Light Metals 2015
Edited by: Margaret Hyland
TMS (The Minerals, Metals & Materials Society), 2015

SUCCESSFUL START-UP OF FIRING CONTROL SYSTEM AT VLISSINGEN

Nicolas Fiot[2], Pierre Mahieu[2], Bart van Garsel[1]
[1]Century Aluminum Vlissingen B.V. Frankrijkweg 2a Haven 5977 4389 PB Ritthem, The Netherlands
[2]Fives Solios, 32 rue Fleury Neuvesel, BP24, 69702 Givors Cedex, France

Keywords: Carbon, Anode, Baking, Furnace, Control, Injector, NOx, Safety, Century, Fives, Solios.

Abstract

In 2013, Century Aluminum carried-out large investment to restart an anode production facility in The Netherlands to produce world class anodes for parent aluminum smelters. Along with the partial refractory refurbishment of the existing baking furnace, the project included the upgrade of the firing equipment to comply with new local stringent regulation for NOx emission.

Fives Solios was selected to implement its latest control system (Helios^{RT}) featured with clean and efficient injection technology.

Few months only after the furnace start-up, the plant reached stable operation and production target and welcomes the performances of the new firing system.

Project Background

Century Aluminum is a primary aluminum producer, supplying standard-grade, high-purity and value-added primary aluminum products at a rated production capacity of 1.03 million metric tonnes per year. The company has operations in USA and Iceland, with headquarters located in Chicago.

In June 2012, they purchased the anode production facility of a former aluminum smelter that was closed few months earlier in Vlissingen, The Netherlands. In 2013, they carried out large investment to restart the anode production for their operations in Iceland. The existing production unit was modernised to optimize the anode flow and to allow increasing progressively the size of the anodes to support the production growth in Iceland.

A few months after start-up, the carbon plant is run by 50 staff members with a production capacity of approximately 150,000 tons of carbon anodes per year.

The production facility includes 2 baking furnaces. During this first phase of the project, only the furnace D (36 sections of 7 pits) and its 2 fire groups operating with Natural Gas was restarted after a partial refurbishment of its refractory (See figure 1).

Figure 1. Anode Baking Furnace D at Vlissingen

Regarding the Anode Baking Furnace, one of the main concerns of the project team was the NOx emission management to meet the new local stringent regulation. The NOx are mainly produced by the Firing Control System and there is no simple abatement method at the chimney. They have to be reduced at the source. According to the measurements made in 2010, both Firing Systems formerly in operation did not meet the new emission limit. Fives Solios was selected to implement its latest control system (Helios^{RT}) featured with clean and efficient injection technology able to outperform the requirement of the contract guarantee of 200 mg/Nm^3 NOx measured at stack.

With the combined effort of Century and Fives Solios teams, less than 7 months were necessary to upgrade and restart the complete Firing Control System in November 2013. The furnace was restarted smoothly without dry-out phase at a 24 hours cycle duration. The next phase will be to decrease the production cycle time to 22 hours while increasing the anode size.

Latest Control System

In the last couple of years Fives Solios has developed a new Control System using the latest available technology such as EtherCAT for the communication network [1]. This new system is not only Safe but operation and maintenance User Friendly.
With only redundant computers that controlled basic Inputs/Outputs on each mobile ramp, the system architecture is more robust and simple to understand and to maintain. The hardware is reduced and simpler than with the conventional Control System Architecture. There are no active components with their own specific settings on the ramps. The maintenance people can easily and quickly change any components.

To achieve the same Safety level as expected by most users and as promoted by Fives Solios, very complex systems using Safety Integrated Programmable Logic Controller (SIPLC) were implemented. EtherCAT Network with its simple but efficient

management of safety components allows meeting the last version of the European Standard regarding fuel combustion at reasonable cost with minimum disturbance to the day to day operations.

A modern baking furnace like Century's is supervised by only one operator that follows not only the Firing Control System but also the anode handling system and the fume treatment center. This operator that spends his time between the control room and the field, needs to have all the information wherever he is. Helios^{RT} has a unique interface so the operator can dispose of the same information either on the fixed screens located in the control room or in the furnace (See figure 2). For very specific operations, this interface is also available on mobile tablet PC. It allows operating the system closer to the action and the operator can really see in live the change he did. For example, in case of blocked flue wall, the injector power can be adjusted while looking inside the flue wall to measure in real time the effect of the modification.

Figure 2. Firing Control at your fingertips

Helios^{RT} allows minimizing the operator actions, such as during the fire moving where the ramps are automatically and accurately localised and restart automatically. This feature and many others improve the Safety and allow the operator to really focus on others tasks that improve the overall performances, such as checking the position of the mechanical dampers that close the flue walls or the plastic sheet covering the pre-heating zone for any unwelcome air ingress in the pre-heating zone.

Advanced Injection Technologies

In addition to these ergonomic improvements, the upgrade of the firing equipment includes the up-to-date technologies developed by Fives Solios to promote clean and efficient combustion and achieve high baking homogeneity:

- Advanced control algorithms to optimize fuel to air ratio,
- New generation of gas injectors designed to limit NOx formation and improve thermal distribution inside flue walls.

The last version of the baking control software includes a set of advanced control algorithms dedicated to the combustion optimization:

Anti-flooding system

The first step in optimizing the combustion starts with an algorithm that limits the amount of fuel injected per flue wall line according to the amount of air available. For a given flue wall in standard operating conditions, the maximum amount of fuel that can be injected before the formation of unburned fuel depends only on the level of the draft pressure (See figure 3).

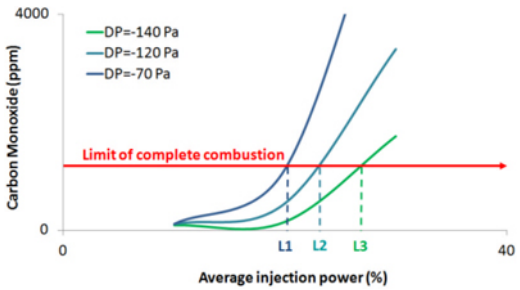

Figure 3. Gas injection limits per flue wall line

Based on this principle, the system calculates in real time the maximum injection limit for a given flue wall as a function of the draft pressure available. If the instant calculated injection power to follow the set points is higher than the authorized maximum, the algorithm limits each injector's power according to a predefined distribution rule and proportionally to the demand (deviation between temperature measured and the set point).

CO module

The second step of combustion optimization is based on online CO measurement for an adaptive control that takes into account outside standard operating conditions [2]. In case of bended flue walls, fume flow disturbance, shifted pitch burning area or other baking deviation phenomena leading to high CO content in the exhausted fumes, the module automatically searches for the responsible flue wall and manages the appropriate actions by moderating fuel quantity injected or by increasing the volume of blown air. The innovative method of identification is based on CO content comparison after the total fuel injection stoppage during a short period for the pre-selected flue walls upon stoichiometry criteria.

Figure 4. CO Exhaust duct equipped with CO analyzer

Injection Matrix Control

This module is the last generation algorithm dedicated to the improvement of the combustion process in anode baking furnace. It allows the optimization of the oxygen available by sequencing gas injection pulses along a flue wall line. According to the baking cycle time, a fire group can be composed of 2 to 4 heating ramps, which means that 4 to 8 injectors are operating in the same flue wall line. In such configuration, it can happen that an injector liberates gas in the same volume of air used previously by an upstream injection, leading to local flooding situation with unburnt volatiles formation.

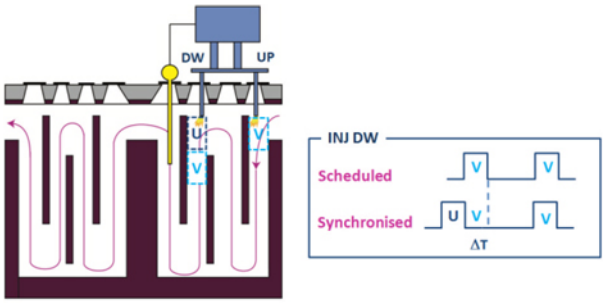

Figure 5. Injection Synchronization

The new Central Control System built around a single controller with a real time network allows the synchronization of the injectors of the same flue wall line. The algorithm combines the injection demand with other measurements such as CO, temperature and negative pressure to calculate the optimal injection sequences. This synchronization management is a further step for combustion improvement and flame development stability.

New generation of gas injector

The latest generation of gas injectors installed in Vlissingen is the result of a research program for the development of a clean and efficient injection technology [3]. This program is based on experimental tests performed in a pilot unit equipped with an actual scale flue wall. The main objectives of this study that started in 2012 were to develop an injector with the following improvement criteria:

- Allow a more homogeneous temperature distribution along the flue wall to improve baking consistency,
- Limit the formation of nitrogen oxides to comply with environmental regulation.

With this new injector, a large improvement of the flame temperature homogeneity was obtained thanks to an adapted configuration of the gas jet.

The flame behavior observed in the testing unit with the new injector was confirmed in operation at Vlissingen: large scale turbulence flame distributed over a large volume inside the flue wall (See figure 6). Such flame allows a homogenous heat transfer distribution along the refractory flue wall and consequently improves baking quality.

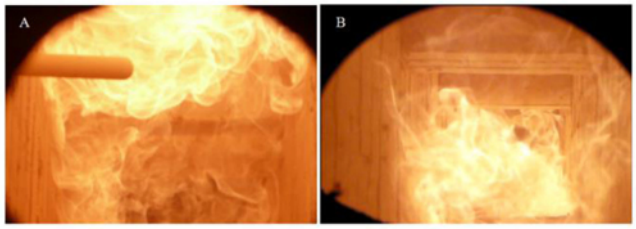

Figure 6. New injector flame profile in test (A) and in operation (B)

As the volume of the flame increases the heat flux density is reduced and consequently the flame peak temperature decreases. This has a positive impact on the reduction of NOx emissions. It was observed during the trial period that the production of NOx was divided by a factor of 3 for the same thermal efficiency compared with the previous generation of injectors (See figure7). This is in perfect correlation with direct measurements made during operation at Vlissingen.

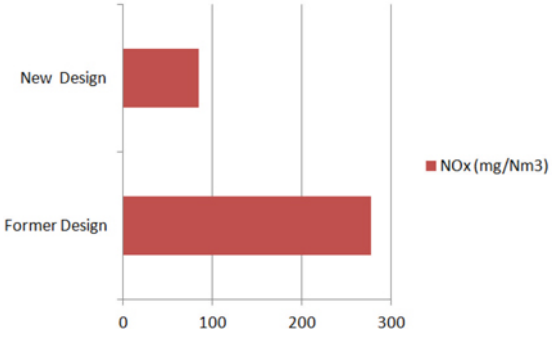

Figure 7. NOx estimated at the exhaust duct from pilot test

Stable operations and baking performances

The anode production started end of 2013, with the first green anode on the 29/11/2013 and the first container of slotted baked anodes ready for shipping on 31/12/2013. After almost one year of operations, Vlissingen records very stable operations and baking performances. The anode quality is checked routinely by collecting sample cores on baked anodes located in different layers from several sections. Most of the analysis are performed in Century laboratory in Vlissingen, except for air permeability and thermal conductivity analysis that are done in their laboratory in Hawesville (USA) (See table 1).

Green density	1,66 kg/dm^3
Baked density	1,63 kg/dm^3
Specific Electric Resistivity	48,6 µΩm
Air permeability	0,43 nPm
Thermal conductivity:	4,2 W/mK
Baked Anode:	
Average real density	2,093 kg/dm^3
Standard Deviation (2 σ)	0,021 kg/dm^3

Table 1. Baking performances

The mean levels of CO recorded at the exhaust ramps are in the range of 250 ppm. These levels are reflecting complete combustion of both gas and volatiles. The gas consumption is 10% lower than recorded before the stoppage with the previous

firing technology. It is reaching 2.3 GJ/tba which is a satisfactory level for an ageing furnace (average lifetime of refractory flue walls).

The continuous NOx measure made at the chimney is lower than 100 mg/Nm^3. This value combines the NOx produced by the anode baking furnace and the RTO (Regenerative Thermal Oxidizer). For comparison, in 2010 the average levels of NOx recorded by formers operators at the outlet of furnace D was about 400 mg/Nm^3 (without RTO).

Conclusion

To meet the new stringent environmental standards, Century Aluminum chose Fives Solios latest control system Helios^{RT} featured with its new injection technology to upgrade their firing control systems.
After just a few months of joint effort between Fives Solios and Century teams, the baked anodes production target was reached within the expected performances criteria.

Century Aluminum is now ready to start increasing its production and the anode size to continue supporting the Iceland operations growth.

Fives Solios' state of the art technology, clean, safe and user friendly has also seduced other customers as two new furnaces equipped with 3 fires will start in China at the end of 2014.

References

[1] Nicolas Fiot, Xavier Génin. « New Central Control Architecture for Anode Baking Furnaces", *Light Metals 2012,* pages 1191-1195.

[2] Pierre Mahieu, Nicolas Fiot, Arnaud Trillat, Ovidiu Balu, Cristian Stanescu. "Anode Baking Process Improvement at Alro", *Light Metals 2013,* pages 1155-1161.

[3] Pierre Mahieu "Improving Fuel Gas Injection in Anode Baking Furnace", *Light Metals 2014,* pages 1165-1169.