Light Metals 2011 *Edited by: Stephen J. Lindsay*
TMS (The Minerals, Metals & Materials Society), 2011

FULL CONTROL OF PITCH BURN DURING BAKING: IT'S IMPACT ON ANODE QUALITY, OPERATIONAL SAFETY, MAINTENANCE AND OPERATIONAL COSTS

Detlef Maiwald, Domenico Di Lisa, Hans Peter Mnikoleiski,

innovatherm GmbH + Co KG, Am Hetgesborn 20, 35510 Butzbach Germany

Abstract

The quality of a baked anode is, amongst other criteria, defined by the heat treatment. Each anode in a pit has to reach a specific temperature overall in a certain time. The heat transfer is determined by the temperature versus time curve of the surrounding flues and the furnace geometry.

Due to the physical design of the open top ring furnace, less energy is introduced to the outer flues in the preheat area. Further, the pitch burn starts and ends at a later point than at the inner flues. As a primary result, the homogeneity of the anode quality will be affected. Secondarily, other disadvantages will occur as well as which are:

- unburned volatile fractions which condense downstream in the furnace, exhaust pipe, ducts and FTC facilities
- higher emissions, especially hydrocarbons (PAH_{16}), CO, CO_2 and NO_x parts
- high operational costs for extensive maintenance to clean equipment, ducts and FTC facilities
- impact on operational safety due to accumulation of ignitable fractions downstream to the FTC
- higher running and energy costs

This paper will describe the different steps and strategies to optimize the baking process, achieving full control of the pitch burn and will show the results as remarkable improvements on anode quality, emissions, fuel consumption and running costs.

Introduction

The physics of pitch burn is quite complex. Once the volatile degasing in the anode has started it behaves exothermically as a gas generator and reacts very sensitively on any variation of the controls. The question is how to establish complete pitch combustion throughout the operation cycle in compliance with the final baking temperature requirement in the upstream burner area?

The final quality of a baked anode is defined by several parameters in the manufacturing process. Within the heat treatment, a specific gradient limits the procedure as well as the maximum refractory temperature. The major task is to energize the cold spot of the anode pack within a section above a certain baking level. To realize this task, many times, part of the anode pack has to be over heated. Consequently energy will be lost at a cost, associated with the green house gas problem which is an important factor these days.

This paper will summarize already known practices and will describe new advanced control philosophies to further optimize the anode quality to a premium baking level by following the physical process limits and providing a homogenized product. This task is not just providing positive aspects within the baking process but influences the potline production as well.

This paper assumes that the general furnace design is known and will therefore focus on the baking process and its specific details.

The anode baking process is running basically as a two convection heat exchanger with a firing zone in between, thus forming three areas. These areas are the preheat, firing and cooling area. Therefore, the basic requirement of the Firing Control System is to control each flue wall as an individual control loop in these three areas. This paper will basically concentrate on the preheat and the firing area, normally called a "6-section-fire" as shown in Figure 1.

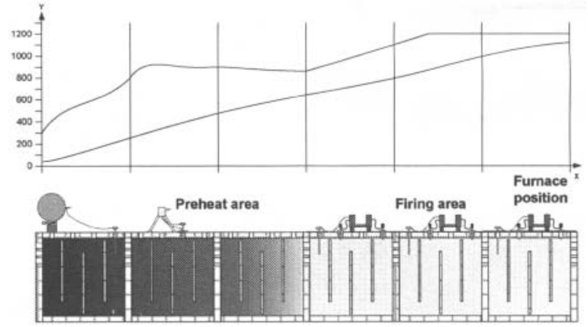


Figure 1 – Typical 6 section fire

In most cases a "6-section" fire arrangement (3 preheat and 3 firing sections) is being used. Due to capacity reasons some application are enhanced by an additional burner ramp forming a seven section fire where the following theories can also be adopted.

Below is a cross section (Figure 2) of a standard triple baffle flue wall with 4 peepholes (1-4) based on a given firing direction for common understanding. This arrangement will be used as a base for all provided sketches and diagrams.

Specific individual flue designs will have influence on the following procedures and should be taken into consideration separately.

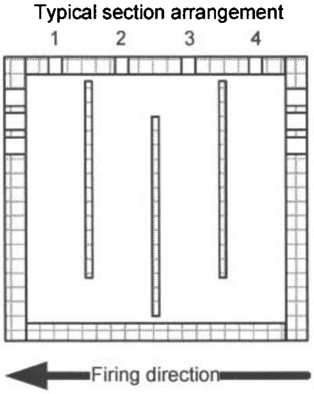


Figure 2 Section arrangement

The equipment placed onto the furnace surface occupies the shown peepholes (PH) as follows:

Exhaust Ramp:
Extracting out of PH 1, temperature (TC) measurement in PH 4.

Former furnace designs utilizing head wall openings for the fume extraction are becoming uncommon and may vary from the following described advantages due to the very high dynamic flow resistances.

Measurement Ramp (MR):
In normal production (Fig. 1), TC and draft measurement in PH 3.

Burner Ramps 1-3:
Fuel injection into PH 2 and PH 4; TC measurement in PH 1.

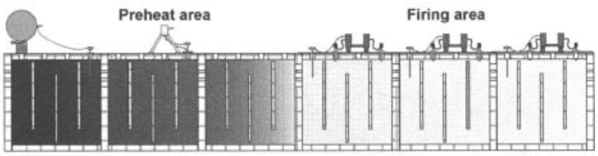


Figure 3 Location of sensors and actuators

Physics of the pitch occurrence in the carbon area

The anode is formed out of a paste consisting of pet coke fractions and liquid pitch as a binder. Since the raw material prices are increasing dramatically, trials on new recipes have proven that pitch contents may be dropped down to a range of 13.5 – 14.0 %, while still achieving comparable anode properties.

During the heat-up to final anode temperature of 1100°C, the following Figure 4 illustrates the thermal conditions in the preheat area where the treatment of the pitch burn takes place.

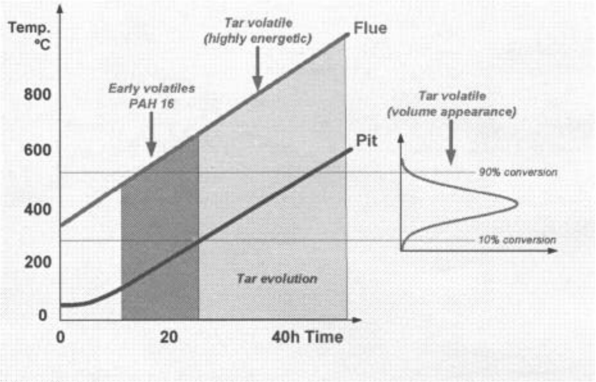


Figure 4 Volatile Kinetics in the preheat area

Modern anode baking processes provide ignition temperature and the required oxygen content at the right moment necessary to establish complete volatile combustion within the baking furnace.

The major task is to burn pitch volatiles within the baking process to almost 100% to reduce the consumption of high cost fuel down to a minimum. It is therefore also essential to focus on the so called "early volatiles" of the PAH 16 group, and find a strategy to burn them as well.

Former control strategies and practices (double jump practices, opening peepholes) have had limited success in improving pitch burn. If gradients are too low in the preheat area, conditions are not conducive to proper combustion.

Quality of pitch burn

Incomplete pitch burn generates numerous problems in the process and the downstream facilities. Figure 5 indicates inefficient pitch combustion at a level of 97% or less.

Figure 5: Bottom view of a flexible exhaust boot (97% pitch burn)

There are 'experts' around the world calling these negative results the 'price to be paid' achieving high quality anode properties. Over the last 10 years a continuous development to a state of the art control strategy replaced these rumors.

The following Figures 6 and 7 show typical inside views of an exhaust ramp with two years of service at full pitch burn and excellent anode properties as shown later in this paper. Soot and tar residues are non-existent.

Figure 6: Inside of an Exhaust Ramp after 2 years operation

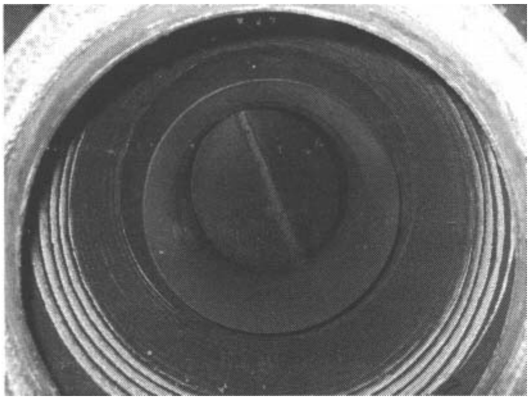
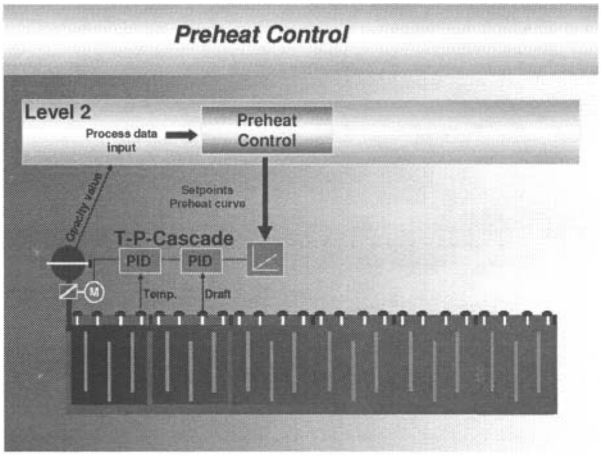


Figure 7: Bottom view into a flexible Exhaust boot

Control of the Preheat area for full pitch burn

The baking process is a temperature oriented process. Former production crews were manually focusing on equalized draft values within the preheat area assuming homogenized heat development. Due to different flow resistances within the individual flue walls variations in gradients could be observed.

Since the relevant process value is the temperature gradient, a temperature-draft cascade control loop for the preheat area is implemented into the firing control system as shown in Figure 8.



Preheat Control

Level 2

Process data input

Preheat Control

Setpoints Preheat curve

Figure 8: Preheat control T-P cascaded loop

For the production of a consistent anode quality, the firing area is not the main influence on the final temperature homogeneity. The final temperatures of the anodes are also highly influenced by the treatment in the preheat area. In order to achieve the best baking consistency, the flue gas volume for defined temperature gradients in the preheat area needs to be controlled. Figure 9 shows the temperature development in the preheat area (Section 2) after implementation of this preheat control strategy.

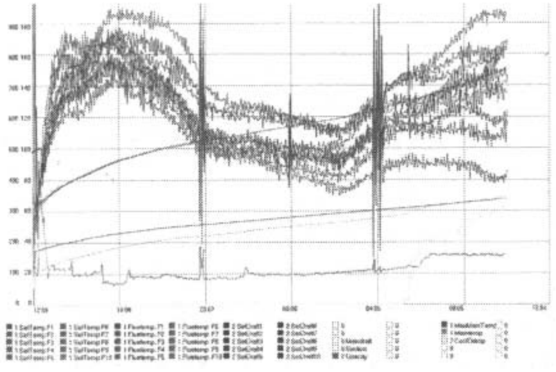


Figure 9: Temperature development in the preheat area

The baking process in the preheat area especially on the top anode layers is negatively influenced by ingress of false air through the packing coke material. To improve this bad situation, PVC covers as shown in Figure 10 have been introduced on most furnaces for the first 2 sections including the headwalls coverage. As a result the ingress of false air is minimized and the preheat temperature is more homogenized from top to bottom and higher overall in addition.

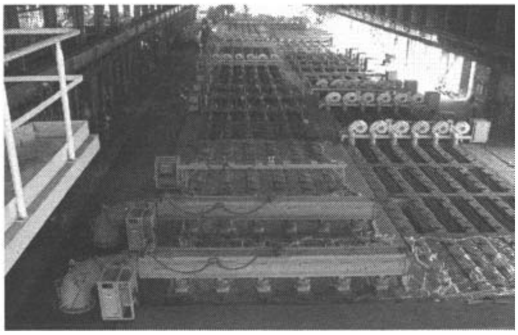


Figure 10: PVC covered Preheat area

Intensity of pitch burn through the fire cycle

To provide ignition temperature and the required oxygen content at the right time it is essential to know when the volatile volume is reaching its peak. The following diagram (Figure 11) indicates the standard volume appearance over the cycle time comprising an optimized preheat development:

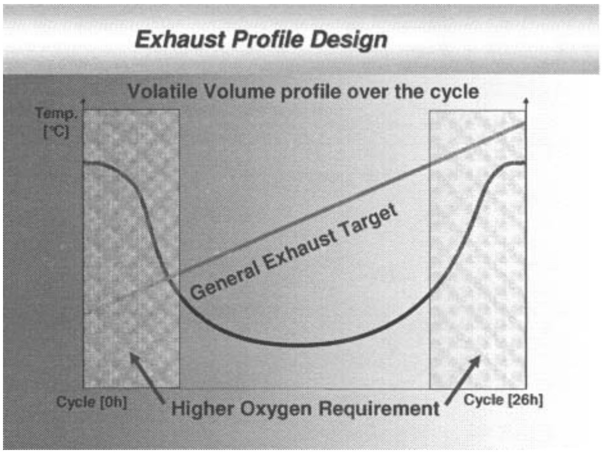


Figure 11: Volatile volume over the cycle time

All process target curves should feature this basic knowledge. Overall, a process quality measurement e.g. opacity meter (optical or electrostatic principle) as shown in Figure 12 or a CO analyzer has to be installed to indicate the quality of the pitch combustion. Only this measurement ensures a transparency of the pitch combustion behaviour, and the development of the pitch front can be optimized and synchronized in relation to the fire cycle time. The corresponding opacity curve is also shown in Figure 9.

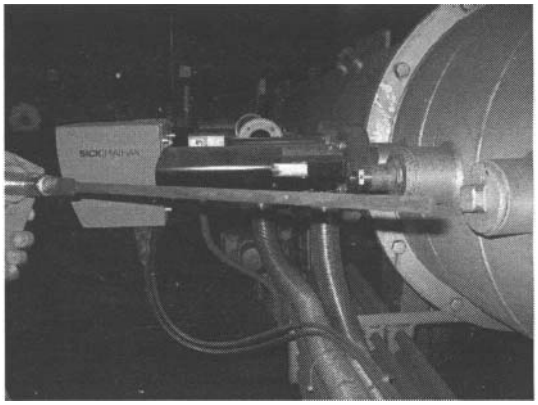


Figure 12: Highly reliable Opacity sensor (electrostatic principle)

The degree of pitch combustion is directly linked to the quality of the preheat control, the oxygen residue out of the burner area and the zero point control upstream.

Based on the optimized preheat control it is now necessary to introduce the required fuel (oil or gas) with a high speed, high pressure burner equipment in order to achieve an optimized fuel combustion. It is absolutely essential to maximize the oxygen level in the flue gas out of the burner area since this feeds the pitch burn area.

Results

The control strategies have been implemented in carbon plants at various smelters in the world for full control of pitch burn. The differences in performance compared to an incomplete pitch burn are measurable. Please find the results and comparison on different data as follows;

Impact on anode quality

Table 1 shows the characteristic values before implementation of a full pitch burn control:

Table 1: Data at incomplete control of pitch burn

	Parameter	**Unit**	**Average**
1	Firing Cycle time	h	26
2	Peak T Exhaust Flue wall.	°C	300
3	Peak T Burner Flue wall	°C	1180
4	Soaking time	h	35
5	Anode Pitch content	%	13,6
6	Energy Consumption	GJ/t $_{\text{baked}}$	2,3
7	Sulphur in green Anode	%	2.42
8	Sulphur in baked Anode	%	1.98
9	Desulphurization rate	%	0.44
10	Baked App. Density	g/cm³	1,573
11	CO_2 Reactivity Residue	%	87
12	Net Carbon consumption	kg/t	418

The data in Table II illustrates the same baking parameters at full control of pitch burn.

Table II: Data at full control of pitch burn

	Parameter	**Unit**	**Average**
1	Firing Cycle time	h	26
2	Peak T Exhaust Flue wall.	°C	370
3	Peak T Burner Flue wall	°C	1150
4	Soaking time	h	39
5	Anode Pitch content	%	13,6
6	Energy Consumption	GJ/t $_{\text{baked}}$	1,89
7	Sulphur in green Anode	%	2.42
8	Sulphur in baked Anode	%	2.135
9	Desulphurization rate	%	0.285
10	Baked App. Density	g/cm³	1,582
11	CO_2 Reactivity Residue	%	89,5
12	Net Carbon consumption	kg/t	402

Tremendous improvements can be shown not only in the direct baking parameters like peak flue temperatures, specific energy consumption, soaking time etc. but also in the parameters influencing the potline performance like CO2 reactivity and net carbon consumption.

Impact on operational safety

Operational safety has become a top priority to all smelter plants in the world. Specially developed components for the anode baking process as well as improved process philosophies result in optimized fuel and pitch combustion which improve the process emissions drastically. Full control of pitch burn avoids accumulation of unburned soot and tar in the exhaust ramps, side main ducts and FTC. Consequently it eliminates the occurrence of wild fires, which is a critical hazard in the baking furnace area.

Impact on emissions

Full control of pitch burn has a direct impact on emissions because it solves the problem at the source. Emissions that are not produced will not be emitted to the environment and will not harm the downstream process or equipment (e.g. the FTC). As a result, the reliability and availability of the FTC will increase tremendously, costs for regular cleaning (up to 2 times per 12 months) and extensive repair of dampers, actuators and sensors will be eliminated.

Impact on maintenance cost

The same advantages mentioned above do have a direct impact on related maintenance costs as well. The frequent cleaning of exhaust ramps, side main ducts and FTC ducts and structures can be eliminated. Flexible exhaust legs will last much longer and therefore minimize maintenance attention. Reduced peak temperatures result in less maintenance for burner equipment, thermocouples, cables, peephole covers and reduced refractory costs. The overall cleaner anodes and their improved behavior in the potline process will reduce anode cleaning and handling. . Every prevented wild fire saves additional repairs, manpower and unknown insurance increases. Cost savings observed at various smelters are in the range of 200.000 US$/annually.

Impact on operational cost

Full pitch burn control also has a direct impact on operational costs. The pitch energy introduced by the green anode will be released, ignited, totally burned and its energy results in being able to reduce the peak temperature later in the process as well as shortening the overall soaking times. These advantages are leading to an energy saving of quite a high extent. A smooth baking process is not just providing less heat stress to all related equipments it also reduces the packing material consumption due to the mentioned lower peak temperature and will also play its part in reducing the running costs. Finally all reduced maintenance and running activities will not require the same amount of manpower anymore.

The energy consumption as shown in Figure 13 prove the significant impact of a full pitch burn after implementation in February 2010.

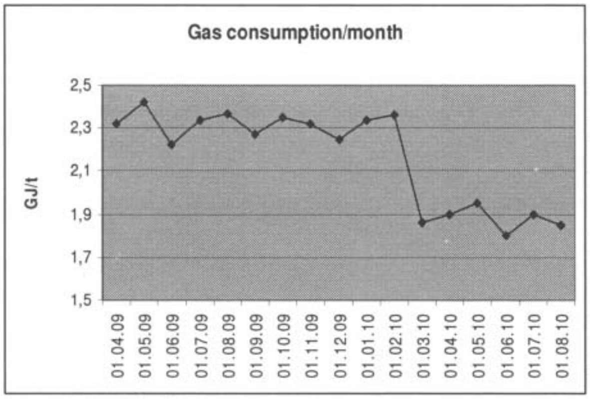


Figure 13: Energy consumption

Conclusions

This paper discussed the impact of a full pitch burn control on several technological parts of the anode baking process. The results demonstrate very impressively the improvements that have been achieved.

The anode baking process as a link within the carbon production does play its roll in the anode quality and is normally the highest cost portion of anode production. Optimizing strategies on the process to achieve at least the same if not improved anode quality on a lower cost level are always worth looking into it.

References

[1] W. Leisenberg, Flue Gas Management, Light Metals (1999)

[2] J. Ameeri; K. M. Khaji; W. K. Leisenberg, The Impact of the Firing and Control System on the Efficiency of the Baking Process, Light Metals (2003) 589-594.

[3] W. Leisenberg, Firing and Control Technology for Complete Pitch Burn and its Consequences for Anode Quality, Energy Efficiency and Fume Treatment Plant, 9th international Conf. on non ferrous metals, July 8-9, 2005, Pune.

[4] W. Leisenberg: "Modellierung thermischer Prozesse" Ergebnisbericht Forschungssemester 1999, University of Applied Sciences Giessen-Friedberg, FB ET II, 2000,

[5] D. Maiwald, D. Di Lisa "Conversion of the firing and control system and the impact on the efficiency of the baking Process" *Aluminium World 2008*

[6] D. Maiwald, D. Di Lisa "Innovatherm Advanced Control Modules and Control Philosophy – The Success for High Quality Anode Production in Open Top Ring Furnace" A*luminium World 2008*

[7] D. Di Lisa, H.P. Mnikoleiski, D. Maiwald "Homogenized Anode Baking Quality" *Light Metals 2009*

[8] Demedde et.al.:"Kinetic Phenomena of the Volatiles in Ring Furnaces", *Light Metals 1986*

[9] Hameed Abbas, Khali Khaji, Danial Sulaiman "Desulphurization control during baking", *Light Metals 2010*