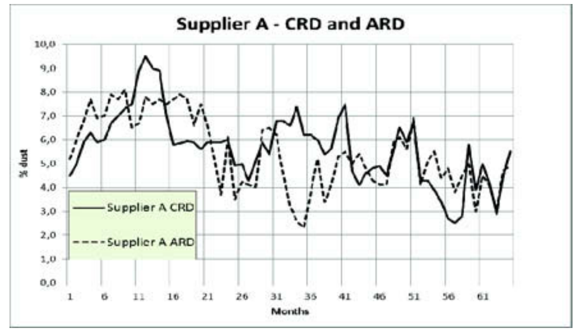


Figure 7: Carboxy reactivity dusting (CRD) and air reactivity dusting (ARD) for supplier A.

<u>Supplier B, dusting excursions:</u>

Figure 8 shows the SER and sum of reactive elements for anodes from supplier B over a period of 54 months.

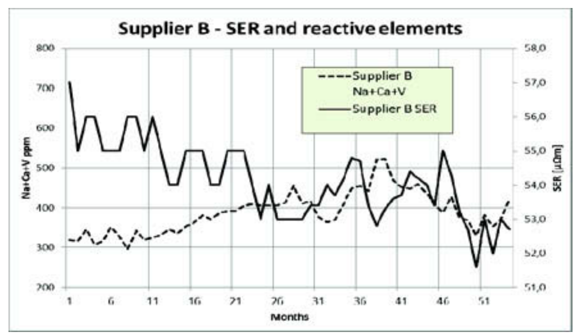
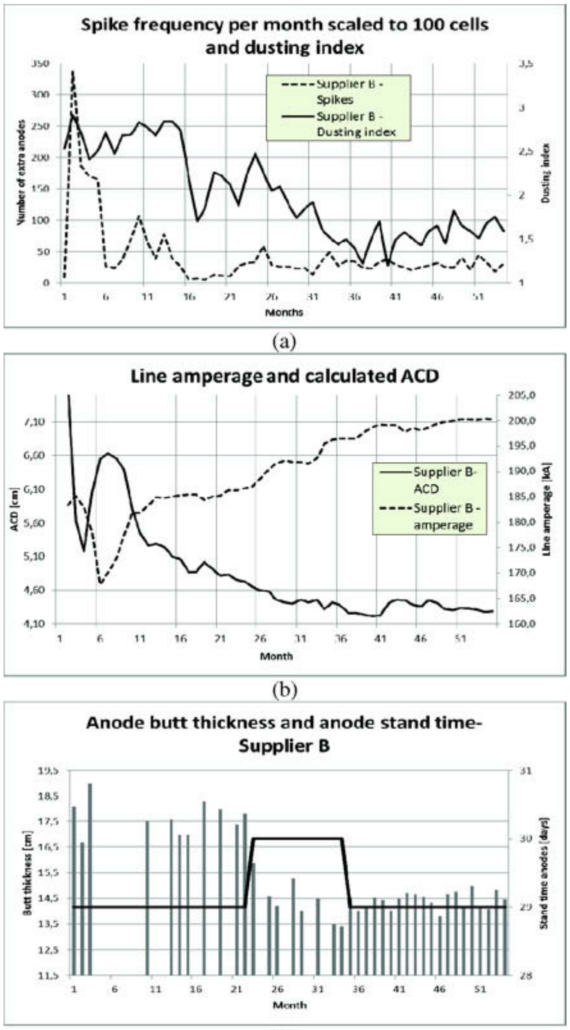


Figure 8: SER and reactive elements for supplier B.

Figure 9 shows the spike frequency, dusting index and relevant operational data for this same period.

Supplier B anode were used during a startup and the dusting index remained high for the first 16 months. Spike frequency was initially quite high but dropped as the ACD was increased by dropping the line current and maintaining a high voltage. Around month 16 the dusting and the spikes drop while the ACD is fairly high at 5.1 cm. As the dusting drops during the next 25 months up to month 41, the line current is increased and the ACD decreases. From week 41 to 56 the dusting is fairly constant at 1.5 and the spike frequency remains below 50. Note that the dusting does not increase in the period of month 23 to 33 during a temporary increase in anode stand time with a corresponding reduction in butt thickness. Figure 8 shows that the SER value was quite low during this period.

As Figure 8 shows, the reactive elements remain very stable and low during this period compared to supplier A (Figure 6). The SER drops however for anodes from supplier B indicating a greater level of baking and the dusting drops accordingly. The CRD and ARD values in Figure 10 do not change much except for a jump in ARD which could be related to an increase in reactive elements (Figure 8). In this case the air and carboxy reactivity dusting measurement is not a good measure of dusting in the cells.



(c)

Figure 9: (a) Dusting index and spike frequency. (b) Line amperage and calculated ACD. (c) Anode butt thickness and anode stand time.

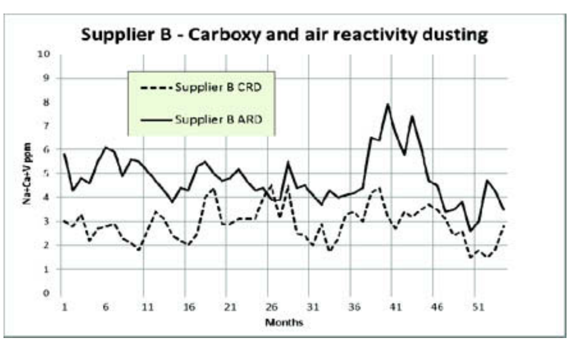
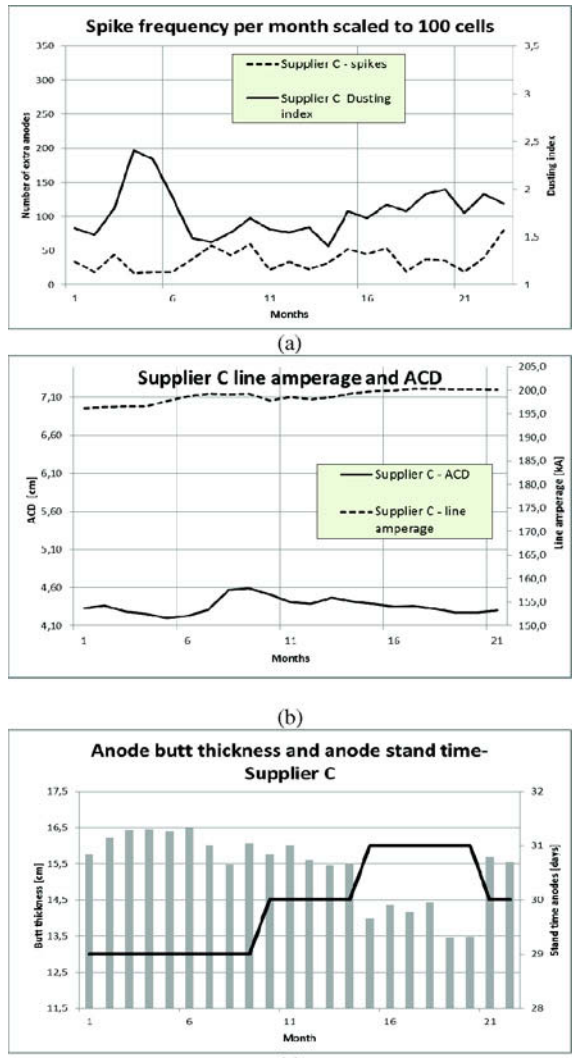


Figure 10: Carboxy reactivity dusting (CRD) and air reactivity dusting (ARD) for supplier B.

Supplier C, dusting excursions:

Figure 11 shows the spike frequency, dusting index and relevant operational data for supplier C over a period of 22 months.

The spike frequency remains low for supplier C during this period. There is a period of increased dusting but it does not lead to an increase in spikes. The ACD is slightly squeezed but the anode butts are thick to begin with which may have reduced the impact of the initial level of baking on the anode dusting [3]. Figures 11 (a) and 12 show that the dusting drops as the SER values drop indicating improved baking. The dusting creeps up a bit as the SER value increases again but remains below a dusting index of 2. The reactivity values remain low and do not correlate well with the level of dusting (Figure 13).



(c)

Figure 11: (a) Spike frequency and dusting index. (b) Line amperage and ACD evolution. (c) Anode butt thickness and anode stand time.

As for supplier B, the temporary increase in standtime for supplier C between months 15 and 20 does not lead to an increase in dusting.

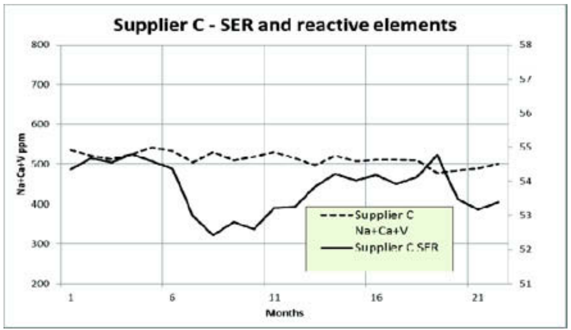


Figure 12: SER values and reactive elements for Supplier C.

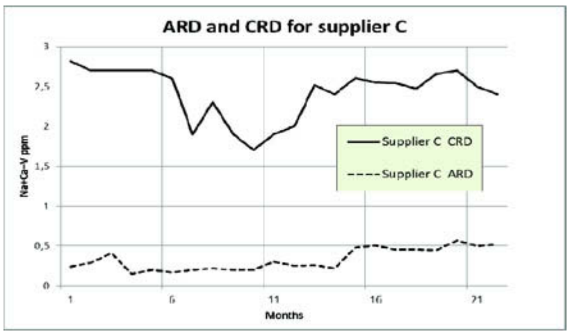


Figure 13: Air reacitvity dusting values (ARD) and carboxy reactivity dusting values (CRD) for Supplier C.

Conclusion

In this paper are shown the results of studies over an elongated period of time from real-time data on anode dusting excursions experienced from the use of anodes from three different anode suppliers.

The anodes produced by Supplier A show during this period of study in general more dusting and a higher level of anode spikes when compared to the other two suppliers. The data in Table 1 supports this as the reactivity values are generally higher. The level of baking by Supplier A has greatly improved during this period but a period of increased reactivity due to reactive elements still caused some problems. The moulded slots are a likely source of additional dusting, both due to higher permeability of the anode block around the slot and filler coke that is left behind from baking inside the slots [7]. Furthermore, because the sulphur level of this anode is lower than in the anodes from the other two suppliers the Supplier A anodes are more sensitive to increases in reactive elements [4,5].

The anodes produced by Supplier B anodes improved greatly during this period of study and the level of dusting and spikes appears to correlate mostly with the SER value as the reactivity values have consistently been at fairly low levels. A slight increasing trend again in dusting is being addressed in cooperation with the supplier with specific actions on relevant anode parameters.

According to Table 1 the anodes from Supplier C anodes are the least reactive and this is reflected in the dusting index and the frequency of anode spikes. In this case there appears to be a slight correlation of dusting with SER. Here there is also a slight increasing trend in dusting that is being addressed in cooperation with the supplier.

This simple evaluation system of dusting observed in the tapholes has been shown in this study to correlate well with anode spike excursions if done in a systematic and objective way. Cell operating parameters must also be taken into consideration because increasing the standtime of anodes or squeezing the ACD can increase the anode spike frequency for a given anode quality.

Evaluating the dusting level in the tapholes of cells is designed to measure low dusting and to establish a level of dusting that could lead to anode spiking excursions. Nordural uses the dusting index now in communications and meetings with anodes suppliers to spot anode dusting trends and address them with timely specific actions in order to avoid future anode spiking excursions.

References

1. B. Rolofs, N. Wai - Poi, “The Effect Of Anode Spike Formation On Operational Performance”, Light Metals 2000.
2. B. Sadler, B. Welch, “Reducing Carbon Dust? – Needs And Possible Directions”, 9th Australasian Aluminium Smelting Technology Conference and Workshops, Terrigal, Australia, 2007.
3. R. C. Perruchoud et. al., “Dust Generation And Accumulation For Changing Anode Quality And Cell Parameters”, Light Metals 1999.
4. R. C. Perruchoud, M.W. Meier, W.K. Fischer, “Survey On World Wide Prebaked Anode Quality”, Light Metals 2004.
5. P. Stokka, “The Effect Of Petroleum Coke Sulfur Content On The Loss Of Sodium During Baking”, Light Metals 1994.
6. P. Stokka , T. Berge, “Anode Carbon Dusting in Aluminium Electrolysis Cells”, Slovak-Norwegian Symposium on Aluminium Smelting Technology, Stara Lesna, Slovakia 1999
7. J.J.J. Chen, “Slotted Anodes”, University of Auckland 2008 MEng Studies Lecture Notes.